AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

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Batch 94

1. SUBJECT CLASSIFICATION	A. PRIMARY Food production and nutrition	AP10-0000-G200
	B. SECONDARY Water resources and management--Ghana	

2. TITLE AND SUBTITLE
Lake Volta, man-made lake in Ghana; annotated bibliography and inventory

3. AUTHOR(S)
Aziz,M.A.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1973	79p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Smithsonian

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

10. CONTROL NUMBER	11. PRICE OF DOCUMENT
PN-AAG-186	

12. DESCRIPTORS
Ghana
Inventories
Lake Vol.ta,Ghana
Reservoirs

13. PROJECT NUMBER
931087000

14. CONTRACT NUMBER
CSD-2608 GTS

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

931-11-995-878
AID/csd-2608
PN-AAE-186

LAKE VOLTA

Man-made Lake in Ghana, Africa

Annotated Bibliography and Inventory

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Acknowledgments

Most sincere thanks are due to Mr. William L. Eilers, Mr. Peter H. Freeman, Dr. Dale W. Jenkins, Mr. Kenneth U. Mowll and particularly to Miss Helen Davidson for their enthusiastic help throughout this work.

M. A. Aziz

Annotated Bibliography and Inventory

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Lawson, G.W., 1963.

Volta Basin Research Project.

Nature, (London), Vol. 199, No. 4896, pp. 858-859.

Abstract: A brief note on the formation of Lake Volta and its possible effects or benefits.

1. hydro-electric production.
2. estimated aluminum production is 120,000 long tons/annum.
3. freshwater fishery.
4. inland water transport system.
5. relocation of local population.
6. medical problems.
   a. Schistosomiasis.
   b. Onchocerciasis.
7. aquatic weeds.
8. possible effects of flooding on plankton and fish products.

Pre-lake fishery of Volta is estimated at $260,000 per annum. River clam (*Egeria radiata*) production high in the dry season when the river is low.

Comment: This paper is of no scientific value. It is just a survey of the creation of Lake Volta and its possible effects.

Beauchamp, R., 1966.

Dams Create Unique Laboratories.

New Scient., Vol. 36, p. 676.

Abstract: A general report on the Symposium on Man-made Lakes organised by Ghana Academy of Sciences at Accra, Ghana (1966). It is suggested that the man-made lakes may be very valuable "laboratories" where the following aspects of tropical hydrobiology may be studied.

1. Interspecies ("biotic") interactions in a community functioning under relatively constant (physical) tropical environment.

2. The value of the "biological cycle" in tropical waters.

3. Population dynamics of the important commercial fishes, e.g., Tilapia.

4. The differences (and their implications) that exist between the water budgets of natural and man-made lakes.

Comment: None.

Biswas, S., 1966a.

Oxygen and Phytoplankton Changes in the Newly Forming Volta Lake in Ghana.

Nature, (London), Vol. 209, No. 5019, pp. 218-219.

Abstract: A resumé of changes in oxygen and phytoplankton in the water following the formation of the lake. Prior to the closing of the dam in 1964, the riverine water was super-saturated with oxygen (110 - 170% saturation).

Prior to the closure of the dam, the blue-green alga Anabaena aphanizomenoides Forti was declining, but the formation of the lake (following May 1964) led to a phenomenal increase of the alga accompanied by a rise of oxygen in the lake-water to 324% saturation. This rise is attributed to:

a. the super-saturation of oxygen in the river water.
b. photosynthetic activity of Anabaena.

Later in the year, Anabaena declined and oxygen level dropped to 16% saturation (June 19). A succession by another blue-green alga, Microcystis flos-aquae, reached a peak on July 10; oxygen rose to 36% saturation. There was a decline of Microcystis and oxygen reached record low-level on July 31 (10-15% saturation). Later the green alga, Ankistrodesmus falcatus (Corda) Ralph. began to increase; oxygen rose to 33% saturation.

Biswas, S., 1966a, cont'd.

Additional pertinent observations: on July 31, the water was isothermal at 27.4° C.

Comments: A significant short report on the changes in aeration of water and plankton production accompanying the formation of the lake. A rapid rise in oxygen-level of the water following damming did not last long; an overall dimunition of oxygen has occurred in Lake Volta. A clear relationship is established between phytoplankton blooms and oxygen concentration of water.

Biswas, S., 1966b.

Ecological Studies of Phytoplankton in the Newly Forming Volta Lake of Ghana.

Jour. West African Sc. Assoc. (Ibadan, Nigeria), Vol. II, No. 1-2.

Abstract: Changes in Ammonia (NH_3), Nitrogen-Nitrate ($N-NO_3$), Phosphate (P_2O_5), Iron (Fe^{++}; Fe^{+++}), and colour accompanying the formation of Lake Volta are recorded and related to the production of phytoplankton (Melosira granulata (Ehr) Ralfs; Synedra acus Kuetz; Anabaena aphanizomenoides Forti; Microcystis Flos-aquae (Wittr) Kirchn.; Ankistrodesmus falcatus (Corda) Ralfs and Cryptomonas). Changes from September 1963 (riverine) to February 1965 (lacustrine) are plotted on graphs. The following trends are noted:

NH_3..........0.01 - 0.06 mg/lit (1963)	to	0.28 mg/lit (1965)
$N-NO_3$........0.05 - 0.16 mg/lit (1963)	to	nil (1965)
P_2O_5.........0.04 mg/lit (1963)	to	0.16 (July 1964)

From September 1963 to March 1964, phytoplankton was very low (0-17 cells of diatoms/mg), but in May 1964, a bloom of Anabaena (over 10,000 cells/mg) led to a super-oxygenation (over 300% saturation). From February 1964 to February 1965, a steady succession of phytoplankton species is noted; this succession is related to changes in the turpidity of the water as well as

Biswas, S., 1966b, cont'd.

to the production and use of oxygen. Biswas (p. 18) explains this as follows:

> "The frequent occurrence of phytoplankton peaks followed by their abrupt decline may be explained as a result of a cycle between ferrous and ferric forms of iron compounds. The ferric condition will impart a brownish opalescent turbidity, cutting down light penetration and thus rapidly reducing the phytoplankton population. This will in turn reduce the dissolved oxygen and under this condition ferric iron will be converted into the soluble ferrous form. The result will be an increased transparency of water followed by phytoplankton growth."

Comment: A fairly detailed account of changes in major ions, light, oxygen and phytoplankton in the lake. Although detailed tables of recorded values of the various ions at different times of the year are not given, the data does permit some tentative conclusions about changes accompanying damming of Volta River.

Since all the changes recorded are from Ajena (close to the dam), it is conjectural if these conditions are representative of the whole lake. Further, the fluctuations recorded are not adequately related to the annual flooding cycle of the rivers.

Ewer, D. W., 1966.

Biological Investigations on the Volta Lake, May 1964 to May 1965.

in: Man-made Lakes, Edt. R. H. Lowe-McConnell.
Symp. Inst. Biol. No. 15, Academic Press, London, pp. 21-31.

Abstract: In the early months of its formation the following water weeds were noted on Lake Volta: Lemna, Pistia, and Ceratophyllum. There was no explosive development of these weeds.

Soon after closure, the oxygen content rose suddenly to over 300% saturation; within 4 weeks it dropped to 16% saturation on the surface while no oxygen was found below 10 m. Oxygen content is related to phytoplankton activity (Secchi Disc reading = 1 m). Stratification of the lake is noted. Temperature as well as chemical factors show this (Epilimnion 0-10 m; metalimnion 10-25 m and hypolimnion 25 m+). Measurements of iron suggest extensive mixing in the lake; details, however, are not known yet. Benthos is limited to the top 4-5 m. The initial deoxygenation of the lake led to mass-mortalities of Chrysichthys. Initial catches show Alestes, Hydrocynus, Lates, Labeo Clarias and Chrysichthys as dominant fishes. Finally the effect of damming on clam (Egeria) is noted.

Petr T., 1966

Fish Population Changes in the Volta Lake Over the Period May 1965 - July 1966.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Report, X 14, 4 pp. Tables.

Abstract: Changes in the fish fauna and fishery in Lake Volta following the completion of Volta Dam are outlined; data were collected from Akosombo, Ampem Kpandu, Kete Krachi and Yeji. Because of differences in the location of these sites in relation to the dam and also of the physical nature of the lake-shore around each one of them, fish species do not exhibit a uniform pattern of success. At Kpandu and Ampem (both shallow water and partially cleared of vegetation) considerable development of phytoplankton resulted in the drowned-forest beaches and this favored a substantial increase in the populations of cichlid fishes (Tilapia spp. Pelmatochromis spp.). In various localities the cichlids accounted for over 50% of the fish catch in early 1966. Data on other fishes are summarized below:

Citharinidae (Citharinus, Distichodus): no substantial change following the formation of the lake.

Centropomidae (Lates): has increased in the lake.

Mochocidae Synodontis spp. have declined in the south, but no change in the north.

Petr, T., 1966 - contd.

Schilbeidae: many species have decreased in the south, but they retain their strength in the north; only Physailia pellucida has increased in the southern portion following damming.

Bagridae: no substantial change except that Chrysichthys has increased in the south - replacing Alestes nurse.

Mormyridae: a phenomenal failure of most species of this family is recorded in the lake.

The formation of Lake Volta has led to the success of Cichlidae, Anabantidae and Centropomidae while Mormyridae, Characidae and Schilbeidae have declined.

Comment: A preliminary but significant report on the effect of the creation of Lake Volta on the fishes of Volta River. Family Cichlidae has responded most favorably to lacustrine conditions while the important Family Mormyridae for unknown reasons - has declined. The report has very useful "catch data" from various localities all over Lake Volta.

Proszynska, M., 1966.

A Quantitative Study of the Cladocera and Copepoda in the Volta Lake.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Rept., X 10, pp. 3.

Abstract: A preliminary report on the planktonic crustaceans (Cladocera and Copepoda) at Ajena Station, Afram Confluence and Volta River (below the dam); observations were made between May 1964 and December 1965. The genera mentioned are:

1. Cladocera: Diaphanosoma, Ceriodaphnia, Bosmina, Moina
2. Copepoda: Cyclops
3. Diaptomid: Diaptomus

A very unpredictable picture of distribution and quantity is reported at all stations. Immediately following the closure of the dam, planktonic crustaceans were found through the water column (10 m. deep). However, in 1965 most species were restricted to the upper layer of the water. Sudden disappearance of the planktonic crustacea is attributed to "mass mortalities" the causes of which are not presented. A mass mortality of zooplankton and fishes was recorded in July 1964; the author suggests that the fishes perished because of the disappearance of zooplankton.

Proszynska, M., 1966, cont'd.

Only adult crustaceans were found at Ajena Station; the author suggests that the origin and growth of most species occurs elsewhere in the lake - perhaps at Afram confluence and other such sites.

Comment: A highly preliminary and qualitative report (without a complete list of species of planktonic crustacea). It is dubious that the fish mortality observed was caused by the crash of zooplankton population. Mass mortalities which commonly occur in all the major African lakes are associated with local "overturns" or "seiche" movements which reduce oxygen in the water. Presumably the aerobic zooplankton also disappear for the same reason. Conclusions about the so-called "mass mortalities" of zooplankton can only be made when we know more about the limnology of the lake. Also, the role of annual flooding, as well as temperature, needs to be taken into account.

Reynolds, J. D., 1966.

The Clupeids of Lake Volta and Their Possible Exploitation.

Volta Basin Res. Project (Univ. of Ghana), Tech. Rept. X 15, pp. 6.

Abstract: Two closely-related clupeid species, Cyanothrissa mento and Microthrissa miri, live in Lake Volta; their characteristics are as follows:

1. Cyanothrissa mento: this is the larger of the two species (150 mm; 40 gm); and it is predominantly piscivorous. In the early part of the lake's history it was mainly caught near Kete Krachi and Yeji. Breeding season: ?

2. Microthrissa miri: a smaller species (80 mm; 8 gm) is caught all over the lake; it is insectivorous and probably also feeds on scales of other fishes. Breeding season: July, August.

These clupeids exhibit a diurnal vertical migration which is probably associated with the emergence of aquatic insects in the evening. At this time, the fishes form shoals which later disperse on the surface of the lake. At dawn, the shoals re-form and disappear into deeper waters.

Very little is known about the breeding biology of the species except that they probably attach their eggs to a substrate in shallow water areas. It is noted that these clupeids do not migrate into the flooded areas during high water season; survival of the stock is therefore probably assured by some mechanism protecting the young from the predators.

Reynolds, J. D., 1966 - contd.

The occurrence of periodic large shoals are associated with limnological conditions in the lake.

Earlier in the paper a very brief account of freshwater clupeids of Africa is given.

Local methods of fishing are presented and a case is made against the introduction of non-indigenous clupeids into Lake Volta. The ecological status of Lake Volta clupeids is presented. There are also comments on the commercial aspects of the clupeid fishery.

Comment: A good introduction to the biology of Lake Volta clupeids.

Worthington, E.B., 1966.

Introductory Survey.

in: Man-made Lakes, Ed. R. H. Lowe-McConnell, Symp. Inst. Biol, No. 15, Academic Press, London, pp. 3-6.

Abstract: A general survey of man-made lakes (including Lake Volta) in Africa.

Comment: None.

Biswas, E. R. I., 1967a

Bacterial Ecology of Volta Lake at Ajena.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Rept. X 18, pp. 12.

Abstract: Observations of weekly bacterial counts throughout the water column of Volta Lake were made at Ajena from August 1964 to December 1965.

The results show that during the rainy season bacterial populations increase - the contrary being true in the dry months. The highest counts were obtained from the surface close to the bank, but the difference in population density between the surface and midwater was only small (1.68:1 ratio). This is very different from that reported in some temperate lakes (Lake Geneva 4000:1 and Lake Windermere 200:1). Lake Volta bacteria are dominated by vegetative forms (67%) followed by chromogenic (10%) and small numbers of coliform.

Comment: A valuable report on preliminary studies of bacteria in a tropical lake. Bacteria play a vital role in the breakdown of organic matter and the recycling of nutrients. Very little information on the bacteria of natural lakes in Africa is available.

