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Ecophysiological Studies on Water Lettuce in a Polluted Lake

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ABSTRACT

Water lettuce is one of the dominant aquatic weeds in fresh waters, polluted lakes and streams of Nigeria, which has a tropical climate characterized by wet and dry seasons. The Oba lake, where this investigation was conducted, receives polluted water which has a BOD of 14.2 mg/l. The lake water has higher conductivities and pH during the dry season. The area where the lake receives the polluted influent has a high turbidity and water lettuce produces more vigorous growth with smaller root systems. Phenological observations indicate considerable flowering and yellowing of leaves during the dry season. Based on the Importance Value Index, the lake has a *Pistia-Salvinia* community. Water lettuce is capable of surviving saturated soil for a period of four months.

Key words: Population dynamics, biomass, evapotranspiration, water quality, Phenology.

INTRODUCTION

Conditions for an excessive development of aquatic weeds are usually favourable in the tropics as a result of which there is a perpetual problem of aquatic weed infestation throughout the year. The dense stands of these weeds obstruct navigation, impede drainage, destroy wildlife resources, constitute a hazard to life and cause enormous financial losses. One such weed in Nigeria is *Pistia stratiotes* L. which is commonly known as 'water lettuce' and is widespread in tropical and subtropical areas of the world (Holm *et al.*, 1969; Pieterse, 1977; Sculthorpe, 1967). Holm *et al.* (1977) described the plant as one of the world's worst weeds and pointed out that it is probably most troublesome in African waters. In Nigeria, Cook (1966) recorded the plant at Kainji Lake, while its explosive growth in the Oba Lake, Agodi Lake and IITA Lake and other channels at Ibadan were reported by Sridhar and Sharma (1980). It is these features of the plant that prompted the author to undertake the ecological studies which are likely to provide a greater insight towards its biology and ecological behavior, particularly in a waterbody affected by organic pollution.

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METHODS AND MATERIALS

The study was conducted at Ibadan (7°22′N latitude, 3°58′E longitude) in Oba Lake, 700m long, 135m wide and with a maximum depth of 5.5m (Figure 1). The lake is situated in the South-West of the University of Ibadan campus and receives water from two inflowing streams. Shango stream has comparatively clear water, while Oba stream has contamination from halls of residence, staff quarters, zoological gardens and adjoining farms. The

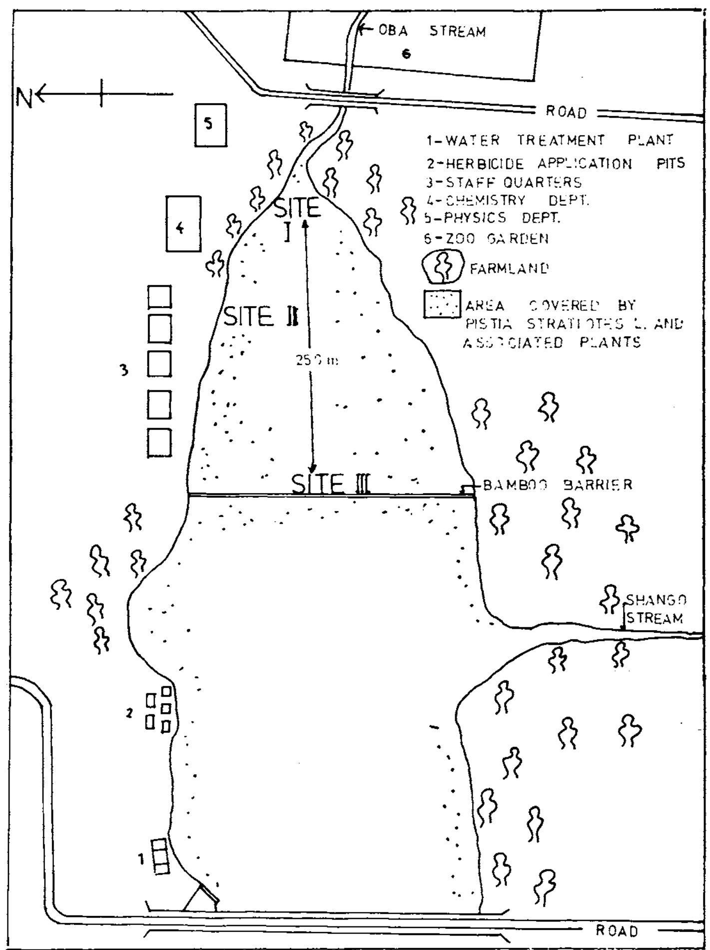

Figure 1. Map of study Sites on Oba Lake, University of Ibadan, Ibadan, Nigeria.

