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AQUATIC WEED
DEVELOPMENT, IMPACT AND CONTROL
AT VOLTA LAKE — 1967 — 71

by

Phillip C. Pierce
USAID Aquatic Advisor
USAID/Ghana

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AQUATIC WEED DEVELOPMENT, IMPACT AND CONTROL
AT VOLTA LAKE--1967-71

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 four 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-Salvinia. 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, these 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 Polyporus beds are beneficial to the Lake's fishery. However, observations made during 1971 showed that the flooded Polyporus 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.

The purpose of this report is to summarize aquatic weed work accomplished under Project Agreement 641-AC-22-AA-36 dated May 31, 1963, and Project Agreement 641-11-190-028 dated December 4, 1967. These agreements include fisheries and aquatic weed control studies, the latter's objective being "to outline a contingency program for aquatic weed control and recommend adequate quarantine arrangements," which this report covers.

INTRODUCTION

In April 1961, nine months before Dam construction commenced and three years before the Dam was finished, Ghana government officials were busy making world-wide inquiries concerning aquatic weed development and control in man-made lakes. This interest in aquatic weeds was stimulated primarily by the highly publicized aquatic weed problem that had developed at Kariba Lake in Rhodesia and Malawi during the first two years of lake fill. One article in Ghana's Daily Graphic dated April 17, 1961, and entitled "Professor Walks on a Man-Made Lake" stated, "A 200 lb. (over 14 stones) professor from Salisbury got out of a boat and walked about in the middle of Kariba, the world's largest man-made lake, without even wetting a sock.

"It was just a reminder that an amazingly prolific and little-known water fern known to scientists as Salvinia auriculata, is covering the surface of the Kariba waters like some gigantic rug.

"So far, its grip extends over 175 square miles--lots of it in floating mats about six inches thick.

"Even if Salvinia is not yet a threat to the turbines which churn the lake waters hydro-electric power for the

Federation of Rhodesia (Zambia and Rhodesia) and Nyasaland (Malawi); it certainly looks like putting an end to some of the elaborate secondary plans for the £80,000,000 Kariba project. These range from a big fish stocking scheme (400,000 bream so far) to the building of harbours and resorts on the lake, now 200 miles long and up to 50 miles wide."

It was soon learned that Salvinia auriculata is not native to Africa, but was introduced (how and when unknown) into the head waters of the Zambezi River, possibly from its native home in South America. Since this species of water fern was not known to be present in Ghana, there was speculation and great hope by Government officials that Volta Lake would not be plagued with a similar aquatic weed problem when it was completed. However, this hope was shattered when scientists at Kariba attributed their explosive weed problem at Kariba not only to the presence of a non-indigenous aquatic plant (Salvinia auriculata) that apparently had no natural enemies in its new environment, but to the high nutrient level of the new lake's waters, brought about by the flooding of large quantities of terrestrial vegetation and fertile land.

Volta Lake's basin was also extensive, covered with terrestrial vegetation of relatively rich soil, and therefore, the Lake's water would be potentially fertile during the first few years of lake fill. On this subject, Mr. A. J. Emmanuel, Secretary, Kariba Lake Co-ordinating Committee, wrote Mr. O. W. Snow, Advisor on Agricultural Science, Ministry of Agriculture, Ghana, in May 1961, stating: "Your remarks about Salvinia auriculata not being on record in your part of the world confirms the information we gathered, in that there are several species of the same genus but not auriculata. This may be a

years in Lake Nyasa without becoming a problem. However, that may not follow when the Volta Dam is completed as you may well find a similar cycle to ourselves with a very high nutrient level in the water being maintained over several years as the basin gets progressively covered with each season's inflow, causing seasonal rapid expansion of weed growth of hitherto seemingly innocuous species."

Based on this very important information, the Ghana Government had renewed interest in learning not only which potentially dangerous weed species (indigenous and non-indigenous) were present in Ghana, or nearby, but also what methods were available for their control.

In May 1962, letters went out to workers in the United States, East Pakistan, Rhodesia, Union of South Africa, and Ceylon concerning the control of Alternanthera philoxeroides, Eichhornia crassipes, Pistia stratiotes, Salvinia spp., Naias spp. and other aquatic weed species that anyone felt might pose a problem.

By March 1963, over 100 letters and reports were submitted to the Government of Ghana through the Volta River Authority (VRA), which was established in April 1961 concerning aquatic weed control and related subjects.

It soon became VRA's concensus of opinion that it would be advisable for the Government to acquire the services of specialists in the fields of fisheries development and lakeside health. In January 1963, a request for such services was sent to the USAID Mission in Ghana. In partial response to the VRA request, the U.S. detailed Aquatic Biologist, Edward T. Heinen, from USAID/Sudan (Khartoum), who made a two-week survey of the conditions and problems at the Lake, resulting in a report dated April 26, 1963. His report states that three principal

pest weeds—*Eichhornia crassipes* (water hyacinth), *Salvinia auriculata* (water fern), and *Alternanthera philoxeroides* (alligator weed)—were not at that time known to be present in Ghana. But, since they could be accidentally introduced, or other weeds now present could become explosive when environmental conditions changed as the Dam filled, a weed control expert should be on full-time duty from then until a season or two after the Dam filled.

Following Mr. Heinen's recommendations, the VRA amended its original request for a specialist in each field, to one U.S. technician who would be both a aquatic weed control and a fisheries expert, since the work would consist of observation with respect to weeds and preliminary planning with respect to fisheries.

In September 1964, Mr. Heinen accepted a mid-tour transfer to Ghana from Khartoum, Sudan, to work on the Volta River Project. The primary objectives of the aquatic weed control phase of the USAID project were:

1. To study the aquatic weeds present in Ghana and identify those which might have become explosive in the new environment of the filled Volta Lake; and
2. To maintain vigilance over present weeds and establish emergency control measures for use if weeds threatened to get beyond control.

The project had two other objectives, but they pertained to fisheries development and therefore will not be discussed here.

In 1963, the University of Ghana set up the Volta Basin Research Project (VBRP) to undertake research on many of the problems that would be created by the formation of the Lake. During this same year, a survey of the Volta area was started

with a view to ascertaining what species of natural aquatic weeds occurred, and in what quantities. It was also intended to gather ecological data on such weeds so that if a weed problem should arise with the formation of the Volta Lake, as much basic information as possible would be at hand (Lawson, 1964).

Also in 1963, VBRP personnel were asked by the Government to advise it of biological effects of the calcination (burning) of the vegetation of the Volta basin prior to flooding. The subsequent study showed that there were two conflicting hazards.

1. If the vegetation is not burned, there is the possibility of the deeper water layers becoming completely depleted of oxygen. If these conditions are established and the lake waters are subsequently violently mixed, as can happen, heavy fish mortality might result. It should be understood that it is not possible to predict the probable behavior of the Volta Lake in this respect since present scientific knowledge of the behavior of lakes in the humid tropics of the world is limited.

2. If the vegetation is burned, the content of the water in nutrient salts will be increased and this might lead to an explosive growth of weeds which could seriously impede fishing. Again, no satisfactory prediction can be made while the conditions which lead to such explosions are not fully understood.

It was therefore necessary to decide which was the lesser hazard. Very extensive destruction of fish might have resulted in a long period before the Lake could be fully exploited as a source of fish food. Explosive development of weeds could have interfered permanently with the development of fisheries.

It appeared that of these, the development of extensive weed beds could be regarded as the greater hazard as there is no known satisfactory and economical way of destroying weed beds once they have been established. On the other hand, had

there been serious fish mortality, the loss is not irreparable and could be made good by an active restocking program (Lawson, 1966).

The decision was made that no extensive burning or clearing of the vegetation would be made in the Volta basin prior to flooding.

In February 1965, the Institute of Aquatic Biology (IAB) was established. The objective of the IAB is to conduct basic as well as applied research in the field of hydrobiology. This includes studies of aquatic plants with special emphasis on their ecology, biology, distribution, growth, propagation, and importance to the ecosystem; and the investigation of factors which affect their control and eradication (IAB, 1966).

DESCRIPTION OF THE STUDY AREA

Volta Lake is the largest man-made lake in the world and is located entirely within Ghana's boundaries (Map 1).

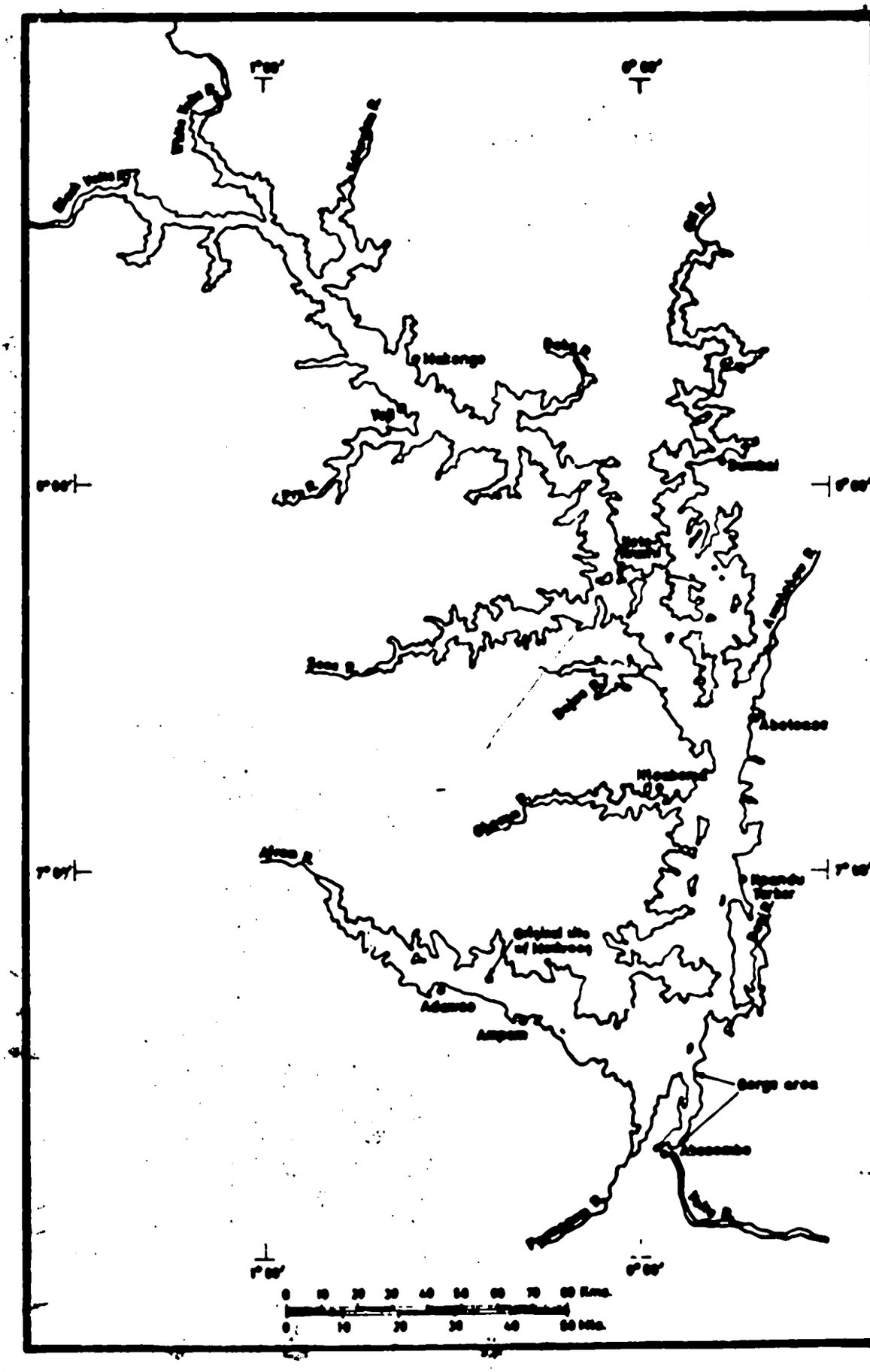
The primary purpose of constructing this mammoth impoundment is to provide hydroelectric power to meet Ghana's rapidly expanding industrial and domestic needs for electric power. However, the Lake's transport, irrigation, fishery, and tourism potentials are immense and are destined to play an ever-increasing role in the future.

The Akosombo Dam, located on the Volta River, was closed in May 1964, and the Lake filled to its highest retention level of 84 meters in November 1968.

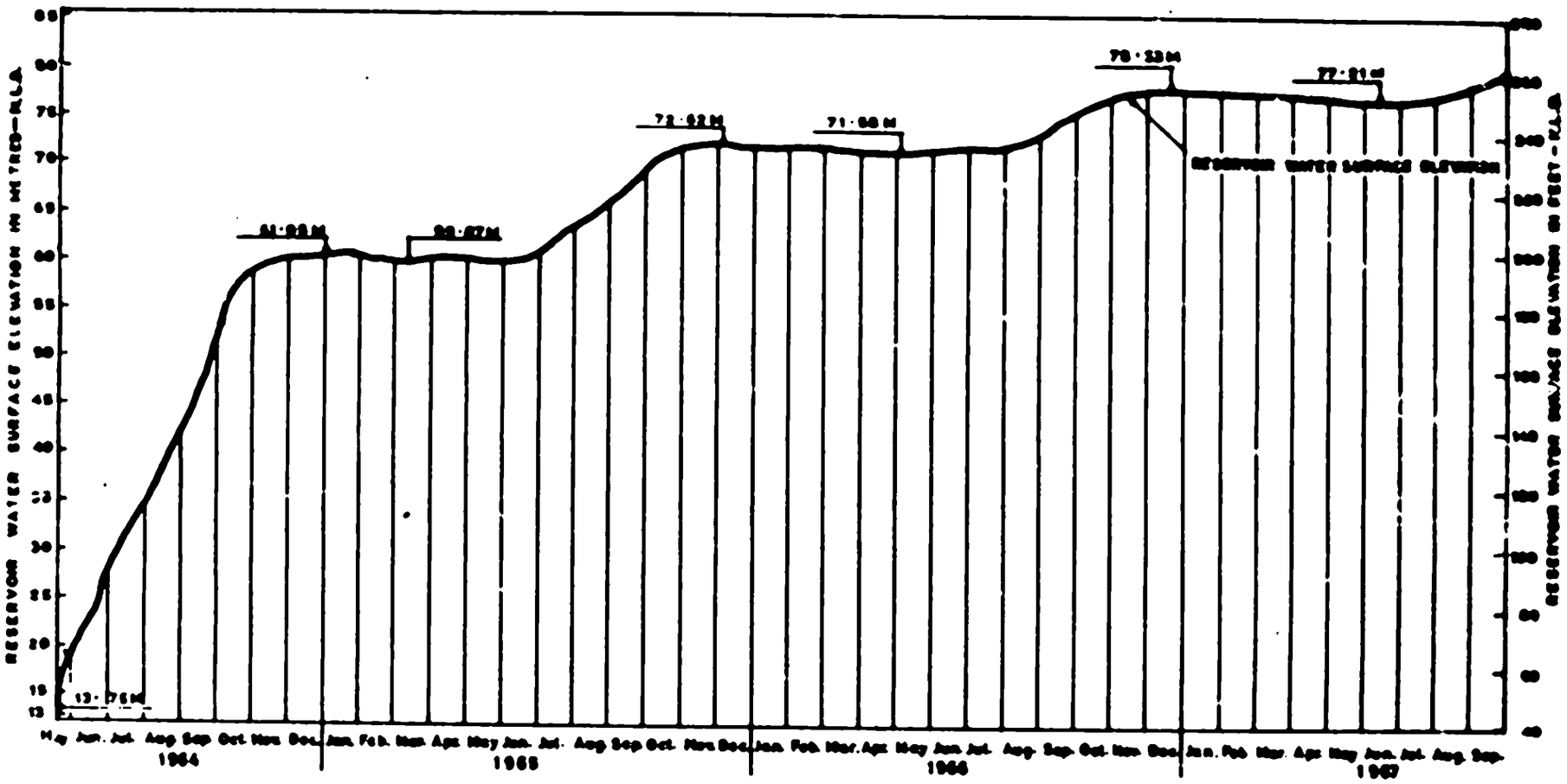
The reservoir is over 400 km. in length, has a surface of 8,348 km^2., a shoreline of approximately 5,000 km., a volume of 149 km^3., and has an average depth of 20 meters when full. The water level fluctuates an average of three vertical meters, rising between July and November and falling between December and June each year (Figure 1A and 1B).

VOLTA LAKE

MAP 1.

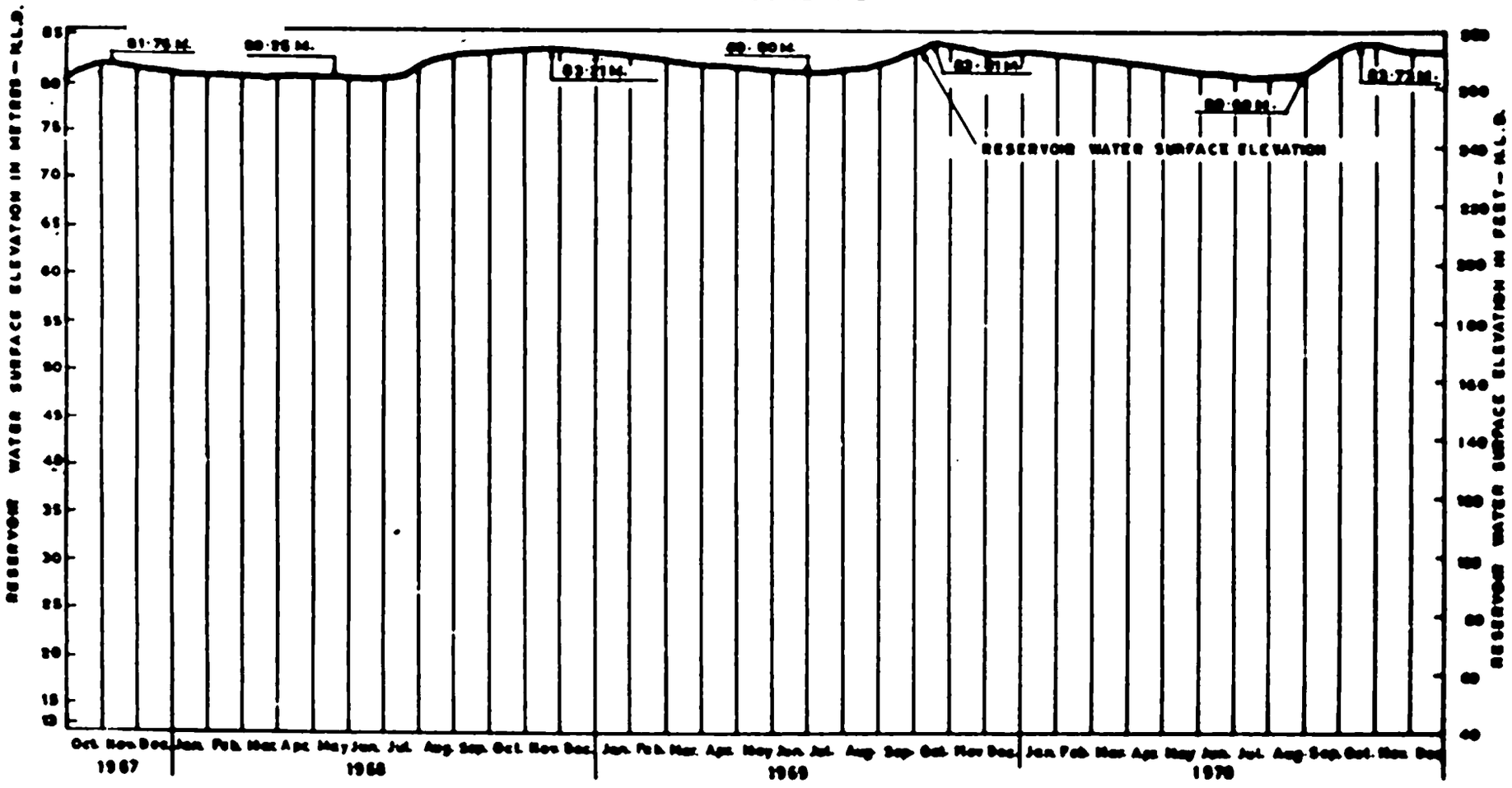


RESERVOIR FILLING CHART
FIGURE 1 A



N.L.D. = NATIONAL LEVEL DATUM

RESERVOIR FILLING CHART
FIGURE 1 B



N.L.D.= NATIONAL LEVEL DATUM

The lake basin was not cleared of standing timber prior to flooding, resulting in virtually all of the Lake being covered with underwater obstructions. Much of the shoreline area of the Lake out to a depth of 10 meters is also covered with trees that extend above the surface of the water. In some areas, particularly in the Afram and Pawpaw sections where large forest trees existed before the Lake was formed, tree tops extend above the water surface in water over 20 meters in depth.