Biswas, S., 1967b

Some Limnological Innovations.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Rept., X 19, pp. 7

Abstract: Descriptions of a water sampler, depth correcting gadget, plankton counting cell, substitute battery for pH meter, and lead acetate method for sulfide estimation.

Comment: None.

Lawson, G. W., 1967.

"Sudd" Formation on the Volta Lake.

Bull. de l' I. F. A. N., Tome XXIX, Ser. A., No. 1, pp. 4.

Abstract: A short report on the formation of "sudd" on Lake Volta. Although species of Eichhornia crassipes and Salvinia auriculata exist in the Volta basin, they have not become "weeds."

When the dam was closed in May 1964, mats of Pistia stratiotes and islands of "sudd" (Vossia cuspidata and others) appeared in the lake - particularly at Afram. At Ampem, a mat of Scirpus cubensis and other species appeared between crowns of drowned trees.

A development of subaquatic plants - Ceratophyllum and Utricularia - is also noted.

Comment: Aquatic weeds are very important for the fishes in any tropical lake. An explosive development of weeds leads to loss of nutrients, oxygen, etc.; however, a limited development leads to the formation of rich periphyton and "periphytic benthos" on which many fishes feed.

Petr, T., 1967a

Fish Population Changes in the Volta Lake in Ghana during its First Sixteen Months

Hydrobiologia, Vol. 30, No. 2, pp. 193-220.

The following changes in fish fauna of the newly-formed Lake Volta were observed between 1965 and 1966.

1. Family: Characidae

In Rivers Black Volta as well as the Niger, characid fishes are recorded in low numbers in the dry season and high numbers in the wet.

In 1965 a great increase of characids was recorded at Akosombo and Kpandu in the dry season (more than 1/2 the total catch of characids was recorded). But in the following dry season, the catch of characids at both stations went down while remaining high at Kete Krachi. Most of the changes recorded were due to Alestes spp (particularly Alestes nurse), while the predatory Hepsetus and Hydrocynus remained relatively unchanged. The entomophagous Alestes spp were feeding mostly on terrestrial insects, but showed some changes in diet; whenever the pelagic fishes e.g. the clupeids became abundant, Alestes fed on these. Similarly, whenever the terrestrial insects were low, these fishes fed on aquatic insects or even plankton.

2. Family: Cichlidae

In Black Volta River the catch of the cichlids never increased above 0.32% of the total catch. Although in the initial phase of lacustrinisation they remained low. The following August, 1965, cichlid catches increased drastically at Akosombo, Kpandu, and Ampem; at several stations they now represent over 65% of the total catch. The most abundant cichlids are Tilapia galilaea and Tilapia nilotica; both of these species are algae or detritus feeders. The predatory Hemichromis spp and Pelmatochromis have also shown increase; Pelmatochromis is insectivorous while Hemichromis spp feed on insects and small fishes.

3. Family: Mormyridae

The mormyrids are the commonest and most abundant species in Black Volta River in the dry season. During high water, they carry out breeding migrations. The formation of the lake led to the disappearance of the mormyrids in most of the lake. Since the biomass of insects in the lake has increased manyfold, food does not seem to be a limiting factor. The mormyrids, however, prefer well-oxygenated waters and riverine rocky habitats for breeding. In the initial stages of its formation, Lake Volta became largely anoxic and the rocky habitats were drowned. This may account for the decline of the mormyrids.

4. Family: Cyprinidae

In the riverine habitat, the abundance of the cyprinids varies a great deal in the

4. cont'd. - wet and dry season because they migrate at highwater. In Lake Volta, they increased at the beginning, but in the subsequent wet season they declined. It is possible that this "decline" was due to a migratory movement. Labeo spp are the commonest cyprinids in the lake - particularly in the south. They feed on detritus, aufwuchs and mud.

5. Family: Citharinidae

The citharinids are not very common in the river or the lake except Distichodus rostratus and Citharinus distichoides have increased somewhat at some stations in the lake. Distichodus feeds on macrophytes - although when phytoplankton blooms it may feed on this; the increase of Distichodus is probably due to the increase of phytoplankton as well as that of subaquatic macrophytes e.g. Ceratophyllum. Citharinus spp feed on mud, plant detritus and aufwuchs.

6. Family: Centropomidae

Lates niloticus has increased much in the lake - presumably due to the creation of weed beds which it uses for reproduction as well as the increase of prey species of fish (e.g. cichlids, clupeids, and schilbeids).

7. Family: Mochocidae

A number of specialised species of *Synodontis* live in Lake Volta but their identification is difficult. As a whole the mochocids have declined in the south of the lake while maintaining their initial numbers in the north. *Synodontis membranaceous* feeds on benthic algae and bottom mud, but other species feed on chironomid larvae, etc.

8. Family: Schilbeidae

Three schilbeids, *Schilbe mystus*, *Eutropius niloticus*, and *Physailia pellucida* are found in the lake. Although *Schilbe mystus* has increased at Kete Krachi and *Physailia pellucida* has become quite abundant in the south, the schilbeids have not succeeded remarkably in the lake. *Schibe* and *Eutropius* feed on insects and fish, but the pelagic *Physailia* feeds on chironomid larvae. It undergoes vertical migration diurnally - apparently responding to the timing of emergence of the chironomids.

9. Family: Bagridae

The abundance of the bagrids has not changed much in the lake except in the south where *Chrysichthys* replaced *Alestes nurse* as the most abundant species at Akosombo in 1965. *Chrysichthys* is insectivorous while *Bagrus* spp feed on insects and fish.

10. Family: Clariidae

The clariids of Lake Volta include *Clarias* spp and *Heterobranchus* spp; *Clarias* spp occur all year (particularly *Clarias angullaris* which is omnivorous).

Other fish families of Volta River show the following tendencies in the lake: Malapturidae (not recorded in the lake); Osteoglossidae (*Heterotis niloticus* has increased in the lake); Anabantidae (*Ctenopoma* has increased in the lake); Ophiocephalidae occasional specimens recorded) while Gymnarchidae, Tetraodonlidae and Polypteridae remain rare in the lake.

Food and feeding regimes of fishes

1. PLANKTON

The commonest plankton spp include *Peridinium*, *Volvox*, *Melosira*, *Fragillaria* and *Microcystis*

Obligatory planktivores: *Tilapia galilaea*, *Tilapia nilotica*
Facultative Planktivores: *Tilapia zillii*, *Tilapia guineensis* (?), *Distichodus*, *Citharinus*, *Labeo*, *Alestes*, *Synodontis* and *Clarias*.

Petr, T., 1967, cont'd.

2. MACROPHYTES AND AUFWUCHS

The commonest plants eaten are Ceratophyllum, other aquatic weeds, and the periphyton (aufwuchs) growing on them.

Obligatory macrophytophagous species: Tilapia zillii, Tilapia guineensis, Distichodus rostratus and Distichodus engycephalus

Facultative macrophytophagous species: Ctenopoma, Chrysichthys and Synodontis spp.

3. MUDSUCKERS

Labeo senegalensis, Labeo coubie, Citharinus citharus, Tilapia zillii, Tilapia guineensis, Distichodus, Clarias and Synodontis spp all use bottom mud as food periodically.

4. INVERTEBRATES

Terrestrial and aquatic insects, zooplankton.

Ctenopoma, Auchenoglanis, Hemichromis, Chrysichthys, Synodontis, Alestes, Polypterus, Protopterus, etc.

5. PISCIVOROUS

Obligatory piscivores: Lates, Hydrocynus, Hepsetus

Facultative piscivores: Clarias, Hemichromis, Eutropius, Alestes, Schilbe, Ophiocephalus, Bagrus, Polypterus

6. OMNIVOROUS

Heterotis, Clarias spp

Conclusion: The majority of abundant species of fishes in River Volta were benthic invertebrate feeders. In the dry season the mormyrids were the most common species while in the wet season Alestes and some schilbeids became dominant. Following the creation of the lake the mormyrids have nearly disappeared while a number of herbivorous (planktivorous as well as macrophytophagous) species have become very abundant. This is particularly reflected in the dramatic rise of the herbivorous cichlids - particularly in the south. A number of invertebrate feeders have also increased by utilising the rich invertebrate fauna associated with the periphyton which developed on the submerged trees.

Lake Volta is compared and contrasted with Lake Kariba as follows:

(1) In both lakes plankton-feeding species have increased.

(2) Whereas Lake Kariba is dominated by planktivores, Volta is dominated by insectivores.

(3) Mudsuckers increased in Kariba while they have decreased in Volta.

(4) The shallowness and periodic overturn of Volta will favor the the development of a benthic as well as shore invertebrates. Fishes feeding on them will remain important.

Finally, reasons for the disappearance of the mormyrids in Volta are discussed.

Petr, T., 1967b

International Symposium on Man-made Lakes (21-24 November 1966 in Accra, Ghana)

Hydrobiologia, Vol. 30, No. 3/4, pp. 600-604.

Abstract: A summary of papers delivered at the "Accra Symposium" on man-made lakes; three papers on Lake Volta fishes are mentioned. It is noted that since the formation of the lake, the cichlid and clupeid fishes are increasing while the previously common mormyrids are declining.

Comment: None.

Petr, T., 1967c

Food Preferences of the Commercial Fishes of the Volta Lake.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Rept. X 22, pp. 7

Abstract: Describes the food of the 22 most important commercial fishes of Lake Volta in the early phase of its formation (Nov 1964 - 1966). The food sources are as follows:

1. Macrophytes.
2. Phytoplankton
3. Epiphytic Aufwuchs.
4. Zooplankton.
5. Organic bottom mud.
6. Aquatic insects.
7. Terrestrial insects.
8. Fish (and fish scales).

Prior to the formation of the lake, the majority of riverine fishes performed "lateral migration" into the surrounding innundated plains. These plains provided breeding sites for the adults and also food and protection for the alevins. The flooded Volta basin created a permanent flood-plain and unlike the situation in the rivers, the fishes do not have to return to the river following the floods. Because vast areas

Petr, T., 1967 - contd.

of the lake-bed were not cleared of vegetation, the lake became highly anoxic - particularly close to the bottom. This discouraged the formation of benthos, but the drowned trees provided much surface for the development of epiphytic diatoms and algae (periphyton). The trees and the periphyton on them led to the development of a very rich invertebrate fauna. Fishes readily shifted their feeding from the benthos to the insects on the drowned trees.

Schilbe mystus and Eutropius niloticus now feed on Povilla adusta (Ephemeroptera) which has developed on the tree surfaces all over the lake. The cichlids have greatly benefited by the formation of the lake. The macrophytophagous and the microphytophagous species of Tilapia have both increased just as the predominantly insectivorous Pelmatochromis and Hemichromis. The success of several species of pelagic fishes, e.g., Pelonulla and Physailia will favor the piscivorous Lates and also Hemichromis. Heterotis niloticus is increasing very rapidly - this is due to the increase of zooplankton in the lake.

Comment: None.

Reynolds, J. D., 1967.

Notes on Juveniles of Commercial Fish Attracted to Light on the Volta Lake, 1966-1967.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Rept. X 21, pp. 15.

Abstract: An analysis of young pelagic fish caught by "light fishing" method at night; the fishes examined only include the commercially important species. In the riverine northern section of the lake about 22 species (10% of these are pelagic) are recorded while in the south, all of the 5 common species are pelagic. This work does not concern the small, unexploited pelagic species Pellonula afzeliusi, Physailia pellucid and Cyanothrissa mento; for some of the fishes examined "condition factor" (K) and "fecundity coefficient" (f) are calculated.

1. Family: Centropomidae
   Lates niloticus (Linné, 1762): This species has established a breeding population in the lake; this has been probably facilitated by the development of areas of subaquatic vegetation on the shores. The catch has increased from 1% or less in the river to about 10% in the southern part of the lake. The breeding season in the lake is probably from December to January, and it is possible that the season has been extended in the stable lacustrine environment.

Reynolds, J.D., 1967, cont'd.

2. Family: Cichlidae
   In Black Volta River, cichlids represent only 1% of the total catch of fish, but in the lake, they have increased up to 75% of the total catch in some stations. In this survey very few young specimens of cichlids were caught; they include: Tilapia zillii (Gervais, 1848), Tilapia galilaea (Artedi, 1757), Hemichromis fasciatus (Peters, 1857), and Hemichromis bimaculatus (Gill, 1862). Of these, Tilapia galilaea was found to be the most abundant species at some stations. The stomach contents of Hemichromis bimaculatus include insect larvae and zooplankton.

3. Family: Schilbeidae
   Schilbe mystus (Linné, 1762). This was caught only at Yeji. Although it can breed in the lake, it lives only in the shallow water close to the shores. It spawns in high water during June and July. Its food includes Povilla adusta and other insect larvae as well as fishes.

   Eutropius nilotricus (Ruppell, 1829). It was caught at most stations, but seems to be most prevalent in the northwest. In the riverine habitat, it lives deep in the water and does not migrate into the flood-plain to breed; it spawns in June and July. In the lake its breeding season is more drawn out and it also grows faster. Stomach contents include aufwuchs, insect larvae and beetles.

4. Family: Bagridae
Chrysichthys auratus (Pellegrin, 1909). In the river it migrates and reproduces during the rainy season. Although it is uncommon in the lake, it does reproduce there and most probably has an extended breeding season.

Chrysichthys nigrodigitatus (Lecépède, 1803). This is more common than the previous species and has been caught at most stations. It breeds between June and October, i.e., during and after the rainy season. Its food includes benthic insects, terrestrial insects, zooplankton and fish.

Bagrus bayad (Forskål, 1775). Only one specimen recorded at Yeji; it was probably spawned in June, at the beginning of the flood season.

5. Family: Mochokidae
Synodontis eupterus (Boulenger, 1901) Only one specimen was recorded at Yeji; it probably reproduces during the high water season.

Synodontis gambiensis (Günther, 1864). This is the commonest species of this genus in commercial catch - chiefly in northwestern part of the lake. In the river it spawns just prior to the floods, but in the lake it spawns during the floods (July to August).