bamboo barrier in the lake was constructed to prevent the spread of water lettuce and other plants towards the west end of the lake. The herbicide pits were prepared almost a a meter away from the water margin for experimental control of water lettuce. Most of the area around the lake is used as farm land.

Sharma and Sridhar (1981) have analysed the waters entering the lake and have established that the wastes from student hostels supplied considerable amounts of ammonia nitrogen (2.4 mg/l), permanganate value (7.5 mg/l), water soluble phosphorus (0.16 mg/l), biological oxygen demand (14.2 mg/l), and other minerals (Ca 25.6, Mg 15.5, SO_4 19.2, Cl 41 mg/l) via the Oba stream.

The choice of the sampling sites in the lake was made on the basis of plant size and distance from the point of entry of polluted water through the Oba stream. Site I was near the entry of polluted water where the plants are luxuriant with vigorous growth. Site II was about 75 m from I and contained plants that were intermediate in size, and site III was about 300 m from I and contained plants that were small and exhibited poor growth.

The climatic data were obtained from the Geography Department of the University of Ibadan which maintains a weather station where the various meteorological instruments are located at ground level. The station is located approximately 200 m from the lake. However, the temperature and relative humidity around water lettuce plants were determined with a sling hygrometer. The conductivity, pH, and turbidity measurements were done with a Philip-Harris Conductivity Meter, Philip-Harris pH meter and Secchi disc, respectively. Organisms at the three sites, including those in the roots of water lettuce were carefully identified. Morphological study was based on a number of plants, while phenological observations were noted through regular visits.

Phyto-sociological studies were carried out by using a 1 m^2 wooden quadrat placed randomly at the three sites. A total of twenty quadrats were established and all individual plants within the quadrat were counted and their diameters recorded. Frequency, density and cover were calculated and through their relative values, Importance Value Index (IVI) of each species was derived (Curtis & McIntosh, 1951). The Indexes of Species Association (AI), based on presence or absence of species with respect to water lettuce, was calculated to Jaccard's formula (Mueller-Dombois and Ellenberg, 1974):

$$AI = \frac{c}{a + b + c} \times 100$$

where, c = Number of quadrats in which water lettuce occurs with a named species

b = Number of quadrats in which water lettuce occurs alone

a = Number of quadrats in which a named species occurs alone other than water lettuce.

Biomass and leaf area ratio of plants were determined as suggested by Chapman (1976). Transpiration was determined by keeping the plant in a petridish and weighing at 2-hr. intervals from 0800 to 1600 hours and comparing to a control dish set up simultaneously. Buoyancy of the plant was determined by placing weights on it, and finding the maximum weight that it can support without sinking.

Determination of evapotranspiration and evaporation was made according to the method suggested by Ambasht (1970). Transplant experiments involving transfer of water lettuce plants to buckets with soil having water levels 5 cm, 2.5 cm, saturated soil and moist soil were carried out to determine the behavior of the plant as it grows towards a land habit.

RESULTS AND DISCUSSION

The variation of climatic data during the year 1980 are presented in Table 1. The climate is tropical and characterized by wet and dry seasons which extend from April to October and November to March, respectively. The microclimatic data actually recorded by the author from November, 1980 to April, 1981 indicate the lowest atmospheric temperature 30 cm above the water surface as 25 C in December and the highest as 37 C in January (Mean 30.3 $\pm$ 2.8). Similarly, the lowest temperature 5 cm below the water surface was 23 C, and highest 33 C (Mean 28.4 $\pm$ 1.8). The highest humidity was 96% in November and lowest was 35% in December (Mean 54.34 $\pm$ 13.5).

