ISSN 0331-6734

KAINJI LAKE RESEARCH INSTITUTE
TECHNICAL REPORT SERIES NO. 16

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Kainji Lake Research Institute
New Bussa, Nigeria, 1985

ISBN 978-177-020-1

ISSN 0331-6734

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ABSTRACT

Echinochloa stagnina growing in Lake Kainji is identified, described, and separated from *Echinochloa pyramidalis* and *Echinochloa colona*. *Echinochloa stagnina*, which requires the annual 10m draw-down of the lake for successful establishment and survival, shows a marked zonation and contributes to evapotranspirational water loss from the lake; accounting for the reduction of the effective lake volume by up to 17%, for example in 1979.

A management strategy which demands the harvest and removal, for livestock fodder, of 75% of the total yearly standing crop (up to 120, 965.4 tonnes) in order to maintain the grass as a renewable source of dry season fodder without significantly affecting power generation is discussed. The effect of harvesting on the grass and the number of sustainable harvests in a given area is estimated. With such removal an estimated 3×10^6kg of nitrogen and 4×10^5kg phosphorus are removable from the lake ecosystem. Sources of nutrients to balance these removals are discussed.

INTRODUCTION

The growth of *Echinochloa stagnina** in association with *E. pyramidalis* and other emergent and floating macrophytes in Lake Kainji is of considerable interest from the standpoint of livestock production. It is common knowledge that ruminant livestock in the savanna areas of Nigeria lose form and weight in the dry season because of scarcity of suitable fodder, as terrestrial grasses and herbs dry up at this time and are usually burnt. This has been identified as one of the factors that limit livestock production in Nigeria (Oyedipe *et al.*, 1981).

In the Kainji lake basin nomadic livestock production is presently facing a crisis because of land use pressures exerted by physical land development (see Ayeni *et al.*, 1982). The emphasis now should be on the settlement and integration of the nomadic livestock farmers into utilizing residues from large scale farms such as one being developed by the Niger River Basin Development Authority. The progress of settlement and integration has been slow so far, but a few nomadic livestock farmers can be described as settled.

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* Plant nomenclature according to Flora of West Tropical Africa. Huchinson, J. and Dalziel, J.M. (1952 - 1972).

These farmers have already recognised the dry season fodder potential of Echinochloa stagnina and thus harvest large quantities of the grass to feed their stock during the dry season. It is expected that human activities on the Echinochloa - lake ecosystem will increase as more pastoralistis settle. The pattern of utilization of the Echinochloa - lake system is then likely to udergo a rapid transition from the present subsistence use by a small population, to a sophisticated manipulation of the ecosystem for the benefit of large resident groups.

The grass has, however, been viewed as a problem to the lake hydrology and also to navigation with small crafts. N.E.P.A. hydrologists at Kainji, believe that the grass which covered a total of 92.4km^2 in 1979 - 1980 (Fregene pers. comm.) has blocked one of the major inflow channels of the reservoir. They contend that this blockage coupled with evapotranspiration from the grass (unestimated) is responsible for the reduction of the effective lake volume by 15.1%. The hydrologists advocate the extermination of the grass with herbicides, but the grass stand is a spawning and feeding ground for a variety of economically important fish species (Imevbore and Bakare, 1974).

It may not be desirable, therefore, to exterminate the grass; rather it might be exploited as a renewable resource and kept within "safe" limits such that, it does not affect power generation significantly and is available to the livestock industry. Such exploitation can only be based on sound biological knowledge of the plant. This report gives a summary of results of studies on the possible management of the grass for dry season livestock fodder.

MATERIALS AND METHOD

STUDY AREA

The Kainji lake reservoir is located 9°50' - 10°55'N; 4°25' - 4°45'E (Fig. 1). It is 136.9km maximum length and 24.1km maximum width, with a surface area of approximately 1300km^2. At full volume, the water level is at latitude 142m; maximum depth 60m, mean depth 11m.

The climate of the location of the lake, the hydrology, physical and chemical characteristics of the lake and the geology of the lake site have been reported elsewhere (see Morton and Obot, 1984; Henderson, 1973; El-Zarka, 1973 and Imevbore, 1975).

DESCRIPTION AND IDENTIFICATION

Echinochloa stagnina is a large perennial grass occasionally behaving as an annual with straggling or precumbent stems up to about 1m long under non-flooded conditions and elongating up to 7 - 9m (very rarely up to 11m) in flooded areas. The spongy stem, 3 - 5cm in diameter, roots sparsely at the nodes. Under flooded conditions the stem trails on the surface of the water, but the leaves and inflorescence are held in an upright position above the water. The length of the internodes is variable; up to 18cm.

Leaves are ligulate. The leaf ligule is represented by a fringe of pale coloured bristles about 5mm long at the base of the leaf blade. The blade is up to 60cm in length and 2cm broad at the widest point and hairless although roughly silicaceous to the touch and with tiny prickles along the margins. The leaf blade is dark green with a whitish mid-rib. The leaf sheaths, as long as the internodes, may be brown or green in colour.

Plants flower whenever the root zone is flooded. The inflorescence is paniculate, the peduncle being up to 25cm in length. Panicle branches are crowded, alternate, the basal ones being up to about 6cm long. The sessile spikelets are acute-accuminate up to 5cm in length, the upper lemma ending in a stiff bristle 5 - 20mm long. Spikelets are secund to the branches of the panicle and are not persistent but fall off when mature to leave a bare panicle with fractiflex branches.

E. stagnina is usually found in swampy areas and along the margins of streams and lakes. Sometimes it forms floating mats on water surfaces.

A voucher specimen (Obot/Echi 01) is preserved in the University of Ife herbarium (IFE).

This grass is often confused with E. colona and E. pyramidalis.

E. colona is erect annual up to 60cm high rooting at the lower nodes. The leaf blade is up to 13cm in length and 5mm broad at the widest point, hairless and smooth on the margins, without ligules. The sheaths covering the internodes are up to 15cm long.

The inflorescence is paniculate, the peduncle is up to 23cm long. The branches of the panicle, usually under 3cm long, are spaced about half their length apart and alternate.

The secund spikelets are sessile, 1mm long and lack bristles.

E. colona occupies similar habitats to those of E. stagnina but is usually restricted to shallow water areas not more than 30cm deep.

A voucher specimen (Obot/Echi 03) is preserved in the University of Ife herbarium (IFE).

E. pyramidalis is a rhizomatous perennial up to 2m high. The leaf blade is up to 6cm long and 2cm broad at the widest point. The leaves have a ligule represented as a fringe of pale hairs 2mm long at the base of the leaf blade. The sheaths are up to 11cm long extending to just over half the length of the internodes.

The inflorescence is paniculate, the peduncle being up to 25cm long; the alternate branches, up to 6cm long, are crowded as in E. stagnina. The sessile secund spikelets are up to 4mm long and lack bristles. A dense stand of E. pyramidalis appears bluish-green from a distance. The plant is restricted to wet (not flooded) areas.

A voucher specimen (Obot/Echi 02) is preserved in the University of Ife herbarium (IFE).

COLONIZATION CHARACTERISTICS OF Echinochloa stagnina

Definitions Required to Explain Colonization Characteristics

Draw-down period: A draw-down period in lake Kainji refers to the period between the highest water elevation and the lowest water elevation in a given year (between February and August).

Flood period: A flood period refers the the period between the lowest water elevation of a given year and the highest water elevation of the next year (effectively; August - January).

New area: A new area is exposed mud which had remained inundated during the previous draw-down period.

Acquired area: An acquired area is an area of draw-down which maintains a stand of E. stagnina in at least two consecutive draw-down periods.

General Observation of Colonization

For each 1m drop in water elevation, up to $80km^2$ of mud are exposed (Table 1). This exposed mud can be colonized by E. stagnina both by seeds and by tillers from the nodes of old stems, provided the mud is wet enough for germination of the seed and establishment of tillers. The mud is exposed during the rainy season so conditions are usually suitable. The internodes of the stem die after the new tillers are established.

If the exposed area is 'new', it is colonized mainly by seedlings of E. stagnina. A new area may become 'acquired' if it is exposed in the next draw-down period when it is colonized mainly by the production of tillers from nodes of the previous season's plants. If the area is not exposed, the colonizing plants of the previous season usually die. An acquired area may also remain inundated during the next draw-down period. Plants in such areas are also killed.