To date, over 50 species of aquatic and semi-aquatic plants are known to exist at the Lake (Table 1). Semi-aquatic plant species that can tolerate flooding are the most abundant by far and become well established on the exposed lake bottom during each drawdown period. The width of this weed band is dependent on the slope of the exposed lake shore. In some areas these weeds extend 150 meters out from shore at high water. However, the average width is closer to 50 meters when the lake level is high.

In addition to the semi-aquatic plant species mentioned above, certain areas of the Lake are inhabited by true aquatic plants, particularly Ceratophyllum demersum, Pistia stratiotes, Lemna, Salvinia nymphellula, and Utricularia inflexa.

AQUATIC PLANT DEVELOPMENT AND DISTRIBUTION

This portion of the report discusses the development and distribution of aquatic and semi-aquatic plant growth at Volta Lake and its basin during the period July 1963 through June 1971. For that period when this writer was working at the Lake (July 1967 through June 1971), each survey discussion is accompanied by a map showing the route taken and the fishing villages visited on the Lake. This information should assist future workers in locating earlier survey stations at the Lake and to

know precisely what type of plant growth was present there at that time. Such data should also be valuable for determining and understanding the changes that are likely to develop in the aquatic plant population as the Lake matures.

Aquatic Weed Survey Data--July 1963-July 1967

A survey of the Volta basin in the Yeji and Kete Krachi areas was started by the VERP in July 1963 (Map 1).

Lawson (1964) reported that the main plant species in the riparian forests included Adansonia digitata, Anogeissus leiocarpus, Crataeva religiosa, Daniellia oliveri, and Pterocarpus erinaceus.

A number of lagoons were surrounded by a zone of grassland. The dominant species here was Andropogon sp. and was found growing to a height of 12 feet. Near the edges of the lagoon, where the water table reached the soil surface, the tree Mitragyna inermis, and Polygonum tomentosum were present. A short distance from the water's edge, Echinochloa pyramidalis grew.

Masses of Utricularia, Pistia, Lemna, Azolla, Salvinia, and Ceratophyllum were reported growing in the lagoon. When these same areas were visited again nine months later, all of the above species were absent apart from Ceratophyllum, which was scarce. Vossia cuspidata, however, was present and there was evidence of early stages of "sudd" formation. This was also observed at Kukrukui Lagoon near Kete Krachi, though here only the Pistia and Utricularia had disappeared completely.

The lagoons on the western side of the Volta, north of Kete Krachi, were visited by helicopter in July 1964, two months following the closure of the Dam at Akosombo. The lake level was at elevation 32 meters and rising fast during that survey (Figure 1A). Rooted plants, such as Ipomoea and Jussiaea

TABLE 1

Aquatic and Semi Aquatic Plant Species Collected at Volta Lake

Amaranthaceae

Alternanthera sessilis

Araceae

Pistia stratiotes

Boraginaceae

Heliotrophium indicum

Ceratophyllaceae

Ceratophyllum demersum

Compositae

Ethulia conyzoides
Zelipta prostrata

Convolvulaceae

Ipomoea aquatica

Cyperaceae

Cyperus articulatus
Cyperus dictamo
Cyperus sphacelotus
Fimbristylis dichotoma
Scirpus cubensis
Torulinium confertum

Gramineae

Andropogon gayanus
Brachiaria mutica
Echinochloa pyramidalis
Echinochloa stagnina
Imperata cylindrica
Leersia hexandra
Leptochloa coerulescens
Oryza longistaminata
Paspalum orbiculare
Phragites karka
Sacciolepis africana
Schizachyrium sanguineum
Sorghum arundinaceum
Vossia cuspidata

Lemnaceae

Spirodela polyrrhiza
Lemna paucicostata
Wolffia arrhiza

Lentibulariaceae

Utricularia inflexa

Marantaceae

Thalia welwitschii

Mimosaceae

Mimosa pigra
Neptunia oleracea

Nelliciaceae

Glinus oppositifolius

Nymphaeaceae

Nymphaea micrantha
Nymphaea lotus

Onagraceae

Ludwigia erecta (previously Jussiaea erecta)
Ludwigia leptocarpa (previously Jussiaea leptocarpa)
Ludwigia stolonifera (previously Jussiaea repens)
Ludwigia hyssopifolia

Papilionaceae

Indigofera paniculata
Tephrosia platycarpa

Polygonaceae

Polygonum senegalense

Rubiaceae

Nitraqyna inermis

Scrophulaceae

Sphenoclea zeylanica

Typhaceae

Typha australis

Ferns

Ceratopteris cornuta
Azolla africana
Cyclosorus striatus
Salvinia nymphellula

(Ludwigia), and rooted ferns were common, but there was little evidence of floating weeds (Lawson, 1964).

In September 1964, Mr. E. T. Heinen, USAID Aquatic Advisor, arrived in Ghana for a one-year tour and was assigned to the VRA as an aquatic weed control and fisheries specialist. His first major aquatic plant survey at the Lake was conducted by air in October of that year. The elevation of the water during that period was 55 meters and rising fast (Figure 1A). This survey covered the Afram and Oti River sections and the eastern shore of the Lake as far north as Kete Krachi.

Data collected during this flight showed that Pistia patches were common on the north side of the Afram as far west as Mankrong (Map 1). An estimated total of 80 hectares of this species was present, and Lemna covered the surface of the water in protected cover near the mouth of the River.

No floating vegetation was observed near Kete Krachi or in the Oti River, with the exception of a few water lilies observed growing in a small pond east of the Oti. Heinen reported that this large tributary appeared to be much more turbid than the Volta River.

Large masses of Lemna and some Pistia were reported growing along the shoreline of the main River from 18 km. north to about 33 km. south of the Kpandu Torkor (Map 1). Also, a few floating masses of what appeared to be Ceratophyllum were seen about 56 km. south of Kpandu Torkor, due east of the Afram confluence.

A boat trip during November 1964 revealed that Pistia, Lemna, Ceratophyllum, and Azolla were scattered along the east bank of the Lake between Kete Krachi and the Asakawkaw River, but no large concentration of aquatic plant growth was noted anywhere during the trip (Map 1). The water level during that

survey trip was at elevation 59 meters and rising slowly (Figure 1A).

At the mouth of the Asakawkaw River, Heinen reported seeing a series of small floating "sudd" islands, the largest being seven to 10 meters across. All but one island contained dead grasses held together by numerous roots entwined in black soil and being about .6 meters thick. The one island with live vegetation consisted of the same general structure as the others. It was speculated that these grasses had been growing in wet areas and had floated after being flooded by the rising water.

Subsequent surveys conducted by Heinen during his one-year tour showed that even though floating aquatic plants were developing as the Lake filled, no unusual explosion was occurring.

Because of Volta Lake's size and its inaccessability, which make it very difficult to survey properly, Mr. Heinen felt that if an exotic aquatic weed species like water hyacinth (Eichhornia crassipes) were present at the Lake it might become well established before it was detected and control measures organized. Therefore, he recommended that a number (10,000) of posters showing several potentially dangerous exotic weed species be printed in several different local languages and posted at villages around the Lake and its tributaries. Such a program had worked for him in the Sudan for locating isolated nursery areas containing water hyacinth that otherwise would not have been detected. Instructions on the posters asked anyone who should happen to see any of the plants (Eichhornia crassipes, Salvinia auriculata, Cyperus papyrus, Alternanthera philoxeroides) shown on the colored poster to advise the nearest VRA or other Government office. With this information, a work crew could be dispatched, a verification made, and the necessary control initiated.

Mr. Heinen left Ghana before the posters were printed, but fortunately they were not needed since none of these plant species have been detected at the Lake to date.

Prior to Mr. Heinen's departure from Ghana, he placed an order for VRA for the purchase of three boat spray units (John Bean model 1010K) to be used for aquatic weed control should an unexpected weed problem develop. He also left instructions on how to operate the spray units, the size of the boat and outboard motor that was needed, and the type of herbicides to use. In addition, Mr. Heinen submitted a report concerning aerial spraying techniques using a helicopter, should large-scale treatments be required during his absence. It should be noted here that Mr. Heinen intended to return to Ghana for a two-year tour, but because of personal reasons he decided against it. Therefore, the above instructions were of an interim nature, and had he returned, he would have used the spray units to conduct aquatic weed control tests using selected herbicides and at the same time, train VRA employees in aquatic weed control techniques.

In August 1965, IAB personnel travelled to the Afram section of the Volta Lake and found the area heavily infested with mats of floating *Pistia stratiotes* and *Azolla africana*. These mats were restricted primarily to the original river channel and were scarce beyond the partly submerged trees that had bordered the banks of the River before the Lake started filling. A later trip to the Kete Krachi area by boat revealed that there was a general movement of floating *Pistia* towards the Dam and that these plants were scattered over 75 percent of the Lake just below the Afram junction. However, by mid-August these plants had washed and settled along the shoreline forming patches up to 3.5 meters wide. The water level at that time was at elevation 65 meters and rising fast (Figure 1A).

Above the Afram confluence to Kete Krachi, *Pistia* was sighted floating between emergent trees, and *Ceratophyllum* and *Utricularia* were seen entangled among submerged portions of the flooded timber. Near Kete Krachi, *Salvinia nymphellula*, *Azolla*, *Spirodela polyrrhiza* and *Lemna sp.* were reported to be abundant.

The following 12 species of aquatic plants were collected at the Lake by the IAB during 1965-67:

1. *Pistia stratiotes*
2. *Spirodela polyrrhiza*
3. *Azolla africana*
4. *Ludwigia leptocarpa*
5. *Ludwigia stolenifera*
6. *Scirpus cubensis*
7. *Cyperus distans*
8. *Salvinia nymphellula*
9. *Ceratopteris cornuta*
10. *Lemna sp.*
11. *Ceratophyllum demersum*
12. *Utricularia inflexa*

The IAB stated that *Pistia* was the most common aquatic plant at the Lake during the first year and that this plant species is known to harbor vectors, insects, and mollusks. They also reported that swarms of flies were found in the wake of the boat as it passed through beds of *Pistia*. A number of these insects were captured and were identified as mostly biting mosquitoes, tsetse flies, horseflies (*Tabanus sp.*), and at least two species of dragon flies. (Mosquitoes of *Mansonia sp.*, which are vectors of rural filariasis, are known to breed in relation with *Pistia*.)

Aquatic Weed Survey Data--July 1967-March 1971

This writer arrived in Ghana in July 1967, approximately three years after Volta Lake started forming and 22 months after the previous USAID Aquatic Weed Control Advisor, Mr. E. T. Heinan, had left. The remaining portion of this section of the report discusses data collected by the writer and his staff during 19 survey trips on the Lake between December 1967 and February 1971.

Survey Trip 1 (Map 2)

During a three-day boat trip to the Obosum River area in December 1967 with Dr. I. Paperna, National Institute of Health (NIH), who was conducting a snail survey in the area, the author found no evidence of an aquatic weed problem existing. However, some *Alternanthera sessilus*, *Utricularia inflexa*, *Azolla africana*, and *Vossia cuspidata* were observed. The latter species was most commonly seen growing on the wind-swept shores facing north and east, which is the direction of the prevailing winds in that area.

At the time of this study, the water level was at approximately elevation 80 meters and falling slowly (Figure 1B). The previous year's high water mark had reached elevation 78 meters. This two meter rise in the water level in 1967 flooded land that had not been inundated previously. This resulted in the shallow shoreline's being covered with dead and rotting terrestrial vegetation. No rooted aquatic or semi-aquatic weeds were seen growing in that newly flooded zone; however, some floating aquatic plants were present.

The rooted plant species mentioned above were seen growing immediately off-shore within the zone that had gone through a complete flood and drawdown cycle the previous year, but the plant density was very light (Pierce, 1967a).

Survey Trip 2 (Map 3)

Between January 4 and 7, 1966, the writer accompanied Dr. I. Paperna to the Afram section of the Lake to census the current aquatic weed growth and snail population. The water level at that time was at elevation 80 meters and falling slowly (Figure 1B).

This section differs from most other parts of the Lake in that, prior to the flooding, this area was an extensive forest several kilometers across in places. Because of this, large quantities of dead timber exist above, as well as below, the surface of the water. The Afram basin is relatively flat and wide, and it is understood that prior to flooding, many aquatic weeds filled lagoons bordering the River's edge.

Vossia was noted growing at the Afram confluence, but not westward up the River. In the Ampem area, Ceratophyllum was well established near shore and out to a depth of three meters in places. Fragments of this species were seen throughout the Afram. Also, near Ampem and westward to Adawso, floating islands of Pistia-Scirpus were seen growing among the flooded timber. At the Adawso ferry crossing, these islands were very extensive, but did not present a problem to the ferry at that time. However, it is understood that they did the previous year and had to be removed manually before the ferry could dock.

Other aquatic weed species noted during this survey were Spirodela polyrrhiza, Salvinia nymphellula, Cyperus sp., and small amounts of Polygonum senegalense scattered here and there along the shore (Pierce, 1966a).

Survey Trip 3 (Map 4)

In late April and early May 1966, a survey trip was conducted along the northern shore of the Afram from Kongo Bator Kope west to Foso #1. The water level during this survey was

year's high water mark had reached elevation 81.5 meters during the previous November; therefore, a considerable amount (10 meters) of lake shore was exposed. The most common plant species growing on this exposed area was Ludwigia stolonifera, but some Polygonum senegalense and Alternanthera sessilis were also seen. No true aquatic weeds were observed until we had travelled westward beyond Flamanjo #2. From here the Lake stays within the confines of the tall dense forest, and Pistia-Scirpus islands, Ceratophyllum, and Utricularia were seen growing among the flooded timber (Pierce, 1968c).

Survey Trip 4 (Map 5)

In mid-June 1968, a survey trip was made from the northern bank of the Afram confluence north along the western side of the Lake to the Obossum River area. Stops were also made on the east side of the Lake at Kpandu Torkor and Dodi. The area surveyed is characterized by having extensive areas of flooded low to medium-sized trees, and occasionally, a steep rocky shoreline--particularly in the Ahorkiti Kope area.

The water level at that time was at elevation 80 meters--the lowest level it had reached during that drawdown period (Figure 1B). The exposed shoreline that was not unprotected from strong wave action, or that was not too rocky or steep, was covered with Ludwigia stolonifera and Alternanthera, with an occasional patch of Vossia. Vossia increased in abundance as we travelled north; and near Korga, this species had virtually covered the shoreline that had been exposed during the current drawdown period. However, near Abukyere, which is located approximately one kilometer west of Korga, Polygonum still dominated the shoreline along the coves.

At Yamda Tochor, which is an important fish market center at the Lake, very little plant growth was noted on the exposed lake shore near the main landing. This lack of growth was attributed to the constant human activity and heavy wave action there.

In a small sheltered cove near the canoe landing at Dodi, Ceratophyllum was found; but because of the relatively steep bank and deep water near shore, it was not wide spread nor should it be expected to be in the future (Pierce, 1968a).

Survey Trip 2 (Map 6)

In mid-July 1968, a survey was conducted half-way up the Lake near Kete Krachi and in the Oti River area. The water level at that time was 80.5 meters and rising far (Figure 1B).

It was interesting to note that very few signs of aquatic weed and semi-aquatic weed growth was observed along the Oti River from Kete Krachi north to the Dumbia ferry crossing and south and east to Abotoase.

Only an occacional small cluster of Pistia-Scirpus was seen floating, and on shore Ludwigia stolonifera and Alternanthera sessilis were scarce. However, much of the shoreline was not checked, and those areas that were checked consisted primarily of beaches or small stones and wind-rowed debris. Local fishermen said that Pistia and Scirpus had been much more plentiful during previous years.

At Abotoase, which was probably the busiest fish market center at the Lake at that time, the water was fairly deep; and during the survey, very little aquatic plant growth was present. This market center is located in a well-protected cove that has relatively steep banks. Therefore, the amount of exposed shore is minimal during the drawdown; hence, very little shoreline vegetation is possible. However, pollution from so many people

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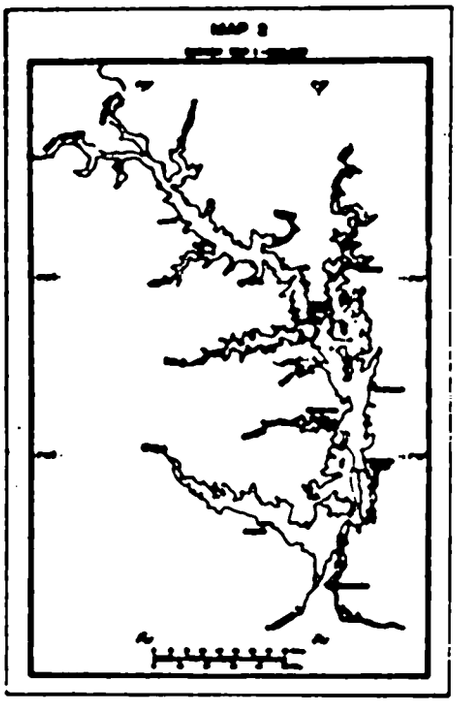

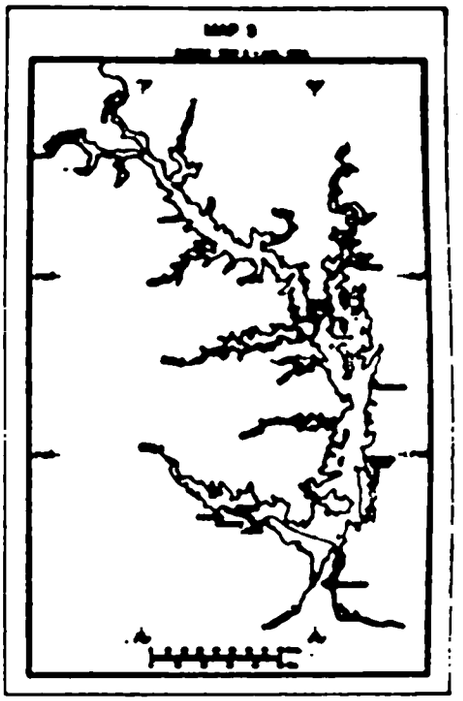

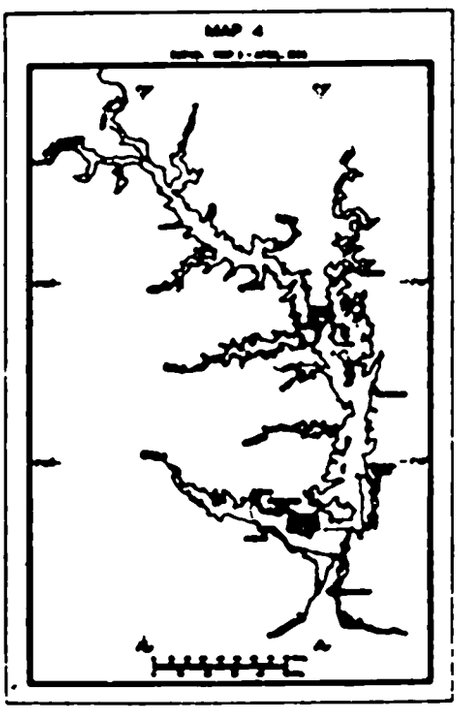

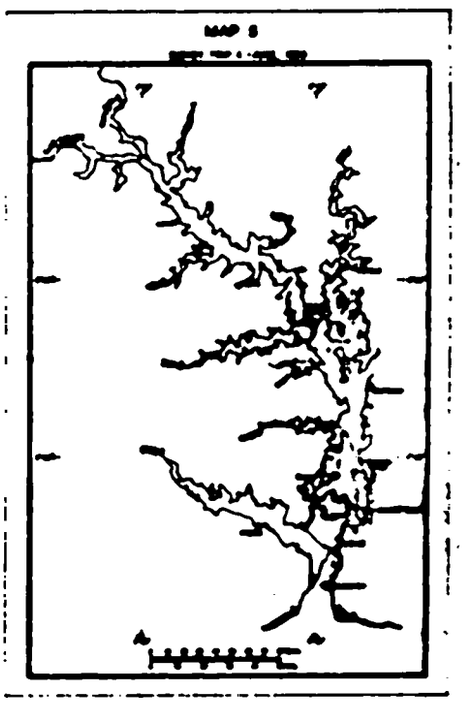

crowding around the market center makes it ideal for increased aquatic weed growth in the future (Pierce, 1968f).

Survey Trip 6 (Map 7)

The Afram area was revisited in early October 1968. The water level was at elevation 83.5 meters (Figure 1B) and rising steadily (the Lake filled to its high retention level of 84 meters in November 1963).

The amount of aquatic weeds had increased significantly since the previous survey trips to the area in January and May 1968. Marked increases of *Pistia*-*Scirpus* islands and *Ceratophyllum* were noted near Arpem, but the most dramatic increase was in the amount of *Polygonum senegalense* on the southern shore and *Alternanthera sessilis* along the northern shore of the Afram. The latter two species extended out into the Lake to a depth of three meters and formed solid mats as far off shore as 70 meters. These plant species had become established on the exposed lake shore during the previous drawdown period and had been able to grow fast enough as the Lake filled to stay above the water's surface. Based on data collected from local fishermen, this was the first year that these two plant species had been abundant during the flood season (Pierce, 1968g).

