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CARPET CHARACTERISTICS OF *Eichhornia crassipes* [MART.] SOLMS (Water hyacinth) IN THE WINAM GULF (LAKE VICTORIA, KENYA)

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ABSTRACT

The occurrence and spread of the water hyacinth (*Eichhornia crassipes* [Mart.] Solms), in the Winam gulf has created numerous attributes to the human population that live around the lake, thereby making its control a priority. Navigation within the lake is a major economic activity that has been greatly affected. Before this study, little was known about the characteristics of these weed carpets, and specifically the weight that a healthy inter-connected or entangled carpet can support before it was able to sink or even get submerged. Can a light herbivore or human stranded in the lake walk on a healthy carpet to safety?. In order to better understand these unknown, a study was initiated at five locations (i.e; Dunga beach, Kisumu pier, Kusa, Kobala and Kendu bay) within the lake that appeared to contain healthy dense carpets. Carpet connectivity, mat buoyancy, distribution of mass, biomass density, rhizome length and population density were calculated. Carpet connectivity was determined as the difference in pressure when weights were added on a mesh wire measuring 0.434m2 until the carpet submerged and the pressure on the same carpet that was required to submerge it after a complete disconnection. Standing population density was determined by counting the number of plants found within quadrants measuring 1 m2; while biomass density was determined when oven dried plant materials collected from quadrants measuring 1 m2 was weighed. Plant mass and rhizome length measurements were correlated, while population density was correlated to biomass density. These observations show that water hyacinth distribution in the Winam gulf is seasonal and adopts residence in secluded bays, carpets measuring 0,434m2 in size that have a connectivity of 288.4 Pa (pascals) are able to support a weight of only 12.6 kg, with any additional weight causing them to submerge. Distribution of mass was normal except in locations that are subjected to external factors.

1. INTRODUCTION

Eichhornia crassipes is an ornamental hydrophytic angiosperm plant, which belongs to the monocot family Pontederiaceae. Its culture in private ponds and dams has led to global spread and hence numerous negative attributes [1]. Massive colonies build-up when *E, crassipes* is introduced into new areas conducive for its proliferation [2]. Within a short time large biomass piles up in these new areas where the hydrobiological regime has been interfered with by the activities of man, and the level of nutrients in the water has been increased. Throughout all its introduced range, it has increased to become an extremely serious problem [3]. In all major

East African lakes like Kyoga, Naivasha and Victoria there is an urgent need to put in place long time self-sustaining control measures [1]; [4].

This ornamental plant with beautiful lilac flowers is known to reproduce mainly by a vegetative method known as clonal propagation; rarely does it reproduce by seed production. As the stolon grows, a new plant is formed at its tip such that in a matter of days the parent plant is surrounded by several offspring's. [3] when all the conditions suitable for growth were fulfilled, two single parents were surrounded by 300 offspring's in 23 days and by 1200 in 4 months [3]. Such a spontaneous spread results in the creation of free floating carpets that get translocated from place to place by the wind action [1]. The floating islands were reported to affect biodiversity, transport, fisheries, macrophyte recovery and water treatment plants in the Winam gulf [1] among other problems, and a resurgence reported after an initially successful biocontrol exercise in the Winam gulf . Recently incidence of boat traffic being stranded within these carpets were reported thereby leading to possible lose of life or property [4]; [5] leading to a study question (1) Can a human being or a small animal walk on these carpets to safety? and (2) what weight should a combine weed harvester deployed on the lake be able to withstand?

Before this study, knowledge pertaining to the mat characteristics of water hyacinth in the Winam gulf were unknown [6] thus making the selection and design good weed harvester machine for mechanical control exercise difficult. It was imperative therefore that any information on distribution and the carpet characters of the weed population [1]; [4]; [5] would go a long way to fill a big gap of the unknown.

2. MATERIALS AND METHODS

An accurate identification of the water hyacinth [6] ; [4] was required; otherwise incorrect results would have been obtained by the use of a different plant. In determining the carpet character, mats were sampled from six different parts of the gulf. The samples collected represented growth in different nutrient conditions and populations of young, dynamic and older, established plants. Before data was gathered, the physical characteristics of plants that might be useful in the prediction of population density, Rhizome length and mat buoyancy were not known. Therefore plant lengths, leaf length, plant mass, root length and leaf number were recorded as possible useful attributes. The number of plants sampled in a mat was seven, and the sample size was a compromise based on time constraints and calculation of sample variance of plant length [7].