An acquired area may stay exposed for more than two flood cycles. In this situation, the mud may become dry enough for other terrestrial plants to establish, and the area will be lost to E. stagnina through competition. Thus the area of draw-down colonized and acquired by E. stagnina for a given year is largely determined by the highest water elevation (January) and the lowest water elevation (August) of the previous year. (See also Obot and Morton, 1984).

Estimation of the Colonization Factor (R)

As stated above, the expansion of E. stagnina into new areas is mainly by seedlings while retention of previously colonized area is achieved largely through tillering from the nodes of previous seasons plants. An estimation was made of such colonizing ability on an area basis and termed the 'colonization factor, R'. This factor was estimated from tiller density and seed production per m^2 of E. stagnina stand.

Eight $1m^2$ seed collectors (seed collectors were $1m^2$ trough hollowed out of polyurethane packing materials; this material floats easily) were randomly placed in the grass stand at Monai (Site 2, see figure 1), and seeds trapped in the collectors were counted daily throughout the fruiting season (November - February). The mean number of seeds collected for the total period was 1009 seeds m^{-2}. Mean tiller density was 197 tillers m^{-2} in January, 1982. Thus, each tiller has effectively produced 5.1 seeds (1009/197), R.

If the recorded tiller density and seed production data are representative of the entire *E. stagnina* stand, then seed production from each tiller is enough to produce 5.1 tillers and therefore, each $1m^{-2}$ of *E. stagnina* stand can expand to $5.1m^{-2}$ of *E. stagnina* stand, provided that the seed is dispersed evenly.

The Effect of Flooding on the Establishment of Echinochloa stagnina

E. stagnina has been observed growing in the lake rooted in areas of 9.5m depth. Also, stems of the grasss have been observed floating. Such stems may not come in contact with the wet mud during the draw-down. New tillers produced by these stems are less vigorous at the outset and eventually die. The draw-down is thus seen to be a condition for the survival of *Echinochloa stagnina* in the lake. This premise was investigated further as described below.

Laboratory Investigation of Nodal Tillering

Three pieces of mature stems of *E. stagnina* bearing three nodes each were placed in a planting pot filled with soil collected from the lake shore. The pots were wetted every day with tap water but not flooded. This was replicated three and marked treatment I. Treatment II was set up in a similar manner but the pots were flooded such that the stem cuttings remained floating and not in contact with the soil. After five days periodic observations were made, the number of open leaves per tiller and the mean tiller length per pot were observed as an index of plant performance under the two treatments.

Field Investigations of Nodal Tillering

Two treatments similar to the laboratory investigations were set up in the lake. Twenty stem cuttings carrying three nodes each were used in each of 10 replicates. The floating stems were kept in place by a floatable ring tied to a stake. For the sediment treatment, the stems were placed on the wet mud close to the water edge. Investigations were carried out from December to January.

The treatments were first observed after 12 days at which time the number of stems producing actively growing tillers were counted. Observations on the performance (mean tiller length of selected and labelled tillers - the largest as of the 12th day) commenced 33 days after the experiment began.

SEED GERMINATION

Laboratory Tests of Germination

The seeds of Echinochloa stagnina when mature usually fall directly into water. It has been suggested (Muenscher, 1936) that for proper storage, seeds of aquatic plants, should be kept in water.

E. stagnina collected for this investigation were, however, stored dry because of difficulties posed by bacterial and fungal infection when the seeds were stored in water.

Seeds were collected in January, 1982. Part of this seed lot was at once tested for germination: 10 seeds in three replicates were placed on filter paper in petri-dishes. The filter paper wetted every day. After 14 days, of observation, no seed germinated.

Part of the same seed lot was stored dry until May, 1983 when the experiment was repeated. This time, there were two treatments. In Treatment I, 66 seeds were planted in three replicated directly from the storage flask. In Treatment II the seeds were soaked in water for 5 days, sun-dried for three days and then planted. Sixty-six seeds were planted in three replicates. All the replicates of both treatments were wetted every day and observed for 14 days. Rates of germination is presented under results.

Distribution and Zonation of E. stagnina in Lake Kainji

Stand and species data collected on the distribution of macrophytes in lake Kainji was analysed by reciprocal averaging ordination (Hill, 1973) and association analysis (William and Lambert, 1959). Details of methodology has been described elsewhere (see Obot, 1984).

STANDING CROP, GROWTH RATE, PHOSPHORUS AND NITROGEN CONCENTRATION

Site of Data Collection

Data for standing crop and nutrient levels were collected in site 2 (Monai, see Fig. 1) where grazing and harvesting could be effectively controlled. This site was also easily accessible at all seasons.

Data Collection and Analysis

For determination of standing crop above sediment, the density of plants was first determined at nine random points using a 1m² floatable quadrat. At each point an individual plant was recovered by a diver. The deepest dive was 9m. Sampling was carried out at monthly intervals. Dry weight of the individual plants were combined with density data for conversion to standing crop on an area basis. Thus dry weight of an individual plant, W, multiplied by the density, D, of plants at the point it was collected was regarded as the standing crop at that point.

Mean monthly standing crop is thus given by:

$$\frac{\sum_{i=1}^{9} W_i \times D_i}{9}$$

Growth rate was calculated using the reltaionship:

$$r_t = \frac{\log_e N_t - \log_e N_o}{T}$$

where r_t is the growth rate, N_t is the monthly standing crop and N_o is the standing crop at the beginning of the study. T is time in months.

Utilizable standing crop (the portion of standing crop usually harvested for livestock) was estimated by clipping plants shoots extending above water within a 0.25m² floatable quadrat. Sampling was carried out from a boat. The boat was rowed a random number of Oar strokes (number drawn from a bag of random numbers) in a randomly chosen direction (chosen by tossing a 10k coin, using the base of the palm tree as pointer). Plants were oven dried at 65°C (as recommended by The International Institute for Tropical Agriculture, Ibadan (I.I.T.A.) for chemical analysis) to constant weight. Data on water elevation were obtained from National Electric Power Authority (N.E.P.A.).

Nitrogen and Phosphorus Concentration

Plant materials collected and treated as described above were separated into stem, leaf (including leaf-sheath) and inflorescence. Chemical analysis was carried out at the Laboratories of the International Institute for Tropical Agriculture (I.I.T.A.) Ibadan. Replicate samples were analysed in the Kainji Lake Research Insitute Laboratories.

EFFECT OF CONTINUOUS HARVESTING ON E. stagnina

Ten 1m² plots were randomly located in the E. stagnina stand at Monai (site 2 see Fig. 1). This plot size was chosen for ease in sampling from a boat. The plots were visited at intervals from 35 - 45 days. Thirty days was chosen as a minimum because, from a preliminary study, the plant was found to grow to a reharvestable height within this time. During each visit, the tiller density in each plot was recorded and the above water biomasss of the grass was determined. To determine biomass, the above water part of the grass was clipped. During a preliminary study, it was observed that plants cut below the water level usually die, so harvesting in this study was done above water. Plant material was oven dried at 80°C to constant weight.

CONTRIBUTIONS OF MACROPHYTES TO THE EVAPOTRANSPIRATIONAL LOSSES FROM LAKE KAINJI

The role of the emergent vegetation in the evapotranspirational losses from Lake Kainji was investigated using the water balance method. (see also Sokolov and Chapman, 1974). The study of water balance is the hydrological application of the principle of conservation of mass. This states that, for any arbitrary volume and during any period of time, the difference between input and output will be balanced by the change in water storage within the volume.

For Lake Kainji, the major inputs are: surface inflow, F_i; and precipitation in the form of rainfall R. The major outputs are: turbine and spill-way flow F_o; evapotranspiration, E_R; and losses due to seepage, I.

A simple water balance equation for Lake Kainji will thus be:

$$\Delta s = F_i + R - F_o - E_R - I$$

where Δs is the change in storage in a given time interval.