6. Family: Characidae
All riverine species of Alestes migrate into the flood plain during the flood to breed and utilize a new and abundant source of food. When flood waters recede, they return into the main stream.

Alestes dentex sethente (Curvier et Valenciennes, 1849). This species is less common than Alestes baremose in the Volta basin. It probably spawns following the flood.

Alestes baremose (Joannis, 1835). This species was frequently caught at various stations. In the river it breeds at the end of the flood season only, but in the lake it has several successive spawnings. Stomach contents revealed insects, grass seeds, blue-green algae and zooplankton.

Alestes macrolepidotus (Cuvier and Valencinnes, 1869). Although it is common in the lake, its juveniles were not caught. It lives and feeds in the marginal shallows. In the lake, it probably enjoys an extended reproductive period.

Alestes nurse (Ruppell, 1832). In the rivers, A. nurse migrates up the river at the end of flood season. In the lake, two successive spawnings have been recorded; the spawnings occurred at the start and middle of high water. Food consists of terrestrial and aquatic larvae and cassava scrapings.

Reynolds, J.D., 1967, cont'd.

Alestes leuciscus (Günther, 1867). In Lake Volta this species is only common in the riverine northwestern arm and reproduces at high water. Food consists of aquatic and terrestrial insects, cassava and grass seeds.

Alestes imberi (Peters, 1852). A small number of this species have been recorded in the lake, but very little is known about its ecology.

7. Family: Citharinidae
Distichodus engycephalus (Günther, 1864). It is only common in the riverine section of the lake. Its food consists of seeds, pieces of wood, detritus and aufwuchs.

Distichodus rostratus (Günther, 1864). In the river it reproduces at the start of the flood and the young later migrate into the flood plain. In the lake it frequents the shallow flooded areas.

8. Family: Cyprinidae
Labeo senegalensis (Cuvier and Valenciennes, 1842). In the river this species frequents rocky habitats; it is very rare in the lake - presumably because its habitat has changed in the lacustrine environment. But there is evidence suggesting successive spawnings in the lake.

Reynolds, J.D., cont'd.

Labeo coubie (Ruppell, 1832). This species is more common in the lake than the last one. In the rivers it reproduces over an extended period at high water, but in Lake Volta it probably breeds at the end of the rainy season. Food consists of aufwuchs and zooplankton.

The northern riverine section of Lake Volta is dominated by a number of migratory species (Alestes spp, Labeo spp, etc.). Any attempts to initiate exploitation of pelagic fishes in this region will adversely affect the entire fishery of the region.

Wuddah, A. A., 1967.

A Bibliography of <u>Tilapia</u> (1930 - 1967).

<u>Volta Basin Res. Proj</u>. (Univ. of Ghana) Tech. Rept. X 20, pp. 9.

<u>Comment</u>: An incomplete but useful bibliography of the genus <u>Tilapia</u> (Pisces, Cichlidae).

Thys van den Audenaerde's "<u>Annotated Bibliography of Tilapia</u>" (<u>Mus. Roy. de l' Afr. Cent</u>. Docum. Zool. No. 14, 1968. Tervuren, Belgium, pp. 406), is at present the most complete annotated work on <u>Tilapia</u>.

Attionu, R. H., 1968.

Some Limnological Investigations in the Ajena Bay (Volta Lake, Ghana), July 1965 - April 1966.

<u>Volta Basin Res. Proj</u>. (Univ. of Ghana) Tech. Rept., X 26, pp. 8

<u>Abstract</u>: During the rainy season (April - July) there is a rise in the level of the lake due to increased inflow from the rivers; the rise occurs towards the end of the rains (July). Temperature of the water from July to September is low (26° - 27° C.), but it rises to 30°C. in October and November. It drops again between December and February followed by a rise in April. In July - September 1965 and December - March 1966, the temperature difference between top and bottom is only 0.4°C but in November it is 3.6°C. The July - September low temperature is due to the cool moist southerly air that blows over the lake; the December - March low is due to the northerly dry "harmattan" winds which cool the lake surface by evaporation. The "cool" periods are characterised by maximum mixing of the water up to 5 m. deep. Because the bay is sheltered, complete mixing does not occur; complete mixing does occur in the main channel. There is seasonal variation in the transparency of the water - presumably controlled by the amount of iron in the water. The pH of the water does not vary much because of the high buffering effect of the carbonate - bicarbonate content. The water has adequate silicate and phosphate for the production of phytoplankton. High ammonia concentration was recorded during phytoplankton development. No correlation between oxygen concentration and phytoplankton maxima was found.
Annual flooding is very important in the productivity of the lake.

Biswas, S., 1968a

Hydrobiology of the Volta River and some of its tributaries before the formation of the Volta Lake.

Ghana Jour. Sci., Vol. 8, No. 384, pp. 152-166.

Abstract: Hydrobiological conditions in Volta prior to and following damming are presented (Sept. 1963 - 1964).

From Sept. 1963 - Jan. 1964, Volta River was very poor in phytoplankton. The latter began to appear in Mar. 1964 and reached a peak in May. Melosira and Synedra showed earlier peaks, followed by Anabaena.

Upper Volta is richer in phytoplankton than the lower basin. Peaks of Arthrospira appeared at Yeji and a few other northern stations. Reasons for this peculiar abundance are unknown. Tributaries of the Volta are poor in phytoplankton and are dominated by diatoms.

Changes in phytoplankton density have caused the oxygen in the water to fluctuate.

The paper also discusses quantitative changes in nutrients during the period of investigation.

Biswas, S., 1968, cont'd.

Phytoplankton species discussed:

- Melosira granulata (Ehr) Ralfs
- Synedra acus Ktz.
- Anabaena aphanizomedoides Forti
- Peridinium africanum Lemm
- Cosmarium moniliforme (Turp) Ralfs
- Staurastrum paradoxum Meyen.
- Arthrospira tenuis Bruehl et Biswas
- Nitzschia sigmoidea (Nitasch) W. Sm.
- Phormidium tenue (Menegh) Gom.
- Pinnularia stauroptera (Grun) Rabh
- Nitzschia acicularis (Ktz) W. Sm.
- Ankistrodesmus falcatus (Corda) Ralfs

Biswas, E.R.I., 1968b

Some microbiological observations on the Volta Lake.

Ghana Jour. Sci., Vol. 9, No. 1, pp. 21-29.

Abstract: Since 1964 heterotrophic bacteria in the lake have been declining. In the same period there has been a shift in their distribution from the surface to the bottom. The influence of temperature and rainfall on the bacteria is not fully known yet. The bacteria consist of mainly chromogenic forms; coliforms remain low. Observations showed that bacteria increased following flooding in July 1965.

Freshwater Biology Abstracts, 1968

Ghana Jour. Sci., Vol. 8, No. 1 & 2, pp. 14-16.

Abstract: Very short abstracts of the biological work on Lake Volta. These abstracts are from reports presented at the 5th Biennial Conference of the Ghana Science Association (27th - 30th December, 1967).

Lawson, G. W., et. al., 1968

A Review of Hydrobiological Work by the Volta Basin Research Project, 1963-1968.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Rept., X 25, pp. 4

Abstract: The temperature of water in Lake Volta varies between 26° - 31° C. annually. The coolest months are July - August and January - February. In the north, temperature is higher than the south. Oxygen concentration also shows seasonal trends - it is minimum during the floods (April - July) and during the "harmattan" period (September - October) when mixing is maximum. Highest oxygen is recorded in the epilimnion during maximum stratification (in May and November). During this period the metalimnion is at about 20m. Plankton and fishes do not generally occur below the metalimnion because of the lack of oxygen. Temporary stratification up to 5m deep forms and breaks down diurnally.

Microbiology
The bacteria count is highest in the epilimnion all year round except in September. In 1965, highest count of bacteria was associated with the rainy/flood season. Bacteria are mainly heterotrophic.

Primary productivity

Phytoplankton: Prior to the formation of the lake peaks of Anabaena occurred; however, since damming Synedra and other species have shown

Lawson, G. W., cont'd.

great periodic blooms. Phytoplankton is maximum during stratification and diminishes in the "mixing" seasons. The productive shallow water is dominated by Myxophycaea while diatoms dominate the deeper water.

Macrophytes: The most significant of these are Pistia and Ceratophyllum. These act as substrate for the rich aquatic invertebrate fauna that has developed in the lake. Ceratophyllum is also the cause of the great increase of periphyton in the lake. Pistia and Certophyllum increase following the flood and these changes are also reflected by the invertebrate fauna.

Aufwuchs: This includes periphyton as well as the invertebrate fauna associated with it. The increase of periphyton is mainly due to the presence of submerged trees in the lake. These have acted as a substrate for the growth of periphyton as well as the success of wood-boring insect-larvae, e.g. Povilla adusta.

Secondary productivity

Zooplankton: Of the planktonic crustacea, the copepods dominate the cladocerans. By 1967, 90% of the zooplankton was composed of Rotifera; 10% is formed by the crustaceans and ciliates.

Lawsón, G. W., cont'd.

Benthos: Between 1964-1966, the benthic fauna was restricted to the surface oxygenated zones of the lake only. But as the lake gets more oxygenated, it is expected to penetrate deeper. Much of the benthos is composed of chironomid larvae.

Epiphytic "benthos:" The success of Povilla adusta on tree surfaces in the lake has been mentioned. At present the biomass of Povilla far outstrips that of the benthic organisms, e.g. chironomid larvae.

While some families of riverine fishes have disappeared from the lake, the characids now dominate the lake in the north (over 51% of the total catch) while the cichlids dominate the south (over 65% of the total catch). Some pelagic clupeids and characids have also increased in the south.

Petr, T., 1968a

Distribution, Abundance and Food of Commercial Fish in the Black Volta and the Volta Man-made Lake in Ghana during its First Period of Filling (1964-1966)., I Mormyridae.

Hydrobiologia, Vol. 32., No. 3-4, pp. 417-448.

Abstract: A detailed study of the common mormyrid species of River Volta at Bui Gorge Area. Information includes feeding and breeding habits. The mormyrids are dominant fishes in the river, but have disappeared from the lake. The report concludes that food cannot be the limiting factor for the mormyrids in the lake since a rich insect fauna has developed in the lake. Two possible reasons for their disappearance could be:

(1) the anoxia of much of Lake Volta in its initial stage.

(2) the disappearance of riverine rocky habitats which the mormyrids use for breeding.

Valuable data on the ecology of the following riverine mormyrids is given:

(1) Hyperopisus bebe Lacèpède, 1803.

(2) Mormyrus rume C & V., 1846.

Petr., T., 1968, cont'd.,

(3) *Mormyrus hasselquisti*, C & V, 1846.
(4) *Mormyrus macrophthalmus*, Gunther, 1866.
(5) *Mormyrus delicionsus*, Leach, 1818.
(6) *Gnathonemus tamandau*, Gunther, 1862.
(7) *Gnathonemus senegalensis*, Steindachner, 1870.
(8) *Gnathonemus pictus* ?
(9) *Gnathonemus cyprinoides*, Linné, 1784.
(10) *Petrocephalus bane*, Lecépéde, 1803.

Petr, T., 1968b

Population Changes in Aquatic Invertebrates Living on Two Water Plants in a Tropical Man-made Lake.

Hydrobiologia, Vol. 32, No. 3-4, pp. 449-485.

Abstract: Between February and November 1965 two aquatic macrophytes *Pistia stratiotes* L. (floating) and *Ceratophyllum demersum* L. (submerged) have increased substantially in the littoral of Lake Volta. Many invertebrates use these plants as substrate and as a source of food (they either feed on the plant itself or on the periphyton); the increase of *Pistia* and *Ceratophyllum* has has led to a dramatic increase of such invertebrates (several of these are important vectors of human parasites).

This investigation was carried out in the Gorge Region (Akosombo).

I. *Ceratophyllum demersum*

1. *Inshore Region*. Rising water-level, breakdown of stratification and greater transparency of water following June 1965 led to a rapid increase of this plant which in July formed a strip 50-200m wide which was visible on the surface. Between August and October much wave action uprooted the plant and by November it was found at a depth of 2 m.

Chironomid larvae (with Chironomus fractilobus Kieffer in overwhelming dominance), odonata and zygoptera nymphs (particularly Pseudagrion sp), crustacea and oligochaetes were recorded from the plant. The invertebrate fauna shows a resting phase (February - May), an expanding phase (June - August) and another resting phase (October -). During the flood (June - July) while the plant increased, the fauna was low but by August all invertebrates were increasing.

2. Offshore Region. Ceratophyllum appeared in offshore water between February - April, and then disappeared. The invertebrate fauna on the offshore plants was much lower than recorded on the inshore plants. The offshore fauna was dominated by ephemeroptera nymphs and oligochaetes - the chironomids were present in lower numbers.

   The lower invertebrate fauna here is due to the instability of the plant (due to waves) and heavier fish predation.

II. Pistia stratiotes

This floating weed was restricted to a strip 0.5 - 2 m. wide in February - June. But in July it spread rapidly to form a mat 200 - 300 m. long and 150 m. wide. In August wind-action broke up the mat which disappeared in December. Between February - May, the abundance of

invertebrates was low and dominated by dipteran larvae and odonata nymphs. During the flood (July), the fauna decreased but in August all invertebrates were increasing. By December, the invertebrates disappeared along with the plant.

Taxonomic Groups of Invertebrates associated with Ceratophyllum and Pistia

1. ANNELIDA

   (a) Oligochaeta

   Naididae: The most frequent annelid of Lake Volta - found on both plants (prefers Pistia roots).

   on Cerato. (Allonais paraguayensis ghanensis Hrabě
(Dero digitata. Michaelsen
(Nais variabilis Piguet

   on Pistia (Aulophorus ghanensis Hrabě
(Branchiodrillus cleistochaeta Dahl.

   The population of Naididae increases from February to April, but by June very few remain. Following the flood (July - August) the population is highest but by October-November it is curtailed by predation.

(b) Enchytreidae

Only two specimens.