Quality of Water. The highest conductivity occurred in January, 1981, while the lowest occurred in April (Table 2). This is more likely the effect of an increased concentration during dry season and dilution during the wet season. Further, the conductivity decreased from Site I to Site III due to the highly polluted influent water at Site I. The pH

TABLE 1. VARIATION OF CLIMATIC DATA FOR THE UNIVERSITY OF IBADAN CAMPUS, NIGERIA FOR 1980.

Climatic Parameters	Variation	
	Minimum	Maximum
Mean daily minimum temp. (C)	20 (December)	23.4 (April)
Mean daily maximum temp. (C)	28.2 (July)	35.1 (February)
Average mean daily temp. (C)	25	29
Total sunshine hours	83.7 (July)	214.5 (January)
Total monthly precipitation (mm)	Nil (December)	529 (August)
Highest precipitation in a single day (mm)	—	214 (August)
Total annual precipitation (mm)	—	1939
Mean Relative Humidity (%) 0700 hours	86 (December)	96 (October, November)
1000 hours	66 (December)	87 (August)
1600 hours	43 (February)	80 (July, August)
1800 hours	50 (February)	84 (August)

ranged from 6.8 to 7.6, with the highest in the month of January (Table 2). However, the values increased from Site I to Site III indicating the existence of almost acidic waters at Site I. Chadwick and Obeid (1966) found that growth of water lettuce in the laboratory at pH 4.0 was optimal, but such low pH has never been recorded in Oba Lake.

It is evident that the highest turbidity occurs at Site I, it decreased at Site II while Site III has fairly clear water (Table 2). This is quite obvious because of the influent polluted water at Site I which gradually clears away at Site III. Further, the water is comparatively clearer in April. The highest turbidity at the three sites is in January and the dust of harmattan during this month of dry season, in addition to the decaying vegetation, are the likely causative factors for such a situation.

Associated Organisms. The various organisms associated with water lettuce plants are listed in Table 3. It is seen that some organisms like *Anopheles* sp. larvae and pupae, *Limnea* sp. and *Paramoecium* sp. are constantly associated with water lettuce, while some organisms are found only at certain sites, for example, *Hirudo* sp. at Site III and *Simulium* sp. at Site I.

Morphological Features and Phenology. The mature leaves have an area varying from 30 to 40 cm^2 at Site I, 21 to 25 cm^2 at Site II and 10 to 15 cm^2 at Site III. There is considerable variation in the length of roots at different sites and varies from 13 to 18 cm at Site I, 40 to 45 cm at Site II and up to 62 cm at Site III.

Phenology embraces relationships between climatic factors and periodic phenomena in organisms. The plants were healthy at all the three sites during November and December, however, leaves were larger at Site I and smaller at Site III. This is probably due to decreased nutrient levels at the latter site. Towards the end of the dry season, leaves have poor vigour and there is senescence and decay of most of the outer rosette, especially at Site III. Although abundant flowering was observed in the early dry season, mature fruits were rare. However, plants at Site III were abundantly flowering. My observation conforms with that of Hall and Okali (1974) that indicated the rarity of seedlings may be due to the non-availability of exposed mud where the dispersed seeds may fall, which is a prerequisite for seed germination according to Datta and Biswas (1970).

During the dry season, the lake water level was reduced by approximately 30 to 50 cm which affected Site I in particular, where part of the soil, previously covered by water, became dry, resulting in the death of plants. However, the plants became partly rooted where soil remained saturated. Another interesting observation was recorded at Site I where the plants were vigorously attacked by the variegated grasshopper, *Zonocerus variegatus* and their leaves were consumed.

Although there is a yellowing of leaves during the dry season, the annual die-back of water lettuce associated with an epidemic of an aphid transmitted virus infection, characterized by leaf yellowing and brittleness, reported for the Ibadan area of Nigeria by Pettet and Petter (1970), has not been observed in the Oba Lake of Ibadan. Okali and Hall (1974b) in their studies on Volta Lake, Ghana observed that aphids were rare in the water lettuce populations, and there was no evidence that virus disease was of primary importance in causing leaf yellowing or brittleness. The yellowing of leaves during the dry season may result from the low nutrient status. The same is further confirmed as water lettuce is known to respond sensitively to substrate nutrient level (Attionu, 1970). With the onset of rains, there is an enhanced mineralization in the inflow, restoring explosive growth and green leaves. However, it may be mentioned that a limited yellowing of leaves does occur throughout the wet season, but appears to be related to increasing leaf age.