The floor of Lake Kainji is silty alluvium, and it is commonly held that losses due to infiltration and seepage are negligible in reservoirs over fine textured soils (Talsma and Leliji, 1976). Moreover, if water balance in Lake Kainji is considered on an annual basis, errors due to infiltration will be negligible because the lake returns to almost the same volume each year (see also Sokolov and Chapman, 1974). Thus the water balance equation for the lake reduces to the form:

$$\Delta s = F_i + R - F_o - E_R$$

To estimate total evapotranspiration, the equation can be written as:

$$E_R = F_i + R - F_o - \Delta s$$

This equation was used to estimate total evapotranspiration from Lake Kainji. For this estimation, all parameters in the equation were treated as flow rates per year in $m^3 \times 10^9$. Data on inflow, outflow, precipitation and storage were obtained from the hydrology division of the National Electric Power Authority (NEPA) at the Kainji Dam. Estimates of open water (pan) evaporation were also obtained from NEPA.

RESULTS AND DISCUSSION

Laboratory Investigation of nodal Tillering

The results are shown in Table 2. All stems in treatment II died while stems in treatment I showed a steady growth throughout the seventeen days of observation.

Field Investigation of nodal Tillering

After 12 days the percentage of surviving stems in Treatment II (floating) was 20.3 ± 6.2* and the percentage of surviving stems in Treatment I (sediment) was 78.60 ± 10.4.

Results of the performance of labelled tillers are shown in Figure 2. Analysis of variance (Table 3) shows that there is a significant effect of the treatment on the performance of the grass. The shape of the curve of the

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* All confidence intervals at P = 95% unless otherwise noted

sediment treatment (Figure , 2) indicates a long lag phase in the growth of the grass. At the start of the experiment, the stems were placed on wet mud but by the 47th day the water level had risen such that the root zone of the new tillers was flooded. This might explain the sudden fast growth.

From the two investigations, it is clear that stems that are in contact with wet mud have a higher chance of survival than those remaining floating.

Bidwell (1976) observed that during the draw-down in Lake Kainji, the emergent flora, mainly Echinochloa sp. does not die by being stranded but refloats when the lake rises. Van der Valk and Davis (1980), working in a prairie glacial marsh, reported that periodic draw-downs enable several emergent species to co-exist in a community because of their diverse response to disturbance. Cook (1980) reviewed the use of lake level draw-down as a macrophyte control technique and concluded that the technique can be effective but is species specific, some species being stimulated.

The low percentage of stems that survive the floating conditions and the highly significant effect of the treatment on the performance of the grass indicates that the draw-down is necessary for successful establishment and growth of Echinochloa stagnina.

Seed Germination

The result of seed germination tests is tabulated in table 4. The wetted, dried and re-wetted seeds show a much higher percentage germination.

Field Observation

The seedlings of E. stagnina are usually found on the draw-down area during the low-water season. Since the seeds are mature from January to February, when the water level is at its maximum, seeds, therefore, must have stayed in water for up to seven months before the mud is exposed in August. Once exposed, the seeds may likely become somewhat descicated and re-wetted before germinating. The failure of the laboratory test of seed to germinate in January 1982 immediately after collection suggests that seed germination may also be age dependent, although failure to treat these seeds by wetting, drying and re-wetting may have led to germination failure.

Distribution and zonation of E. stagnina in Lake Kainji

Macrophyte zonation in Lake Kainji is shown in Figure 3. The zones are determined largely by the frequency and duration of inundation. There are four major plants association in the draw-down area of the Kainji Lake. These associations may better be described as:

Savanna zone

Mimosa pigra zone

Echinochloa/grass zone

Mud communities

Figure 4. is a schematic representation of these vegetation zones at Wara (Figure 1).

The savanna zone is, strictly, not in the draw-down area. This zone lies above usual high water mark and carries a herbaceous flora typical of the Northern Guinea Savanna, for example, *Indigofera bractiolata*, *Tephrosia platycarpa*, *T. elegans* and *Cassia mimosoides*. The most frequent grass is *Vetivera nigritana*.

The *Mimosa pigra* zone is readily recognized by the tangle of *Mimosa pigra* with an undergrowth flora made up of *Ipomoea aquatica*, *Digitaria horizontalis*, *Vetivera nigritana* *Echinochloa pyramidalis*, *Leptochloa caerulescens*, *Ludwigia leptocarpa* and *Sorghum arundinaceum* which frequently forms dense almost pure stands. These are killed when the area is flooded. *Echinochloa stagnina* is present in this zone but not frequent. Soil pH is between 5 and 6.

The *Echinochloa*/grass zone is characterized by a dense stand of *Echinochloa stagnina* on acid soil (pH < 5); other plants in this zone are *Polygonum senegalense* which forms sudds with the grass *Vossia cuspidata*, *Sacciolepis africana* and *Leptochloa caerulescens*. Broad leaved herbs in this zone include *Alternanthera sessilis* and *Ludwigia leptocarpa*.

The mud communities are characterised by the high frequency of plants of the family Cyperaceae, mainly *Cyperus dilatatus*, interspersed with seedlings of *E. stagnina* and *Polygonum senegalense*. Broad leaved herbs in this zone are the floating *Ludwigia stolonifera*, which may anchor *Pistia stratiotes* among its roots, *Sphenoclea zeylanica*, *Ludwigia leptocarpa* and *L. erecta*. This zone is only exposed when the water level fall below 132 AMSL. The soil pH is between pH 5 and 6.

Echinochloa stagnina forms dense stands only in the Echinochloa/grass zone, between elevation 132.6m AMSL and 137.5m AMSL. The grass, however, grows without forming dense stands in other areas of the draw-down, between elevation 141.7m AMSL and 131.0m AMSL (see also Chachu, 1977). E. stagnina therefore, seems to prefer shallow areas with water depths between 3m and 9m (see also Henderson, 1973), inundated for eight months and completely exposed for up to four months in any draw-down-flood cycle. The distribution of E. stagnina may thus be determined by seasonal inundation (water regime) and water depth. It is not clear whether the acid soil under the grass is a determining factor in its distribution or whether the presence of the grass has a modifying influence on the soil.

Standing Crop and Growth Rate Estimation

The monthly standing crop of Echinochloa stagnina, July 1981 to January 1983, is shown in Figure 5).. The super-imposition of the monthly water elevation in the lake on the standing crop curve suggests obvious relationship between the two. The regressive relationship is indicated in figure 6., The relationship is not linear but approaches the exponential: $Y = ae^{bx}$ or $\mathrm{Ln}\ Y = \ln a + bx$. The best fit regression is $\ln Y = -34.4 + 0.29x$ ($r^2 = 0.56$, $n = 17$), where Y is the standing crop and x is the monthly mean water elevation.

Figure 7 shows the relationship between growth rate of E. stagnina and the rate of change in water elevation. The growth rate seems to be related to the rate of change of water elevation but no statistically significant correlation was found between the two. Other factor may be equally important.

The relationship between standing crop and climatic variables was investigated. There is no significant correlation between standing crop and radiation balance, nor is there significant correlation between standing crop and minimum air temperature. There is, however a significant negative correlation ($r^* = -0.66$) between standing crop and mean lake temperature. A higher rate of respiration is expected at high water temperatures, (e.g. Abdulrahman and Williams, 1981). This may partly explain the lower net production (standing crop) at high lake temperatures.

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* Significant at $P < 0.05$

Nitrogen and Phosphorus Concentration

The trend in nitrogen concentration of the stem and leaves throughout the growing season is shown in Figure. 8. There is a decrease in the nitrogen concentration in the stem between July and October (the period when new growth begins; the nodes of old stems becoming active to produce new tillers), after which there is a steady accumulation of nitrogen in the stem. There is increase in nitrogen concentration of leaves during the active growing period (July to December) and a sharp decline after December. Isichei (1981), working in the derived and guinea savanna zones of Nigeria, showed that there is loss of nitrogen from the below-ground parts of grasses during the flush and mid-growth phases and an accumulation of nitrogen in the below-ground parts after peak biomass. Morton (1977), working in a Molinietum in Berkshire, U.K., reported that 75% of the nitrogen and phosphorus in Molinia leaves was withdrawn before abscission. In Echinochloa stagnina the nodes of the stem are the major organs of propagation. A nitrogen partitioning to the nodes during the growing season to be used in early regrowth during the next growing season is therefore hypothesized here.