(c) Hirudinea

Leeches increase on inshore Ceratophyllum following floods.

Batracobdella nilotica Johnels 67.9%
Batrocobdella tricarinata Bl. 14.3%
Helobdella conifera Moore 17.8%

2. MOLLUSCA

Gastropoda: Found on both plants. Highest numbers prior to flooding. Silted water probably destroys their eggs. The specimens found on these plants are mostly young.

Bulinus forskali Ehrenberg
Anisus coretus Blainville
Ferrisia sp

3. ARTHROPODA

(a) Crustacea

(i) Cladocera: Only one species was found on both plants: Ilyocryptus sordidus Liévin

(ii) Copepoda: unidentified copepods were found on Pistia.

(iii) Ostracoda: The following species were recorded. They occur on both plants but predominantly on Pistia. Disappears when oxygen is low.

Cypricercus sp 60.9%
Chrissia sp A 20.3%
Acocypris sp 7.3%
Strandesia sp 3.5%
Stenocypris sp 1.6%
Chrissia sp B 0.6%
Cyprettinid sp 0.1%

(iv) Conchostraca: Only one species was recorded from both weeds. In July it is absent from *Ceratophyllum*.

Cyclestheria hislopi Baird.

(b) Arachnida

Hydracarina: Their abundance on *Pistia* is three thimes that on *Ceratophyllum*.

(c) Insecta

(i) Ephemeroptera: One species - *Cloeon smaeleni* found on both weeds. It shows violent oscillations during the year.

Cloeon smaeleni Gillies

(ii) Odonata

(A) Anisoptera: These occur predominantly on *Pistia*.

Orthetrum sp
Acisoma sp
Trithemis sp

Petr, T., 1968, cont'd.

Thylomis tillarga Fabricius
Brachythemis leucosticta Burm.

(B) Zygoptera: The females lay eggs in plant tissue.

Pseudagrion sp (90%)
Enallagma sp
Ischnura senegalensis Ramb.

(iii) Hemiptera

(A) Corixidae: non-predatory.

Micronecta christiniana Lausb.
Micronecta scutellaris scutellaris Stål.
Micronecta sp

(B) Belostomatidae: predatory.

Diplonychus grassei Poiss.
Diplonychus cf. *nepoides* Fabr.

(C) Pleidae: predatory; more abundant on *Pistia* than *Ceratophyllum*.

Plea pullula Stål

(D) Nepidae: predatory.

Ranatra parvipes vicina

(iv) Coleoptera

Laccophilus 65%)
Synchortus 25%) Ceratophyllum
a species of Hydrophilidae 10%)

Synchortus 87%)
Hydrovatus 8%)
Hydrocanthus 3%) Pistia
Canthydrus 1%)
Hydrobiinae 1%)

(v) Diptera

(A) Culicinae: Peak populations in February - March; June - July; November.

On Pistia:
Aedomyia africana N.L. 49.5%
Ficalbia splendens Theobald 37.4%
Mansonia africana Theobald 8.7%
Mansonia uniformis Theobald 2.6%
Ficalbia pallida Edwards 0.7%
Culex poicilipes Theobald 0.7%
Anopheles squamosus Theobald 0.2%
Anopheles coustani Lav. 0.2%

On Ceratophyllum:
Aedomyia africana
Culex poicilipes

(B) Chironomidae: Five times more abundant on Ceratophyllum than Pistia.

Chironomus fractilobus Kieffer 90%
Chironomus imicola Kieffer
Chironomus formosipennis Kieffer
Chironomus calipterus Kieffer

Chironomus tranvaalensis Kieffer
Chironomus pulcher Weid.
Cryptochironomus diceras Kieffer
Dicrotendipes chloronotus Kieffer
Dicrotendipes multispinosus
Paradentipes sp
Polypedilum sp
Ablabesmyia nilotica Kieffer

(C) Ceratopogonidae

Bezzia pistiae I & M is the commonest ceratopogonid. Mainly found on Pistia.

The aquatic weeds Ceratophyllum and Pistia are utilised as food by several Lake Volta fishes; the weeds are most important because they support a rich epiphytic fauna which is utilised by many invertebrates. The latter are also utilised as food by many fishes. A few invertebrates of Lake Volta are medically important.

The invertebrate fauna of each weed is distinct and shows a cyclic behavior just as the weed (particularly ceratophyllum) itself does.

Petr, T., 1968c

Problems of Assessment of Periphyton Production in a Tropical Man-made Lake.

Rept. Reg. Meeting of Hydrobiol. in Tropical Africa. Makerere Univ. College, Kampala, Uganda (20-28 May, 1968), UNESCO Reg. Cent. for Sci. and Tech. for Africa, pp. 144-145.

Abstract: In Lake Volta the initial deoxygenation of the hypolimnion has prevented the formation of much benthos. The drowned trees along its shoreline support a very rich periphyton which in turn allows the development of a rich invertebrate community associated with it. The most successful invertebrate on the submerged vegetation is Povilla adusta (Ephemeroptera) which is being increasingly utilised by insectivorous fishes. Of all the invertebrates living in the lake Povilla has the highest biomass. Some of the fishes now actively utilising this source of food are: Alestes, Eutropius, Pellonula, Physailia.

Petr, T., 1968d

The establishment of lacustrine fish population in the Volta lake in Ghana during 1964 - 1966.

Bull. de l' I.F.A.N. Tome XXX, Sér. A., No. 1, pp. 257-269.

Abstract: In the earlier phase of the formation of Lake Volta, a mass mortality of Chrysicthys occurred - presumably due to the deoxygenation of water following the development of an algal bloom. During this phase fish catches were dominated by Alestes, Chrysichthys, Hydrocynus, Lates, and Labeo. A few months following damming the schilbeid Physailia and the clupeid Microthrissa both appeared as pelagic species; these species were almost unknown in the river. By the end of the first year (May 1965), Alestes nurse was the most common species followed by Labeo, Distichodus and Lates. This was essentially the high season pattern of abundance in the river prior to damming. By May 1965 a radical change in the fish fauna was evident in the great increase of cichlids in the southern stations; by October 1965 the cichlids formed 3/4 of the total catch of Kpandu, Ampem, and Akosombo. The mormyrids which formed 68% of the total dry season catch in the river almost disappeared in the lake.

Petr, T., 1968, cont'd.

At the end of its first year, Lake Volta has a typically lacustrine fish fauna (dominated by the cichlids and clupeids) while north of Yeji the fauna was still riverine (dominated by the characids). During lacustrinisation, the herbivorous and insectivorous fishes have enjoyed great success. As the bottom water gets more oxygenated bottom feeders will also benefit. Similarly, the increase of pelagic characids and clupeids will help the predatory Lates and Hydrocynus. Perhaps the fastest growing species in the lake is Heterotis niloticus - a zooplankton feeder.

Proszynska, M., 1968.

Bibliography of Cladocera and Copepoda of Inland Waters.

Ghana Journ. Sci., Vol. 7, No. 1-2, pp. 37-49.

Abstract: A thorough bibliography of Cladocera and Copepoda of African fresh waters. Includes papers from 1845 - 1964.

Ram, J., 1968.

Eyes on the Volta Lake.

New Scient., Vol. 39, pp. 540-541.

Abstract: A very general note on the events in Lake Volta following damming.

Comment: The report is of no scientific value.

Reynolds, J. D., 1968.

A Bibliography of African Fresh-water Clupeids.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Rept. X 24, pp. 6

Comment: A thorough and very valuable bibliography of African fresh-water clupeids.

Adiase, M. K., 1969

A Preliminary Report on the Food of Fish in the Volta Lake.

in: Man-made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 235-237.

Abstract: An analysis of food habits of some Lake Volta fishes.

Comment: None.

Biswas, S., 1969a

The Volta Lake: some ecological observations on the phytoplankton.

Verh. Internat. Verein. Limnol., Vol. 17, pp. 259-272.

Abstract: Temperature: In June 1966, the epilimnion was at 31° C. and the hypolimnion 27°C. - 29°C. At Afram, Kpandu, Kete Krachi, the metalimnion was at 20m. Ajena did not have a well defined metalimnion; Yeji had the entire water column homothermal.

June - September 1966 and January - February 1967 were periods of greatest circulation in the lake. For the rest of the year the lake is stratified.

In September 1966, the metalimnion broke down; it reformed in April 1967.

Oxygen: In June 1966 dissolved oxygen increased 6% - 7% in daytime. At the time of greatest circulation oxygen reaches the bottom. During stratification there is no oxygen below 15m; the epilimnion has 80% - 90% saturation.

Phytoplankton: Plankton shows much variation from one station to the next. In July - August 1966, green algae were dominant in the lower part of the lake.

Biswas, S., 1969, cont'd.

green algae	(Scenedesmus acutus (Meyen) Chod. (Scenedesmus bijugus (Turp.) Ktz. (Scendesmus quadricaudus (Turp.) Breb.
diatoms	(Melosira granulata (Ehr) Ralfs (Nitzschia acicularis (Ktz) W. Sm. (Synedra acus Ktz.

Various species show different dominance periods in the different stations. Diatoms, however, are becoming increasingly important in the lake.

Biswas, S., 1969b

Thermal Changes in the Volta Lake at Ajena.

in: Man-made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 103-109.

Abstract: The report covers the early development of Lake Volta (1964-1966). During floods (June - August), the epilimnion shows a cooling trend which the hypolimnion warms up. Although mixing occurs, the water was never found to be homothermal - the epilimnion being generally warmer than the hypolimnion. Mixing also occurs in the harmattan season (January - March). For the rest of the year the lake is stratified - with peak temperature in October, November or preceding the flood. The metalimnion was found between 10-35 m. At Ajena there was a general decrease in oxygen following closure, but the situation has improved each year (oxygen concentration August 1964 = 19%; August 1965 = 31%; June 1966 = 100%). Much of the oxygen is found in the top 5 m. Even during mixing full oxygenation of the water column does not occur.

The lake neither stratifies fully nor does it mix completely.

Comment: None.

Denyoh, F.M.K., 1969

Changes in Fish Population and Gear Slectivity in the Volta Lake.

in: Man-made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 206-210.

Abstract: The nets show some specific size composition in their catches according to mesh size.

(a) 1 1/2" - 2" nets: Alestes nurse, Alestes dentex, Alestes macrolepidotus, Hydrocyon sp, Lates niloticus, Ctenopoma kingsleyae, Synodontis nigrita.

(b) 3" nets: Labeo senegalensis, L. coubie, Tilapia galilaea, T. zillii, T. nilotica. In deeper water Synodontes and Lates are caught.

(c) 4" nets: Clarias spp, Lates, Distichodus spp and Synodontis in deeper water.

(d) 5" nets: Clarias spp, Heterotis niloticus, Labeo spp.

Fishes are most available in the flood season (May - November); in the dry season (December - April) there are only a few.

Entz, B., 1969a

Limnological conditions in Volta Lake, the greatest man-made lake of Africa.

Nature and Resources (Bull. Int. Hydrol. Decade), UNESCO, Vol. V, No. 4, pp. 9-16.

Abstract: The Volta Dam at Akosombo was closed May, 1964 and the lake reached its maximum height in September, 1968. Due to its shallowness 80% of the total water mass is suitable for habitation by aquatic organisms (including fishes). The lake has a shoreline 5,300 km; the mean depth of the main arm is 18.9 m. while that of the tributary basins is 6.9 m.

Temperature and oxygen.

1964-1966 oxygen was found only in the top 5 m. or 10 m.; the lake was as a whole oxygen deficient. In this period very little change in oxygen quantity occurred.

1967-1969 oxygen in the water increased and seasonal variations became apparent. In the top 20 m. - 30 m. oxygen attained 50% - 100% saturation. The lake began to circulate periodically allowing oxygen to reach the bottom.

Entz, B., 1969, cont'd.

Observations suggest that the phytoplankton does not contribute significantly to the oxygen content of water. Wind action remains the key to oxygenation of water. A steady breeze of 4 m. - 5 m./sec. can oxygenate water quite rapidly. Rapid changes in the quantity of gas at various depths are characteristic. It is expected that with time the lake will become even more aerated than it is at present.

The temperature of the water varies between 27° C. - 31 ° C.; diurnal overturns occur in the shallow water zone.

Effect of Rainfall

A. Local Effect:

(1) drop in temperature.
(2) introduction of solids, colloidal and dissolved matter.
(3) increase in turbidity.

B. Regional Effect:

This results in the flooding of most rivers feeding into the lake. Nutrients are introduced into the lake and the main arm becomes turbid. Fish migration.

Entz, B., 1969, cont'd.

Division of Lake Volta

(1) Lower Basin (south of Kpandu)

Lacustrine section; S.D. reading = 200 - 240 cm

(2) Middle Basin (Kete Krachi to Kpandu)

November - June (dry season): Lacustrine.
July - October (wet season): Riverine.

(3) Upper Basin (north of Kete Krachi)

Semi-riverine conditions all year.

Chemistry.

Chemically Lake Volta is oligotrophic; sulfate and chloride ions are low in the water. The metalimnion is also the "chemocline." The epilimnion (pH = 7.5) is poorer in nutrients than the hypolimnion (pH = 6.7). The content of iron below the metalimnion is high - 1-30 mg/L; in the epilimnion it is 0 - 0.2 mg/L.

Entz, B., 1969b

Observations on the Limnochemical Conditions of the Volta Lake.

in: Man-made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 110-115.

Abstract: Using "Maucha diagrams" the chemical composition of Rivers Dayi and Volta, and the newly formed Lake Volta is compared. The Volta system waters are of the Ca-HCO_3 group of β-limno type while those of River Dayi belong to Ca-Na-HCO -Cl group of the α-limnohaline type.

In October 1966, there was very little difference in chemical composition of water from a given layer at various localities. However, HCO_3^-, CO_2, Ca^{++}, Fe^{++}, NH_3^- increase with depth while O_2, pH and temperature decrease. SO_4^- and NO_2-NH_3 were also recorded.

The water of Lake Volta is as a whole reductive.