Phyto-sociological Studies. Results of phyto-sociological studies are presented in Table 4. Based on the IVI, the existing community was a *Pistia-Salvinia* community. *Marsilea quadrifolia* and *Cyperus difformis* also had fairly high IVI. *P. stratiotes* had the highest frequency and density. Other most frequent plants were *Alternanthera sessilis, Polygonum salicifolium, C. difformis, Ludwigia leptocarpa* and *Floscopa africana.* Likewise, the plants having high density were *Salvinia nymphellula* and *M. quadrifolia.* Species having the least frequency and density were *Rhynchospora corymbosa* and *A. sessilis* respectively. Okali and Hall (1974a) have observed *R. corymbosa* to be a problem sedge in the Berikese Lake in Ghana, but fortunately, it is not so in the present lake. The same authors observed that *P. stratiotes* was being invaded by *Scirpus cubensis* tillers in the Volta Lake, but in our study it has been observed that so far water lettuce alone is the dominant plant with regard to frequency, density and cover.

TABLE 2. CONDUCTIVITY (SM^{-1} x 10^{-4}), pH AND TURBIDITY (SECHHI DEPTH CM) OF OBA LAKE WATER AT THE THREE STUDY SITES (N = 3).

Site	Parameter	Month					
		Nov. 80	Dec. 80	Jan. 81	Feb. 81	Mar. 81	Apr. 81
I	Conductivity	248.0	248.0	257.6	248.0	229.0	219.4
	pH	6.8	7.0	7.3	7.2	6.9	6.8
	Turbidity	32.0	27.5	26.5	31.0	32.0	33.5
II	Conductivity	190.8	209.9	219.4	219.4	190.8	183.3
	pH	7.0	7.1	7.4	7.1	7.0	6.9
	Turbidity	39.5	36.0	34.5	38.5	38.5	39.5
III	Conductivity	171.7	181.3	190.8	181.3	162.2	143.1
	pH	7.3	7.3	7.6	7.4	7.1	7.0
	Turbidity	63.0	60.0	60.0	64.5	67.0	67.5

TABLE 3. ORGANISMS ASSOCIATED WITH *Pistia stratiotes* L. IN OBA LAKE, NIGERIA (+ = ORGANISM PRESENT, — = ORGANISM ABSENT).

Organism	Site I	Site II	Site III
Millanoides tuberculata	+	+	—
Chobolus sp.	+	—	+
Anisopteran larva	+	—	+
Anopheles sp. (larva & pupae)	+	+	+
Simulium sp.	+	—	—
Limnea sp.	+	+	+
Hydrachna sp.	—	+	+
Hygrobates sp.	—	+	+
Hirudo sp.	—	—	+
Euglena sp.	+	+	+
Paramoecium sp.	+	+	+

TABLE 4. FREQUENCY, DENSITY, IMPORTANCE VALUE INDEX (IVI) AND ASSOCIATION INDEX (AI) OF ASSOCIATES OF *Pistia stratiotes* L. IN THE OBA LAKE.

Species	Frequency %	Density	IVI	AI %
Alternanthera sessilis (L.) R. br. ex Roth	90	0.35	8.98	90
Ageratum conyzoides L.	50	1.10	5.40	50
Cyperus difformis L.	75	22.10	16.88	75
C. tuberosus Rottb. Briton	55	2.00	6.19	55
Echinochloa pyramidalis (Lam.) Hitch & Chase	35	0.75	3.71	35
Fuirena umbellata Rottb.	50	2.40	6.84	50
Floscopa africana sub sp. *majuscola* (C.B.U.) Brenan	75	2.65	8.32	75
Ludwigia leptocarpa Vahl.	75	2.15	10.42	75
Marsilea quadrifolia L.	60	44.30	19.73	60
Mariscus alternifolius Vahl.	50	0.80	5.23	50
Nymphaea lotus L.	45	1.15	6.05	45
Pentodon pentandrus (Schum & Thonn.) Vatke	40	2.85	5.31	40
Pistia stratiotes L.	100	152.95	146.95	—
Polygonum salicifolium Brouss	85	2.20	9.14	85
Rynchospora corymbosa (L.) Britton	20	1.00	2.98	20
Salvinia nymphellula Desv.	60	85.85	32.61	60
Torulinium odoratum (L.) Hopper	50	1.05	5.27	50

The Association Index of each species associated with water lettuce was calculated to determine the sociological and ecological relationship. It was seen that *A. sessilis* had the highest AI (90%) followed by *P. salicifolium* (85%). Several associates had an index of 75% while only *Pentodon pentandrus, Echinochloa pyramidalis, Nymphaea lotus* and *R. corymbosa* had indices below 50%.