Connectivity, mat buoyancy, biomass density and population density measurements were made on the same portion of the weed carpet. Connectivity was measured based on the principle that as connectivity increases in a mat, more weight/ pressure is required to submerge a plant within the mat. This is because it is supported in part by the rest of the mat. Without connectivity, each water hyacinth plant in a mat would be free floating and supported by buoyancy [7]. Connectivity, buoyancy, and standing density were measured using a rigid mesh wire measuring 62cm x 70cm, weights and a scale. The mesh steel frame was placed on top of an undisturbed mat in stagnant lake waters, weights were placed on it until it submerged [7]. The weights were then removed and the mat under the frame disconnected from the surrounding plants by cutting all the attachments such as leaves and stolons, weights were then added on again to determine the weight required to submerge the weed carpet [7]. After each test, individual plants under the frame were counted; seven plants were characterized, and weighed [7]. Mat buoyancy equaled the pressure (Pa) required to submerge the mat under the frame when cut from support by surrounding mat; connectivity was calculated as the difference of pressures (Pa) required to submerge connected and disconnected mat. The best least square relations predicting population density and buoyancy from other mat characteristics were sought [7]. This it was hoped would provide any information at the occurrence of any relationship between two variables like plant mass and plant height amongst other variables [7].

In order to determine the distribution of mass within a mat and to compare different types of mats, ten to fifteen plants were sampled from mats located in the six different parts of the gulf waters, and a classification system [7] was used to establish the mass clusters;. This classification system developed to account for the variability in plant sizes a distribution curve produced was used to determine whether mass was distributed normally or not [7]. Plant mass in this study was classified into six classes indicated as; Class 0 contained plants which weighed less than 0.1 kg, class-1represented plants weighing between 0.1- 0.2, class-2 (0.2- 0.3), class–3 (0.3-0.4), class-4 (0.4-0.6), while class-5 had plants which were heavier than 0.7 i.e. > 0.7kg [6]. This means that the smallest plant fell into class-0, while class-5 represented plants which were the largest and hence heaviest. It was important to note that the presence of a leaf or two which weighed approximately 40.0g could shift the class into which the particular plant would fall in, possibly in the next class category [7].

3. RESULTS AND DISCUSSIONS

Plant mass distribution indicated normal distribution and the mats studied appeared to be well established in several of the areas where date was collected, even though the mean values of plant mass differed from one collection point to the next (Figures 1-4). In all the four-collection spots plant specimen of mass class– 4 seemed to be the dominant category of plants. Plant mass appeared to be normally distributed and the mean plant mass appeared to vary with age and habitat of the affected plants.

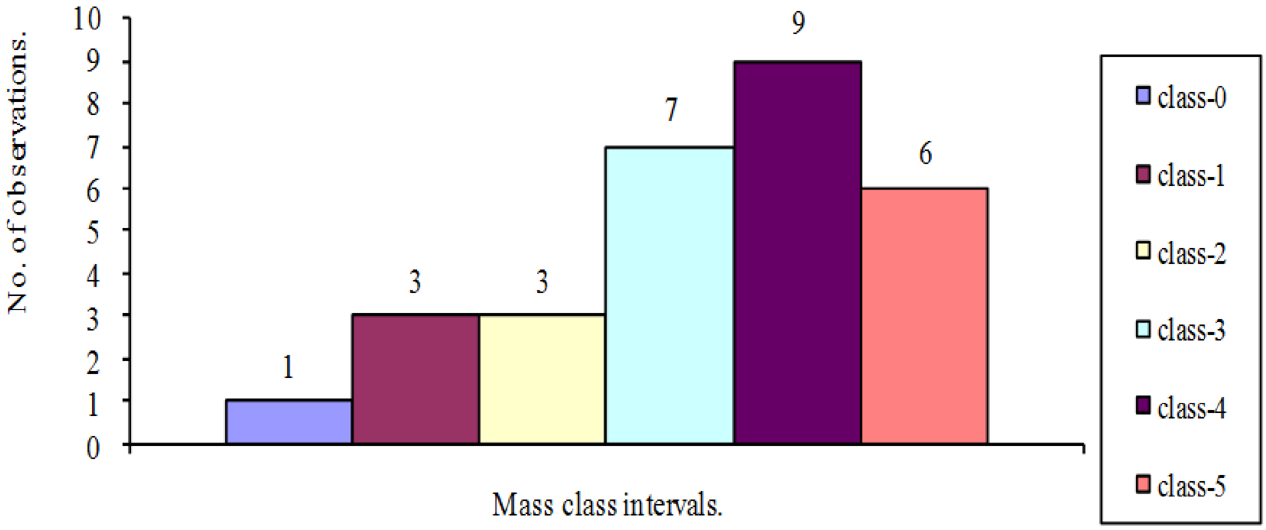

Figure-1. Showing a well established and nomaly distributed plant mass at the Kisat-bay-, next to pier (class-4 dominated).

Source: Opande [5].