Hall, J.B., E. Laing, M. Hossain and G. W. Lawson, 1969

Observations on Aquatic Weeds in the Volta Basin.

in: Man-made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 331-336.

Abstract: An account of the aquatic weeds of Lake Volta with a list of species found in various habitats and formations. Experiments on growth of *Pistia* and observations on "sudd" formation.

Comment: None.

Holm, L. G., L. W. Weldon, and R. D. Blackburn, 1969

Aquatic weeds.

Science, Vol. 166, pp. 699-709.

Abstract: Includes a note on the increase of the floating water weed - *Pistia stratiotes* - in Lake Volta.

Lawson, G.W., T. Petr, S. Biswas, E.R.I. Biswas, and J.D. Reynolds, 1969.

Hydrobiological work of the Volta Basin Research Project, 1963-1968.

Bull. de l'I.F.A.N., Tome XXXI Sér. A., No. 3, pp. 965-1003.

Abstract: A summary of hydrobiological work of the Volta Basin Research Project (University of Ghana) from 1963-1968.

Most of Lake Volta lies in the single rainfall Guinea Savanna zone; only its southern extremity (Afram arm) lies in the *Antiaris* - *Chlorophora* tropical forest.

Rainfall occurs between July - September; the floods occur towards the end of the season. From December - January, the lake is under the influence of the dry northerly "harmattan" winds. The rest of the year southwesterly winds dominate.

Limnology (Physical/Chemical)

(a) Short-term Changes. All important limnological changes can be related to the rainy season (June - September) and the dry "harmattan" season (December - January). With the approach of the rainy season, the temperature of the river (32° C.) and the lake (31° C.) rise to a maximum. Temperature is high again in November following an interim fall. In the cool period (September - October and January - March) water temperature drops to 27.2° C. - 27.8° C.

Lawson, G.W., et al, 1969, cont'd. 2

During the flood and "harmattan" seasons the lake experiences maximum turbulence and break-down of stratification. Ammonia and iron (Fe++) increase; the latter increases turbidity. Oxygen content of the water goes down but the lake is enriched by nutrients released from the hypolimnion. These effects are more marked in the flood than in the "harmattan" season.

Calcium, potassium and sulfide do not exhibit much seasonal variation; however, nitrate is highest between September - December.

(b) Long-term Changes. As the lake has matured, its water has become increasingly clear (Secchi Disc Readings 1965: 50 cm.; 1967: 400 cm.). Prior to flooding Volta River was supersaturated with oxygen (over 100% saturation); as soon as the dam was closed (May, 1964) there was a phenomenal rise of the gas which later dropped to below 100% saturation. In the earlier phase, the lake was devoid of oxygen below the epilimnion, but with maturation and increase in circulation, the gas is reaching deeper. Hydrogen sulfide has fallen - particularly since 1965. When the dam was closed the temperature of water fell to 27° C. and continued to fall in the hypolimnion, but by October 1964 it began to rise. Since 1965, the bottom temperature has stabilized around 27° C. Surface temperature fluctuates much more seasonally. During stratification the metalimnion is at 20 m. Alkalinity increased gradually until 1966, when it became stable but orthophosphate has fallen.

Microbiology

The micro-organisms (bacteria) show high densities on the surface and bottom, being low mid-water. Most belong to the Aerobacter group; no nitrifying agents are reported. Since 1967 the microfauna is on the decline. Almost 1/4 of the colonies are chromogenic (90% Gram negative rods). Spore forming bacteria show great fluctuation during a single year.

PRIMARY PRODUCTIVITY

(a) Phytoplankton.

The primary productivity varies in different parts of the lake; it is estimated between 0.8 - 5.2 gm. cm^3/24 hrs. (oxygen utilisation). The productivity of the littoral region is much higher than that of the deeper areas. The composition of phytoplankton has undergone long term fluctuations; such fluctuation is also evident during each year.

1965	Two maxima:	April:	Actinastrum
		Sept.:	Cryptomonas
1966	Three maxima:		
		March:	Peridinium
		July:	Peridinium
		Oct.:	Nitzschia
1967	Two maxima:	May:	Synedra
		Nov.:	Synedra

Phytoplankton is low during the flood and high between October - November; the rest of the year it remains at moderate or low concentration. Low temperature, light intensity and high turbidity of water discourage phytoplankton. In the flood much dilution of phytoplankton is evident. Superficially it seems that diatoms predominate in deeper water while Cyanophyceae are more common in shallow water.

(b) Phanerogamic Vegetation.

The non-aquatic trees which have been drowned support a rich periphyton. A number of aquatic invertebrates use these tree surfaces for burrowing and as a source of food. Of particular importance is the increase of *Povilla adusta* Navas which has become an important food of many fishes.

The flooding of Volta basin created a permanent inundated plain rich with grass cover and debris. The plain is used for reproduction as well as a source of vegetative food by macrophytophagous fishes, e.g. Tilapia zillii, Alestes macrolepidotus, etc.

The lake will have an annual draw-down of 1.5m which will annually expose 200-400 sq. miles of the bottom. Periodic drying will be beneficial for the fishes.

Other significant plants include Vossia cuspida, Najas spp, Ceratophyllum demersum and Pistia stratictes. The latter two are very important habitats of invertebrates. Several of these use them as a source of food (e.g. pyralidids). Pistia attains a dry weight of 500 g/m^2. The aquatic macrophytes increase following the flood and then subside later in the year.

Aufwuchs has increased greatly in the epilimnion, but is used by only a few species of fish. But it supports a large invertebrate fauna which maintains much of the lake's fish production.

SECONDARY PRODUCTIVITY

(a) Zooplankton

When the dam was closed crustacean zooplankton was found throughout the water column. From July 1964 they have exhibited periodic appearance only. The populations do not seem to develop in situ, but come from the north.

1965 - 1966. Copepods (Cyclops, Diaptomus) were most numerous at all depths; cladocerans (Diaphanosoma, Ceriodaphnia, Bosmina, Moina, Bosminopsis) are fewer and restricted to 5-15 m. depth.

1967. At Ajena and Afram, the zooplankton consists of 90% Rotifera and 10% Crustacea and Protozoa.
Rotifers include: Anuraeopsis, Polyartha, Trichocera and Keratella.

(b) Invertebrates associated with Pistia and Ceratophyllum.

Ceratophyllum: utilised by zygopterans, chironomids and laccophilus bettles; oligochaetes.
Biomass of invertebrates: 76.75 gr/kg. (inshore).

Pistia: utilised by anisopteran nymphs, culicine larvae, coleopterans, etc.
Biomass of invertebrates:
(i) on leaves: 57.50 gr/kg.
(ii) on roots: 107.27 gr/kg.

(c) Benthos

In 1964-1966 benthic fauna was limited to the epilimnion (3 m. - 7 m.). Since 1967 with better oxygenation of the deeper water, they have extended their distribution down to 10 m. In 1966-1968, the benthic fauna consisted of chironomids 58.96% and Povilla 30.17%. As the lake has stabilised, the benthos is beginning to show a vertical migration seasonally - it is deeper following mixing of water and in shallow water during stratification.

(d) Fishes

The fishes of River Volta were mostly bottom-living, insect-feeding species. But the formation of the lake has favored pelagic species (*Pellonula afzeliusi*, *Physailia pellucida*, etc.). The mormyrids - which were very significant in the river in the dry season - have become very rare in the lake. The fishery picture of Lake Volta is as follows:

(i) Northern (riverine) Basin

Characidae 51% of total catch.

(ii) Southern (lacustrine) Basin

Cichlidae 81% of total catch.

All of Lake Volta fishes can be placed in the following trophic groups:

(1)	Macrophytophagous	18.9%
(2)	Insectivorous (aquatic)	18.3%
(3)	Piscivorous	13.1%
(4)	Detritophagous	13.1%
(5)	Insectivorous (terrestrial)	11.3%
(6)	Planktivorous	9.2%
(7)	Aufwuchs	2.7%
(8)	Zooplankton	1.4%

Finally the report discusses some changes in River Volta below the dam.

Comment: None.

Lelek, A. and A.A. Wuddah, 1969

A Note on the Occurrence and Length Frequency Distribution of Tilapia Species Caught in Gill Nets in Volta Lake.

in: Man-Made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 186-189.

Abstract: Using gill nets of various mesh size, the following data on Tilapia spp catch are recorded:

Tilapia galilaea	55.9%
Tilapia nilotica	23.4%
Tilapia melanopleura	20.7%
Tilapia zillii	----

Comment: None.

Obeng, L. E., 1969.

The Invertebrate Fauna of Aquatic Plants of the Volta Lake in Relation to the Spread of Helminth Parasites.

in: Man-made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 320-325.

Abstract: Gives a list of invertebrates associated with the aquatic weeds Pistia and Ceratophyllum.

Comment: None.

Petr, T., 1969a

Fish Population Changes in the Volta Lake Over the Period January 1965 - September 1966.

in: Man-made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 220-234.

Abstract: No fish-fauna surveys were carried out in Volta River prior to damming. This report summarises changes in the fish-fauna of Volta Lake during filling and compares the fauna with that found in Black Volta River at Bui Gorge upstream.

Inundation of the Volta basin led to the near disappearance of the mormyrids - possibly due to the elimination of rocky spawning sites. Some characid species e.g. Alestes performed irreversible migrations and have declined in the lake. However, the cichlids have increased enormously at most stations. Increases have also been noted in Lates, Hydrocyon, Heosetus, Cyanothrissa and Pellonula. In 1965-1966 as Alestes became rare at Akosombo, Chrysichthys increased.

Comment: None.

Petr, T., 1969b

Regional Meeting of Hydrobiologists of Tropical Africa (20-24 May, 1968 in Kampala, Uganda).

Hydrobiologia, Vol. 33, No. 3-4, pp. 507-512.

Abstract: A report of the proceedings of the meeting.

Petr, T., 1969c

On the Preference of some Aquatic Insects for Hard or Soft Wood Trees.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Rept. X 33, pp. 2.

Abstract: Since much of Volta basin was not cleared of vegetation prior to damming, the lake has a very large number of drowned trees. Tree surfaces have been colonised by a number of invertebrates which feed on the periphyton. The invertebrate fauna of the tree surfaces is very important because the formation of benthos has been retarded by the early deoxygenation of the lake water. Povilla adusta (Ephemeroptera) is the commonest inhabitant of three surfaces except where wave-action is strong; in latter areas trichopterans (Amphipsyche and Enomus) predominate.

This investigation is about the ability of various invertebrates to colonise hardwood (at Avudzega) and softwood (Afram - Pawmpawm confluence) trees.

(i) Hardwood trees. Trichopterans comprise 99% of the biomass on these trees. Amphipsyche is dominant, followed by Enomus.

(ii) Softwood trees. Povilla adusta forms 99% of the biomass on these trees.

Petr, T., 1969, cont'd.

Inability of Povilla to colonise hardwood trees is due to its inability to burrow through hardwood. The Trichoptera do not burrow into wood.

Comment: None.

Petr, T., 1969d

Development of bottom fauna in the man-made Volta Lake in Ghana.

Verh. Internat. Verein. Limnol., Vol 17, pp. 273-282.

Abstract: During circulation the benthos in Lake Volta reaches deep into the lake, but abundance is low. In the northern (riverine) basin benthos is found at the bottom mostly and is evenly distributed.

During stratification the benthos also stratifies and is found in great concentration.

The biomass of the benthos is maximum during stratification and minimum during mixing.

The chief benthic organisms are chironomids (59% of the total biomass) and Povilla (30.2%). In the littoral region, wherever Pistia and Ceratophyllum occur, there are many Bulinus sp gastropods. In certain localities the benthos is dominated by Ecnomus and Dipseudopsis. Between 1966-1968, Povilla has colonised the entire lake. It buries itself in the submerged trees during daytime and emerges at night to feed on periphyton. The increase of Povilla has led to a change in the diets of many insect-feeding fishes. These now feed overwhelmingly on Povilla whereas previously they had broader spectra of diet. In the north Alestes, Eutropius and Schilbe - all of which utilise Povilla - have become the dominant species.

Petr, T., 1969, cont'd.

As the lake has matured, the biomass of benthos has decreased. But considering that insects in the tropics produce many generations in a single year, the productivity must be high.

Petr, T., and J.D. Reynolds, 1969.

Fish Population changes in the Volta Lake in 1968.

Volta Basin Res. Project (Univ. of Ghana) Tech. Rept. X 32, pp. 3.

Abstract: In 1968 Lake Volta rose 2 m. This survey shows that in the southern basin (Ampem, Pawmpawm, Lomnava, Aveme and Aglama) cichlids form 80.98% of the total catch (Tilapia galilaea is the dominant cichlid). Cichlids are also gaining ground in the north (at Yeji 40.88% of the catch is due to Tilapia galilaea alone); however in the river section the cichlids form only 12% of the total catch.

In 1968 the characids have dropped in numbers from previous years. Alestes macrolepidotus remains dominant but other species of this genus have declined. Alestes baremoze has been replaced by Eutropius niloticus. The change in the characid population may be due to migrations in the flood.

Other species mentioned are:

Labeo coubie: increased at Yeji and Kete Krachi in the flood. This is a migratory fish.

Citharinus citharus: there was no peak of this species at Kete Krachi in April - May as was recorded in 1967. But at Yeji this peak occurred again.

Petr, T., and J.D. Reynolds, 1969, cont'd.

Lates niloticus: many young of this species were caught at Yeji showing that it is succeeding in the lake.

Synodontis spp: several species were caught; they are dominant in the north.

Cyanothrissa: showed a dramatic increase at Yeji (from 39% - 70% of the catch); it is more successful in the north because it needs a riverine environment to breed.

Mormyridae: remain restricted as before.

Comment: None.

Proszynska, M., 1969.

A Preliminary Report on the Quantitative Study of the Cladocera and Copepoda in the Volta Lake, 1964-1965.

in: Man-made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 127-132.