Survey Trip 7 (Map 8)

On October 29, 1968, this writer accompanied Volta Lake Research Project (VLRP) personnel on a general aerial survey of Volta Lake. The flight was made in a Ghana Air Force single engine "Beaver" airplane flying at an elevation of approximately 300 meters and at a speed of 145 km. per hour. The flight lasted eight hours, five of which were actually used for surveying over the Lake. At the time of the flight, the Lake's water level was nearing its anticipated annual maximum high retention level of 84 meters elevation (Figure 1B).

Therefore, the extent of the flooded semi-aquatic and aquatic weeds were able to be observed fully.

The main objectives of the aquatic weed portion of the aerial survey were to:

1. Assess the current aquatic weed problem in the Lake;
2. Locate specific aquatic weed infestation that should be visited by boat for closer scrutiny;
3. Determine how effectively aerial surveys can be conducted to accurately assess aquatic weed developments; and
4. Become familiar with the Lake in general in order to better understand the physical factors that influence aquatic weed development in only certain areas, and to have a better insight into changes that are likely to take place in the future as the Lake matures.

The writer considered the flight to have been completely successful in accomplishing the above objectives and recommended that at least one aerial survey should be made each year.

The previous aquatic weed surveys that were conducted by the writer assisted in more accurately identifying the plant species during the aerial reconnaissance. This was accomplished by properly identifying the common species of aquatic plants situated near known and easily distinguishable landmarks by water and/or land, so that when these areas were checked from the air it was known which plant species were being observed. Of course, these observations could not be totally accurate, particularly for small scattered or deeply submerged species, but it was considered sufficiently accurate for this type of general survey. The location of weed infestations in the Lake

were recorded on a large map for future reference. Aerial photographs were also taken for future species identification and growth comparisons.

From the information that was available concerning the changes that have taken place in the Lake's aquatic weed community during the previous two to three years, it was obvious that the species of aquatic plants and their distribution had changed considerably, particularly during the previous six months.

Two areas of the Lake still contained extremely heavy concentrations of floating islands of Pistia-Scirpus. The largest area by far is in the upper Afram beginning approximately two miles above the Adawso ferry crossing and extending solidly upstream to the mouth of the River. This area of infestation consisted of several thousand hectares (estimated), but was not creating immediate threat to normal lake functions since this area is only sparsely inhabited and has what appears to be very limited development potential. However, it was decided that this large nursery area for floating aquatic weeds should be watched closely to assure that it did not spread or break away and endanger adjoining areas of commercial importance. The other area of floating aquatic weed infestation was in the upper end of the Pawpaw River above Dawa Kope. Even though this infested area consisted of less than 25 surface hectares (estimated), it needed to be watched very closely to be sure that the important Dawa Kope road head landing was not blocked to boat traffic.

The marginal aquatic plants that had become so well established on the exposed lake shore during the previous six months consisted primarily of Polygonum, Alternanthera, and Vossia. The former two species were bordering much of the shoreline in

the Afrah and northward to the Sene River. Above the Sene River to just beyond Yeji, the marginal vegetation consisted primarily of Vossia.

Even though only an estimated 25 percent of the western shore of the Lake was then infested with these marginal plants, the writer considered this to be very significant since just six months earlier these species were considered of secondary importance and were not at all populous. Therefore, if this trend continued, which it was expected to do, much more of the Lake's shallow shoreline would become infested with these semi-aquatic weeds in future years.

These marginal species were not expected to create serious problems relative to hydroelectric generation or lake transport. However, it was feared that these permanent weed beds would provide vector snails with an ideal habitat which could increase greatly the spread of Bilharziasis at the Lake.

The entire length of the eastern shore of the Lake was relatively clear of aquatic weed growth. This was probably due to the area's steeper banks, more active wave action, and the rocky shoreline (Pierce, 1968h).

Survey Trip 8 (Map 9)

In January 1969, a five-day aquatic survey trip was made by boat between Akosombo and the mouth of the Sene River. The water's elevation during that study was at 83 meters and falling slowly (Figure 1B). Data collected during this survey indicated that semi-aquatic weeds, particularly Vossia, were becoming well established along much of the shoreline along the western side of the Lake.

Comparing these data with earlier surveys of the same area (December 1967 and October 1968), it became obvious that the semi-aquatic weeds Vossia, Polygonum, and Alternanthera had

The water level at the outer edge of the flooded aquatic vegetation was in excess of three meters which indicated that the future anticipated annual lake level fluctuation of three to four meters would not have an adverse effect on the above species. It appeared, in fact, that the gradual water fluctuation stimulated their growth since Vossia stems measuring over seven meters were found growing in only three meters of water near Kabu below the Obossum River.

It also appeared that Vossia can withstand relatively strong wave action since it was commonly found along wave-swept shorelines and exposed points, whereas Polygonum and Alternanthera were not. It was interesting to find that aquatic weeds were not well established in the Dwija River during this trip, even though conditions appeared favorable. A similar condition existed in the Obossum River during the writer's first visit to that area in December 1967. However, some aquatic weeds, including Vossia were found growing in the Obossum River area during the January 1969 trip; therefore, it was speculated that aquatic weeds would eventually establish themselves in the Dwija River as well (Pierce, 1969b).

Survey Trip 9 (Map 10)

During February 1969, an aquatic weed survey was conducted as far up the Afram River as possible and along the northern shore of the Afram between the Adowso ferry crossing and Kwame Djomba, due north of Anpem. The primary purpose of this trip was to take a closer look at the heavy aquatic weed growth that had been observed in that area during the aerial survey that was conducted three and one-half months earlier in October 1968. The water level was at elevation 82.5 meters and falling during the survey (Figure 1B).

As had been recorded during the aerial survey, the main

10 km, west of Adawso this growth became too dense to penetrate by boat. This area was characterised by having large concentrations of flooded, emergent dead timber which afforded the plants the necessary protection and anchorage to form a solid mass of floating weeds. These floating mats were comprised of Pistia-Scirpus, Cyperus sp. and also Ceratopteris cornuta. The water was extremely clear and a distinct current was noted. The clear water would be expected since the Afram water shed is heavily forested; therefore, silting should be low and very little algal plankton could survive the shading of the several thousand acres of solid weed cover that exists there. It is also likely that much of the nutrients that flow into the Lake from the River are utilized by the large mass of floating aquatic weeds.

Travelling east of Adawso along the northern bank of the Afram, we noted fewer and fewer floating islands of Pistia-Scirpus. At a point approximately due north of Asuboni, these masses were scarce, and Polygonum and Alternanthera increased. These species became more abundant as we travelled east to Kwame Djomba. Some scattered Ceratophyllum and Utricularia were seen entangled in flooded trees off-shore (Pierce, 1969d).

Survey Trip 10 (Map 11)

In February 1969, an aquatic weed survey trip was made above Yeji. Since this particular trip was designed to collect data in the extreme upper reaches of the Lake, and time did not allow, no attempt was made to visit shoreline areas along the way to assess the current aquatic weed problems. However, Vossia was observed almost everywhere the boat came in sight of land, particularly along the western side of the Lake to the Sene River. Above the Sene River, Vossia was readily seen on both banks, but appeared to be particularly abundant on the western shore. The uneven spreading is attributed to prevailing

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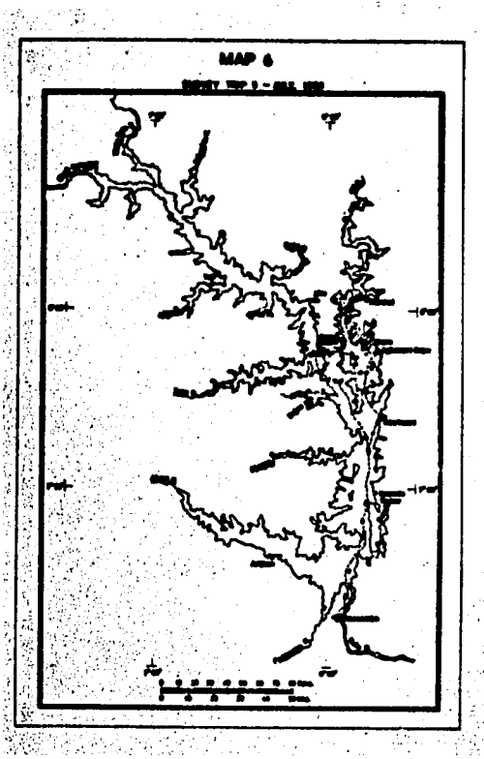

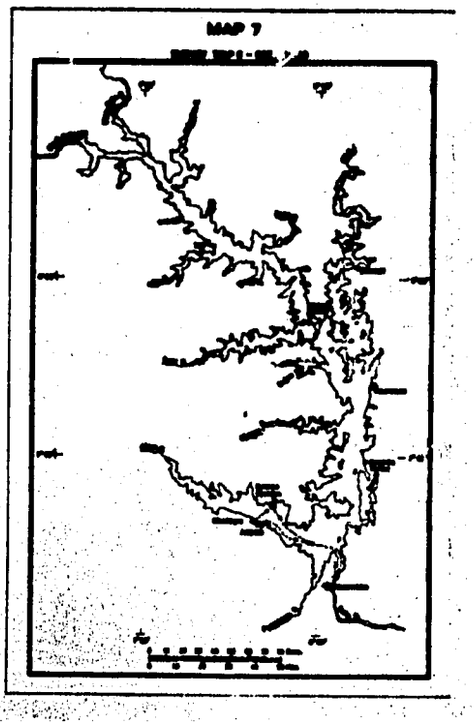

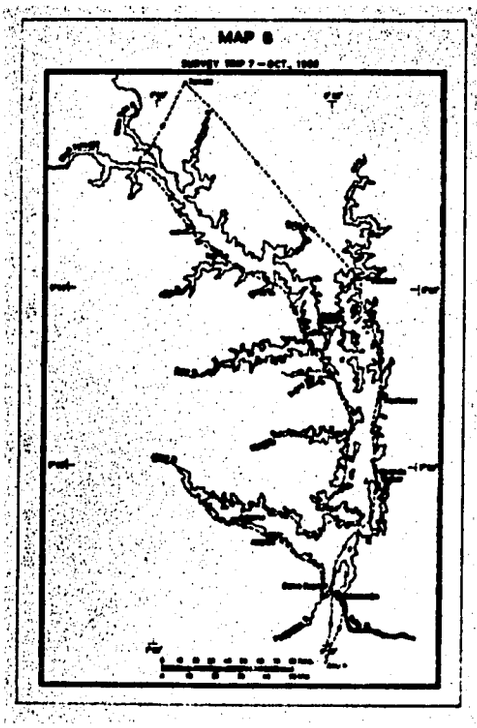

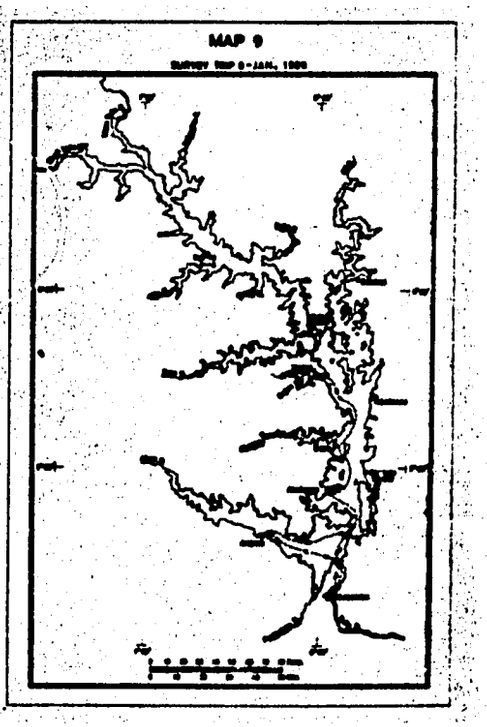

westerly winds. Vossia was also seen growing along the shores of islands; and in a few cases, floating mats of Vossia were observed in the flooded timber. The Lake elevation was 82 meters and falling during this survey (Figure 1B).

The area around Aklor #1, located approximately 18 km. south of the confluence of the Black and White Voltas, contained scattered patches of Vossia near shore, as well as fragments of Ceratophyllum and Utricularia which were present in gill nets the following morning.

From Aklor #1 to a point 10 km. up the Black Volta, Vossia was present, but became less abundant as we moved up river. Most of the Vossia was located in the broad flooded timber area at the confluence of the two rivers.

It was interesting to note that no Vossia was observed in the White Volta (approximately 10 km. above the river's confluence) which indicates that the Black Volta may have been the original source of Vossia that now infests large portions of the Lake's western shoreline almost to the Dam.

Another interesting observation made during this trip was the enormous quantity of plankton algae in the water immediately above Aklor #1 and extending up each of the rivers as far as we travelled. Most of the surface of the Lake in this area, particularly in the sheltered flooded bush, was covered with a skin of dead algae believed to be Microcystis.

On the return trip the writer stopped at Yeji to determine to what extent aquatic weeds were interfering with the ferry crossing and normal shoreline development. Vossia appeared to have spread considerably since the aerial flight made in late October 1968, but did not present any immediate danger to the ferry operation. However, much of the shoreline adjacent to the ferry ramp was lined with a strip of Vossia ranging up to

30 meters (estimated) in width and growing in water that was 2.5 meters deep.

Observations made during a short stop at Kete Krachi indicated that aquatic weeds were not a problem near the landing even though some Vossia, Leersia (cut grass), and Ludwigia were present in the area. The shore around Kete Krachi was somewhat unique, since it consisted of a sand and small pebble beach. This beach had been produced by the water and wave action eroding away the exposed shoreline outcrops of conglomerate rock formations which are so prevalent in that area. This type of infertile shifting strata is not conducive to aquatic weed establishment; therefore, it is unlikely that aquatic or shoreline weeds will become a serious problem in this area as long as the above conditions persist.(Pierce, 1969c).

Survey Trip 11 (Map 12)

In April 1969, a six-day aquatic weed survey was conducted by boat in the Dwija and Sene Rivers, as well as other points which were visited while travelling to and from Akosombo. The water level during this survey trip was at elevation 81.5 meters (Figure 1B) and falling steadily (2.5 cm. per day). Since November 1968, the lake level had dropped almost two vertical meters, thereby producing extensive mud flats along the edge of the Lake. These flats were becoming covered with Alternanthera, Polygonum, Ludwigia, and Vossia. The latter species was becoming more abundant along the main Lake and at the mouth of the rivers, while the former three species were more prevalent in the sheltered bays and coves.

Based on what had happened in the previous flood period, it was expected that these marginal semi-aquatic plant species would form an even heavier band of emergent vegetation during the following flood period (Pierce, 1969f).

Survey Trip 12 (Map 13)

An aquatic weed survey was conducted in May 1962 in the Ampem and Adawso area of the Afram. The water level was approaching its annual low elevation of 80 meters during this trip (Figure 1B).

The primary purpose of this survey was to determine how extensive the marginal weed problem had become on the mud flats that had been exposed during the previous drawdown period, and to observe the status of the floating Pistia-Scirpus-Cyperus islands in the upper Afram above Adawso. Continual observations made at Ampem indicated that marginal aquatic plants, particularly Polygonum, had spread steadily as the lake level receded. This resulted in a broad expansion of marginal semi-aquatic plants that varied in size and maturity. The older and larger plants were growing at the greatest distance from the water's edge. In general, the larger Polygonum plants were approximately 1.3 meters high, flowering, and growing 45 meters to 70 meters from the water's edge (last year's high water mark). Between 30 and 50 meters from shore, the Polygonum was .8 to 1.3 meters high with only a small percentage being in flower. From 10 meters to 30 meters from the edge of the water, the plants ranged from .3 to .6 meters high, and none were in flower. Those plants growing near the edge of the water were seedlings or plants in the three- to five-leaf stage. From these observations, it was obvious that most of the Polygonum was becoming established by seeds and not from wind-rowed plant fragments and rhizomes, as was often the case with other marginal plant species at the Lake; particularly Vossia. Because of the extremely heavy stand of Polygonum that was present in the Ampem area the previous year, the bottom of the Lake must have been literally covered with Polygonum seeds near shore since recently

germinated seeds were found in large quantities--hundreds per square meter--at the edge of the water a few days after the seeds had been exposed.

The next area that was visited was near a village called Fraamajo, Twi for "The Wind Never Stops," which is located north-north-east of Anpem and approximately six kilometers due east of Bonne Djoube.

This area is typical of the northern shore of the Afram which is characterized by a gradually sloping shore which is partially covered with flooded bush. Plant species growing on these extensive mud flats included Polygonum, Alternanthera, Ludwigia, and sedges. Even though the Polygonum was not as well established there as it was at Anpem, it was felt that a well-defined border of emergent aquatic plants should become established during the following flood period. No aquatic plants were found growing in the water near this village, and absolutely no snails could be found.

The following day, May 21, 1969, we travelled up the Afram along the northern shore to a village approximately 13 km. above Adawso, called Bompata--Twi for "Place where Tilapia are Abundant." This area is characterized by flooded timber and bush which extend above the water all the way across the Afram, with the exception of the original river channel. This section is further characterized as being the area where the islands of floating aquatics start (see Survey Trip 9). Some of these islands were anchored in place by obstructions that extended above the water, while others were moving according to the direction and velocity of the wind. Many of these islands had been blown into shore in front of Bompata. This made it necessary for the villagers to cut a small trail through approximately 30 meters of the floating vegetation in order to get in and out of

their villages by canoe (Plate 1). No motor launches visit the village, according to the fishermen, primarily because of the aquatic weeds; therefore, the fishermen have to travel 10 km. across the Lake to a market center on the southern shore. The villagers stated that the weed problem had increased during the previous year (Pierce, 1969h).

Observations made at the Lake by this writer showed that Scirpus usually colonizes floating masses of Pistia, rather than the reverse. The grassy islands develop from Scirpus seeds that are deposited by wind or waves in the rosette leaf arrangement of floating Pistia. As the Pistia leaves die, they form an ideal stratum for the Scirpus seeds to germinate and grow. Within a short period of time, these young Scirpus plants form well established root systems that become entwined with those of its host. If conditions are favorable, the Scirpus will grow until the Pistia can no longer be seen, except along the outer edge of the floating island (Plate 2). Eventually, the Scirpus may kill the Pistia underneath by shading--which may cause the island to sink. If this happens, and it often does, the Scirpus will also die and rot away. Pistia will then become established once again in the newly created open water, and the whole process will start anew. However, in areas where the islands are well protected and where the mass of floating vegetation is extensive, the Scirpus may stay afloat indefinitely if the roots of the plants have entrapped enough gas to support the weight of the island. After several generations of plants have passed, the density of the island mass may be thick and buoyant enough to support the weight of a man (IAB, 1968). These are usually referred to as "sudd" formations. As mentioned above, such formations have become established in the upper end of the Afram and Pasupasu Rivers where both shelter and water

fertility are sufficient to support large masses of floating aquatics.

Survey Trip 13 (Map 14)

In June 1969, an aquatic plant survey was conducted between Daghamukpo and Dodi #2, located on the western side of the Lake between the Afram and Dwija Rivers. The water level at the time of this study was at 80 meters--the lowest anticipated retention level (Figure 18).

The shoreline in the areas checked were relatively flat; therefore, the width of the exposed lake shore was as wide as 100 meters, and averaged 50 meters in width. The plant growth on the exposed shoreline varied from station to station, but Alternanthera sessilis was definitely the dominant species, followed by Polygonum senegalense, Ludwigia stolonifera and leptocarpa, and Vossia cuspidata. Vossia dominated the upper reaches of the exposed shoreline; whereas, the other species mentioned above, which reproduce primarily from seeds, dominated the lower half of the exposed shore (Pierce, 1969i).

Survey Trip 14 (Map 15)

This survey trip was conducted in October 1969 as a follow-up to the June trip discussed above. The purpose of the survey was to determine what effect the rising water would have on the semi-aquatic plants that had established themselves on the exposed lake shore during the previous drawdown period. To assess this, the same areas were visited that were checked during the June survey; however, additional areas were also checked. The water level at the time of this survey was nearing elevation 84 meters--the anticipated annual high retention level (Figure 18).

Data collected during this survey showed that Polygonum had tolerated flooding better than Alternanthera and Ludwigia.