No systematic trend in phosphorus concentration of the plant can be discernible from the present data although there is variation from one sampling period to another sampling period.

Effect of continuous harvesting on E. stagnina

The results are tabulated in Table 5. The change in tiller density at each visit is shown in Figure 9. There is a clear tendency for increase in tiller density after every harvest. This relationship might be linear if major environmental variable were kept constant. In this case, the level of the water changed continuously throughout the study period, first rising during 140m days, then falling throughout the rest of the observation period. A clear relationship however, in the exponential form $Y = ae^{bx}$ exists. $Y = 322.7\ e^{0.0041X}$ ($r^2 = 0.82$, $n = 6$), where Y is the tiller density and X is time in days. The change in standing crop with time during continuous harvesting is shown in Figure 10. There is decrease in standing crop after each harvest which fits the logarithmic relationship $Y = a + b\ln x$, ($Y = 3549.97 - 645.77\ln x$ ($r^2 = .95$, $n = 6$ where Y = standing crop and x time in days). That there is a decrease in standing crop with each harvest while there is an increase in tiller density indicates a decrease in mean tiller weight with harvest. Figure 11. shows that mean tiller weight does decrease after every harvest. Production of new tillers exerts a nutrient demand on the stump. With the continuous removal of the shoot, the nutrient store in the stump is slowly depleted. Thus as the number of tillers increases, one expects decreasing performance because less nutrients are available in the stump. Also, with increase in density of tillers, the tillers will have a shading effect on each other so that photosynthetic efficiency will decrease without a commensurate decrease in respiration. A lower performance is thus expected.

Figure 12. shows the relationship between the tiller density and the mean tiller weight. The relationship closely fits the logarithmic model $Y = a + b\ln x$, specifically $Y = 91.03 - 14.01\ln x$ ($r^2 = 0.84$, $n = 6$) where Y is the mean tiller weight and x is the tiller density.

One might expect a relationship between the standing crop at, the present harvest, Y and the tiller density x_2 at the previous harvest and time (days) x_1. This relatioship was investigated by fitting a polynomial equation to the data shown in Table 5. The best fit polynomial is $Y = 12.59.98 - 1.94x_1 - 1.14x_2$ (r^2 0.82). The signs associated with the parameters x_1 and x_2 indicate that any increase in the tiller density with harvest will exert a large negative effect on the total standing crop of subsequent harvests.

From a management stand-point, one needs to know the number of harvests that could be made on one plot during one growing season without lowering utilizable harvest to an uneconomic level. This was investigated by regression analysis. The regression $Y = 2629 - 444.32x$ ($r^2 = 0.65$, $n = 7$, Y = standing crop, x = number of harvests; 1st, 2nd etc) shows that up to five harvests could be made in one growing season with the standing crop reduced, however, after each harvest. For Lake Kainji, if the grass is harvested every thirty days, five harvests will span the dry period, January to April when cattle fodder is in short supply.

EFFECT OF PLANT REMOVAL ON THE NUTRIENT STATUS OF LAKE KAINJI

The effect of harvesting and removal of *Echinochloa stagnina* from the Kainji Lake ecosystem was investigated by a modelling approach. This model is an extension of the Kainji Lake Echinochloa Model (Morton and Obot, 1984).

The part of E. stagnina utilizable for livestock fodder is the part which extends above water bearing the few (usually five) leaves. It is known, from field observation, that the elongated stems are used for thatching and as fuel for fish smoking. This, however, is negligible compared to harvest for livestock fodder. The utilizable part is approximately 10% of the total plant and the utilizable standing crop (UT) is thus given by:

$$UT = 0.1 \times APROD$$

The nitrogen concentration of the utilizable part of the grass is approximately 2% while the phosphorus concentration is approximately 0.2% (see Table 3.1. of Obot, 1984).

The nitrogen removable (in tonnes) is given by:

$$NREM = 0.02 \times UT \; t$$

The phosphorus removable (in tonnes) is given by:

$$PREM = 0.002 \times UT \; t$$

Model Predictions Including Standing Crop, Nitrogen and Phosphorus Content

The result of applying the model to years 1972 to 1983 is shown in Table 6. With a cutting regime of 75%, up to 3200 tonnes of nitrogen may be removed per year while up to 320 tonnes of phosphorus may be removed. For a renewable resource management the nutrients removed must be made up by inputs to the system so that the system sustains itself.

At present, however, the nutrient budget of the Kainji Lake is not understood well enough to know whether particulate and soluble nutrient input into the lake is enough to offset the estimated removal.

Estimates of Evapotranspiration Losses

The result of applying the water balance equation to five year's data are shown in Table 7 also shown in Table 7 is the area of lake surface colonized by emergent vegetation in the years 1978 - 1982 as calculated using the Kainji Lake Echinochloa Model (Morton and Obot, 1984). One would expect there to be a correlation between E_R and area colonized by the vegetation A, assuming that leaf area increases with area colonized. In fact there is regressive relationship, the best fit being the exponential form:

$$E_R = 0.62e^{2.2 \times 10^{-3}A} \quad (r^2 = 0.56,\ n = 5).$$

Stern (1965) also found an exponential regressive relationship between evapotranspiration and leaf area index in safflower.

Based on the theoretical volume of the lake given as $13m^3 \times 10^9$, the percentage reduction in lake volume due to evapotranspiration varied from 12.6% (1980) to 17.7% (1978) with a mean of 14.5%. This agrees reasonably with estimate of 15.1% of the hydrology division of NEPA.

Also shown in Table 7 are estimates of evaporation based on pan evaporation (E_p) observations at the dam site. The actual open water evaporation from the lake is probably lower than these estimates due to the "blanket effect" (Ward, 1975), but these estimates might be reasonable estimates of the potential evaporation in the Kainji area. The relationship between E_p (the evaporation from a free water surface) and evaporation from a plant covered surface is $E_R = fE_p$ where E_R is the evaporation from a plant covered surface and f is a correction factor. These estimates of E_p were used to calculate a correction factor $f = E_R/E_p$ for the aquatic vegetation of Lake Kainji.

The calculated correction factor (Table 7) varies from 1.01 (1980) to 1.57 (1978) with a mean of 1.19. Correction factors reported for emergent plants in humid regions are always greater than one. (Sokolov and Chapman, 1974). Thus a quick estimate of evapotranspiration from Kainji given by:

$$E_R = 1.19E_p$$

Errors exist, however, in the estimation of E_R due to errors in the measurement of inflow in the lake. NEPA's hydrologist, Fregene (per. comm.) agrees that estimates of inflow into Kainji Lake is only approximate, because of water use for irrigation and domestic activities. Using the expression $E_R = 1.19Ep$, estimates of evapotranspiration were made for the years 1978 - 1982.

The result are shown in Table 8. The mean approximate evapotranspiration loss from the lake is $1.86m^3 \times 10^9$. The mean percentage reduction in effective lake volume is 14.30%. This is not very different from its estimates of 14.50% using the water balance equation above. The figure 15.1% for 1982 agrees with NEPA's estimate.

The overall trend in the present estimate indicates that the emergent vegetation contributes to the water losses of the lake, probably accounting for the reduction of the effective lake volume by up to 17%.

MANAGEMENT OPTIONS

THE RATIONALE FOR MANAGEMENT

The growth of Echinochloa stagnina in association with other emergent macrophytes in Lake Kainji has attracted widely varied interests. While the power generation authorities at the Kainji dam view it as a problem to the lake's hydrology and optimal power generation, the cattle farmers see it as an important source of dry season fodder for their stock, while fishery experts view the grass stand as a valuable spawning ground for a variety of economically important fish species. Wildlife experts and conservationists also see the grass as the only hope left for the return of the manatee, a herbivorous mammal that live in the River Niger before impoundment.

The grass, although a perennial, behaves as an annual in Lake Kainji (see also Yabuno, 1970a), growing and producing maximally during the drier months of the year when the lake is at full volume. Figure 13 shows the monthly standing crop of E. stagnina in Lake Kainji compared with the monthly standing crop of terrestrial herbacious materials in two major vegetation types in the Kainji Lake National Park for 1981 - 1982. Also shown in Figure 13 is the monthly precipitation to evaporation ratio (average of three years' observation) for the National Park as a measure of monthly moisture availability. Figure 13 shows that E. stagnina is superior, in productivity, to terrestrial herbs especially in the drier months of the year. Compared nutritionally with terrestrial grasses (Table 9), E. stagnina at peak biomass is nutritionally superior to most terrestrial grasses. Thus, ideally, the grass should be left to grow as a forage crop in the lake. However, the grass contributes to the evapotranspirational losses of the lake which lowers the effective volume of the lake perhaps up to 17%; furthermore, this effect will increase with increase in area covered by Echinochloa.