Abstract: Following closure of the dam (1964), zooplankton was distributed throughout the water column. In 1965, it was concentrated in the top 5 m. - particularly between 2-5 m. A repeated crash of the populations was observed; the disappearance is related to the annual flood season. Evidence indicates that much of the zooplankton does not develop in situ but comes from other localities, e.g. the Afram confluence.

Comment: None.

Rajagopal, P.K., 1969

Preliminary Observations on the Vertical Distribution of Plankton in Different Areas of the Volta Lake.

in: Man-made Lakes, The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 123-126.

Abstract: The plankton of the southern basin is poorer in quality and quantity compared to the northern basin of Lake Volta. However, in the shallow water areas of the south very high densities of plankton are recorded.

1. Zooplankton. Ciliates and rotifers (Filinia) are dominant in composition; crustacean plankton is sparse.

2. Phytoplankton. Of the stations studied, Ampem is richest in phytoplankton. Ampem also appears to be an area where resident zooplankton multiplies.

Comment: None.

Reynolds, J. D., 1969a

Field Key to Commercial Fishes of the Volta Lake.

Volta Basin Res. Proj. (Univ. of Ghana), Tech. Rept., X 28

Abstract: A useful field key for Volta fishes.

Reynolds, J.D., 1969b

The Biology of the Clupeids in the New Volta Lake.

in: Man-made Lakes. The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 195-203.

Abstract: About 20 species of clupeids have adapted themselves to estuarine or freshwater existence in Africa. They have undergone complex speciation and cannot readily be identified. In West Africa, the closely-related species of *Pellonula* complex are found in rivers from Senegal to Niger. The Volta clupeids belong to this complex.

1. *Cyanothrissa mento* Regan - 170 mm. total length (140 mm. S.L.); 41 gm. in weight; with a long preorbital snout; massive jaws protruding in front.

2. *Pellonula afzeliusi* Johnels - 98 mm. total length (81 mm. S.L.); 8.2 gm. in weight; less well developed snout and lower jaw.

Both are well-distributed in the lake, but *Cyanothrissa* is more common in riverine areas (Yeji, Kete Krachi). They appear in the Gorge Region periodically; mass mortalities of clupeids have been recorded in this region periodically. These mortalities are caused by anoxia.

Migrations. Cyanothrissa carries out longitudinal migration; diurnal vertical migrations accompanied by schooling are recorded for both the species. At 5:30 p.m. the fishes appear on the surface as shoals and later disperse to feed. At full moon they feed scattered and close to the surface. They move about in "feeding association" following schooling. At dawn shoals reform prior to disappearance into deeper water at 7:30 a.m.

Food and Predators. Pellonula feeds on aquatic and terrestrial insects mainly. It is an annual species whose population dynamics are controlled by predation.

Cyanothrissa is a predator and feeds on young Pellonula.

Reproduction. Pellonula breeds in July - September and perhaps again in December. It probably produces transparent pelagic eggs. Cyanothrissa possibly does not spawn in the lake - preferring riverine habitats.

Reynolds, J.D., J.A. Adetunji and H.O. Ankrah, 1969.

Length-weight Relationships of some Volta Lake Fishes.

Volta Basin Res. Proj. (Univ. of Ghana) Tech. Rept. X 29, pp. 12

Abstract: Initial fish population studies in Lake Volta used fish lengths for stock assessment, etc. But future studies will be based on weight. This is a preliminary paper which tries to find a possible correlation between length and weight of the important commercial fishes of Volta.

Comment: None.

Taylor, B. W., 1969

Volta Lake Research Project, Further Considerations of Possible Follow-ups.
3. Fisheries and Hydrobiology

Cyclostyled, 15 pp.

Abstract: Management aspects of fresh-water fishery on Lake Volta.

Taylor, G. T., and J. McAlister, 1969.

A proposal for fisheries development at Kpandu Tokor, Volta Lake.

Volta Lake Res. Proj., Ghana. Cyclostyled, pp. 9

Abstract: A proposal of fishery development on Lake Volta with recommendations on the establishment of port and marketing facilities.

Comment: None.

Viner, A.B., 1969

Observation of the Hydrobiology of the Volta Lake, April 1965 - April 1966.

in: Man-made Lakes. The Accra Symposium, Ed. Letitia E. Obeng, Ghana Univ. Press, Accra, pp. 133-143.

Abstract: Lake Volta has three layers of water during stratification. The top 5 m. are well-oxygenated; between 5-20 m. there is a fair amount of the gas while below 20 m. there is no oxygen during stratification. Sudden squalls only aerate the top layer, but a constant wind can cause much mixing even in the deeper water. Deeper water of the lake is more stable than the littoral zone.

Phytoplankton. At Ajena the phytoplankton is distributed all over the water column. Elsewhere it shows stratification - being restricted largely to the eplimnion (particularly in the north). In the southern basin, the dominant phytoplankton is Bacillaris phyceae; northwards, Myxophyceae and Chlorophyceae increase. The occurrence of these families is related to the stability - instability conditions in the lake. Under less stable conditions Bacillanophyceae have an advantage over the other families.

Estimates of primary productivity at various stations is given; it varies from 0.8gC/m^2/day at Afram to 5.2 gC/m^2/day. Areas with steady wind and consequently mixed waters have higher productivity than those in calm conditions.

Biswas, S., 1970.

Limnological Observations During the Early Formation of Volta Lake in Ghana.

Paper presented at the Man-made Lakes Symposium, Knoxville, Tennessee, 1970.

Abstract: The Volta Lake started forming with the closure of the dam in 1964 and practically reached its full extent in 1968. During this period continuous limnological observations have been possible at an offshore station two miles upstream. The lake filled actively in the flood season and evaporation caused a slight drop in level in the dry season. The flood and northerly harmattan winds regularly overturned the lake. This was evident from a near homothermal condition of the watermass together with the spread of a brown colour, iron, phosphates, ammonia, nitrites and sulphides from the bottom to the upper layers. The brown colour was mainly due to colloidal iron and it caused a decrease in the transparency and dissolved oxygen in the upper layers. In the intervening periods the lake showed a tendency to stratify forming a warm metalimnion rich in oxygen but poor in colour and mineral substances. In the first two years the hypolimnion was relatively low in temperature and oxygen while high in colour and minerals. In the subsequent years these conditions were appreciably reversed probably due to more frequent overturns caused by increasing weather disturbances as well as outflow through the turbines and spillways.

Czernin-Chudenitz, C., 1970.

Recent Limnological Status of Volta Lake, Ghana.

Paper presented at the Man-made Lakes Symposium, Knoxville, Tennessee, 1970.

Abstract: Limno-chemical observations, mostly at two-month intervals, along the main axis of the lake were carried out for a period of two years (1968/70). Changes in different aspects of physico-chemical conditions due to two main seasons, dry and rainy, were recorded in each year.

The oxygen conditions are still improving and are in close relationship to the temperature.

The thermocline is descending to greater depths. Starting at 17 m. in 1965, it was at 27 m. in 1968, and 1970 was in the 30- to 35-meter range.

The difference in temperature between surface and bottom is low (about 3° C.). The difference in temperature between upper and lower borderline of the thermocline is 0.4 ° C. only. Partial mixing is therefore possible at anytime.

Total mixture occurs mainly during the rainy season and during "Harmattan" time. The deepest parts of the southern lake sections are not regularly influenced by mixing. Most of the time there is a completely deoxygenated water layer just above the old river bed.

Czernin-Chudenitz, C., 1970, cont'd.

Nutrients: Just after filling started, the lake was very rich in nutrients which resulted in an enormous peak of phytoplankton. With the progressive decay of the flooded vegetation, especially the flooded trees, the open water is now relatively poor in phosphates and nitrates. Sources of the nutrients are from the hypolimnion during mixing, the shallow water areas with their decaying weeds, and the yearly flood.

Total alkalinity is very low.

The flooded trees are still present throughout the lake, although some have been underwater for seven years. At first, these trees were abundantly inhabitated by may fly larvae, but the larvae were recently found now to use *Polygonum* beds most abundantly for feeding and breeding.

Beds of aquatic weeds, mainly *Pistia*, started to grow first in the upper parts of some tributaries in shallow water. In the two years of observation, *Pistia* has now become completely displaced by *Vossia* and *Polygonum*.

Ranking first in numbers as well as in weight among the fishes are the non-commercial species of the family Cyprinidae (*Pelonulla* and *Cynothrissa*), which are the main food for the Nile perch, *Lates*. *Lates* prefers mainly the deep and open water. *Tilapia* is abundant in shallow and sheltered water areas. In the northern part of the lake, fish of the riverine type are dominant.

Denyoh, F.M.K., 1970.

Fishery Development, Volta Lake, Ghana.

Paper presented at the Man-made Lakes Symposium, Knoxville, Tennessee, 1970.

Abstract: When Volta Lake started to form in 1964, it brought about a major revolution in the fishery of the Volta River basin.

Before the construction of the Volta Dam at Akosombo and its subsequent formation of the lake, there were not more than 2,000 fishermen operating in the Volta basin. These fishermen were mostly nomadic and lived in temporary huts scattered along the main river and its main tributaries, namely the Black Volta, White Volta, Oti, and Afram. The Sene, the Dwija and the Obosum rivers were just small streams which did not support any signficant fishery.

Fish catch and fishing village surveys conducted in 1968 and 1969 revealed at least 1,000 fishing villages with 20,000 fishermen scattered along the lake shore. Canoe counts gave a result of between 11,000 and 14,000 fishing canoes and led to estimates of catch in 1969 of between 50,000 and 70,000 metric tons, as compared with an annual take of about 10,000 metric tons from the previous riverine fishery.

Denyoh, F.M.K., 1970, cont'd.

As the ecology of the whole Volta basin changed, so did the fish population. The relative abundance of species changed drastically with _Tilapia_ species now forming more than 50% of processed fish entering the major fish markets along the lake. Other commercially important fishes like _Lates niloticus_ and species of _Labeo_, _Distichodus_, _Citharinus_, and catfishes have also relatively increased in population from the former riverine conditions.

Before the formation of the lake, multifilament nylon gill nets had replaced the old cotton nets in use a few years back. When the Volta Lake Research Project commenced, a series of comparative fishing experiments were carried out with multifilament nylon nets and monofilament nylon nets to compare their efficiency (monofilament nets are not yet in use in Ghana). Both types of netting materials were constructed to the same specifications, and were joined end to end during the fishing operations. Shallow inshore waters as well as deep offshore waters were fished. The results of this experimental fishing were conclusive in showing that monofilament nets are far superior to multifilament nets in fishing efficiency for the important species of commercial fishes in the lake.

Denyoh, F.M.K., 1970, cont'd.

It was also found that change in the prevalent methods of hanging nets could improve the catch. Traditionally, local fishermen do not use enough floats on their surface nets when setting them. They use on the average very few floats, spacing them 30 to 50 yards apart, resulting in a considerable sagging of nets in the water. Experiments have proved that by using more floats and therefore avoiding sagging, the catch is increased by at least 50%.

There are also indications that fish inhabit very deep waters of the lake, sometimes to 100 ft. or more. By sinking gill nets in these deep waters, some of the important commercial species inhabiting these depths can easily be exploited.

Trap fishing has rapidly become very popular, especially for inshore Tilapia. Traps are made of cane or wire netting. Gill nets do not seem very efficient in the exploitation of Tilapia and hence most of the Tilapia fishing is done with traps, mostly during the dry season when the lake level starts to fall and its waters recede from the flooded vegetation.

Denyoh, F.M.K., 1970, cont'd.

The bulk of the fish which get to the market are those already processed either by smoking or by salting and sundrying. Almost all processed Tilapia are salted and sundried. The other species are mostly smoked. Attempts are being made to improve the quality of processed fish in its present form by reducing the salt content and by making smoked fish drier but avoiding cooking during smoking.

Completely new fish markets which did not exist before have come into being since the formation of Volta Lake. Four of these are major markets - Kpandu and Abotoase on the Eastern shore, Yeji in the north, and Adoroso on the Afram arm. In between these major markets there are many small ones scattered along the lake shore.

A large fleet of transport canoes (ocean-beach canoes powered by outboard motors)has developed at these major market centres. These transport canoes convey, on the average of twice weekly, fish loaded in baskets and fish sellers from the various fishing villages to these fish markets. From the fish market a number of "mammy" trucks carry the fish to the big towns in the various parts of the country.

It is interesting to note that the Volta Lake has brought about a complete change of occupation of most people residing along the lake. Women who were once engaged in pottery work or farming are now fishmongers, and many men who used to be farmers have turned full-time fishermen. It has also resulted in a wholesale population movement from one section of the country, Lower Volta District, to areas along the lake.

Evans, Willis A. and John Vanderpuye, 1970a.

Fish Population Sampling at Volta Lake, Ghana, 1969-1970.

Paper presented at the Man-made Lakes Symposium, Knoxville, Tennessee, 1970.

Abstract: For determining the species composition and relative abundance of the fish population in the recently formed Volta Lake, emphasis was placed upon obtaining data that would be useful in guiding the development and management of the lake fisheries.

Initial effort consisted of devising a system of sampling related to the lake conditions and available facilities. This consisted of fishing a battery of 45 gill nets ranging in square-mesh sizes from 1/2 to 8-inches at various designated stations throughout the lake 3 times each year in 1964 and 1970. Sampling with rotenone was added to a supplement during 1970.

It is anticipated that comparable monitoring of the fish population will be undertaken on a continuing basis, especially during these initial years while the population is likely to be very unstable. Comparison of the data with catch statistics from the commercial fishery disclose trends of over- or under-exploitation of species stocks.

Evans, W.A., and J. Vanderpuye, 1970b

Early Development of the Fish and Fisheries of Volta Lake, Ghana.

Volta Lake Res. Proj., Cyclostyled Rept., pp. 16.

Abstract: The following data on the present fishing activity on Lake Volta are given: 12,500 plank canoes; 25,000 fishermen; 900 fishing villages; 1969 catch = 60,000 metric tons; principal species caught include Tilapia, Labeo and Lates. The fishery is restricted to 1,000 m. wide water margin along the littoral and an estimated 4 canoes per sq. mile use this region.