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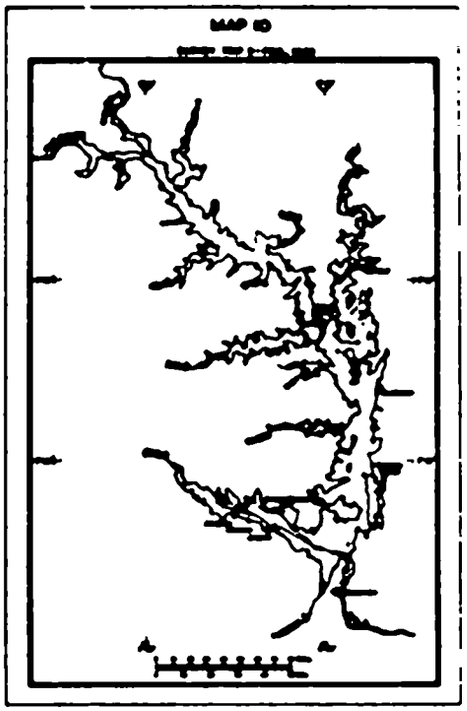
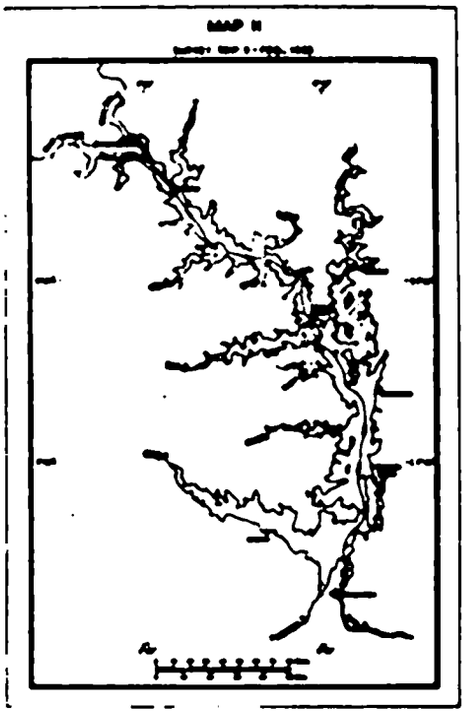
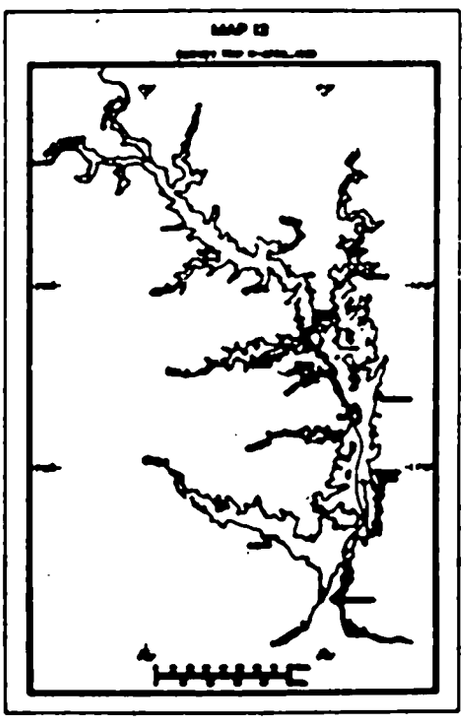
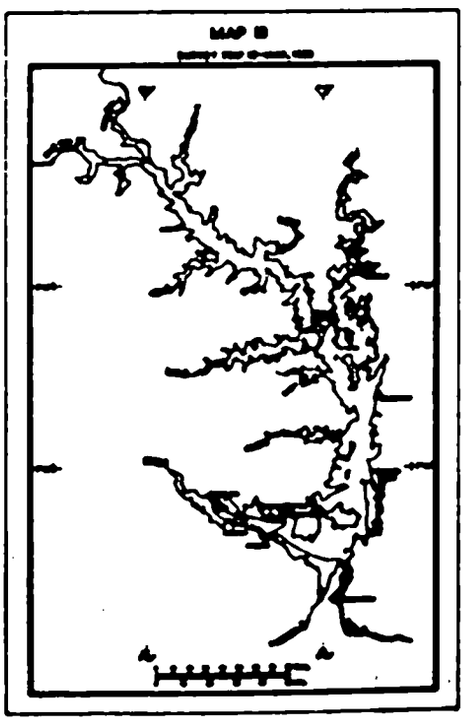








Very little emergent growth of the latter two species was seen, however, large quantities of these plants were noticed below the surface of the water. The rate of flooding had apparently exceeded the plants' growth rate, or their ability to stay afloat. Because of this, the the plants were submerged completely, except near shore in water less than one meter deep. These flooded plants, even though still green, appeared to be dying and were becoming defoliated. Polygonum, on the other hand, was growing vigorously out to a depth of three meters and extending as far as .5 meters above the water surface. Unlike Alternanthera and Ludwigia, Polygonum has hollow expanded stems that make it suitable for floating on the water's surface. Ludwigia also has floating devices, but they did not appear to be sufficient except in areas protected from wave action.

Of the plant species observed growing on the exposed lake shore during the June survey, Vossia had increased the most during that current flood period. This grass species had virtually replaced Polygonum and Alternanthera in areas that had had only a few scattered patches of Vossia during the previous drawdown period. The density of these weed beds were impossible to penetrate by boat, unless a path had been created beforehand. Vossia was seen in flower at several different points, which the writer later learned was relatively uncommon.

In the Obosum River near the Ntoaboma Resettlement village landing, floating patches of grass (Sacciolepis africana), and lilies (Nymphaea lotus), were noted. The amount of grass increased up river above Ntoaboma, and the grass was very dark green and in flower. A heavy phytoplankton bloom was also noted in this area (secchi disc reading of .5 meters). However, as we travelled east toward the mouth of the River, the phytoplankton decreased significantly (secchi disc reading two meters),

as did the amount of grass. Also, those patches of grass that were present along the shore near the mouth of the River did not appear to be growing nearly as vigorously as the patches farther up stream.

It was speculated that the increased growth rate of the plants observed up stream could be attributed to the apparently higher nutrient level of the inflowing water, as evidenced by the relatively large quantity of phytoplankton seen there (Pierce, 1969j).

Survey Trip 15 (Map 16)

This 10-day aquatic plant survey trip in November and December 1969 was the most extensive single survey made at the Lake by the writer.

From data collected during this survey, it was obvious that a marginal weed problem existed virtually everywhere around the Lake--with the exception of the few shoreline areas that were rocky, wave-swept, steeply banked, or recently flooded. During interviews with the lake fishermen, however, it was learned that this marginal weed growth does interfere seriously, in many cases, with their inshore fishing effort during the flood period. Bilharziasis was reported to exist in many of the areas visited, but there was no indication of a high snail population being present at the time of the survey.

The following discussion mentions only those dominant species of potentially dangerous aquatic weeds observed and does not include the many other sparsely populated species. However, samples of each were collected, pressed, and placed in the project herbarium for future reference. It should also be mentioned that the survey stations listed below were only used as general landmarks for future reference since the surveys usually extended a great distance from the actual village sites mentioned.

Akorombo to Abotoase

Vossia had continued to spread slowly along the western shore of the Gorge, but because of the steepness of the banks, it was not considered to be a serious threat to lake operations. Rather large--but scattered--quantities of Pistia were seen floating in mid-lake. It was guessed that these plants had been blown off-shore, probably from the Pawpaw River. On the return trip, Pistia was also seen floating off-shore around "Monkey Island." These plants could have been the same plants that were observed farther down the Lake nine days earlier--or at least from the same source. Vossia was also seen growing around islands we passed on the way to Abotoase. We generally cruised too far from shore to tell how heavy the weed growth was on the mainland below Abotoase; however, we were advised that some weeds were present in the water in that area. The sheltered cove at Abotoase was virtually free of aquatic weeds--a condition attributed to the area's steep banks and prevailing off-shore winds (see Survey Trip 5).

Abotoase to just below Yeji

Aquatic weeds, mostly Vossia, were observed growing extensively around the islands and the shoreline which was viewed on the trip up lake.

Yeji to Makongo to Mamwanco River to Buabadene on the Bonjori River

Vossia was well established along the shore at Yeji, but it was not presenting a threat to the ferry operations. However, its impact on public health is not known, and Bilharziasis was reported to be common at Yeji.

The shoreline at Makongo was also heavily covered with aquatic weeds, but most of it was Echinochloa rather than Vossia. From Makongo, we travelled north and east to the Mamwango River. Here we found the shoreline covered with a

mixture of Vossia, Oryza, and Echinocloa. Also, Polygonum, Ludwigia, and Alternanthera were present. From here, we crossed to the western side of the Lake to Bumbadene on the Bonjari River. The dominant species in this location was Vossia, but Polygonum, Oryza longistaminata, and Alternanthera were abundant. The weed band averaged an estimated 100 meters in width, with some areas exceeding an estimated 130 meters. Fishermen stated that they could not fish among the weed beds there with nets, but traps were generally successful. They said that fishing was generally better among the grass than in the Polygonum beds. This was interesting since other fishermen interviewed indicated that fishing is usually better in Polygonum than in Vossia beds. Two fishermen who fish from a village about 16 km. north stated that the weed beds were even worse there. They also said that their catch had been much lower during this year than in the past and that they attributed this mainly to the weeds that were growing in the shallow water. This information was given completely voluntarily without their having any knowledge of our mission. It was therefore considered to be more reliable than if we had asked them directly if the weeds interfered with their fishing.

Bumbadene to Panbu on the Kalurakan River

From Bumbadene, we crossed the Lake to Panbu on the Kalurakan River. Apparently, this river bottom was very marshy prior to the formation of the Lake, since there were extensive open areas free of trees, and the margin of the Lake had an abundance of marshy aquatic weeds--such as Cyperus, Scirpus, Alternanthera, Ludwigia, Polygonum, Vossia, and other grasses. Bilharziasis was reported to be widespread here.

Paribu to Korpedeke #2 on the White Volta

Marginal grass was found growing in abundance each time the boat travelled in sight of the mainland. Also, several patches of Vossia were seen among the tall trees adjacent to the original river channel. However, very few marginal aquatic plants were seen near Korpedeke. Ceratophyllum was present, but it was reported to be much less common than in past years. The lack of marginal aquatic weeds in this area was due to the fact that water covered what was originally the first trough (flood plain) behind the first natural terrace that commonly parallels major rivers. Therefore, the water level was surprisingly deep immediately off-shore in this trough. This, and the relatively high turbidity of the water, might have been another explanation for the reported reduction in Ceratophyllum.

Korpedeke #2 to Kolangbanan to Mopti to Dzeblasu on the Black Volta

More weeds, particularly grasses, were seen while we travelled up the Black Volta, than were evident on the White Volta. However, because of the rather steep bank along the southern shore of the Black Volta, few weeds were present. Large quantities of Oryza were seen growing on what apparently had been islands or high terraces prior to this year's flooding. Vossia, Oryza, Polygonum, Alternanthera, Ludwigia, Utricularia, and other aquatic and semi-aquatic species were very abundant around Dakupe, which is located on the north bank of the Black Volta. This area is very flat and therefore subject to heavier marginal weed infestation than the southern bank. Because of the flatness of this area, the first "trough" of the River is located far off-shore; and therefore, it does not influence the shoreline vegetation--as was reported for Korpedeke #2 on the White Volta.

Akanien to Kete Krachi

The marginal weeds around Akanien consisted primarily of Vossia, but Oryza and Echinochloa were also abundant. It was interesting to note that generally where these three species grow together, Vossia dominates the outer edge of the strip while Oryza and Echinochloa are much more plentiful closer to shore. This same thing was observed during the early stages of marginal weed development farther down the Lake, but the condition changed considerably during the previous flood season. Therefore, it was probable that this "zoning" was unique to the first few years of lake fill and could be less distinctive in the future.

The weed problem immediately around Kete Krachi continued to be scattered. However, within one kilometer on either side of the main landing, the aquatic grasses were well established along the shore. It was reported that Bilharzinsis was still common here.

Kete Krachi to Abobafufu and Mama's Village on the Dwija River

Because of the Dwija River's unique rocky characteristics, it is unlikely that aquatic weeds will ever present a serious problem there. Furthermore, this area has been designated as a future game reserve; therefore, all of the fishermen, hunters, and farmers were scheduled to be resettled from this location. Because of this, public health and fishery problems associated with aquatic weeds should not develop.

Mama's Village to Torgbe Glah

The trip down lake to Torgbe Glah was uneventful since we were forced to travel far off-shore --too far to effectively survey the shoreline. However, some Vossia was present; but because of the steep rocky shore in this area, the width and density of the weed band was relatively sparse (Pierce, 1969k).

Survey Trip 16 (Map 17)

During November 1969, a survey of 42 fishing villages was conducted along the northern shore of the Afram River by Mr. Peter Westaway of the VLRP. The primary purpose of this survey was to obtain fish marketing data; but upon the request of the writer, Mr. Westaway also collected aquatic weed distribution information. The water level was at elevation 83 meters and steady during the survey (Figure 1B).

Data collected during that study showed that Polygonum was sighted near 88 percent of the villages, followed by Alternanthera (55 percent), Vossia (45 percent), Ceratophyllum (14 percent), and Pistia (7 percent).

Vossia dominated the shoreline area along the southern shore of the major peninsula, whereas Polygonum and Alternanthera were the most common species found along the northern bank of the Afram. This condition also existed during the previous flood season (1968), but the density of the vegetation had apparently increased according to the information provided by Mr. Westaway (Pierce, 1969m).

A study conducted at Arpem by this writer in November 1969 revealed that the larvae of the mayfly, Povilla adusta, readily burrow into and occupy the hollow stems of Polygonum. This was the first recorded observation of this at Volta Lake. In the past, these larvae--which are known to be an important source of fish food--were almost exclusively found burrowed into the soft wood of the flooded timber (Petr, 1968 and 1969). There is no doubt that the flooded timber will still support far more of these larvae than the flooded Polygonum, but it was evident that these flooded weed beds will play an important role in the future by supporting these insects when the flooded timber has rotted away. Some Povilla larvae were also found

burrowed inside the hollow stems of Vossia; but because of the Vossia stem's extremely hard and smooth surface, relatively few signs of penetration have actually been noted to date.

Polygonum, however, must be suited well since studies conducted by this writer and the Aquatic Weed Control Unit (AWCU) staff found 488 Povilla larvae, ranging from 6 to 22 mm. in length, occupying 42 meters of randomly selected Polygonum stems--for an average of 11.6 larvae per linear meter of hollow stem. Penetration was usually made near the nodes of submerged hollow stems.

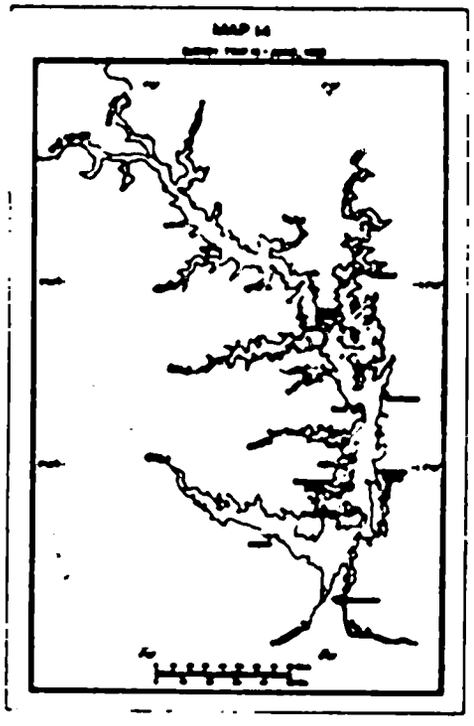
At the rate that the Povilla larvae were attacking the Polygonum, the writer is not certain whether or not this plant can survive in sufficient quantity to support a significant number of the larvae in the future. This uncertainly is based on the fact that during the 1970-71 flood period, the Polygonum beds near Ampon--which were attacked heavily by Povilla larvae--seemed to have disappeared earlier than in previous years. There is no doubt that the many holes that are bored into the hollow stems not only weaken the plant, but also reduce its ability to stay afloat.

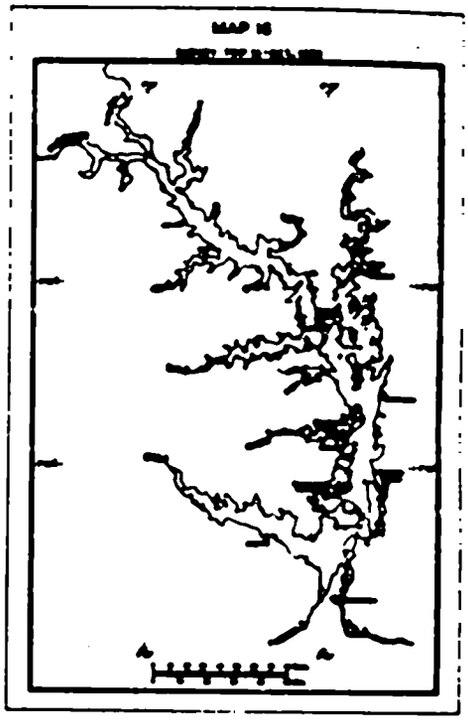
The important thing to determine is whether or not Polygonum plants can produce viable seeds successfully before the plants are destroyed by the Povilla larvae. If so, it is likely that the Polygonum will continue to re-establish itself as it has done in the past. If not, it is highly probable that less and less Polygonum will be seen at Volta Lake in the future.

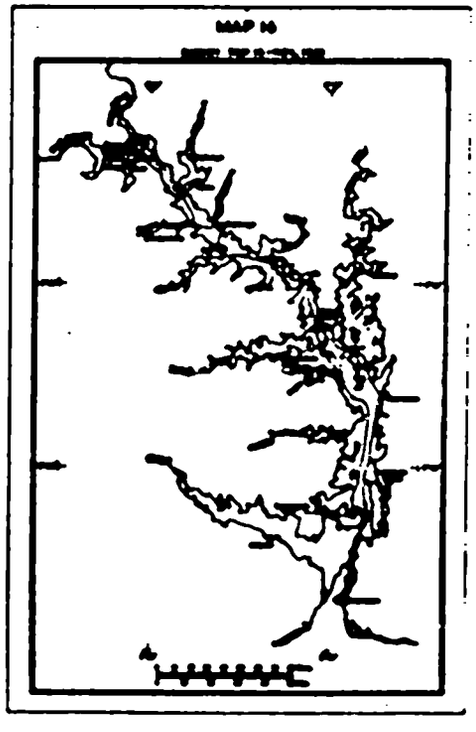
To determine to what extent Povilla larvae are utilized by lake fish, the writer and his staff used the larvae for bait on small fishhooks and caught the following 16 species of fish:

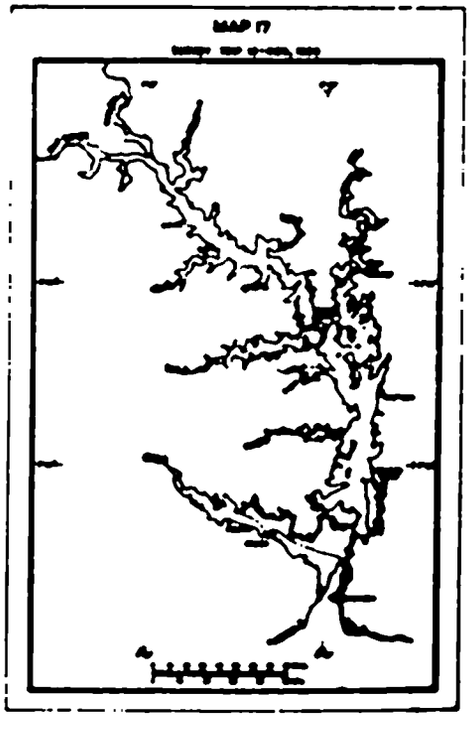
- Heterotis niloticus;
- Alestes macrolepidotus;

VOLTA LAKE









- Hepsetus odoe;
- Chrysichthys sp.*;
- Clarias sp.;
- Malopterurus electricus;
- Synodontis sp.;
- Ophiocephalus obscurus;
- Lates niloticus;
- Gnathonemus kingsleyae;
- Tetraodon fahaka;
- Hemichromis bimaculatus*;
- Hemichromis fasciatus*;
- Pelmatochromis guentheri*;
- Tilapia zillii*; and
- Barbus sp.

Based on these findings, it is obvious that the Polycomum beds play an important part at the Lake; therefore, extensive control measures should not be encouraged unless serious consideration is given to the potential loss it could cause.

Survey Trip 17 (Map 18)

In February 1970, a survey trip was made between Korga and Dunse. The water level during this period was at elevation 82.5 meters and falling (Figure 18), thereby exposing approximately 50 percent of the shoreline vegetation that had been flooded during the previous high water period.

Near Dunse, in the Sene River, relatively little vegetation was seen in the water; however, the exposed shoreline was becoming heavily infested with young Polycomum, Alternanthera, and Ludwigia plants.

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*Most commonly caught.

The same condition was observed in the Duija River, and some Vossia was seen growing there for the first time.

Near Korga, Vossia was still growing 60 meters off-shore, and in the Abukyere area--which had been used as a check point for determining the rate of Vossia growth for the past two years (see Survey Trip 4)--the shoreline was virtually solid Vossia. In 1968, this area was predominantly Polygonum (Pierce, 1970b).

Survey Trip 18 (Map 19)

This survey was conducted in May 1970 in an attempt to locate areas for conducting aquatic weed control experiments. The areas visited were based on data provided during Peter Westaway's study (see Survey Trip 16).