Physiological Studies. The biomass of root and shoot systems was highest at Site III and lowest at Site I (Table 5). The root system was poorly developed at Site I in comparison to Site III where the nutrients are considerably low and the root system is strongly developed. The average biomass (559.8 g/m^2) for the species compares well with that determined by Okali and Attionu (1974), 500 g/m^2 by Petr (1968), and 690 g/m^2 by Hall and Okali (1974), all at Volta Lake; and also the mean biomass of 463 g/m^2 by Odum (1957) at Silver Springs, Florida, U.S.A.

Leaf Area Ratio (LAR) is the ratio of leaf area to total dry weight (Chapman, 1976). In this investigation, LAR was the highest at Site I and lowest at Site III indicating that the leaves of water lettuce are more luxuriantly growing at the former site.

Results of studies on rate of transpiration of water lettuce carried out in the petri-dishes near Oba Lake indicate that the rate of transpiration was comparatively low during 0800 to 1200 hours (0.32 g/hr), increased during 1200 to 1600 hours (0.77 g/hr) and was at its peak during 1600 to 1900 hours (0.93 g/hr). However, the rate of evaporation was lesser during the peak transpiration and this might be the causal factor for the highest net transpiration. Otherwise the highest transpiration loss of 4.9 g/hr was during 1200 to 1600 hours. Computing the data in terms of g/cm^2, it is seen that the rate of transpiration was 0.0035 $g/cm^2/hr$; 0.0084 $g/cm^2/hr$, and 0.0075 $g/cm^2/hr$ during the three periods specified above.

TABLE 5. STANDING CROP BIOMASS AND LEAF AREA RATIO OF *Pistia stratiotes* L. IN THREE SITES OF OBA LAKE. (JANUARY, 1981; n=3)

Parameter	Sites I	II	III
Fresh weight (g/m^2)			
Shoot system	1304.9	1428.1	2560.0
Root system	258.2	788.5	3286.0
Dry weight (g/m^2)			
Shoot system	137.2	149.5	214.0
Root system	62.2	242.5	874.0
Total Biomass (g/m^2)	199.4	392.0	1088.0
Leaf Area Ratio	65.4 ± 7.6	59.2 ± 1.65	47.7 ± 10.0

Evapo-transpiration studies were carried out by placing two 250 ml glass cylinders of radius 1.8 cm in the lake close to the bank. One large sized water lettuce plant was placed in one cylinder. The rim of the cylinders were kept just above the water level so that no water could flow into the cylinders already filled with lake water to the 250 ml mark. Readings were taken at four hour intervals every week from November, 1980 to April, 1981. The data are presented in Table 6. More water was lost through evapo-transpiration than through evaporation alone. The highest evapo-transpiration and evaporation occurred between 1100-1500 hours followed by 1500-1900 hours. The least loss was in the morning hours. The maximum water loss through evapo-transpiration and evaporation was 18.5 ml and 3.2 ml on 20th January, 1981. Evapo-transpiration and evaporation values computed on monthly basis are the highest in January, which experiences the maximum temperature. However, there is an increasing trend from November to January followed by a decrease until April.

Buoyancy. The leaf of *Victoria amazonica* is capable of supporting the weight of a child or even an adult if weight is distributed evenly over the surface of the leaf (Cutter, 1971). This prompted us to determine, for academic interest, the buoyancy of water lettuce with respect to the maximum weight which a single plant could support without sinking. The weights were placed evenly on the plant and it was observed that the highest buoyancy occurred in plants from Site I (214 ± 14.4 g), followed by Site II (119 ± 9.7 g) and lastly Site III (44.5 ± 6.9 g). The buoyancy corresponds with the plant size and vigour.