Most of the fishing activity is carried out in the wet season when fish (particularly Tilapia) are most abundant in the littoral zone; in the dry season Tilapia move into deeper water and operations come to a near halt.

The fishery is not being fully utilised owing to inefficient gear, effort and the difficulty of fishing in areas with flooded trees. Fishermen commonly use static, coarse meshed (size 14 cm.) gill nets which are mostly set in 5 m. of water.

The aim of this investigation was to assess fish stock in Lake Volta. Direct estimation of the stock is impossible under the present conditions. The authors recommended that an assessment be obtained by indirect means, e.g. through the expansion of the present fishery until changes in catch

Evans, W.A., and J. Vanderpuye, 1970, cont'd.

in relation to effort, size or species composition begin to change.

The investigators carried out sampling on the lake at various stations and attempted to correlate their catches with those reported in the commercial fishery.

A. Changes in fish stocks.

The anoxia that accompanied the initial filling of the lake (May 1964) caused much Chrysichthys sp. mortality; with maturation the lake water has improved in aeration (79% of the lake volume is now aerated, 1970). The fishery of Volta River was dominated by Labeo, Chrysichthys and Alestes. Lacustrinisation has reduced these species in the south, but in the riverine north they still persist. The cichlids have become very successful in the south. The mormyrids - another important family of the riverine fauna - have nearly disappeared from the lake.

The open water (pelagic) habitat has been increasingly colonised by Cynothrissa, Pellonula, Eutropius and Physailia. A similar increase is also evident in Lates, Labeo and Distichodus.

Evans, W.A., and J. Vanderpuye, 1970, cont'd.

B. Present Species Composition (1969 - 1970)

At present the clupeids (*Cyanothrissa*, *Pellonula*) represent 3/4 of the fishes in number and 1/4 of the total ichthyomass in the lake. This vast resource is not commercially utilised. Fishes of Lake Volta can be grouped into the following "eco-groups:" aufwuchs-detritus herbivores, piscivores, semi-pelagic omnivores and benthic omnivores. Of the semi-pelagic fishes the clupeids account for 99% of the ichthyofauna by number and 1/2 of the total ichthyomass in that "eco-group."

The herbivores (*Tilapia*, *Labeo*, *Distichodus*, *Citharinus*) form 3/4 of the total commercial catch but represent only 1/4 of the total ichthyomass. *Tilapia* forms 1/2 of the total commercial catch but only 10% of the ichthyomass. The piscivores form 1/5 of the total ichthyomass. The development of fish stocks shows that it increased from 1964 to 1969 but following this phase the stocks have been reduced - not by overfishing, but by the general stabilisation of the lake itself. The fishery of Lake Volta is concentrated in the wet season when the turbidity and the water is high. In the dry season *Tilapia* migrate into deeper water and are unavailable to fishermen.

The report includes data on relative abundance as well as length frequency distribution, etc.

Institute of Aquatic Biology, 1969-70.

Fourth Annual Report.

Council for Scient. and Indust. Research, pp. 109.

Abstract: Includes resumés of biological work of Lake Volta and other freshwater bodies in Ghana (1969-70). Lake Volta work includes:

1. Limnology
2. Water weeds
3. Algae and Phytoplankton
4. Zooplankton
5. Aquatic invertebrates
6. Fishes

Comment: None

Lawson, G.W., 1970

Lessons of the Volta - A New Man-made Lake in Tropical Africa.

Biol. Conservation, Vol. 2, No. 2, pp. 90-96.

Abstract: Summary of changes in Lake Volta since its formation. The paper reviews all salient literature on limnology, water weeds, algae, fishes, etc.

Limnology: In the rainy season cool and oxygenated water enters the lake; stratification is broken down. The turbidity of water increases. Following flooding the water clears up and phytoplankton blooms form. Stratification is re-established.

Plankton: Phytoplankton: Blue-green algae predominate in shallow water while diatoms are more numerous in deep water.

Zooplankton: Rotifers are the dominant component.

Macrophytes: The flooded macrophytes are being utilised by *Tilapia zilii*, *Alestes macrolepidotus*, *Synodontis* spp. The flood plain also provides breeding grounds for many Volta fishes.

Annual drawdown will expose 518 - 1036 km^2 of the lake bottom - renewing productivity annually.

Lawson, G.W., 1970, cont'd.

Explosive development of water weeds e.g. *Scirpus cubensis* and *Vossia cuspidata* has occurred only locally in some cases (e.g. Afram). *Pistia stratiotes* and *Ceratophyllum demersum* have also increased. These are eaten by *Alestes macrolepidotus* and *Distichodus* spp. The real significance of these macrophytes lies in the rich invertebrate faunas they support. Invertebrates are also richly developed on the surfaces of the drowned trees. These invertebrates support many insectivorous fishes in the lake. The increase of algae in the lake has helped several species of microphylophagous *Tilapia*.

Comment: None

Obeng, Dr. Letitia, E., 1970a

Man-made Lakes, Their Ecological Implications and National Development.

Paper presented at the First Commonwealth Conference on Development and Human Ecology, Malta, 18-24 October, 1970.

Abstract: A general description of problems of man-made lakes.

Obeng, Dr. Letitia E., 1970b

Volta Lake Research, A Case Study of Man-made Lakes.

Paper presented at the Man-made Lakes Symposium, Knoxville, Tennessee, 1970.

Abstract: A general description of problems of man-made lakes.

Petr, T., 1970a

Microinvertebrates of Flooded Trees in the Man-made Volta Lake (Ghana) with Special Reference to the Burrowing Mayfly Povilla adusta Navas.

Hydrobiologia, Vol. 36, No. 3-4, pp. 373-398.

Abstract: Great increase of periphyton is noted in Lake Volta. It is an important food for some fishes; most of it is utilised by larvae or nymphs of numerous aquatic invertebrates which have increased vastly in the lake.

Invertebrate species	Number %	Standing Crop %
Povilla adusta	74.95	90.42
Amphipsyche	8.50	6.36
Chironomids	4.78	1.17
Ecnomus	5.02	1.06

Highest density of these organisms exists in the south (Ampem), decreasing to the north (Yeji). The south has 30 times the number of organisms found in the north; in terms of biomass the south is 13 times richer than the north. At all stations except Kpandu (where Amphipsyche is dominant) Povilla is the most abundant organism. Most organisms decrease with depth. The effect of oxygen and wave action on the distribution of various species is discussed and the ecology of Povilla adusta is presented.

Comment: None.

Petr, T., 1970b

The Bottom Fauna of the Rapids of the Black Volta River in Ghana.

Hydrobiologia, Vol. 36, No. 3-4, pp. 399-418.

Abstract: Increase in the biomass of invertebrate fauna in Black Volta River is related to increased water flow. The increases are mainly due to the increase of the web spinning Cheumatopsyche larvae. Higher current of water also increases food supply of this species. At the end of the dry season, highest biomass of benthos is achieved; flood affects their density adversely.

Most invertebrates living in the river would be destroyed in lacustrine conditions except larvae of Ecnomus and Cricotopus which may live in the lake wherever riverine conditions persist. Exposed surface of flooded trees and increased wave action will allow Ecnomus and Cricotopus to persist in a lake, e.g. Lake Volta.

Comment: None.

Petr, T., 1970c

Chironomidae (Diptera) from Light Catches on the Man-made Volta Lake in Ghana.

Hydrobiologia, Vol. 35, No. 3-4, pp. 449-468.

Abstract: A list of chironomid species is provided for the Volta Lake in Ghana, a man-made lake in tropical West Africa which started to fill in 1964. Insects were attracted to lights on the research vessel "Tilapia" at six different stations from 1966 to 1968. From the 25,128 specimens collected, 45 species were identified. Twenty-one species are recorded for the first time in Ghana. The most abundant species are: Nilodorum fractilobus, Chrionomus formosipennis and Nilodorum brevibucca. The larger number of species occurring in the transitional river-lake zone, compared with the lake itself, is discussed in relation to the changes in the environment during each year as a result of the alternating dry and rainy seasons.

Pierce, P.C., and A. Opaku, 1970.

Summary of Aquatic Weed Survey and Control Data for Volta Lake During 1969.

3rd. Ann. Meet. National Weed Comm. for Ghana (C.S.I.R., Ghana), Accra, Ghana, (Cyclostyled), pp. 10.

Abstract: Between 1964-1967, Lake Volta was infested by the following floating or submerged water weeds: Pistia, Scirpus, Cyperus, Ceratophyllum and Utricularia. In 1968 marginal rooted aquatic weeds were on the increase; the latter weeds may in the long run pose more serious problems than the former. The new infestation includes Vossia, Polygonum, Alternanthera, and Ludwigia.

In limited numbers the weeds are beneficial to fishes - providing food and shelter for many species. But the uncontrolled development of Vossia etc. on the banks poses serious problems for the present fishery. The vegetation also supports sizeable populations of aquatic invertebrates which act as vectors of bilharzia and other diseases of man.

Experimental control of the weeds is described.

Comment: None.

Regier, H. A., 1970.

Report of Travel to Lake Volta (Ghana) and Lake Kainji (Nigeria) Fisheries Research Projects, from 15 November to 3 December 1970.

FAO Fisheries Travel Rept. and Aide Mem., No. 376, pp. 2.

Abstract: Narrative report of a trip to Lakes Volta and Kainji to start analysis of fish stock assessment problems in these lakes.

Comment: None.

Viner, A.B., 1970a

Hydrobiology of Lake Volta, Ghana.

I Stratification and Circulation of Water.

Hydrobiologia, Vol. 35, No. 2, pp. 209-229.

Abstract: Position: 6° N - 9° N.

Dimensions: 400 km. long; 30 km. wide; area = 8,000 $km.^2$ (4% of Ghana's area) Maximum Depth = 82 m.; average depth = 30 m.; surface is 97 m. above sea level.

Vegetation: The bulk of the lake is in savanna zone; only southern part is in tropical forest zone.

Circulation: The climate and circulation of the lake are mainly under the influence of the Convergence Zone formed by southerly monsoons and northerly harmattan winds. The crucial agency of circulation is air movement rather than rainfall. Winds are even more important in the Gorge Region where much funnelling gives rise to instability of water.

Viner, A.B., 1970, cont'd.

Normally during daytime the water is stratified as follows:

I. 0-5 m...........shows diurnal significant variation.

II. 5-17 m..........shows slight variation.

III. 17 m. & below...no variation.

During the day, surface water warms up; photosynthesis, etc., increase the oxygen content of surface water. In the evening cool and dense water begins to sink into depths carrying oxygen with it. At night the daytime 5 m. discontinuity breaks down and water down to 17 m. is homothermal. But a discontinuity at 17 - 20 m. remains during the night; this continuity is seen in oxygen (none below) and temperature (lower below). This situation reflects conditions in the Gorge Region and at Afram, Kpandu and Kete Krachi. Stability of the lake increases northwards as well as in the tributary entrances. However, at some shallow water stations, e.g., Ampem, complete mixing occurs periodically.

The Gorge Region undergoes irregular, complete or incomplete, mixing. The instability is mainly caused by the southerly winds. There is the possibility that seiches occur in the gorge. Oxygen profiles suggest that density profile currents are a very important limnological feature of the lake.

Viner, A.B., 1970, cont'd.

Complete deoxygenation can occur in the Gorge Region following an overturn; sustained wind action, however, can restore oxygen to a substantial portion of the water. The harmattan season is the period of maximum oxygenation (surface = 100% saturation; 15 m = 1% saturation).

Total solutes in Volta are low, but increasing (surface = 60-80 mg/L; bottom = 100-120 mg/L); conductivity at surface is 60 μmho/cm and at the bottom is 80-100 μmho/cm.

The complex morphometry is the chief cause of stability in Lake Volta; without it, the lake could circulate very often. The Gorge Region undergoes maxim mixing because of strong wind activity. Volta is a polymictic tropical lake.

Comment: None.

Viner, A.B., 1970b

Hydrobiology of Lake Volta, Ghana.

II Some Observations on Biological Features Associated with the Morphology and Water Stratification.

Hydrobiologia, Vol. 35, No. 2, pp. 230-248.

Abstract: Zooplankton. This includes copepods (*Diaptomus*, *Cyclops*), cladocerans (*Ceriodaphnia*), and rotifers (*Keratella*, *Filinia*, *Brachionus*, *Asplanchna*).

Zooplankton is chiefly found in the epilimnion (except during circulation). The copepods show diurnal vertical migration.

Phytoplankton. Some evidence exists showing that population types of phytoplankton are related to morphometry.

Flagellates) Volvocates) Desmidaceae) Dinophyceae)	these do not exhibit much variation in various localities.
Chlorococcales) Bacillariophyceae) Myxophyceae)	differ in various localities.

Viner, A.B., 1970, cont'd.

North of Afram confluence, Bacillariophyceae increase; in some localities chlorococcales are dominant over diatoms. Ampem and Afram show a rich variety of phytoplankton.

Primary Productivity:

Euphotic zone at various localities in Lake Volta is as follows:

Lake George	3.5 m.
Afram (Volta)	4.5 m.
Kpandu "	5.0 m.
Kete Krachi"	5.0 m.
Yeji "	6.0 m.

Primary productivity at various stations is estimated as follows:

Afram	1.2 gm O_2/m^2/day
Afram confluence	0.3 gm O_2/m^2/day
Kpandu	1.0 gm O_2/m^2/day
Yeji	1.7 gm O_2/m^2/day
Ampen	2.9-3.6 gm O_2/m^2/day

Viner, A.B., 1970, cont'd.

Lake Volta falls within the "moderate" productivity category of Talling, 1965.

70% of Volta water lies above 20 m. discontinuity and is therefore productive.

Comment: None.

Czernin-Chudenitz, C.W., 1971.

Physico-chemical conditions of Lake Volta, Ghana.

FAO, United Nations Development Programme, Tech. Rept. 1, (FI:SF/GHA 10), p. 77

Abstract:

1. Temperature. In terms of temperature, the lake is divisible as follows:

   (a) the northern part: riverine, homothermal all year and holomictic. 40% oxygen in the water and found at the bottom. In the flood these conditions extend down to Oti.