The contribution to evapotranspirational losses, however, calls for a control measure. Results obtained in this study indicate that the grass could be managed and maintained within such limits that while it is used as a renewable source of dry season fodder, it does not affect power generation significantly, and also, can satisfy the interest of the fishery and wildlife experts.

MANAGEMENT PLAN

Harvesting Below Water

It has been shown in this study that Echinochloa stagnina requires the 10m annual draw-down of the lake for successful establishment and survival and thus grow in such areas of the draw-down as are inundated for up to nine months in a year. Consequently, it shows a strongly zonal distribution. The area of lake surface covered by the grass in a given year has also been shown to depend on the minimum and maximum water levels of the previous year (Morton and Obot, 1984). The control measure (Morton and Obot, 1984) demanded by this colonization characteristics is the harvesting of 75% of the area covered per year for fodder. It is assumed, due to the relative ease of harvesting below water, that most of the cattle farmers will harvest by cutting the plant below the water surface. In this case, all harvested plants will be killed.

Harvesting Above Water

The grass can, however, be harvested above water. If this is done, the above water nodes, produce new tillers and tiller density increases with each harvest. The same area can thus, be harvested up to five times in one growth season before the harvestable biomass falls below an economic level. During such continuous harvesting, although there is an increase in the tiller density, there is a decrease in the mean weight of the tillers. This implies that the tillers lose vigour with each harvest. The best harvesting regime is a function of the local condition and this need careful study before harvesting is implemented.

NUTRIENT CYCLE

When plants are harvested below water, the harvested plants are usually killed. Plant materials killed decompose rapidly returning up to 2×10^6kg of nitrogen and 7×10^5kg of phosphorus to the lake. The harvesting and removal of plants from 75% of the lake area covered will cause the removal from the lake, of up to 3×10^6kg of nitrogen and 4×10^5kg phosphorus. Harvesting above water will cause the removal of much greater amounts.

At present, the nutrient budget of Lake Kainji is not well enough understood to know whether particulate and soluble nutrient input into the lake are enough to offset the estimated removal. This should be the subject of further investigations.

No estimates are available on nitrogen fixation by aquatic blue-green algae in the lake, although estimates from other lake systems (e.g. Horne and Viner, 1971) and from terrestrial crusts (e.g. Isichei, 1979) suggest that imputs from this source may be considerable. Nitrogen fixation by cyanobacteria crusts in the sediment during draw-down may also be considerable. Particulate nutrients in the dung of cattle and wild ungulates that graze the *Echinochloa* stand during the draw-down also need quantification.

Management of Echinochloa stagnina in other man-made lakes cattle, drinking ponds and fish ponds: a conjecture

Most man-made lakes and cattle drinking ponds in the north of Nigeria draw-down naturally in the dry season. In such ponds, *Echinochloa stagnina* tillers may not establish successfully under the harsh conditions of the dry season thus, dry-season growth as in Lake Kainji may not be obtained. In this situation, an intensive management is required. The grass could be established by tillers and/or seeds at the out of the rains, harvested at peak growth and stored as hay for the dry season. The effect of drying on the nutrient content of *E. stagnina* and loss of nutrient value with storage of dry *E. stagnina* are subjects of on-going study at Kainji Lake Research Institute. Preliminary results indicate that there is no significant loss in the nutrient value with quick drying in Solar Kilns. The effect of sun drying is not yet well established.

In fish ponds where artificial water level control is practicable, the pond could be drawn-down in the rainy season to allow *Echinochloa stagnina* to establish itself then the water level could be drawn-up for good dry season growth. Such management, would depend, however, on the area of fish pond that the pond manager can safely allow for grass development. A careful study of local conditions would always be necessary.

ACKNOWLEDGEMENTS

The materials presented in this report is part of a thesis presented in partial fulfilment of the requirements for the award of the degree of doctor of philosophy, University of Ife. The study was funded by Kainji Lake Research Institute. I wish to thank Dr. J.S.O. Ayeni for useful comments on the manuscript.

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Table 1 - Hypsographic chart for Kainji Lake (Modified from Table 2 of Henderson (1973))

Height of Upper surface (m above M.S.L)	Lake Volume (m^3 x 10^9)	Area of 1-m Stratum (m^2 x 10^9)	Incremental Area of Mud Exposed (km^2)
142	15.6	1.30	0
141	14.4	1.24	60
140	13.2	1.17	70
139	12.0	1.11	60
138	10.9	1.05	60
137	9.9	.99	60
136	8.85	.92	70
135	7.95	.86	60
134	7.10	.78	80
133	6.30	.73	50
132	5.60	.67	60
131	4.90	.63	
130	4.3	.58	
129	3.7	.53	
128	3.25	.48	
127	2.75	.43	
126	2.3	.39	
125	1.9	.35	
124	1.55	.31	
123	1.25	.26	not usually exposed
122	1.0	.22	
121	.85	.18	
120	.7	.14	
119	.6	.09	
118	.5	.07	
117	.4	.05	
116	.35	.04	
115	.30	.03	
114	.25	.02	
113	.2	.01	
112	.1	.005	
111	.05	-	
110	-	-	

Table 2 - Performance of E. stagnina growing on sediment and floating (Laboratory investigation)

Date	Days	Floating (Treatment II)		Sediment (Treatment I)	
		No. of Open Leaves Tiller^{-1}	Mean Tiller Length (cm)	No. of Leaves Tiller^{-1}	Mean Tiller Length (cm)
26/10/82	1	0.00	0.00	1.20 ± 0.48	2.10 ± 1.2
27/10/82	2	0.00	0.00	1.30 ± 0.76	2.90 ± 1.1
28/10/82	3	0.00	0.00	1.70 ± 0.74	3.32 ± 1.2
29/10/82	4	0.00	0.00	2.33 ± 0.66	3.90 ± 1.04
1/11/82	7	0.00	0.00	2.80 ± 0.25	4.23 ± 0.86
2/11/82	8	0.00	0.00	3.00 ± 0.00	4.88 ± 0.39
3/11/82	9	0.00	0.00	3.11 ± 0.25	5.80 ± 0.90
4/11/82	10	0.00	0.00	2.80 ± 2.50	6.73 ± 1.32
5/11/82	11	0.00	0.00	2.80 ± 0.25	6.73 ± 1.32
8/11/82	14	0.00	0.00	2.70 ± 1.50	7.27 ± 1.57
9/11/82	15	0.00	0.00	2.22 ± 0.51	7.27 ± 1.66
10/11/82	16	0.00	0.00	2.22 ± 0.51	7.27 ± 1.66
11/11/82	17	0.00	0.00	2.33 ± 0.66	7.30 ± 1.76

Table 3 - Two way ANOVA of the effect of treatment and time.