Classification key

Class - 0 = < 0.1 kg
Class –1 = (0.1- 0.2) kg
Class –2 = (0.2 – 0.3) kg
Class –3 = (0.3 -0.4) kg
Class –4 = (0.4– 0.6) kg
Class-5= (0.6<) kg

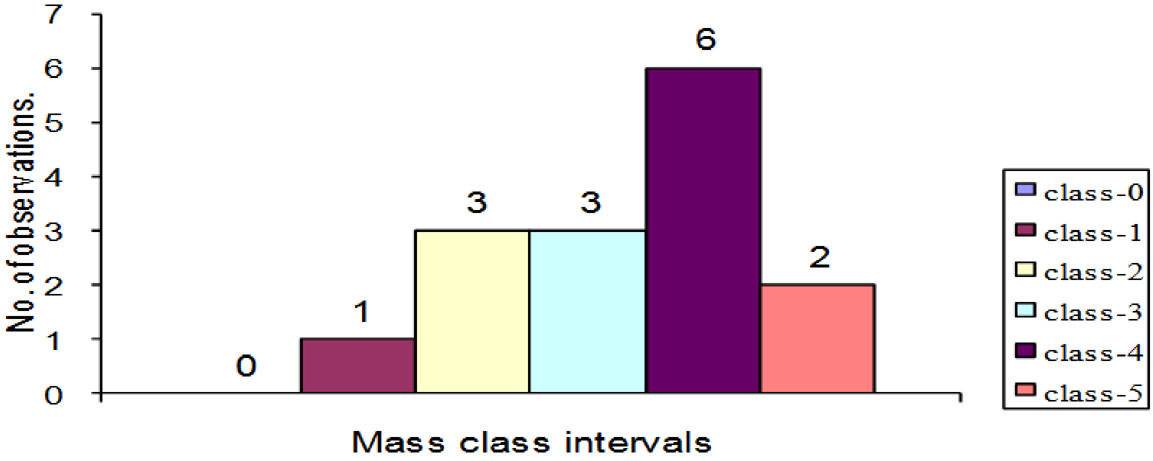

Figure-2. Showing a well established and nomaly distributed plant mass at Dunga beach (class-4 dominated)

Source: Opande [5].

Classification key

Class - 0 = < 0.1 kg

Class –1 = (0.1- 0.2) kg

Class –2 = (0.2 – 0.3) kg

Class –3 = (0.3 -0.4) kg

Class –4 = (0.4– 0.6) kg

Class –5 = 0.6 kg<

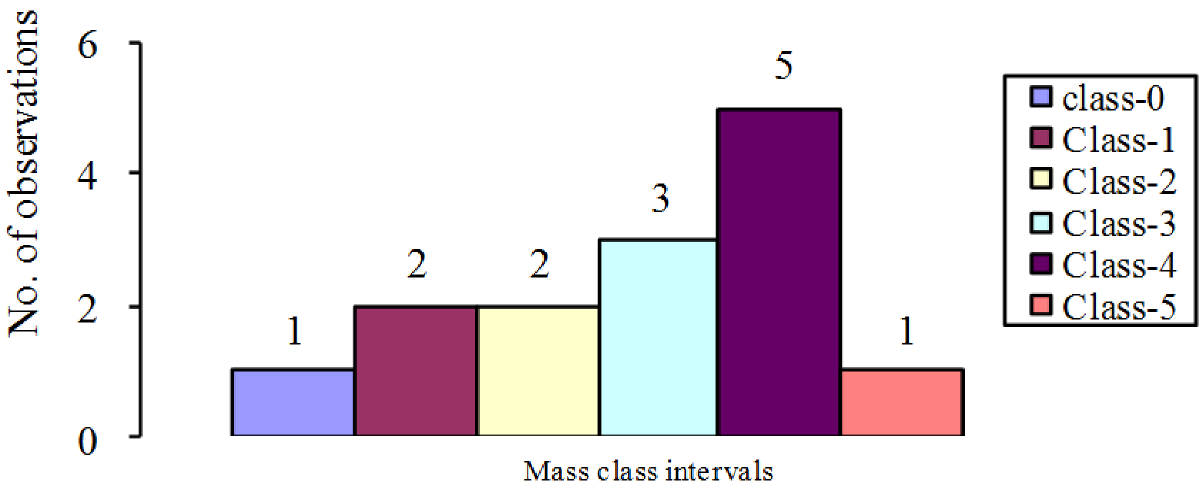

Figure-3. Showing a well established and nomaly distributed plant mass of plants from Kobala beach (class-4 dominated)

Source: Opande [5].