Transplant Experiments. Some water lettuce plants rooted in the moist soil at Site I, as pointed out earlier. This observation prompted us to undertake experiments to determine whether water lettuce can survive the land habit. The duration of the experiment extended from 18th January to 18th April, 1981. All the plants transplanted to moist soil did well for a week by sending out stolons, however, yellowing of leaves soon started, resulting in poor vigour and eventual plant senescence. The plants transplanted to saturated soil evidenced vigorous growth and stolon development for up to two weeks, but then chlorosis, drying of leaf tips, and stunted growth followed. There was a marked phenomenon of guttation up to 1000 hours in this situation. The plants were rooted in the saturated soil, but the size of leaves was considerably reduced by the last day of the experiment. The plants transplanted to pots in which the water level was maintained 2.5 cm and 5 cm above the soil level, reproduced well and covered the whole surface

Table 6. Results of evapo-transpiration for 4 hour periods for *Pistia stratiotes* L. at Oba Lake, Ibadan, Nigeria (November, 1980 to April, 1981).

Date	0700-1100 hours		1100-1500 hours		1500-1900 hours		Mean Evapo-transpiration (S.D)	Mean Evaporation (S.D)	Mean Temperature (C)	Mean Humidity %
	A[1]	B[2]	A	B	A	B				
12.11.80	3.7	0	11.6	0.9	7.1	0.1				
19.11.80	3.9	0	10.0	1.1	6.2	0.1	6.9 ± 2.9	0.4 ± 0.5	29.3 ± 1.5	80.5 ± 11.7
26.11.80	4.0	0	9.8	1.2	6.3	0.1				
2.12.80	5.1	0.1	10.2	1.2	7.2	0.1				
9.12.80	7.1	0.9	13.1	1.3	9.4	0.2				
16.12.80	7.0	0.9	13.9	2.2	10.4	0.3	9.3 ± 3.0	0.9 ± 0.9	27.5 ± 1.9	66.5 ± 12.8
23.12.80	6.1	0.6	12.9	2.1	9.5	0.1				
30.12.80	5.9	0.5	14.0	3.0	7.9	0.2				
6. 1.81	6.0	0.8	18.4	3.0	10.3	0.9				
13. 1.81	7.0	0.5	16.0	2.0	8.0	0.2				
20. 1.81	3.3	0.9	18.5	3.2	9.5	0.5	10.8 ± 5.5	1.3 ± 1.0	32.9 ± 3.2	67.0 ± 19.2
26. 1.81	5.5	1.1	17.8	2.1	9.2	0.4				
6. 2.81	6.0	1.2	13.9	1.3	8.7	0.3				
13. 2.81	7.1	1.3	17.2	2.1	9.0	0.5				
20. 2.81	6.3	1.2	15.3	1.9	7.9	1.0	10.2 ± 4.3	1.2 ± 0.6	30.6 ± 1.4	62.0 ± 22.6
27. 2.81	5.4	0.9	16.7	1.8	9.2	0.7				
3. 3.81	6.1	0.9	16.3	1.9	8.7	0.6				
10. 3.81	5.3	0.8	17.4	2.0	9.1	0.9				
17. 3.81	7.0	1.3	12.5	1.3	9.3	0.7	10.0 ± 3.7	1.2 ± 0.5	30.9 ± 1.7	69.3 ± 17.3
24. 3.81	6.9	1.0	12.7	1.7	9.9	0.5				
31. 3.81	5.7	1.3	13.0	1.9	9.4	0.8				
7. 4.81	7.9	1.0	8.0	0.8	9.0	1.0	7.6 ± 0.8	0.8 ± 0.2	27.9 ± 0.7	78.0 ± 12.9
14. 4.81	7.0	0.8	7.2	0.6	6.7	0.4				

[1]Water loss (ml.) in cylinder containing plant.
[2]Water loss (ml.) in cylinder without plant.

of the buckets up to the 6th of March, when stunted growth and chlorosis of the leaves was noted. There was apparently more guttation in the plants contained in buckets with 2.5 cm level water. However, the plants were very much in living condition even on the last day of the experiment. Stunted growth of plants is probably due to the habitat depleted of nutrients, but otherwise the plants could likely continue for a longer time in saturated soil. However, these aspects of the ecology of water lettuce require further study.

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