Sources of variance	df	SS	MS	FS
A (Treatment)	1	2,650.7532	2,650.7532	146.36 ***
B (Time)	3	3,097.8924	1,032.6308	57.02 ***
AB (Interaction)	3	1,781.0613	593.6871	32.78
Residual	72	1,303.9770	18.1708	

*** Significant at $P < .001$

Table 4 - Percentage Germination of *E. stagnina* Seeds under two treatments (see text for explanation of treatments)

	Replicate	No. of Seeds	No. of Seedlings after 14 days	Percentage Germination
TREATMENT I	1	66	10	15.1
	2	66	10	15.1
	3	66	0.00	0.00
TREATMENT II	4	66	24	36.3
	5	66	21	31.8
	6	66	20	30.9

Table 5 - Effect of Continuous Harvesting of *E. stagnina*

Date	Days	Number of Tillers m^{-2}	Dry weight gm^{-2}	Mean Tiller Weight (g)
20th October 1981	-	120 ± 36.2	3392 ± 128.8	28.2
3rd December 1981	43	408 ± 261.9	1214.3 ± 35.7	2.97
13th January 1982	85 (42)	436.6 ± 20.6	595.3 ± 39.5	1.36
25th February 1982	128 (43)	480.5 ± 17.2	347.4 ± 8.0	0.72
3rd April 1982	165 (37)	799.1 ± 102.9	208.0 ± 13.2	0.26
15th May 1982	207 (42)	639.8 ± 36.7	68.5 ± 3.6	0.10
24th June 1982	247 (40)	952.9 ± 25.2	138.3 ± 6.8	0.14

Table 6 - Kainji Lake Echinochloa Model

YEAR	AREA	PCT	PROD	ACT	APROD	UT(T)	NREM(T)	PREM(T)
1972	428.0	32.3	1194774.0	10.8	391930.5	39193.1	783.9	78.4
1973	593.0	45.6	1606374.0	13.8	484919.1	48491.9	969.8	97.0
1974	578.0	44.5	1606374.0	17.6	634316.9	63431.7	1268.9	126.9
1975	360.0	27.7	800488.0	22.4	647068.1	64706.8	1294.1	129.4
1976	492.0	37.8	1524066.0	28.5	1149334.7	114933.5	2293.7	229.9
1977	439.0	33.8	1382140.0	33.8	1382140.0	138214.0	2764.3	276.4
1978	558.0	42.9	1595544.0	42.9	1595544.0	159554.4	3191.1	319.1
1979	531.0	40.8	1531640.0	40.8	1534640.0	153164.0	3063.3	306.3
1980	470.0	36.2	1396248.0	36.2	1396248.0	139624.8	2792.5	279.2
1981	422.0	32.5	1136280.0	32.5	1136280.0	113628.0	2272.6	227.3
1982	544.0	41.8	1580382.0	41.4	1563096.6	156309.7	3126.2	312.6
1983	579.0	44.5	1612872.0	44.5	1612872.0	161287.2	3225.7	322.6

KEY

AREA = Potential area colonizable (km²)
PCT = Potential Percentage Area Covered (km)
ACT = Actual Percentage Area Covered
PROD = Total Standing Crop (tonnes)
UT = Utilizable Standing Crop (tonnes)
NREM = Nitrogen Removed (T)
PREM = Phosphorus Removed (T)

Table 7 - Result of Applying the Water Balance Equation to Flow Data 1978 - 1982

Year	Total Inflow Fi* m³ x 10^9	Total Precipitation R: m³ x 10^9	Total Outflow Fo* m³ x 10^9	Storage s* m³ x 10^9	Total Evapotranspiration E_R m³ x 10^9	Total Pan Evaporation E_P* m³ x 10^9	E_R/E_P	Area of Lake Surface Colonized by Vegetation km² **
1978	26.33	0.81	22.63	2.20	2.31	1.35	1.57	558
1979	35.61	0.31	33.63	0.62	1.67	1.62	1.03	532
1980	29.62	0.34	29.01	-0.69	1.64	1.61	1.01	470
1981	26.81	0.34	25.13	0.40	1.66	1.60	1.03	422
1982	26.02	0.21	24.39	-0.35	2.19	1.66	1.31	544

* Data of NEPA Kainji

** Morton and Obot (1984)

Table 8 - Result of applying the expression $E_R = 1.19 E_P$ to estimate Evapotranspiration from Lake Kainji

Year	$E_R = 1.19 E_P$ (m^3 x 10^9)	Percentage Reduction in Lake Volume
1978	1.60	12.30
1979	1.92	14.76
1980	1.91	14.69
1981	1.90	14.61
1982	1.97	15.15
Mean	1.86	14.30

Table 9 - Nitrogen percentage and Crude Protein content of *Echinochloa stagnina* and some terrestrial grasses at peak Standing crop

	Kjedahl Nitrogen	Crude Protein	% Ash
Echinochloa stagnina	1.41 ± 0.08	8.81	6.7
Pennisetum pedicullatum	0.41 ± 0.01*	2.66	-
Schizachyrium sanguinium	0.44 ± 0.002**	2.75	-
Pennisetum violaceum	0.37 ± 0.05*	2.31	-
P. americanum	-	13.52+	-
Hyparrhenia involucrata	0.41 ± 0.02*	2.66	-
H. cyanenscens	0.09 ± 0.01*	0.56	-
Andropogon tectorum	0.61 ± 0.01*	3.81	-
A. gayanus	0.38 ± 0.002**	2.38	-
A. africanus	0.66 ± 0.07*	4.12	-
Rottboellia exaltata	0.72 ± 0.04*	4.50	-
Loudatia flavida	0.50 ± 0.06*	3.12	-
Aristidia kerstingii	0.12 ± 0.4*	0.75	-
Andropogon pseudapricus	0.35 ± 0.003**	2.19	-
A. schirensis	0.44 ± 0.001**	2.75	-
Beckeropsis uniseta	0.51 ± 0.01**	3.19	-

Source: * Usman 1981: + Aken 'Ova 1976
** Isichei 1981

Crude protein = % N x 6.25 (see McGinty *et al.* 1982)

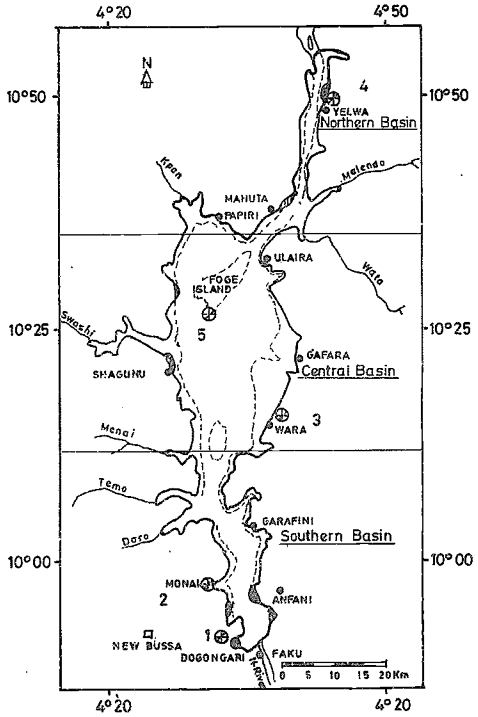

Fig. 1. Map of Lake Kainji Showing Study Sites
⊕ study sites

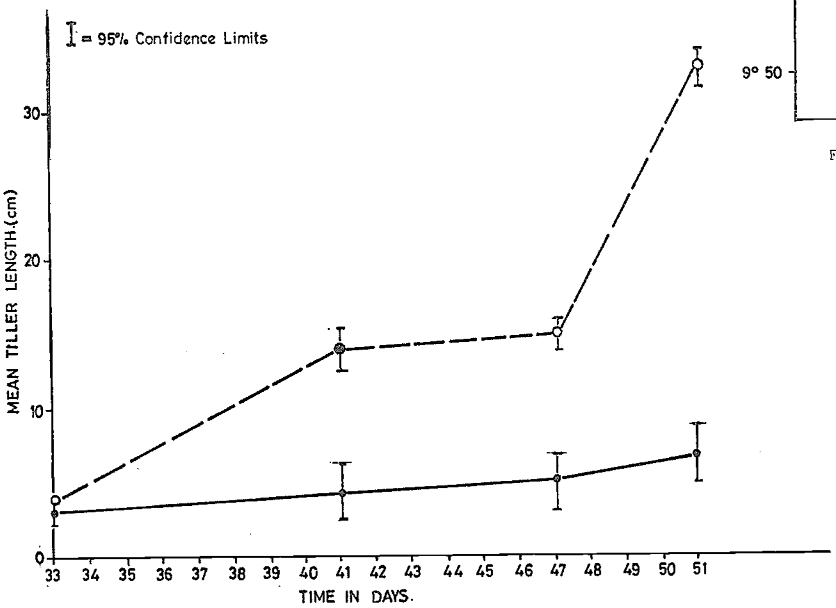

Fig. 2. Performance of E. Stagnina growing in Sediment o——o and Floating ●——● .