The first area we visited was near Kofoade, which is typical of the central portion of the northern shore of the Afram. The primary plant species were Polygonum and Alternanthera, but some Vossia was also present. The width of the exposed lake shore was approximately 100 meters, and the elevation was at 80 meters and falling slowly (Figure 18).

The next area surveyed was near the confluence of the Afram near the village of Akpafiu and Akpabudzi. The shoreline in this area was virtually covered with Vossia for several miles on either side of these two villages. The width of the exposed lake shore was an estimated 90 meters.

Another area was checked farther north along the western side of the Lake near the villages of Abukyere, Korga, and Sokpoe. As has been mentioned earlier in this report (Survey Trips 4, 13, and 17), this area was under observation for two consecutive years to determine the rate of Vossia infestation and the change in species composition. Vossia was still the dominant plant growing on the exposed lake shore in this area, and there was no sign of any other plant species becoming more abundant.

To determine the extent of Vossia infestation near these villages, a survey was made as far west into the bay as Brunberg. Some Vossia was present near this village, but local fishermen advised that this species was not as common in their area as it was farther east toward the main Lake. Young Polygonum and Alternanthera plants were seen growing on the exposed lake shore, but not heavily as in other areas visited. The lack of shoreline plant growth may have been due in part to the extremely large quantities of fallen trees and other dead debris lying all over the exposed area.

The last area surveyed during this trip was near Dawa Kope on the western shore of the Pawmpawn River. This area is more typical of the upper Afram than any other area of the Lake. This section of the Lake has a considerable amount of flood timber extending above the surface of the water. Among this timber were floating islands of grass (Sacciolepis africana) and some Pistia-Scirpus. Local fishermen advised that most of the upper end of the Pawmpawn Bay (approximately five kilometers farther south) was solid in floating Pistia-Scirpus islands.

The exposed shoreline near Dawa was covered with young Polygonum plants, in addition to some scattered patches of Sacciolepis (Pierce, 1970c).

NOTE: Data concerning aquatic weed development at Volta Lake between May and December 1970 are discussed later in this report under the heading "Aquatic Weed Control Techniques, Procedures, and Results."

Survey Trip 19 (Map 20)

In late February 1971, a general aquatic weed survey was conducted between Akosombo and the Dwija River. The water level at that time was at elevation 82.5 meters and falling slowly (Figure 1B). This survey showed that Vossia had become established as far up the Dwija River as Mann's Village; however, Polygonum, Alternanthera, and Ludwigia still dominated.

At Abukyere, cutgrass (Leersia hexandra) was found becoming established at the mouth of a small stream entering the Lake. Polygonum had dominated the area in the past.

At Akpabudzi and Akpafui, Vossia still dominated, even though this shoreline area was burned extensively during the previous drawdown period (see "Aquatic Weed Control Techniques, Procedures, and Results" later in this report).

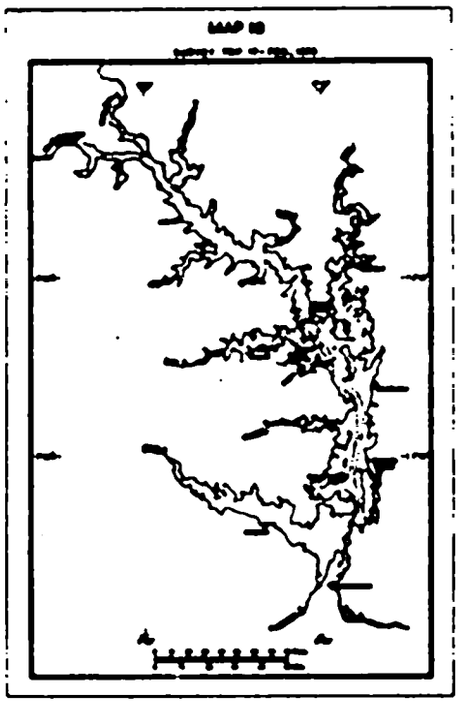
From Akpabudzi, the survey was extended to Dowa Kope on the Pawupawu River. As was discussed under Survey Trip I7, the upper end of the river system was completely covered with floating islands of Pistia-Scirpus. Some cattails (Typha australis) were colonizing these floating island masses, as well as the shallow water near shore. In addition, some Ceratophyllum was observed--particularly near shore where it was entangled in flooded Polygonum (Pierce, 1971a).

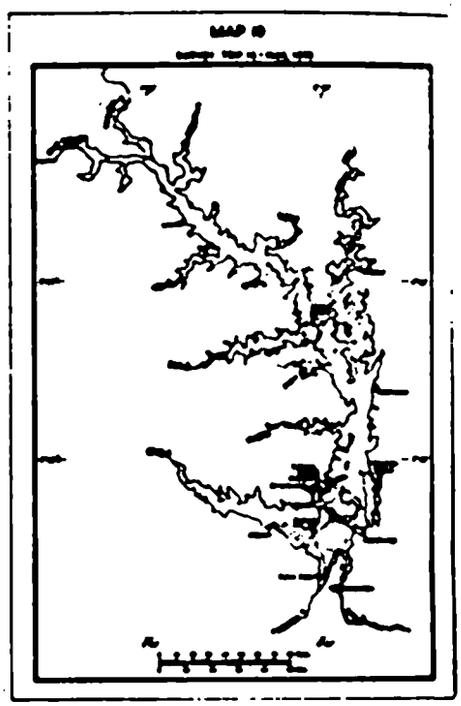
For additional information concerning the distribution and annual changes in aquatic and semi-aquatic plants growing on the drawdown area of Volta Lake, the writer makes reference to a comprehensive report entitled "Observations on the Vegetation of the Lake Volta Drawdown Area, July 1968-February 1970," (VBRP Technical Report X35), by Mr. J. B. Hall, Lecturer, Department of Botany, Legon. The report not only describes plant species, but also details their abundance, location (zone) on the exposed lake shore, and the soil type where they grow.

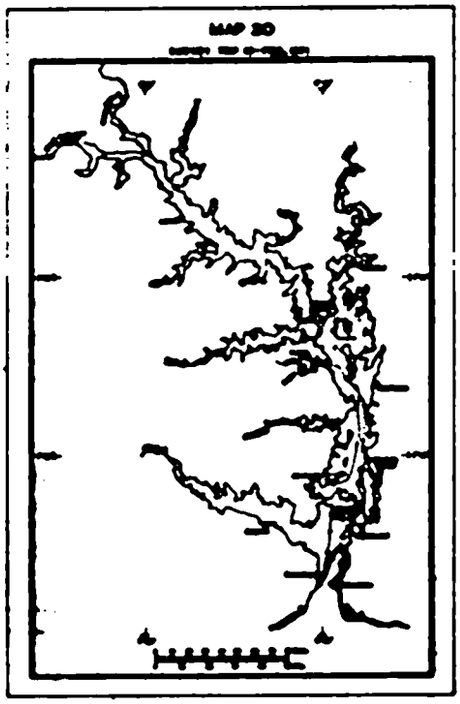
AQUATIC WEED CONTROL TECHNIQUES, PROCEDURES, AND RESULTS

It has already been mentioned in this report that the Government of Ghana (GOG) envisaged an aquatic weed explosion developing on Volta Lake during the first few years of lake fill, and that considerable thought and effort was given to how this pending aquatic weed problem could be controlled.

VOLTA LAKE







This portion of the report discusses recommendations made specifically for the control of aquatic weeds at Volta Lake, and the results of aquatic weed control tests conducted by this writer and the Aquatic Weed Control Unit (AWCU) staff during the period July 1967-June 1971.

Heinen--in a report to VRA following his two-week survey of Volta Lake in April 1963--recommended that even though a serious aquatic weed problem developing on Volta Lake was not assured, it would be advisable for VRA to purchase enough aquatic weed control equipment (boats, outboard motors, spray pumps, and herbicides) to contain a weed problem that might develop until more extensive control arrangements could be organized. He also recommended that an aquatic weed control specialist be assigned to the Lake during the initial Lake fill period to train GOG employees in aquatic weed control procedures and to be present to assist in developing a full-scale weed control program should it be required.

Also, in 1963, the Volta Basin Research Project (VBRP) recommended to VRA in a report entitled "Control of Aquatic Weeds in the Volta Basin" that all of the aquatic weeds growing along the edge of the River and in the lagoons and marshes within the Lake's basin below elevation 85 meters (280') should be killed with chemical herbicides before Lake fill began. The theory behind this recommendation was that if most of the aquatic weeds within the Lake basin were killed before the Lake started filling, the likelihood of a serious aquatic weed problem developing would be lessened considerably.

The herbicides recommended by the VBRP for consideration included sodium arsenite (As_2O_3), paraquat, and diquat. These herbicides had been chosen based on work that had been carried out on Lake Kariba (Hattingh, 1962), and in the U.S. (Lawrence, 1958, and Mackenthun, 1958).

Even though considerable thought was given to the above recommendations, no aquatic weed control was initiated prior to lake fill. However, three spray pumps were purchased in 1966 as Heinen recommended. These pumps were used by this writer for conducting aquatic weed control experiments during his tour (1967-71). Those results of these tests are discussed below. (See Table 3 for a list of the herbicides that were tested during this study.)

Public Health Related Aquatic Weed Control Tests

Earlier studies by Paperna (1964-65) and Obeng (1965) showed that aquatic weed growth at Volta Lake harbor vector snails that transmit Schistosomiasis (Bilharziasis), and *Mansonia* mosquitoes which are vectors of rural filariasis. Paperna also found that the incidence of Bilharziasis infection increased as the Lake filled. This increase was attributed to the expansion of the vector snail population that developed as aquatic weeds became more plentiful, and to the rapid influx of people to the Lake's shore to fish and to farm.

To combat the spread of disease at the Lake, VRA requested that this writer give priority to developing methods for controlling those aquatic weeds that present public health hazards. The following discussion pertains to studies that were carried out by this writer and his staff in response to that request.

Post-Emergent Tests

It was theorized by this writer and many of his associates that if areas around lakeside villages at Volta Lake were made less attractive to vector snails by drastically reducing the amount of aquatic weeds there, transmission of the disease should decrease accordingly. To test this theory, a series of field experiments were performed to determine which herbicides

and techniques were suitable for effectively controlling aquatic weeds at Volta Lake.

Paraquat

The first weed control test was made at Ampem in February 1968 (Map 1). This fishing village is located on the Afram arm of Volta Lake; and at the time of this study, the shallow shoreline was covered with numerous fallen dead trees, Ceratophyllum, and floating masses of Pistia-Scirpus, Lemna, and Salvinia. Some Polygonum also grew on the exposed lake shore. The first herbicide application was made using paraquat at a low rate of .33 ppm. (based on the volume of water within the treated area). Paraquat was selected for testing first because it was known to be a relatively safe and effective non-selective herbicide, and also because paraquat had been reported to have molluscicide properties as well. The test plot measured approximately 600 cubic meters (averaged 1.0 meter deep). The chemical was applied by mixing 1.2 liters of paraquat in 13.0 liters of water and spraying this solution over and under the surface of the water from an outboard motor boat. Immediately prior to--and again in one, six, 24, and 48 hours after--treatment, samples of water, mud, aquatic organisms, and plants were collected from the test site by VBRP and IAB personnel attached to the VLRP for future analysis. No noticeable adverse effect on fish, fish food organisms, or snails was noted during or following this treatment.

Observations that were made following the treatment indicated that the Ceratophyllum had not been noticeably damaged. However, those floating or emergent species that were hit by the spray solution were killed or badly burned. The poor control of underwater plants was attributed to (1) silt (clay) particles that completely covered the Ceratophyllum at the time

of treatment (paraquat is neutralized immediately on contact with clay colloids), and (2) the small size of the experimental plot (600 cubic meters) which allowed excessive and rapid dilution from the surrounding water mass. Paraquat normally requires at least 30 minutes of exposure time at such a low concentration before it is lethal.

However, even if this treatment had been successful, it still was doubtful from the start if paraquat would be economical to use for the control of submerged aquatic weeds (particularly Ceratophyllum) under Volta Lake conditions. The reason is that even at .33 ppm., paraquat would cost nearly N¢75.00 (@ N¢5.00 per liter) per hectare meter[1/] (10,000 cubic meters or approximately 8 acre feet); and it is probable that the treatment, regardless of the concentration, would have to be repeated at least once in order to maintain the area reasonably free of submerged aquatic weeds for one full year. Furthermore, it is this writer's opinion that each treatment would have to be increased to at least .5 ppm.; therefore, the annual cost per hectare would approach N¢200.00.

During this same period, three small floating islands of Pistia-Scirpus were sprayed with three different concentrations of paraquat equivalent to 1.25, 2.50, and 3.75 liters acid equivalent per surface hectare. Each quantity of herbicide was mixed with water (forming a solution equal to 700 liters of spray solution per hectare), and sprayed directly on the islands until the vegetation was thoroughly wetted.

These islands were lodged among flooded trees in water approximately seven meters deep. Samples of water, soil,

1/ A hectare meter is one surface hectare of water averaging one meter deep.

plants, and aquatic invertibrates were collected as described above.

Within 24 hours after treatment, the islands started to turn yellow, indicating that the herbicide was taking effect.

One week later, the island that had been sprayed at the rate of 1.25 liters paraquat per hectare was yellow--but some green growth was still evident near the water line.

The island that was treated with 2.5 liters paraquat per hectare had turned yellow and brown throughout.

The last island, which had been sprayed with paraquat at the rate of 3.75 liters per hectare, was almost totally brown and was already showing signs of "breaking up."

Within five weeks, all of the islands had completely disappeared; and at no time during the course of this study was there any evidence that these treatments had had any adverse effect on the Lake's biota--other than on the islands themselves (personal comniquo from T. Petr, VBRP, University of Ghana; Pierce, 1968b and 1968c).

Copper Sulfate

While reviewing literature in an effort to find promising methods that might be applicable for controlling aquatic weeds and snails at Volta Lake, the writer came across an article in the 1967 summer edition of the Rural Missions Journal which described the preparation of a snail poison that consisted of five units copper sulfate plus .10 units citric acid dissolved in 45 units of water. This solution is mixed with calcium sulfate (plaster of Paris) at the rate of 10 units of calcium sulfate to five units of solution by volume. The mixture is then poured upon a flat surface in sheets approximately one centimeter thick. After the compound has hardened, it is then cut into the desired sizes. The author of the article stated

that the snails are attracted to the small cubes by the calcium and the citric acid (calcium citrate) and are killed by ingesting the copper. Since Ceratophyllum is also known to be highly susceptible to copper sulfate, the writer conducted the following tests to determine whether or not this single compound could control both aquatic weeds and snails.

To test this compound, the writer purchased the necessary ingredients; and with the assistance of Dr. B. A. G. Entz of the Institute of Aquatic Biology of the Ghana Academy of Sciences, the poison was prepared and placed in a small glass aquarium. The aquarium contained approximately 20 liters of water and was stocked with guppies (Lebistes reticulatus); Bulinus, Lymnaea, and Pilla snails; aquatic plants (Ceratophyllum and Salvinia); and several species of aquatic insects. The first experiment consisted of only two aquaria--one for the actual test and one for a control. The test aquarium was treated with approximately 10 grams of the poison mixture. Within 24 hours, all of the animals and plants were dead. Since it was evident that the compound was effective, another series of tests were conducted. This time, five aquaria were set up as before. The first was the control, the second contained three grams of only calcium sulfate-citric acid, the third contained three grams of the total poison, the fourth contained two grams of the total poison, and the fifth contained one gram of the total poison. The second aquarium was treated with the three grams of calcium sulfate-citric acid (minus copper sulfate) to be sure that the copper sulfate was the lethal agent and not the calcium sulfate-citric acid.

Twenty-four hours later, all of the snails were dead in the aquaria containing two and three grams of the total poison. Some of the snails were also dead in the aquarium containing

one gram of the poison; and within 48 hours, all of the snails were dead at this lowest concentration. Also, the Ceratophyllum died in each aquarium within one week. However, no fish, aquatic insects, or floating aquatic plants died in any of these tests.

In the aquarium treated with three grams of calcium sulfate-citric acid alone, no mortality of any of the test plants or animals was noted during the full week of the experiment.

It was believed that the mixture was killing the test specimens by the copper leaching from the compound--rather than from direct ingestion--since the Ceratophyllum was also affected and was not in direct contact with the solid mixture. It was also doubtful that all of the dead snails had come in contact directly with the poison mixture within 24 hours, since they were normally located on the sides of the aquaria near the water line--rather than on the bottom where the poison bait was located.

To further test this promising method of control, the writer decided to conduct a series of field experiments.

Two 60 cm. X 60 cm. X 60 cm. galvanized screen wire boxes were constructed and placed in a pond near Accra. Each box was placed in water approximately .3 meters deep and was stocked with fish, plants, snails, and large aquatic insects. One box was treated with three grams of the poison compound, while the other box--placed about nine meters away--was used as the control. The site was visited each day for one week to assess the experiment. No noticeable control of either snails of plants had occurred, even though the Ceratophyllum appeared to be weakened. However, by the end of the week, the Ceratophyllum had fully recovered.

Since copper and galvinized metal have an electrolytic affinity toward one another, the writer considered that this may have adversely influenced the results. Therefore, two more boxes were constructed using inert nylon wire. The above test was repeated and the same negative results were noted.

At this point, it was concluded that the snails were not being attracted to the poison mixture and that the dilution from the surrounding water was too great for the leached copper to be lethal to the aquatic plants or to the snails.

The final test consisted of placing four cubic centimeters of the poison mixture every one to 1.5 meters along the shoreline where the nylon screened boxes were placed. This procedure is similar to what was recommended by earlier workers who found this technique effective in Florida.

Twenty-four hours later, the area was checked; but none of the snails or plants appeared to be affected.

It was concluded that the calcium sulfate, citric acid, and copper sulfate mixture was not an effective means of controlling snails and Ceratophyllum under conditions similar to those that were tested. Furthermore, since it was obvious that the snails and plants in the aquaria had been affected by copper concentration in the water and not be ingestion of the poison mixture itself, the writer saw no advantage in using this mixture when copper sulfate alone could be used equally as well and more economically.

It was conceded by this writer, however, that under certain conditions where calcium is in great demand by the snail population, the above technique may have definite advantages over copper sulfate alone (Pierce, 1960d).

Pre-Emergent Tests

As work continued at the Lake, it became apparent that treating established stands of aquatic weeds near shore from a boat was impractical in most areas. The primary problems encountered were: (1) shallow water that made it difficult to get close in to shore; (2) rank weed growth that could not be penetrated by boat, making it impossible to spray the weed beds with herbicide; and (3) fish nets that became entangled in the outboard motor's propeller. Therefore, other approaches were sought.

One method that appeared to be well suited for Volta Lake, and which had been tested previously in the United States by this writer, was to treat the exposed lake shore with a soil sterilant during the annual drawdown period--thereby making the treated area incapable of supporting plant growth during the following flood season. Several different herbicides are known to be suited for this type of pre-emergent weed control. Earlier experiments conducted by this writer in the U.S. showed that fenac (2, 3, 6 trichlorophenylacetic acid) was the most effective of five herbicides tested using this technique; therefore, fenac was chosen for testing at Volta Lake. Studies carried out in the United States (Pierce, 1965) showed that liquid fenac applied at rates ranging from 65 to 130 liters (12 to 24 kg. acid equivalent) per hectare on the exposed bottoms of ponds, lakes, and irrigation canals during drawdown gave excellent control of rooted aquatics the following year after flooding. In some instances, this control lasted up to three years. The cost of treating one hectare at the rate of 24 kg. acid equivalent (130 liters) fenac would be approximately N$400.00 at N$3.00 per liter (N$12.00 per gallon). This is approximately 100 percent higher than the U.S. price.

Fenac works by becoming "fixed" to the clay colloid of the soil. Therefore, when a plant's roots extend into the treated soil, the herbicide is taken in along with the nutrients; and the plant dies. For those plants that do not have roots, such as Ceratophyllum, control would occur through absorption when they come in contact directly with the treated soil. Virtually all seeds are killed, including Ceratophyllum, within the treated area soon after they germinate. Interestingly, however, fenac does not appear to be highly toxic to bottom organisms, since these animals--particularly oligochaete--were found in abundance following each treatment. Also, because fenac is fixed on the clay colloid, it stays in place (does not leach) unless the treated soil itself is removed or the chemical has been degraded--through bacterial actions--or absorbed by plants. However, for most soil types, a single application (130 liters or 24 kg. per hectare) of fenac would only be expected to last one year if this area is flooded.

To test this herbicide under Lake Volta's tropical conditions, seven areas measuring 100 square meters each were prepared and treated with fenac between July and October 15, 1968. Four areas were treated near the Ampem fishing village, two near Nkatepa near Amoto, and one at Kwame Djomba on the northern bank of the Afram (Map 7). The purpose for conducting several different experiments was to test varying concentrations of fenac on the different soils and vegetation types that are common along the Lake's margin.