   (b) the southern part: lacustrine, stratified quite often with the metalimnion between 20-25 m. and a more superficial discontinuity in daytime. Maximum mixing periods: in the flood and harmattan seasons.

   (c) the inundated riverine arms: shallow and limnologically similar to the main lake. The metalimnion is at 8-9 m. and some parts overturn quite often.

2. Transparency. This is influenced by the following factors:

colloidal organic and inorganic (particularly iron) particles and by phytoplankton. The influence of transparency on fish catch needs further study.

3. Oxygen: At Afram and Kpandu oxygen is found down to 40 m. in the floods and harmattan period. Yeji has oxygen all year.

Low oxygen values are recorded for the shore stations because of seclusion from wind. The gas is low in the weed beds, but is often recorded below them.

Wind remains the most important factor in aeration of water in Lake Volta.

The phytoplankton does contribute to aeration of water, but only on the surface. As the lake has matured aeration has improved.

4. Chemistry: Very brief notes are given on the distribution of various ions in the lake.

5. Primary productivity: This can be assessed by 1/ oxygen demand; 2/ alkalinity; 3/ phytoplankton and aquatic weeds. The annual drawdown will contribute to the productivity of the lake.

6. Secondary productivity: This is estimated to be higher in the littoral compared to the pelagic region of the lake.

7. Aquatic weeds: a brief note on these.

Comment: None

Hall, J., P. Pierce and G. Lawson, 1971.

Common Plants of the Volta Lake.

Dept. of Botany, Univ. of Ghana Publication (USAID Supported), pp. 123.

Abstract: A list of common plants of Lake Volta.

Pierce, P.C., 1971a

A Comparative Evaluation of Fish Catch and Economics for Multifilament and Monofilament Gill Nets at Volta Lake.

USAID Volta Lake Technical Assistance Project (641-11-190-028) Report, pp. 31.

Abstract: Two nets each of 102-, 127- and 178 mm. stretched measure nylon multifilament and monofilament webbing, and two nets of 229 mm. stretched measure monofilament webbing were tested at Volta Lake during an eight month period in 1969 and their catch data compared. During this study the 14 test nets took 19 species totaling 1,332 fish weighing 1,829.3 kg. *Tilapia* spp. dominated the catch for the 102- and 127 mm. gill nets, and *Lates niloticus* comprised most of 178- and 229 mm. nets' ca ch by weight. Eleven percent of the total catch consisted of species of poor or no economic value. Monofilament nets took 3, 5 and 7 times as much fish by weight as did their multifilament counterparts for mesh sizes 102-, 127- and 178 mm. respectively. Of these three mesh sizes, monofilament webbing was the most economic and proved potentially more profitable as mesh and twine sizes increased. No multifilament gill net tested paid for itself during the study period, however, the 127 mm. mesh should have within the life of the net.

The catch superiority of the monofilament gill nets was found to be due primarily to this webbing material's lower visibility in Lake Volta's relatively clear water. The 229 mm. mesh monofilament flag net (mono=) was the most economical gill net tested, followed by the 178 mm. mono=, 127 mm. mono=, and the 229 mm. (sunken mono+) mesh sizes. The 178 mm. mesh floating monofilament gill net (mono+) was the only net tested that proved highly selective in catching Heterotis niloticus, a species of low commercial value at Volta Lake.

Study period: January - October, 1969.

Comment: None.

Pierce, P.C., 1971b

Aquatic Weed Development, Impact and Control at Volta Lake, 1967-1971.

USAID Volta Lake Technical Assistance Proj. (641-11-190-028) Rept., pp. 89

Abstract: Data collected during a four-year study (1967-1971) at Volta Lake showed that aquatic weed abundance and distribution changed during the early lake fill period (1964-1968).

Prior to 1968, the lake's plant community was dominated by floating Pistia stratiotes, Lemna sp., Salvinia nymphellula, and Scirpus cubenis. Floating "grass" islands were often created when Scirpus cubenis colonized thick mats of Pistia. After 1968, however, these floating weed species became less abundant, in general, and were restricted to sheltered, shallow coves and bays, or near confluences where major streams enter the lake. The later was found to be particularly favorable for Pistia-Scirpus island development if large numbers of emergent dead trees were present to provide suitable anchorage to hold the weed beds in place.

After the lake fill in 1968, the water level fluctuated gradually, and many species of semi-aquatic plants became established on the exposed lake shore during the drawdown period (December-June). Some of these species, particularly Vossia cuspidata and Polygonum senegalense, were found to be tolerant of flooding to a depth of three vertical meters --the usual annual

range of water fluctuation. The former species spread rapidly, and by 1971, it had infested much of the lake's shallow shoreline -- especially along the western side of the reservoir. Polygonum was found to be more abundant in the more protected coves and bays. Also in those areas, Alternanthera sessilis was common, but it did not appear to be well suited to prolonged deep flooding; and therefore, it was seldom seen during the latter part of each flood season. These marginal weed beds, in addition to submerged weeds consisting of mainly Ceratophyllum demersum, were found to support large populations of snails, vector carriers of human Schistosomiasis (Bilharziasis). In an effort to find an effective means of combating this waterborn disease, studies were conducted at Volta Lake to determine if by reducing aquatic weeds and shoreline debris -- a known preferred habitat for these snails -- the snail population could also be reduced to below normal transmission levels. In May 1969, a three-hectare shoreline area at Ampem was cleared of all standing vegetation and sprayed with fenac and diuron at rates of 17 and 4 kilograms equivalent per hectare, respectively. No weed growth became established in the water throughout the test plot during the first year.

Pre-treatment snail surveys showed that the snail population was fairly evenly distributed along the entire shoreline within one kilometer of Ampem. However, after the treatment was made, and the test site was flooded during the following lake fill period, snail surveys produced only

one snail along the test plot's 260 meters of weed-free shoreline -- compared to 98 Bulinus truncatus and 112 Bulinus forskali snails collected along a comparable length of weed-infested shoreline located outside of the cleared area. Four snail surveys conducted during the second year (1970-71) produced a total of 21 snails within the cleared area. Most of these, however, were collected in a partially sunken fishing canoe and therefore should not have been included in the count. At the same time, 201 snails were collected in the uncleared area. Therefore, it was concluded that localized aquatic weed and debris control could be an effective method for reducing snail population at Volta Lake.

Other aquatic weed control tests using 12 different herbicides and their combinations showed paraquat to be effective for the control of floating islands of Pistia-Scirpus. A spray mixture containing one part paraquat and 200 parts of water (equivalent to 2.5 liters of paraquat per hectare) was sprayed over the weed bed until the vegetation was thoroughly wetted. Poor results were noted, however, when paraquat (.33 ppm), 2, 4-D granules (200 kg. per hectare) and diuron granules (100 kg. per hectare) were applied for the control of submerged Ceratophyllum. Also, poor results were obtained when mature Polygonum, either in or out of the water, was sprayed with paraquat (1 to 200 spray mixture) or 2, 4-D amine liquid (1 to 50 spray mixture). However, those same concentrations were found to be totally effective for controlling young plants of all species (except 2, 4-D used on grass species) growing on the exposed lake shore during drawdown. Data collected using other herbicides showed that they too were generally effective for the control of young plant species, but not for mature growth.

Clearing fishing strips, for setting gill nets in flooded weed beds, was successfully demonstrated using a combination of pre-flood cutting, burning, and post-flood wading and weeding. Where Polygonum and Alternanthera were the problem, only pre-flood cutting and burning was necessary. However, where Vossia was encountered, post-flood weeding was required also.

Ecological studies conducted at Volta Lake indicated that Polygonum supported large quantities of fish food organisms -- particularly the mayfly Povilla adusta whose larvae readily burrow into Polygonum's hollow stems. Forty-two linear meters of randomly sampled hollow Polygonum stems produced 448 Povilla larvae, for an average of 11.6 larvae per linear meter. Few signs of these larvae occupying the hollow stems of Vossia were noted.

Further studies showed that Povilla larvae are readily eaten by a wide variety of fish species at Volta Lake. During an estimated 10 man-hours

of fishing using these larvae for bait on small fish hooks, 16 species of fish were taken. These findings clearly indicated that Polygonum beds are beneficial to the lake's fishery. However, observations made during 1971 showed that the flooded Polygonum beds were reduced considerably compared to previous years, and that this reduction was attributed to the damage the burrowing larvae produced in the plants.

Other forms of natural biological control that were either seen or suspected to have occurred at Volta Lake during the study are discussed.

Reynolds, J.D., 1971.

Biology of the Small Pelagic Fishes of the New Volta Lake in Ghana.

II Schooling and Migrations.

Hydrobiologia. Vol. 38, No. 1, pp. 79-91.

Abstract: The small pelagic fishes of Lake Volta include:

Clupeidae	(Pellonula afzeliusi Johnels (Cyanothrissa mento Regan
Shilbeidae	(Siluranodon auritus G. St. Hillaire (Physailia pellucida Boulenger
Cyprinidae	(Barilius niloticus Joannis

I Vertical migration and schooling.

Echo sounding suggests that the pelagic fishes appear on the surface between 1800 - 1930 hours. If the weather is calm they appear as a school and then disperse for feeding at 2 - 3 m. In choppy weather, they remain at 3 - 6 m. During full moon they feed close to the surface.

Reynolds, J.D., 1971, cont'd.

Surface observations showed that Pellonula and Physailia feed on emerging chironomids and Povilla between 1740 - 1845 hours (Yeji, Kete Krachi, Ampem). Larger groups were in deeper water. At Akosombo, these fishes remain on the surface because of inclement conditions close to the dam. Here small groups were observed at 0730 hours, which later on swelled to aggregations of 500 - 5,000 individuals.

Groups of Pelagic species were also seen close to the shore in aufwuchs; however, well defined and large schools are characteristic of open waters.

II Horizontal migration

Cyanothrissa, Barilius and Siluranodon and most probably migrate into rivers in order to breed; Pellonula mostly breeds in the lake.

These fishes also migrate against the wind - which explains their mortality close to the dam.

The development of pelagic habit in these fishes is discussed and it is suggested that schooling favours better utilisation of food and escape from predation.

Vanderpuye, C.J., 1971

Population of Clupeids in Volta Lake.

Lake Volta Res. Proj., Cyelostyled Rept., pp. 20.

Abstract: In addition to *Cyanothrissa mento* and *Pellonula afzeliusi* another clupeid, *Sierrathrissa* sp, is found in Lake Volta.

Field experiements show that "light attraction" method of catching the clupeids is not very good because the fishes did not show much attraction to light.

Length frequency distribution analyses exhibit 3 different modes in clupeid catches (32.2 mm; 47.5 mm and 87.5 mm). The second highest mode is attributed to *Pellonula* (56-60 mm) and the third one to *Cyanothrissa* (85-90 mm.).

Experimental catch data shows that the most effective mesh size for clupeid exploration is 13 mm. (catches 97% in number and 86% in weight). This kind of net catches include 90% *Pellonulla* while the 25 mm. mesh net catches include 90% *Cyanothrissa*. Catch per round of fishes in Volta Lake includes 23% clupeids in weight.

Vanderpuye, C.J., 1971, cont'd.

Although the clupeids are believed to be mostly open-water species maximum catch was obtained closer to the shore (74% by number; 70% by weight in inshore areas).

Like most other fishes, the clupeids decline following the rainy season. Some data on spawning is given.

Comment: None.

Biswas, S., 1972.

Ecology of Phytoplankton of the Volta Lake.

Hydrobiologia, Vol. 39, No. 2, pp. 277-288.

Abstract: During the year, January - March (harmattan season) and July - September (flood season) are periods of maximum mixing in Lake Volta. At these times iron from the hypolimnion comes to surface and forms colloidal suspension of Fe+++ making the water turpid. This results in a low Secchi Disc Reading and also a lower photosynthetic rate with the consequent drop in oxygen production. Opposite events occur during times of stratification. Prior to damming the river was dominated by the green alga Actinastrum gracilimum which disappeared in 1967. Following damming (1965-1966), flagellates Cryptomonas and Peridinium became very common. In the same period Nitzschia acicularis and Synedra acus also consolidated themselves in the lake. A not too well-understood connection exists between physico-chemical conditions and the composition of phytoplankton in Lake Volta.

Comment: None.

Institute of Aquatic Biology, 1972.

Some Freshwater Fishes of Ghana.

Council for Scient. and Indust. Research, IAB 41, pp. 13

Abstract: A list of some freshwater fishes of Ghana.

Comment: None.

Vanderpuye, C.J., 1972

Fishery Resource Assessment and Monitoring in the Development and Control of Fisheries in the Volta Lake.

Volta Lake Res. Proj., Cyclostyled Rept., pp. 23

Abstract: Direct estimation of fish stock in Lake Volta is not possible making it necessary to use indirect methods. It is proposed that the fishery be expanded and utilisation increased until changes become apparent. Evidence indicates that the lake is at present underfished.

This survey included experimental catching and rotenone treatment and correlation with commercial catch in order to assess fish stock.

(1) 13 mm. - 89 mm. mesh nets. Less than 14% of the fishery utilises these small mesh nets. These nets remove the clupeids which are at present not commercially utilised. Using this net one obtains a catch consisting of 73% clupeids.

(2) 102 mm. - 203 mm. mesh nets. Although in the commercial fishery the catch obtained by these nets consists of 50% *Tilapia* spp., in the experimental catch only 15% was *Tilapia*. This difference is probably due to a difference in the areas fished. A fishing pressure index is prepared from this work.

Vanderpuye, C.J., 1972, cont'd.

(3) Rotenone Treatment: This procedure suggests that the standing crop varies from 1.2 kg/ha to 651.7 kg/ha (av. 170 kg/ha) in different localities. Although Bazigos estimates fish yield in Lake Volta to be between 42.90 kg/ha - 45.14 kg/ha, this report suggests that higher yields can be obtained. It is estimated that the total catch in Lake Volta will stabilise at 39,000 tons annually in the future.

Comment: None.