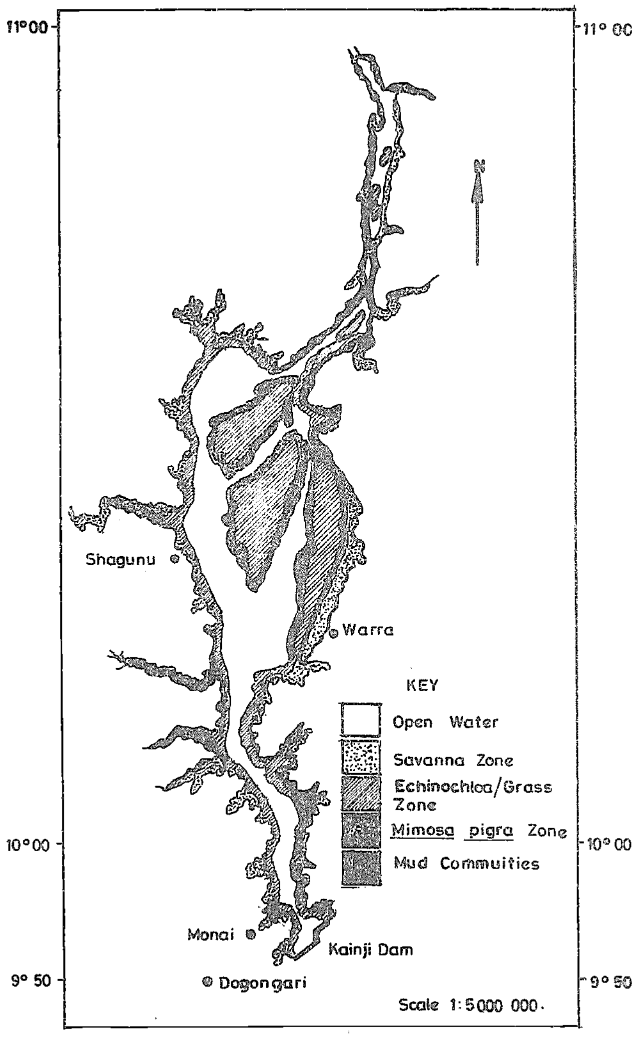

FIG. 3. VEGETATION MAP OF LAKE KAINJI 1983

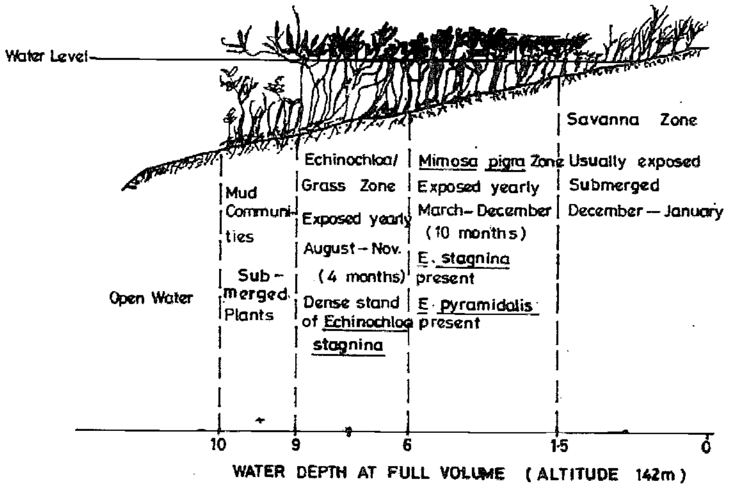

Fig. 4 A Schematic Representation of The Vegetation Zone at Wara (Site 3)

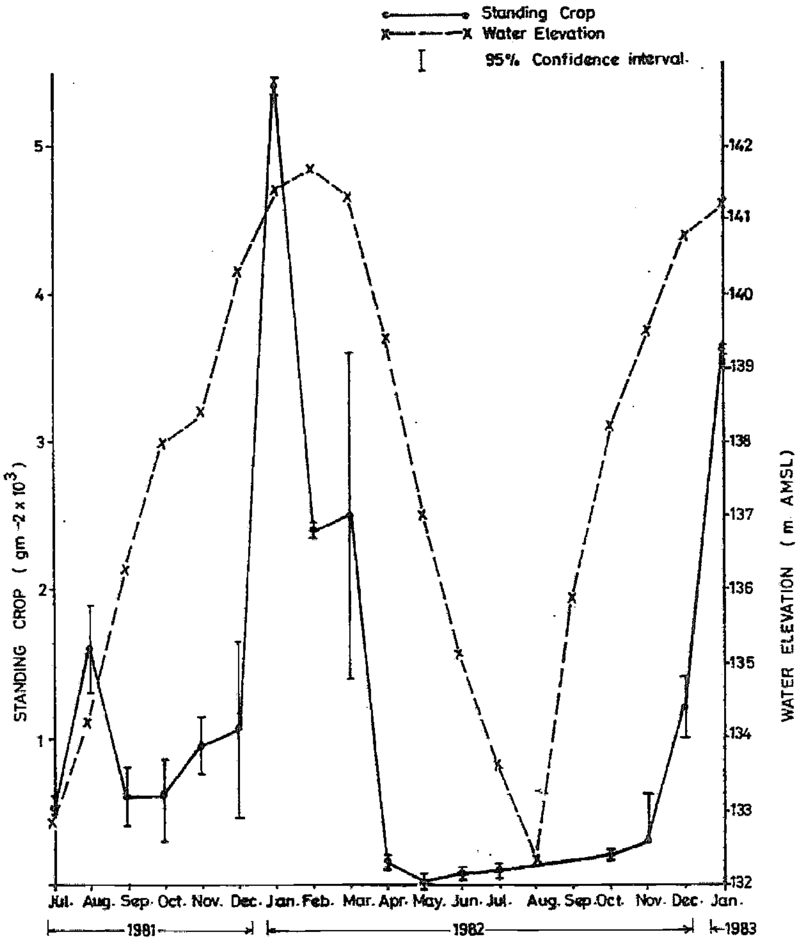

Fig. 5. Total Standing Crops of E. Stagnina for July 1981 — January 1983.

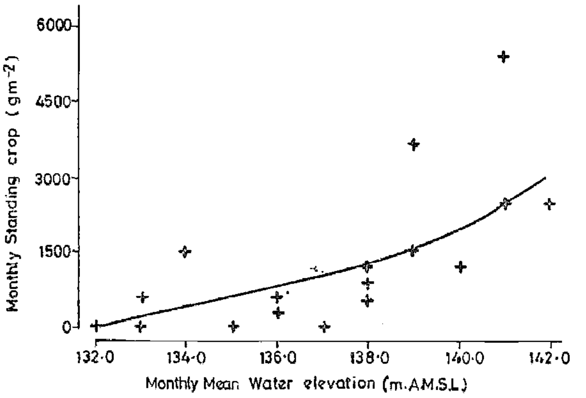

Fig. 6. Relationship between standing crop and mean monthly water elevation.

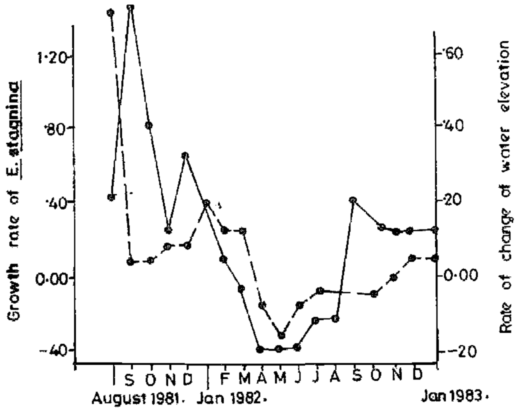

Fig. 7. Growth rate of E·stagnina ●—● compared with rate of change of water elevation ●——●