Each area was first cleared of all terrestrial vegetation and debris to allow the spray mixture to be applied directly to the exposed soil--which is a must if the herbicide is to fix on the clay colloid. Six of the test plots were cleared by local villagers and members of the Aquatic Weed Control Unit

of VBA using cutlasses. The other area was cleared using a tractor and mower and then the cut material was turned under using a disc plow. This technique was tested to compare mechanical clearing against hand clearing, since it was thought that if large-scale clearing and treatment was to be done in the future, hand clearing alone might be too slow. To determine whether or not this unnatural disturbance of the soil could in itself reduce normal aquatic weed growth after this area was flooded, half of the plowed area was treated with fenac while the other half was not. One disadvantage noted in using heavy equipment for clearing land near the Lake's edge was that the ground was sometimes too soft to support the weight of the machinery. Therefore, it was speculated that manual labor would have to be included in any clearing operation near the water's edge in the future.

Experience had shown that fenac would become "fixed" in most soils, if they were not too wet, within 24 hours after treatment. Hence, no long-range weather forecast was required before the chemical was applied; but no treatment was made if it looked as though it could rain that same day.

Each test site was located between elevation 82 and 84 meters in order to evaluate effects that flooding had on the areas during the following lake fill period.

Five of the test sites were treated with fenac at the rate of 24 kg. (130 liters) acid equivalent per hectare and the remaining two plots were treated at the rate of 18 kg. (98 liters) per hectare. Since each test area measured only 100 square meters, the amount of herbicide mixture was small. Therefore, hand operated back-pack sprayers were used for making the aplications. The herbicide was mixed with water at a 1 to 5 ratio and sprayed directly onto the exposed soil. Normally,

three or four spray units were used at one time in order to cover the area as quickly and uniformally as possible. The most effective spraying technique tested was to have the three persons doing the spraying walk abreast back and forth across the area being treated, allowing their spray swaths to overlap (Plate 3). Also, the pace of the sprayers was arranged to allow the area to be covered completely at least twice.

No regrowth was noted on any of the seven areas treated between the time of treatment and when the Lake flooded the plots, one to five months later. However, the area that had been mowed and plowed, but not treated with fenac, became covered with new growth within three months (Plate 4). (Pierce, 1968g and 1969c).

The information gained during the seven experiments mentioned above indicated that fenac would "fix" in a variety of tropical soils and that it would effectively control terrestrial weed growth common to the Afram area of the Lake. However, it still was not known if fenac would control semi-aquatic plants that would surely become established on the exposed lake shore after the lake level dropped during the following drawdown period. (It should be remembered that the initial tests were conducted in areas that had not been previously flooded.) Also, it was not known if the snail population within the treated area would also reduce, which was the primary objective, if no weed growth was present.

To determine this, it was decided that a larger study would be conducted using basically the same techniques described above. The following data describe that study.

<u>Atpem Aquatic Weed Control</u>
<u>Pilot Project</u>

The Atpem fishing village was selected as the site for this study since some background data was already available

Plate 1 Floating islands of Pistia-Scirpus above Adawso

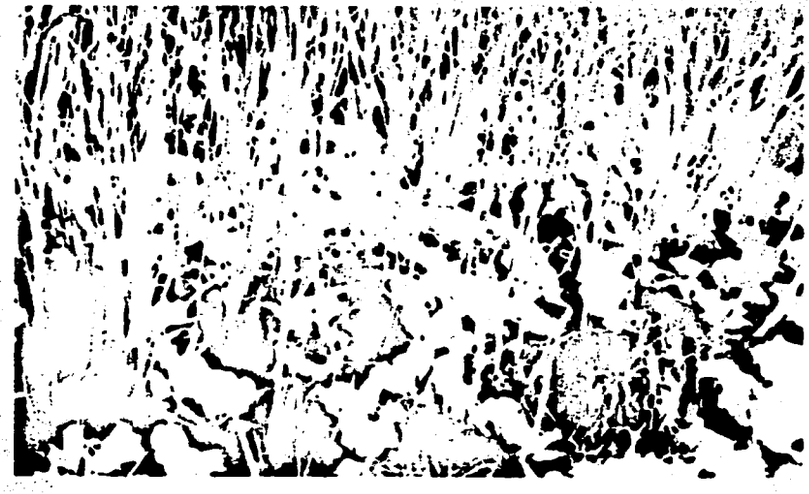


Plate 2. Close-up of Pistia - Scirpus island

Plate 3. Spraying herbicide (Fenac) on cleared Lake shore

Plate 4. Plowed and treated with Fenac (Left). Plowed only (Right)

concerning the aquatic weeds and snail population there, and because it was an important road-head lake-side market center that was easily accessible by road throughout the year (Plate 5).

Clearing the Area

The actual preparation for this study began in February 1969. Activities, prior to the period covered by this report, included a meeting between VRA and residents of the Anpeh fishing village to explain the proposed program, selection of a suitable site for resettling the villagers above the anticipated maximum water level, and the setting of a date for their self-imposed evacuation.

By mid-April, most of the villagers had moved to a new four-hectare site located immediately above their original location (Figure 2).

Based on the amount of fence that was available for the study, a maximum of three hectares could be treated. Therefore, the dimensions of the test plot were determined by measuring the distance from elevation 80 meters (the anticipated maximum low water level) to a marker accurately placed at elevation 84.5 meters (.5 meters above the anticipated maximum high water level of 84 meters). The water level at the time of treatment was 80.2 meters and falling slowly. Based on this information, it was determined that the dimensions of the plot should be 260 meters by 130 meters which gave a plot size of approximately three hectares. This gave 130 meters on each side of the road that leads to the water's edge where most human activity takes place--particularly on market days (Figure 2).

In early April 1969, Mr. C. A. Dadey, Chief Agriculture Officer of VRA, instructed the Agricultural Assistant at Anpeh to provide the necessary heavy farm equipment and personnel to

clear the designated test site and to assist in making the actual herbicide treatment. VBA also provided other equipment and supplies that were not available at Ampen. This equipment included:

1. Chain saws for cutting down large trees growing on the site and for cutting up large dead trees that had washed to shore during past high water periods (Plate 6);
2. Large steel cables for dragging the cut-up logs to a central location above the 85 meter mark;
3. Axes for cutting down small woody bushes and trees and for removing stumps; and
4. Cutlasses for cutting down the remaining vegetation.

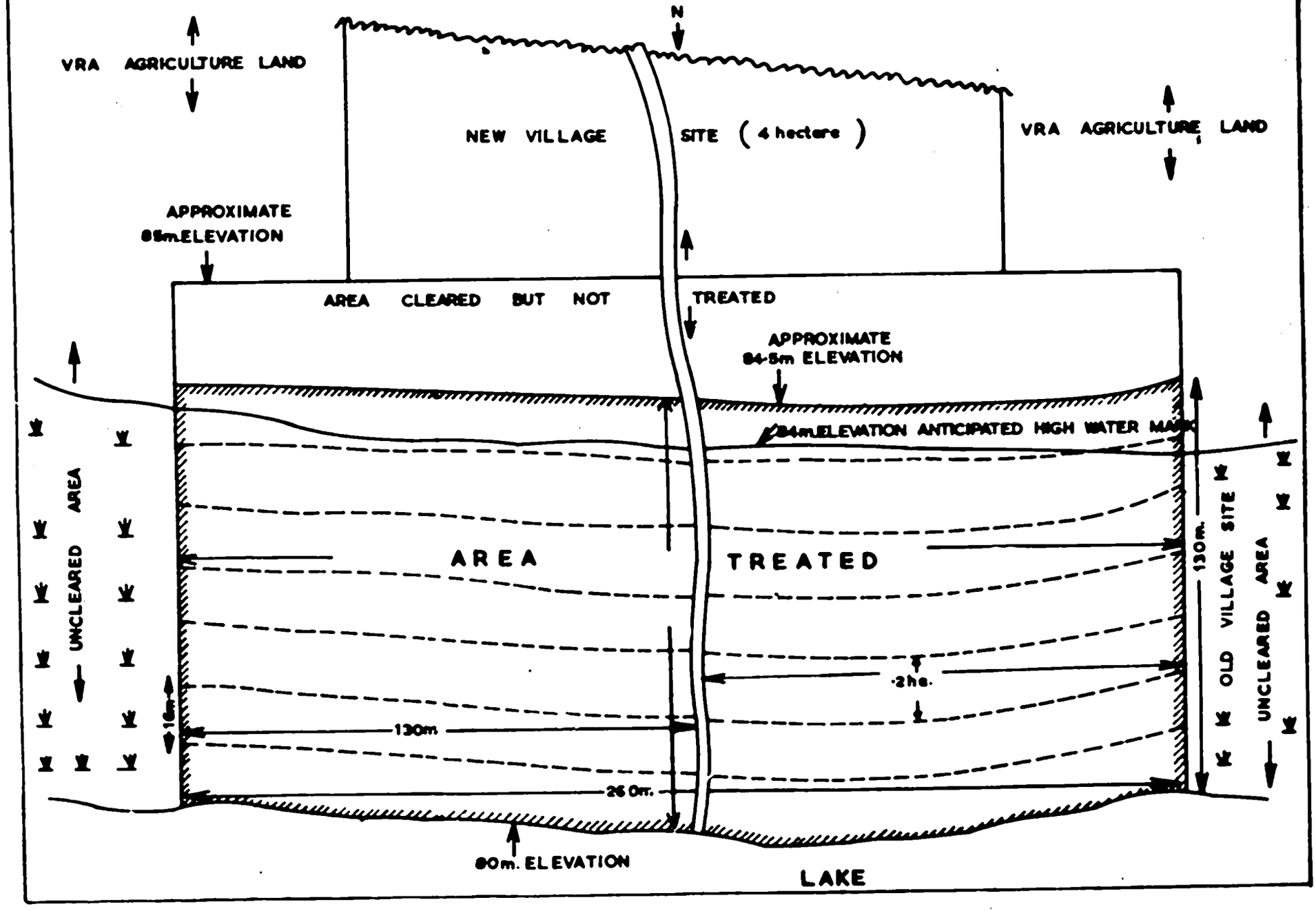
It was agreed that local people would be hired to do the manual labor. Therefore, arrangements were made to hire six men from the Ampen Resettlement Village located approximately .8 km. away from the site.

The clearing operation took 14 working days during the period April 28-May 13, 1969. Initially, all of the small bush clearing was scheduled to be done by the six laborers. However, this proved unsatisfactory because they worked too slowly. Therefore, mechanical clearing using heavy farming equipment was employed.

An attempt was made to clear the area using a disc plow, but this also proved unsatisfactory because it left too much vegetation and would encourage erosion during periods of heavy rain. The second mechanical method included a disc harrow followed by a spring cultivator. This technique was unsuccessful for the same reason mentioned above. Finally, a multi-purpose blade--designed for minor land levelling and road maintenance--was

FIGURE 2

AMPEM WEED AND SNAIL CONTROL PILOT PROJECT



area clean of vegetation and debris. This method was also slow, but appeared to be much faster than using manual labor. Therefore, the laborers were instructed to utilize their time in clearing the stumps and bushes from areas that could not be cleared using the tractor and blade. Once this was done, the vegetation and debris were placed in piles and burned. That portion of the wood that was large enough to be used for fire wood was given to the local villagers. Other clearing included the levelling of old smoking ovens and houses used by the villagers when they had occupied the site (Plate 7).

Table 2, submitted by the Agricultural Assistant, VRA Anpem, gives a breakdown of the actual man-power and equipment used during the clearing operation.

Herbicide Application

On the evening of May 19, 1969, the area to be treated was marked off into small sections measuring 16 X 130 meters to assure complete and uniform coverage. In order not to disrupt the area's commerce and normal day-to-day activities any more than necessary, half of the area was treated on May 20 and the other half on May 22. (May 21 was market day.) Therefore, the east side of the road was treated first, and the people were instructed to use the untreated area on the west side. On May 22, they were requested to use the east side that had already been treated.

Equipment and materials used for spraying included:

1. A four-wheeled flat-bed trailer pulled by a H.P. "165" tractor and also a large lorry;
2. A John Bean Spray-pump, model 1010K, equipped with a Spray Master spray-gun nozzle with a number 6 disc;

drums;

4. Three-hundred liters of fenac containing 2 kg. acid equivalent per liter (1.5 lbs. per U.S. gallon); and

5. 1317 kg. of karmex (80 percent diuron) wettable powder.

The two 210 liter spray drums were placed on the trailer along with the motor-driven spray-pump. The trailer was backed into the Lake, and the drums were partially filled (114 liters) with water. The trailer was then pulled to a central location where the chemicals had been placed. The herbicides were measured out and mixed with the water in each spray tank. The quantity of each herbicide was based on the amount required to treat .2 hectares. Therefore, the mixture was 19 liters of fenac plus 1.1 kg. of karmex mixed with 114 liters of water. The powdered karmex was mixed with the water before the fenac was added.

During the latter part of the second day of treatment, additional water was added to the mixture in order to wet the ground more thoroughly. This was not necessary on the first day, because it had rained heavily the night before. Nor was this increased wetting necessary when spraying near the edge of the Lake where the soil stayed moist. This mixture gave 24 kg. of fenac (acid) and .7 kg. of diuron (acid) per surface hectare (17 and 4 lbs. per acre, respectively).

After the chemicals had been mixed in the drums, the trailer was pulled to the east side of the road to the 16 X 130 meter plot nearest the water's edge. The pump was started and allowed to build up 300 lbs. of pressure. When this pressure was obtained, the tractor driver drove slowly down the plot staying an equal distance between the 16 meter markers. As

The approximate cost of the herbicide for treating one hectare of floating islands of Pistia-Scirpus with granular

TABLE 2

Analysis of Work
Aupem Clearing Operation

Physical Labor

Item	Tools Used	Man-Days Worked	Man-Days Lost by Absence
Weeding	Cutlasses	59	3
Stumping	Felling axes	13	
Burning	-	3	
Carting logs/ debris	-	6	
Total		81	3

Mechanical Operations.

Item	Machine/ Implement Used	Man-days
Sawing logs	Chain-saw "Stibl 070"	4.5
Felling trees	" "	1.5
Carting logs/debris	MF 165/towing chain	6.0
Cultivating	MF/spring-time cult.	7.0
Weeding/Levelling	MF/blade	9.0
Total		28.0

Fuel Consumption

Machine	No.	Gas Oil	Engine Oil	Petrol
Chain Saw "Stibl 070"	1	-	11.4 liters	28.5 liters
MF 165 tractor	2	180 liters	-	-

Mixture for the chain saw "Stibl 070" - ISAE 30 to 25 Petrol.

Plate 5. Aspen shoreline before clearing

Plate 6. Removing dead trees from Aspen test site

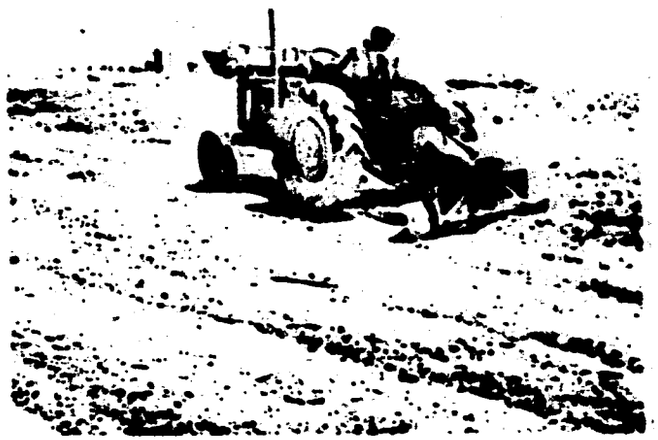


Plate 7. Burning debris from test site before treatment

Plate 8. Spraying cleared area with herbicide (Fenac and Diuron)

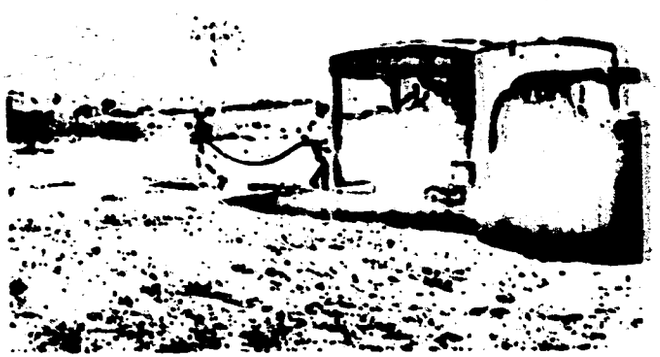


Plate 9. Spraying cleared area with herbicide (Fenac and Diuron)

walked directly behind the trailer while spraying the designated area (Plate 8). The hose attached to the sprayer was eight meters long, and the spray stream carried at least 10 meters when using a number 6 spray nozzle at 200 to 300 lbs. of pressure. Therefore, it was easy for the 16 meter swath to be covered from the center where the tractor-trailer was travelling.

Based on the volume capacity of the pump, each .2 hectare area could be sprayed at least twice before the designated 114 liters of spray solution was consumed. This procedure was repeated for each 16 X 130 meter plot until all of the 14 plots were treated. (Plate 9).

The area was revisited on May 28 and 29, 1969, to determine how effective the treatment had been. Virtually all of the seedling plants were dead. However, several clumps of terrestrial wire-grass were still alive. Also, a few small spots that had apparently been missed were still green. These areas were retreated with back-pack sprayers a few days later, and total weed control was accomplished.

Post-Treatment Results

During the initial flooding in July, Ceratophyllum was growing off-shore in the shallow water (one to two meters deep) immediately in front of the cleared area. By mid-September, when the water level reached 82 meters elevation, most of the Ceratophyllum had disappeared; however, large quantities continued to infest the shallow water outside the experimental plot (Plates 10 and 11).

At no time during the flood period (July-November) did rooted aquatics show any signs of becoming established within the treated area. This was in contrast to the adjacent untreated shoreline areas which became very heavily infested with a variety of aquatic weeds and debris (Plates 12, 13, and 14).

the weeds that washed ashore within the cleared area--particularly fragments of Ceratophyllum and Polygonum--caused some concern since Polygonum was found to be rapidly setting roots, and some of the Ceratophyllum fragments contained snails. When this was first noted, project personnel with occasional help from local fishermen, removed the wind-rowed debris as it accumulated (Plate 15). This clean-up exercise took place weekly, or as needed, and usually required only a few man-hours each time. It was quickly learned that the major debris problem (mostly Polygonum) was not caused by wind and wave action as initially suspected, but by fishermen who discarded the Polygonum stems there after they had used them for covering their fish to keep them fresh. These fishermen responded favorably to our request not to discard these weeds next to the water's edge within the cleared area, and this action immediately reduced the amount of debris along the 260 meters of cleared shoreline.

In addition to Polygonum and Ceratophyllum, the other main forms of debris consisted of large tree limbs, sticks, and floating islands of Scirpus-Cyperus-Pistia. The tree limbs that were too large to be carried away by hand were dragged out of the water by tractor and cable or towed out of the area by boat. In general, these tree limbs did not present a serious problem during the study period.

The floating islands presented more problems than the tree limbs since they became rooted soon after they washed ashore. Also, these islands were found to carry vector snails. Normally, the islands were small and could be easily torn apart and removed. However, occasionally a large island would float ashore, necessitating much more work to remove it.

It was believed that some erosion would be encountered on the denuded three-hectare plot during the rainy season. However,

it was interesting to note that no "gullies" developed, even though some sheet erosion was experienced. This resulted in large quantities of organic debris--particularly small pieces of burned wood--being wind-rowed along the water's edge. This was probably the result of the vegetation that was burned on the area during the clearing operation. However, this type of windrow is common throughout most of the lake shore during the initial part of each rainy season when loose, partially burned bush-remains wash into the Lake. Wave erosion was not serious at Ampem during the lake filling period, even though this area does receive relatively heavy wave action.

With the exception of a few "bumps" that were left during clearing, the lake bottom within the cleared area was relatively clean, flat, and rather firm. This has resulted in its becoming a favorite place for local people to fish with cast-nets, swim and land their boats (Plates 16 and 17).

Vector Snail Survey

As was mentioned earlier in this report, the main purpose of this study was to determine what impact this weed-clear area would have on the snail population wit in the test site. It should be clearly understood, however, that this particular study was not designed to determine what effect this snail reduction would have on reducing Bilharziasis infection, since no one assigned to the weed control team at that time was qualified to make this assessment. However, this evaluation was scheduled to be conducted later, and will soon be initiated.

1. Pre-Treatment Snail Survey

In mid-January 1969, four months before treatment, Mr. Ambrose Tsiko of the VRA Health Unit conducted a pre-treatment snail survey of the propdeed test area at Ampem. The survey also included taking samples outside the experimental

plot for comparison. The water level at that time was at elevation 83 meters and falling.

During this survey, a total of eight *Bulinus forskali* and 30 *Bulinus truncatus* were collected *within* the treatment site--compared to one *B. forskali* and 15 *B. truncatus* found immediately *outside* the proposed site.

As the water level receded, between January and the time of treatment in late May, additional spot checks were made to determine the relative abundance of snails. By the time the water level dropped below elevation 80 meters, most of the emergent marginal weeds were exposed--leaving a practically weed-free mud-flat along the shore. Even *Ceratophyllum* was limited at that time and was only found to be abundant in several small sheltered coves. Correspondingly, the snail population was low along the shoreline--except for the weedy coves which had high snail populations, relatively speaking.

2. Post-Treatment Snail Survey

Another thorough snail survey was conducted by Mr. Tsiko and the AWCU in November 1969, six months after treatment and when the water level was at its highest elevation. Two areas, measuring 3 X 13 meters each, were sampled within the treated area. Also, two areas of similar size were sampled in the untreated area located immediately on either side of the test plot (Plates 13 and 14).

At the time of sampling, virtually no aquatic weeds or debris were present within the treated area; and only one snail (*Bulinus truncatus*) was found within the treated area--it was attached to a piece of *Ceratophyllum* floating into the area from outside.

However, the uncleared areas, comprised of a heterogenous growth of aquatic weeds and debris, were heavily infested with

snails. The primary aquatic weed specimens found growing within the sampled uncleared areas consisted of:

- Polygonum sagacolanum;
- Ceratophyllum demersum;
- Pistia stratiotes;
- Ludwigia leptocarpa; and
- Lemna sp.

From the two uncleared areas sampled, a total of 98 Bulinus truncatus and 112 Bulinus forskali were collected. The snails did not appear to show a particular preference to any one species of plant, and many snails were found on the algal covered debris (Pierce, 1969c, 1970a, and 1970d).

Post-Treatment Herbicide Tests and Results

The following January (1970), the lake level started its slow but steady drawdown. As the water receded, the exposed shoreline became infested with young plants. In checking these plants closely, it was found that they were mostly Polygonum and Alternanthera seedlings. Further investigation showed that the exposed shoreline, particularly where fine debris was deposited, was literally covered with Polygonum seeds. It was therefore obvious that the fenac was no longer active or present in the soil that had been flooded. However, that portion of the treatment area above elevation 84 meters which was not flooded remained free of these seedlings, even though seeds were present. No new plant growth was observed in the portion of the plot that was still flooded, however.

Since it had been decided that the three-hectare plot would be kept free of all aquatic weeds for at least two flood seasons, it was believed that it would be better to control the newly established plants as they appeared, rather than wait

would be mature and deep rooted, and therefore would require much more work to be removed.

Therefore, between January and August 1970, 12 different herbicides and their combinations were tested for the control of these young plants that were becoming established within the test area along the exposed lake shore as the water level dropped. These herbicides included:

1. 2, 4-D amine liquid;
2. 2, 4-D ester liquid;
3. 2, 4-D granules (20 percent 2, 4-D ester acid equivalent);
4. 2, 4, 5-T ester liquid;
5. diuron (80 percent wettable powder);
6. diuron (20 percent granules);
7. paraquat liquid;
8. diquat liquid;
9. fenac liquid;
10. MCPA liquid;
11. dalapon (85 percent wettable powder); and
12. STAM F-34 liquid.

Each herbicide, or combination of herbicides, was sprayed over test plots ranging from 10 to 40 square meters in size. Since the primary objective of these tests was to find a safe, fast, economical method for controlling the new growth on the exposed lake bottom, each herbicide was first applied at the maximum rate recommended by the manufacturer. If it did not give excellent control at this rate within two weeks after treatment barring such complications as heavy rains soon after treatment, the herbicide was not tested further. However, those herbicides that gave at least 90 percent control within two weeks were

was determined. After this was done for each herbicide tested, comparisons were made relating to their cost and safety. It should be mentioned, however, that no herbicide was included for testing in the first place if it was considered potentially dangerous to humans, livestock, and fish at recommended concentrations (Plate 18).

The following information discusses the results of each herbicide or combination of herbicides tested at Ampem during the January-July 1970 drawdown period. (See Table 3 for a list of the herbicides tested and the local distributors.)

1. 2, 4-D ester liquid (approximately .5 kg per liter acid equivalent)

This herbicide is locally available in Ghana and costs approximately N¢2.50 per liter. It is designed to control herbacious (non-woody) broad-leaf plant species, but not grasses.

Tests conducted at Ampem showed that it was very effective for the control of young Polygonum plants not exceeding 30 cm. in height when thoroughly sprayed (foliage wetted completely) with a one-part 2, 4-D in 50 parts of water (1 to 50) mixture.

This herbicide gave satisfactory control of taller Polygonum plants when the spray mixture concentration was increased to 1 to 25. However, mature plants (those in flower) were only temporarily affected and regrowth was heavy within 30 days.

Other plant species that were controlled with this herbicide at the above concentrations included Ludwigia sp., Pistia, and Alternanthera.

Based on the strongest concentration tested, this herbicide would cost approximately N¢7.50 per hectare of area treated.

Caution: Even though this herbicide is reported to be quite safe to humans, livestock, and fish at recommended concentrations, it is volatile (subject to drift) and is very

sprayed [illegible] while these crops are [illegible] sugar cane, and rice are not susceptible to 2, 4-D ester at the concentrations mentioned above.

2. 2, 4-D amine liquid (approximately .5 kg. per liter acid equivalent)

NOTE: These results apply to MCPA as well.

This herbicide is closely related to 2, 4-D ester. The primary difference is that 2, 4-D amine is not volatile, and therefore will not drift as badly as the ester formulation. However, our study at Anpem showed that 2, 4-D amine is not as effective as 2, 4-D ester for controlling weed growth on the exposed lake shore--particularly those plants that exceeded 30 cm. in height. Nevertheless, it was effective for controlling young plants; and therefore, it should be applicable for use at the Lake where minimum herbicide drift is essential. Test results showed that a 1 to 25 spray mixture of 2, 4-D amine was the lowest effective concentration. This herbicide is also readily available in Ghana at a cost of approximately N¢2.00 per liter. Therefore, the chemical cost for treating one hectare of infestation using 2, 4-D amine would be approximately N¢6.00.

Caution: This herbicide should not be applied where the spray can drift on broad-leafed crops, particularly tomatoes and tobacco. However, 2, 4-D amine is not toxic to maize, sugar cane, or rice at recommended concentrations.

3. 2, 4-D granules (20 percent acid equivalent)

Granular 2, 4-D is a special formulation designed for application where a slow release of the herbicide is desired and where "spot treatments" are required. It is not currently available in commercial quantities in Ghana, and its higher price (approximately nine times more expensive per hectare)

TABLE 3

Herbicides Tested

Name or Designation	Trade Name or Other Designation	Chemical Name	Local Distrib
Dalapon	Gramevin	2, 2-dichloropropionic acid	Shell Co. of Ghana, P. O. Box 1097, Acc
2, 4-D amine	Shell D-50	22, 4-dichlorophenoxyacetic acid	Shell Co. of Ghana,
2, 4-D amine	Fernimine	2, 4-dichlorophenoxyacetic acid	ICI (Export) Ltd. P. O. Box 104, Tem
2, 4-D ester	Fernesta	2, 4-dichlorophenoxyacetic acid	ICI (Export) Ltd.
2, 4-D granules	2, 4-D Granular Weed Killer	2, 4-dichlorophenoxyacetic acid	Monsanto[1] P. O. Box 5381, Acc
2, 4-D granules	Aqua Kleen Granules (2, 4-D) (Amchem Prod. Co., Ambler, Penna., USA)	2, 4-dichlorophenoxyacetic acid	None
DPA (Propanil)	STAM F-34	3, 4'-dichloropropionanilide	Shell Co. of Ghana,
Diquat	Reglone	1, 1'-ethylene-2, 2'-dipyridylium dibromide	ICI (Export) Ltd.[1]

1/ Not currently available in commercial quantities.

(continued on reverse)

Table 3 (continued) Herbicides Tested

Name or Designation	Trade Name or Other Designation	Chemical Name	Local Distri
Diuron	Karmex	3 (3,4-dichlorophenyl)-1,1-dimethylurea	Shell Co. of Gha
Diuron granules	Cardi (Fasco, Jacksonville, Florida, USA)	3 (3,4-dichlorophenyl)-1,1-dimethylurea	None
Fenac	Fenac	2, 3, 6-trichlorophenylacetic acid	Shell Co. of Gha
MCPA	Agromone 4	4-chloro-2-methyl-phenoxyacetic acid	ICI (Export) Ltd
Paraquat	Gramoxone	1,1'-dimethyl-4,4'-depyridylium dichloride	ICI (Export) Ltd
2, 4, 5-T ester	Shell T-50	2, 4, 5 Trichlorophenoxy acetic acid	Shell Co. of Gha
2, 4, 5-T ester	Trioxone 50	2, 4, 5 Trichlorophenoxy acetic acid	ICI (Export) Ltd

The writer wishes to thank the chemical companies listed in this table for donating most of the herbicides tested during this study.

chemical is released gradually from the clay granules, the reaction time is very slow compared to liquid 2, 4-D sprayed directly on the plants. It was also noted that if it rained heavily after an application was made, the granules would wash away before the 2, 4-D was released. Therefore, based on our study at Aripen, this type of herbicide is not applicable for treating emerging aquatic weeds growing on the Lake's exposed shore.

However, it was found that 2, 4-D granules were very effective for the control of floating islands of Pistia-Scirpus. This suggests that this formulation may be well suited for controlling these weed masses at the Lake where aerial applications must be made and drift eliminated. Most aerial applications are applied at low altitudes (usually not exceeding 10 meters) above the water's surface when liquid sprays are used. This is necessary to reduce spray drift and to thoroughly wet the plants. Such low altitude spraying would be impossible at Volta Lake because of the standing timber. However, a granular form of herbicide--because of its high density--could be applied at a much higher altitude, with very little danger of the herbicide drifting outside of the designated area.

Furthermore, the granular formulation would be better suited than liquid sprays for penetrating the dense, grassy Scirpus canopy that covers the Pistia which often is the foundation of the floating islands (Plates 1 and 2). Our studies showed that the granules became lodged in the thick mass of roots and between Pistia's rosetted leaves. Therefore, since the island is wet, the granules dissolve rapidly, thereby releasing the 2, 4-D.

ments would have to be made for applying the granules from an airplane or helicopter.

NOTE: In August 1970, three .20 hectare plots of submerged Ceratophyllum were treated with 2, 4-D granules at rates of 100 kg., 150 kg., and 200 kg. per hectare, at an approximate cost of N$75.00 per 100 kg. Each plot was an average of one meter deep at the time of application, but within 60 days, the depth increased to over two meters as the lake level rose during lake fill. Within two weeks of treatment, the Ceratophyllum started to loose its rigidity and laid flat on the bottom of the Lake. This effect was more apparent in the two plots that had been treated at the higher rates. Within one month, these same plants had lost their dark green color, and they had turned light green and yellow. However, within 30 days of treatment, the treated areas had become reinfested with Ceratophyllum that had apparently washed in from outside.

Because of the high cost of this herbicide, therefore, it should only be applied at Volta Lake in areas where liquid 2, 4-D or other herbicides would not be equally as effective.

4. 2, 4, 5-T ester liquid (approximately .7 kg. per liter acid equivalent)

This herbicide is designed for the control of both woody and herbacious plant species. The cost of 2, 4, 5-T is usually 50 percent more than 2, 4-D, and therefore, it should not be used where 2, 4-D would work equally as well.

Studies conducted at Ampen showed no real advantage in using 2, 4, 5-T rather than 2, 4-D for the control of plant species that normally grow on the exposed lake shore at Volta Lake.

that mice that were fed food that had been contaminated with 2, 4, 5-T developed cancer. Therefore, the writer cannot recommend this herbicide for use at Volta Lake.

5. dalapon (85 percent wettable powder)

This herbicide is designed specifically for the control of grass species, and therefore should not be used for the control of broad-leaf species.

Rates of 17 kg. dalapon mixed in 500 liters of water plus 200 grams of detergent per hectare gave good control of *Jussiaea*, *Rhynchelytrum*, *Andropogon* sp. and *Paspalum* sp. growing on the exposed lake shore at Volta Lake. However, it is essential that the plant's foliage is thoroughly wetted with the spray solution. Spraying should be done before the plant flowers, and re-spraying may be required after 12 weeks for effective long-term control.

Dalapon is compatable with most liquid herbicides and therefore can be mixed with herbicides such as 2, 4-D for the spraying areas that contain both grasses and broad-leaf plants.

This herbicide is locally available in commercial quantities at a cost of approximately N¢2.00 per kg.

Caution: Dalapon is not volatile, but care should be given when it is sprayed near grass crops such as rice and corn.

6. paraquat liquid (approximately .3 kg. per liter acid equivalent)

As was been mentioned earlier in this report, paraquat is inactivated when it comes in contact with the soil. Therefore, it cannot be applied directly on the soil as a pre-emergent--it must be sprayed directly on the plant. Paraquat kills most green plant growth with which it comes in contact and is particularly active against grasses. It is very quickly

absorbed into plant foliage, and its performance is therefore not affected by rain falling shortly after application. The effects of this herbicide are usually seen within hours after spraying, and kill is usually complete within three or four days. It has a low mammalian toxicity, and no elaborate precautions are necessary to protect either man or livestock.

During the drawdown period of 1974, paraquat proved to be the most effective herbicide for the control of regrowth on the exposed lake shore at Aropan. Small seedlings (one to 15 cm. tall) were killed within three days using a mixture equivalent to one liter paraquat mixed in 150 liters of water. The mixture was sprayed directly on the vegetation making sure that foliage was wetted thoroughly.

Plants between 15 and 30 cm. in height were controlled better by using a spray solution equivalent to two liters of paraquat mixed in 150 liters of water. Tall grass species were controlled with the same concentration. However, mature Polygonum plants were only temporarily defoliated using the strong mixture, and regrowth was apparent within 14 to 21 days.

Special wetting agents are available and are recommended for mixing with paraquat spray mixture to be applied by airplane. These same wetters can also be used to some advantage when doing conventional ground spraying, but they are not essential.

Paraquat is readily available in Ghana and costs approximately ¢¢3.00 per liter. The cost of the chemical for the lowest concentration tested (three liters per hectare) was ¢¢15.00 per hectare. The higher concentration (six liters per hectare) would double the cost. Therefore, compared to 2, 4-D, paraquat is just as inexpensive to use for controlling the regrowth on the exposed lake shore and does not present as many hazards to farm crops growing nearby.

Caution: Extreme caution must be taken, however, when spraying paraquat close to any green crop, since localized damage will occur any place the spray mixture comes in contact with the green portion of a plant.

7. diquat liquid (approximately .3 kg. per liter acid equivalent)

This herbicide is closely related to paraquat. It is not currently available in Ghana in commercial quantities. The only disadvantage found in using diquat is that it does not control grass species as readily as paraquat.

8. STAM F-34 liquid (approximately .4 kg. per liter)

This contact herbicide is designed for the control of a variety of weed species in rice fields. It is recommended to be applied directly on young weed species at the rate of 15 liters of STAM F-34 per hectare. Complete wetting of the foliage is recommended.

Tests conducted at Volta Lake using the above recommended rate showed that STAM F-34 is effective for the control of young plants growing on the exposed lake shore at Ampen. However, like the contact herbicides paraquat and diquat, STAM F-34 did not kill mature plants--particularly Polygonum--but only defoliated them temporarily.

This herbicide is available in Ghana in commercial quantities, and costs approximately N¢3.75 per liter. At the rate tested, STAM F-34 cost approximately N¢55.00 per hectare treated--over three times as much as paraquat.

Therefore, for the control of young plants growing on the lake shore at Volta Lake, there is really no advantage in using STAM F-34 rather than paraquat or diquat. However, the writer concedes that he did not have an opportunity to test STAM F-34 at low rates (six liters per hectare) and compare the results with that of paraquat and diquat.

The same precautions should be applied for STAM F-34 as for paraquat.

9. diuron (80 percent wettable powder and granules)

This herbicide is not currently available in commercial quantities in Ghana, but it can be ordered through local distributors at a cost of approximately N¢3.00 per kg.

Diuron is effective for the control of wide varieties of plant species, particularly grasses. To be effective, this herbicide must be taken in by the plant's roots; therefore, soil moisture is essential for good control.

Because of diuron's low solubility and its residual effects, it is well suited for applying in combination with other herbicides where long-term control is required. At recommended rates, diuron is safe to the user and to livestock and fish.

A spray mixture equivalent to four kilograms of karmex (80 percent diuron wettable powder) and 500 liters of water per hectare (N¢12.00) gave good control of young plants growing on the exposed lake shore at Volta Lake when applied as an early post-emergent. However, a poor kill was noted where the ground was dry. This herbicide was also successful in killing floating islands of Scirpus-Pistia when the spray mixture was applied directly on the floating mass.

Diuron is slow acting on mature, deep-rooted, broad-leaf terrestrial plants, and therefore it should not be used where quick control of these species is essential.

A granular form of diuron (20 percent) was also tested for the control of young plants growing on the exposed lake shore at Ampem. To compare this formulation with the powdered karmex, the same amounts of active ingredients per hectare were used. The diuron granules were scattered by hand at the rate of 25 kg.

per hectare. Poor results were obtained since the ground was relatively dry and the density (spread) of the granules was extremely light. However, when these granules were scattered on floating islands of Pistia-Scirpus, some control was noted--but not as much as when karmex was used.

Also, when two areas of submerged Ceratophyllum were treated with these granules--at the rate of 100 kg. (granules) per hectare--no noticeable control was noted after 60 days. Lemna and Pistia were killed, however, in a small, shallow area treated near shore.

The cost of this formulation of diuron is not known exactly, but it would be at least three times as expensive as karmex for the same amount of active ingredients. For this reason, and because of the poor showing that it made, the writer does not suggest that it should be considered for use at Volta Lake.

Caution: Since diuron is a non-selective herbicide, care should be taken when it is applied near food crops. Furthermore, no potential crop land should be treated with diuron unless the area will be flooded at least once before a crop is planted.

10. fenac liquid (approximately .2 kg. per liter

The use of this herbicide has already been discussed thoroughly in this report; therefore, the writer will only elaborate here to say that for post-emergent control of plant growth on the exposed lake shore at Ampem, fenac was not successful.

Manual Control

Based on the results of the above herbicide tests conducted on the drawdown area at Ampem, it was concluded that even though chemical control was effective, it could be hazardous to shoreline vegetation nearby. Therefore, manual control

measures were tested and these results compared with the chemical control procedures discussed above.

In testing manual weed control techniques at Arpen during 1970 and early 1971, it was found that the exposed shoreline could be maintained relatively free of regrowth by periodically cutting the weeds down with cutlasses.

It was further learned that there was no distinct advantage in cutting the weeds down as soon as they appeared (young plants) since new growth would develop quickly--thereby making it necessary for the same area to be cleared several times before flooding began. Therefore, the most effective and economical method was to schedule the clearing operation to coincide with lake fill. This allowed the water to flood the newly cut area before the plants' roots had time to put out new growth. Wave action was normally sufficient to uproot any seedling growth that developed from late seed germinations as the water level rose.

However, it is important that the freshly cut material is carried away and deposited above the high water mark, since this material would be attractive to snails and since the stems--particularly Polygonum and Vossia--could set root and become well established in a relatively short period of time along the wet shoreline. The cost of clearing the regrowth at Arpen manually was not determined, since the local people did the work on a self-help basis. However, it was estimated that under average conditions, a hectare of weeds (Polygonum, Alternanthera, Ludwigia, and short grasses) can be removed in approximately 30 man-hours.

This labor requirement would not, however, apply where Vossia is well established. In such areas, the labor force would probably have to be tripled, since Vossia has to be literally dug out of the ground before satisfactory control can be expected.

The writer refers the reader to the next section of this report, "Clearing Fishing Stripe in Aquatic Weed Beds," for possible Vossia control methods.

Second Year Snail Survey

To continue the assessment of what effect the cleared area had on the snail population at Ampem, periodic snail surveys were conducted during the second year after treatment. Equal time was spent surveying inside and outside the cleared area in order to compare the number of snails in each area.

A two-hour survey conducted in September 1970 produced 82 Bulinus truncatus and B. forskali snails in the aquatic weed beds bordering the cleared area, but no snails were found within the cleared area itself. At the time of this study, the water level was at elevation 82.5 meters and rising fast. The weed beds that bordered the cleared area consisted primarily of Polygonum, Ceratophyllum, and floating debris. The snails were collected on Ceratophyllum.

In mid-October 1970, when the Lake was at its annual high retention level of 84 meters elevation, a similar snail survey was conducted. At this time, 90 B. truncatus and B. forskali were collected from the uncleared area, and 21 snails were found within the cleared area. This was by far the most snails that were ever found in the cleared area at Ampem during a single survey. However, it was learned from personnel of the AWCU who conducted the survey that all of the snails were found either on debris that had recently washed into the area or in an old canoe that was partially filled with water. The inside of the canoe was covered with a mass of filamentous algal, indicating that the canoe had contained water for a long period of time. It is this writer's opinion that the snails that were

found in the canoe should not have been recorded in the total snails present in the cleared area. However, this observation was very interesting since the B. truncatus snails that were found there were far larger than any that the survey team has ever collected in the Lake. This larger size suggests that either the micro habitat of the boat was much more productive than the Lake or the boat provided protection for the snails from their natural enemies--thereby allowing the snails to survive longer than they would have been able to in the Lake. The writer considers both possibilities likely, but the latter more probable.