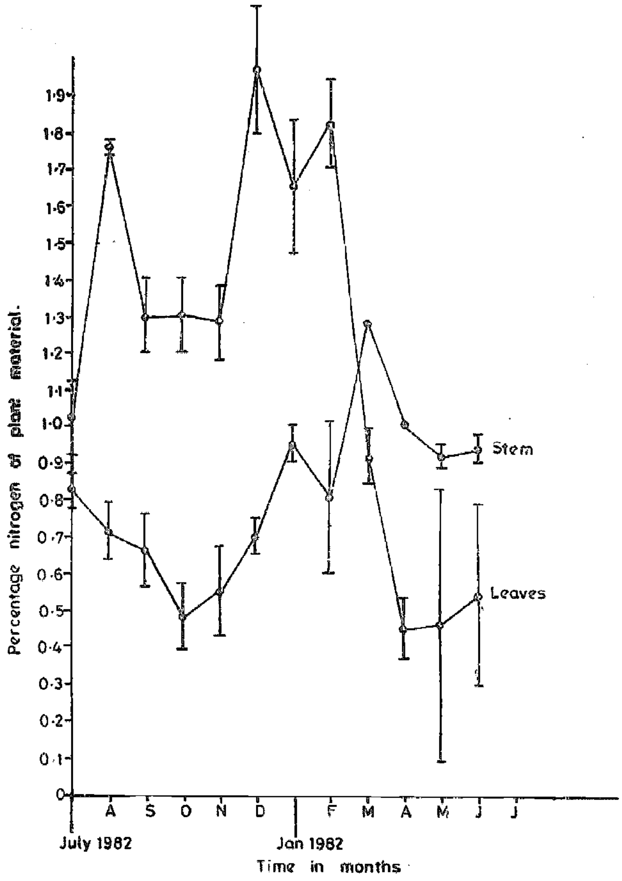

Fig. 8. Changes in the nitrogen content of stem and leaves of E·stagnina with time

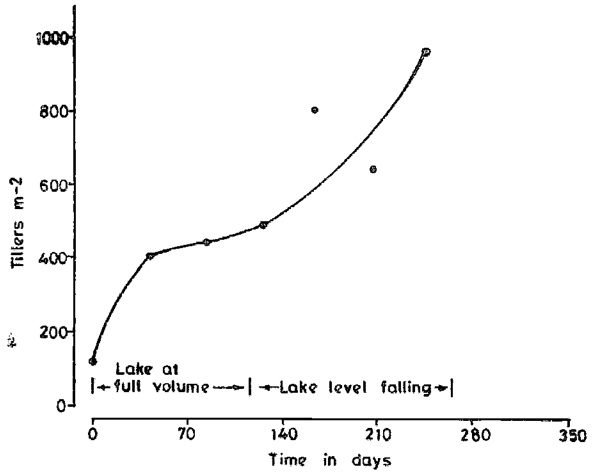

Fig. 9. Effect of continuous harvesting on tiller density

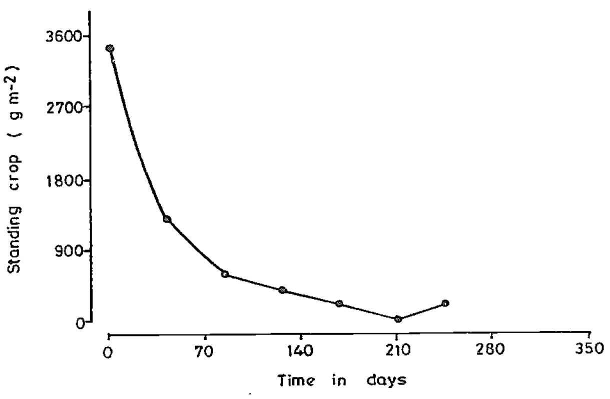

Fig. 10. Change in standing crop with time during continuous harvesting.

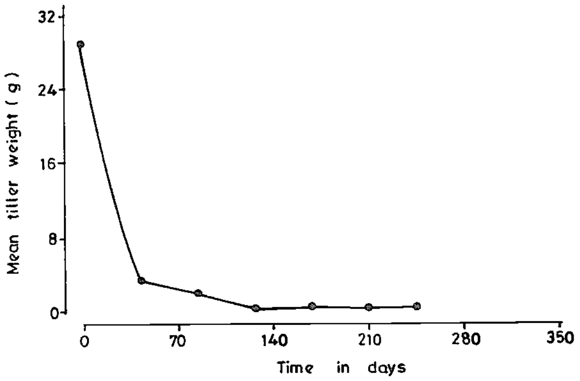

Fig. 11. Effect of continuous harvesting on mean tiller weight of *E. stagnina*.

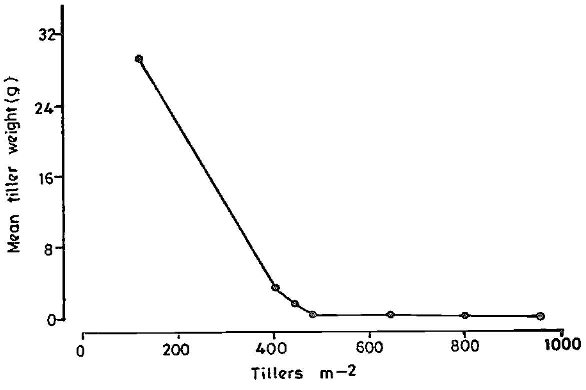

Fig. 12. Relationship between mean tiller weight and tiller density.

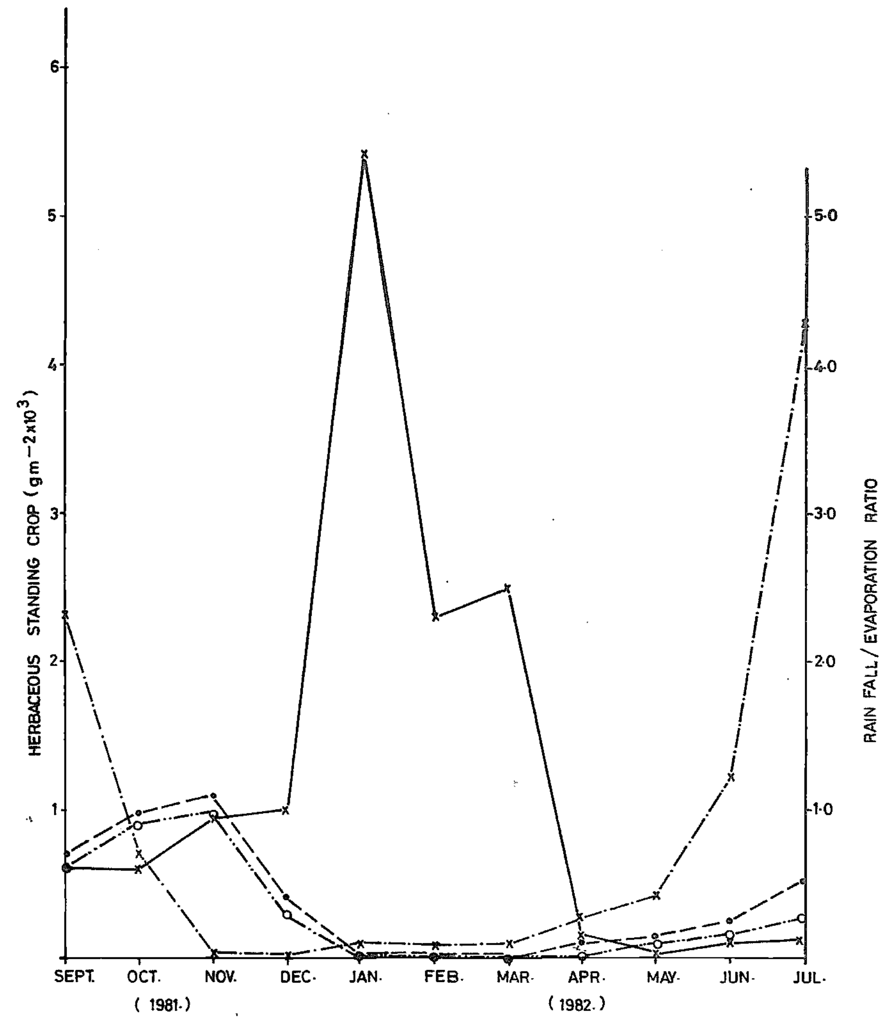

Fig. 13. Standing Crop of *Echinochloa stagnina* x———x, in Lake Kainji compared with the standing crop of herbaceous materials in the Isoberlinia wood land •— — —•, and *Terminalia macroptera* wood lando— ——o· x—·——·—x Rainfall/Evaporation ratio (mean of 3years observation at Kainji Lake Research Institute) Data •— ——•, o—·—o; Obot and Wari (unpublished).

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