In February 1971, a three-hour snail survey at Ampem produced 28 B. truncatus and one B. forskali. All of these snails were collected in a small protected bay located approximately 100 meters west of the cleared area. This small cove (approximately 100 meters square) was infested with Ceratophyllum, whereas the rest of the shoreline was virtually free of aquatic weeds and debris.

During this same period, AWCU personnel conducted snail surveys at Dedeso, located approximately 16 km. east of Ampem, and at Dotorpau, located approximately eight kilometers west of Ampem. At Dedeso, 41 snails were collected in a small bay infested with Pistia, Ceratophyllum, and a mixture of other weeds. At Dotorpau, nine live snails and 16 empty shells were collected among debris that had washed ashore.

In March 1971, when the lake level was at elevation 81.3 meters and falling, another series of snail surveys were conducted at Ampem (inside and outside the cleared area), Dedeso, and Dotorpau. No weeds were present along the lake shore at Ampem, and only four empty snail shells were collected--all of which were found scattered among debris outside of the cleared area.

At Dodoso, where some weeds and debris were still present in the water, 30 snails (five B. *forskali* and 25 B. *pfeifferi*) were collected.

No flooded debris or aquatic weeds were present at Dotorpen, and no snails were found there.

Therefore, the writer feels that it can be safely concluded from the data collected at Ampen between 1969 and 1971 that the snail population was greatly reduced wherever aquatic weeds and debris were removed or were naturally absent.

Based on results of this study, the VLRP has agreed that the three-hectare (240 meters lake frontage) cleared area at Ampen should be increased to include approximately .8 km. of shoreline; and further analysis should be made to determine what impact this localized control (weeds and snails) has on Bilharziasis infection in that area.

This technique, combined with chemotherapy (medication), health education, and possibly molluscicide treatments are also planned for two other lakeside villages (Figure 3) at Volta Lake in 1971 (Pierce, 1971b).

Clearing Fishing Strips in Aquatic Weed Beds

As has been described earlier in this report, several species of semi-aquatic weeds--particularly *Polygonum*, *Alternanthera*, and *Vossia*--become established on the exposed lake shore as the water level recedes during the period December through June each year. This weed growth develops into aquatic weed beds during the subsequent lake fill period (July through November) and for a few months following that time until the water level drops sufficiently to expose the weeds that were flooded. Before 1969, when only a relatively few flooded weeds were present along the shore, fishing in and around these areas

was reported to be very good. However, after 1969, when the emergent shoreline vegetation became much more extensive, the fisherman found that they could no longer fish effectively near shore during much of the year because of the rank weed growth that had become established there.

This portion of the report discusses work done by the AMCU to assist the fisherman in developing effective and economical methods for clearing fishing strips in flooded weed beds where gill nets could be set.

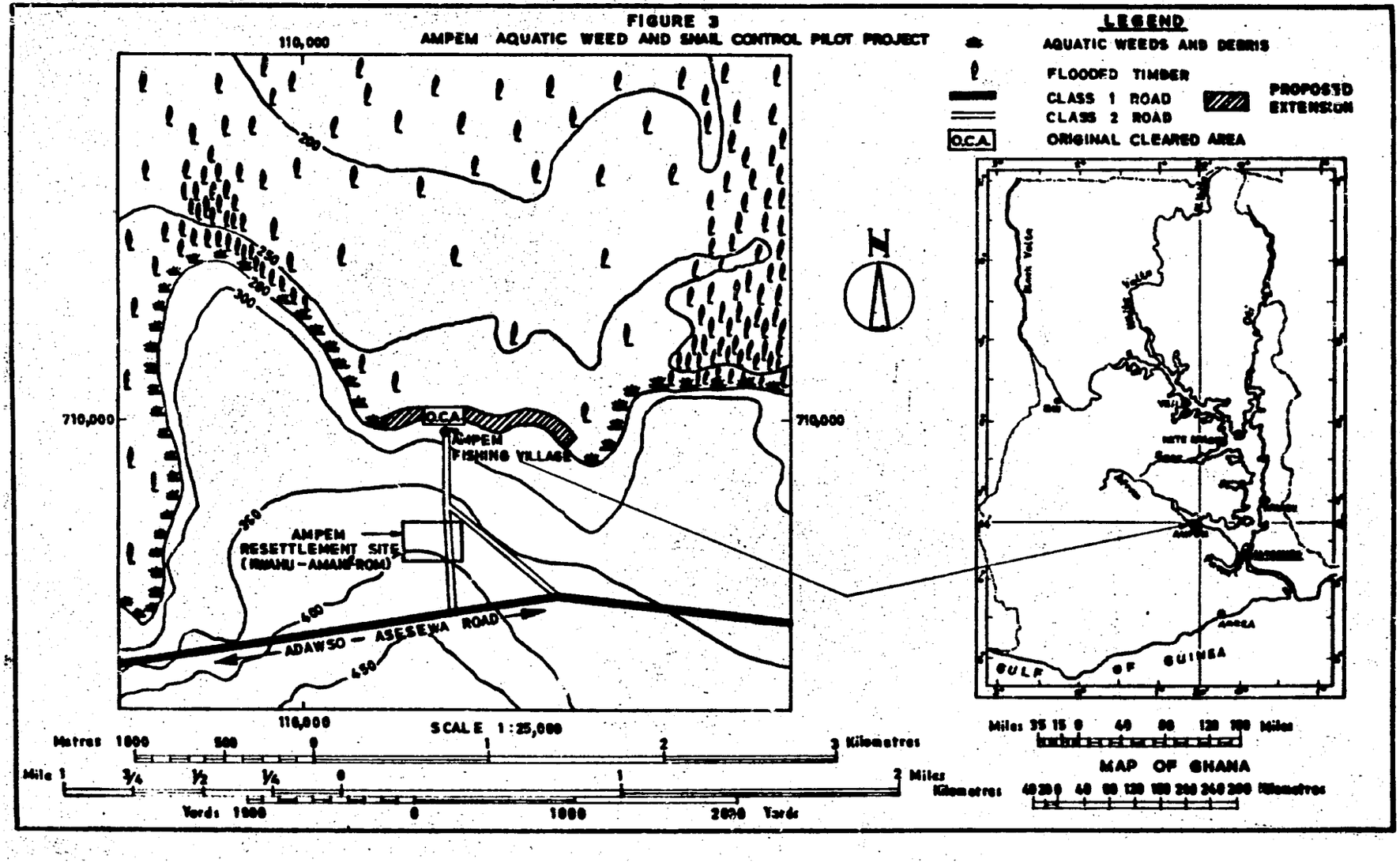
During the drawdown period of 1969, 18 fishing strip clearing experiments were conducted in stands of Polygonum at Anpem. The size of each test plot measured approximately 3 X 30 meters.

At that time, it was not known what clearing methods would work under Volta Lake conditions; therefore, several approaches, including herbicides, were tried. These methods included:

1. Treating standing vegetation with selected herbicides (2, 4-D amine, 2, 4-D granules, 2, 4, 5-T ester, diuron powder and granules, MCBA, and paraquat);
2. Clearing the area of vegetation, treating it with a herbicide, and then placing the cut material back on the plot;
3. Applying herbicides to areas after the vegetation had been cut down and removed;
4. Cutting the vegetation down and removing it from the area (control to method #3 above); and
5. Cutting the vegetation down, but not removing it from the area (control to method #2 above).

Results of this study showed that treating mature standing vegetation with herbicides was not successful at economical

FIGURE 3
AMPEM AQUATIC WEED AND SNAIL CONTROL PILOT PROJECT



concentrations. The best control was noted where areas had been cleared of vegetation, treated with a herbicide, and recovered with the cut material (#2 above). However, good control was also noted for #5, the control area of #2. Therefore, this method appeared to be the most practical and potentially the most effective means of clearing fishing strips at Volta Lake. It was speculated that this method worked by suppressing regrowth by shading the ground from sunlight. It was further found that control was better where the vegetation was piled to the center of the strip to form a thick berm. During the following flood period, the few strips that had been successfully cleared during the drawdown period remained free of aquatic weed growth as long as the strips were used regularly by fishermen (Pierce, 1969n).

To fully test this technique, arrangements were made to have 50 fishing strips cleared at four villages. Each of the strips were cleared by local fishermen on a self-help basis.

Abukyere, Korga, Akoabudzi, and Akoafiu

These small fishing villages are located in a portion of Volta Lake where heavy stands of Vossia are extensive (Map 18).

In May 1970, these villages were contacted, and the people willingly agreed to participate in a fishing strip clearing program. The areas to be cleared were selected by the fishermen. Sample clearing was started during this period in an effort to determine how many man-hours it would take to cut a fishing strip in heavy stands of Vossia. It was quickly learned that clearing a strip by cutting alone (#5 above) was impractical, since the stems and roots of Vossia were as much as one meter thick in places and virtually impossible to cut through with a cutlass. Therefore, it was speculated that if an area was to be cleared in Vossia, it would have to be burned

first in order to destroy the many dead stems and roots that accumulated over the previous three years. This cutting and burning technique was tried near each of the villages mentioned above.

The results of these experiments showed that not only did fire consume the dead material within the cut strips, but also it spread along the upper shoreline. This extensive burning was attributed to the extremely dry weather that had existed in these areas during the previous drawdown period (December through July), which allowed most of the dead plant material that normally accumulates near the ground in weed beds to burn freely. This ground fire was of sufficient intensity to cause the Vossia's tall leafy stems to wither and fall into the smoldering fire below. In most cases, the tops of the plants were not completely consumed by the fire; therefore, the areas had to be burned a second time, and in some areas a third burning was necessary.

After the second or third burning, the surface of the shoreline was virtually clean since even the dead trees and timber that had been deposited there were also consumed by the fire. However, as the water level started to rise in mid-August (one month later than usual), and the rains started, the burned areas soon became covered with young Vossia plants that had sprouted from stems and rhizomes buried beneath the ground. By the time the water level had risen one vertical meter, it was apparent that the Vossia regrowth would be so extensive and dense that setting gill nets in the weed beds would be virtually impossible in most areas if further clearing was not done (Plate 19).

It was known that Vossia cannot re-establish itself after it has been flooded if its stems are removed at least one meter below the surface of the water. Therefore, with the help of

local fisherman, the AWCU tested the effectiveness of post-flood weeding.

The technique used was to wade into the water to a depth of one meter in areas having the least amount of regrowth and dead debris, and to pull the plant material out by hand along a given line. The time (man-hours) involved to clear these strips depended upon the amount of material to be removed, and of course the size of the fishing strip. In one area at Abukyere that had been burned twice prior to flooding, six men cleared a strip measuring 7 X 150 meters in less than 30 minutes. Also, because everyone was working in water and the plant material is fairly easy to pull out, the work is neither hard nor hot (Plates 23 and 24).

However, in clearing fishing strips near Korga, Akpabadzi, and Akpafiu in areas that had only been burned one time, the work progressed somewhat slower, but was not considered hard work by the fisherman (Plate 19, 20, 21, and 22).

The greatest drawback in doing this type of clearing is that the plant material has to be removed from the area either by manual labor or through natural means, such as wind and wave action. However, the fisherman claimed that the wave action would float the uprooted debris away; therefore, little effort was made to physically remove the material from the sites.

An unexpected hazard was experienced at Akpafiu where the workers were shocked by electric catfish (*Malapterurus electricus*) that refused to vacate their weedy abodes. No serious injury was experienced by any of the workers; however, it did appear that because the workers were more cautious when reaching into the water, work progressed slower in this area than in areas where workers were not shocked.

Data collected in Nigeria indicates that this catfish spawns in swamps during August and September, which unfortunately corresponds with the period for removing aquatic weeds by wading at Volta Lake. Therefore, there remains a possibility that a mother may receive severe shock from a large catfish that has chosen to spawn in shallow water where clearing is being done.

In regard to the removal of uprooted debris from the cleared areas, later observations indicated that even though most of the debris had washed to the inshore edge of the cleared strip, it would be better to remove the uprooted material to assure that it did not float around and become entangled in the fisherman's nets.

Some fishermen think, and the writer agrees, that the strips should be narrower (two meters rather than seven meters). They feel that two meters is sufficient for setting nets, and it allows for freer movement of the fish between the weed masses; thereby creating a higher potential for catching more fish. However, wide strips are encouraged where cast-net fishing is practiced or where motor launch lanes are needed. Cast-net fishing during the flood period is usually done primarily to obtain small fish for setting long lines (hooks).

It was decided that fishing strips should be cleared parallel to the shore, mainly because the outer wall of emergent vegetation acts as a barrier to the excessive wave action and floating debris that is common at the Lake. This creates relatively quiet water behind the outer barrier, thereby greatly reducing the "rolling" of the nets and debris entanglement.

An assessment survey trip was made in November 1970, five months after the weed clearing program was initiated. The water level at that time was 84 meters and falling slowly; therefore, virtually all of the area that was covered with

Vossia during the previous drawdown period was rooted. The water depth at the outer edge of the Vossia was approximately three to four meters deep.

In investigating the fishing strips at each of the study areas, it was found that the strips that had been cleared prior to flooding but not weeded after flooding began had become heavily re-infested with Vossia. However, those strips that were cleared by wading and weeding in early September continued to remain clear of regrowth, except for some surface runners that extended inward from either side of the strips. The water depth within these strips at that time was approximately three meters deep and dropping slowly.

The portion of the shoreline that had been burned prior to flooding was re-infested with Vossia, but the plant density was not as heavy as it was in those areas that had not experienced burning. Fishermen were able to set their nets within the previously burned area following a limited amount of weeding; whereas, considerable more work was required before nets could be fished in the unburned areas. Fishermen from each of the villages reported that fishing had been generally poor since the water level started to drop, and they also mentioned that fishing among the Vossia had not been encouraging. However, the fishermen living at Kofoade, where Polygonum predominates, stated that fishing in the sheltered burned areas was very good while the Lake was rising and that they plan to clear more areas in 1971. It should be mentioned that fishing was usually reported to be much better around Polygonum than around Vossia even before the fishing strip clearing program was initiated. Therefore, it is this writer's opinion that Volta Lake fishermen will continue to clear fishing strips in flooded Polygonum; however, it is doubtful that a comparable effort will be made

in the less productive, but more troublesome, Kossie (Plates 19 through 24).

Biological Aquatic Weed Control

No actual planned biological weed control has been carried out on Volta Lake. However, the Government has given consideration to this technique.

Little, in his presentation to the 1966 Man-Made Lake Symposium in Accra, stated:

> "There are four main headings for biological control possibilities--the use of insects, snails, fish and mammals. All of these have interesting and possibly extremely important potentials, though unfortunately, as yet successful biological control is resistance by the organisms concerned to predators and to disease. They must also have a capacity for rapid building up of population to meet the demand of a correspondingly rapid development of the weeds. Where the plants' development and reproduction capacity exceed that of the biological control agent, it is likely that a plant, such as Eichhornia, may well be able to nullify the attack of the organisms. This is very likely to be so in the case of snails and fish where the dense masses of the plant may overwhelm the attackers.
>
> "Insects may flourish where plants are growing in vast numbers; but the problem remains to find insects which are specific to the weeds in question and do not represent a hazard to neighbouring crops.
>
> "As regards to mammals, there has been considerable interest in the manatee (Trichechus sp) as a possible controller of water weeds. But this animal, in spite of its enormous capacity for consuming weeds, seems still to be an impracticable candidate because of its rarity and the slowness with which it breeds. This does not mean that research may not discover means of farming the manatee in a manner akin to land animals by producing new varieties or discovering how the reproductive rate of the animal can be accelerated. But there will simultaneously remain the problem of educating human beings to look after animals such as the manatee and not indulge in their usual propensity for destroying them.
>
> "There still remains a fifth and as yet unknown possible means of biological control briefly referred to earlier. This may be by pathogens or by subtle changes in the environment of the lakes or rivers. But there still seems a long way to go before such an ideal situation can be achieved."

The writer would like to say at this point that it is highly unlikely that any large aquatic animal would be suitable for controlling aquatic weeds at Volta Lake, since they would certainly be destroyed by the fishermen for no other reason than to stop the animals from damaging their gear which is commonly set in the shallow, weed infested areas of the Lake.

It is known that manatee existed as far up the Volta River as Kete Krachi before the Lake formed; but since 1966, none of them have been reported in the Lake itself. Several have been seen, however--one by this writer--in the tailrace below the Akosombo Dam. It may be that these animals normally migrate up and down rivers according to seasons. Therefore, those manatees that may have been trapped behind the Dam when the gates were closed in May 1965 probably went over the spillway--and to their death--when the gates were opened after 1967. The writer knows of two large manatees that were found dead and badly mangled below the Dam during periods when water was being released over the spillways. Hence, if these animals are ever to be stocked into the Lake for weed control, conservation, or tourist attraction purposes, it will probably be necessary to first install some sort of protective barrier in the Lake immediately upstream from the spillway gates.

The writer is also of the opinion that the Lake is still too young for a determination to be made as to whether or not natural biological control (balance) will eliminate, or at least reduce significantly, the problems which are currently attributed to aquatic weeds.

Some biological control for certain species of aquatic weeds at the Lake is already evident. One is the noticeable reduction of flooded Polygonum which is attributed at least in part to the apparent damage Pyrilla larvae do when they burrow into the

plant's stems. Vessis, it is hoped, will be the next species to be attached by these important fish food organisms. (See pages 35 to 37 of this report for further details.)

Also, observations were made during July 1970 of a small beetle (Altica nigrata or senegalensis) attacking Ludwigia leptocarpa growing on the exposed lake shore. It was speculated that those beetles either preferred L. leptocarpa, or possibly are even host specific to it, since no other plant species were seen being eaten by them. By the time the lake level flooded the exposed shoreline in October, no L. leptocarpa--which is known to be tolerant to at least moderate flooding--could be found. However, during the next drawdown period, some new L. leptocarpa plants were noted, but again there was evidence that they were being eaten by these insects.

As far as direct biological control of vector snails is concerned, there are strong indications that certain species of fish in the Lake eat snails. One snail eating species is the puffer fish, which is particularly abundant in the Afram portion of the Lake and is normally taken in weed beds--mainly Ceratophyllum. Since the flesh of this fish is considered to be poisonous, it is therefore not eaten; hence, there is a good possibility that its numbers should increase in the Lake. Unfortunately, because this species in known by the fishermen to be poisonous--and therefore worthless to them--and because it is accused of cutting the fishermen's nets or eating the tails off of other good fish species which are entangled in the nets, the puffer fish is usually killed by the fisherman before it is thrown overboard. This is surely reducing the abundance of this species and its potential as an effective means of reducing the vector snail population in the Lake. Therefore, if the numbers of this species are to increase through conservation management,

the fisherman will have to be advised of how this species benefits them, and encouraged to release the fish unharmed whenever one is caught.

In November 1970, Dr. Clifford O. Berg, Resident Ecologist, Smithsonian Institute, Washington, D. C., visited Volta Lake in search of marsh flies (Sciomysidae) that are known to feed on snails. During a four-day survey at the Lake, Dr. Berg collected one sciomysid along the shore of the northern bank of the Afram. However, he was much more successful while searching for these flies in shallow marshes along the Densu River near Nsawam in the Accra Plains north of Accra. Work done by Dr. Berg in other parts of the world showed that certain species of sciomysid larvae feed on aquatic snails, and in some instances, good snail control was accomplished by the introduction of these flies. However, these flies are not well suited for controlling snails in water deeper than 60 cm., since the larvae does not have gills and therefore must come to the surface for air every few minutes. Furthermore, it is doubtful to this writer that these larvae could survive in large enough numbers to control snails in an impoundment such as Volta Lake where many insect eating fish exist. In marshes, where the sciomysid does well, the fish life is usually very low or maybe even absent; therefore, the insect population would be expected to be correspondingly high.

During the past 13 years, studies conducted in Puerto Rico and other locations have shown that the large Marisa cornuarietis snail has potential as a biological control of schistosomiasis (Bilharziasis). It has also been found to be effective for the control of certain species of aquatic weeds.

In 1968, this writer recommended that a series of controlled laboratory tests be conducted in Ghana to test the feasibility of using this snail as a control of vector snails

in Volta Lake. However, this recommendation was overruled by members of the VLRP Hydro-Biology Advisory Sub-Committee on the grounds that the snail might accidentally escape into the wild and cause damage to agricultural crops, particularly rice. Therefore, the study was not carried out. However, the writer still feels that this snail has potential in Ghana, not only in Volta Lake, but also in the many small ponds and streams where vector snails are common and Bilharziasis is a serious and constant problem. Therefore, it is hoped that when facilities are available in Ghana--facilities that can assure that an unwanted introduction would not occur--reconsideration will be given for a local evaluation of this snail's biological control potential. (See separate listing of literature cited for biological aquatic weed control.)

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