Classification key

Class - 0 = < 0.1 kg

Class –1 = (0.1- 0.2) kg

Class –2 = (0.2 – 0.3) kg

Class –3 = (0.3 -0.4) kg

Class –4 = (0.4– 0.6) kg

Class –5 = 0.6 kg<

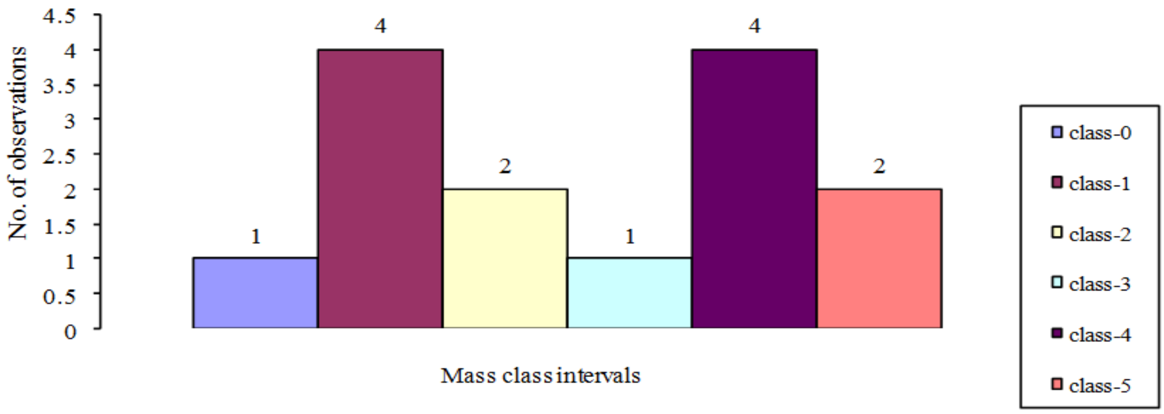

Figure-4. Showing plant abnormal mass distribution at Kusa beach, Nyakach bay (class 1 & 4 dominated).
Source: Opande [5].

Classification key

Class - 0 = < 0.1 kg

Class –1 = (0.1- 0.2) kg

Class –2 = (0.2 – 0.3) kg

Class –3 = (0.3 -0.4) kg

Class –4 = (0.4– 0.6) kg

Class –5 = 0.6 kg<

The measurements of the rhizome length and plant mass varied from location to location, and was determined by weather the plants were healthy or not, the location in terms of nutrients availability, wave action, harvesting exercise and the activity of other biological agents are some of the factors which determined the health of the various plant specimen. The data obtained after measuring the various rhizome lengths from all locations studied, were aggregated and then analyzed, first separately and then together. The rhizome length measurements varied from 9cm to 13cm, while plant mass varied from 0.09 to 0.8. Different least square equations were evident when data from the different locations were analyzed and hence when the rhizome length was correlated to the plant mass, four least square equations were obtained i.e. $r^2 = 0.0066$, $r^2 = 0.0053$, $r^2 = 0.6021$ and $r^2 = 0.4034$. The plants collected from Kobala beach in Nyakach bay seemed to show a correlation between their plant mass and rhizome length (fig 8), while those which were collected from Kisumu pier (fig 5) and Dunga beach (fig 6) showed minimal or almost no correlation. Other specimens collected from Kusa beach in Nyakach bay (fig 7) also showed little or no correlation between these two variables.

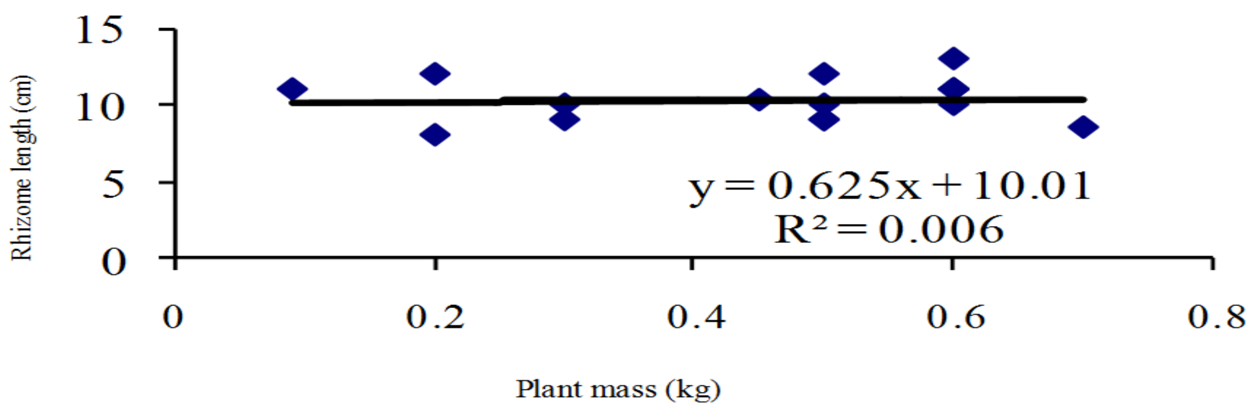

Figure-5. Correlation of plant mass with rhizome length of plants collected from Kisumu pier
Source: Opande [5].

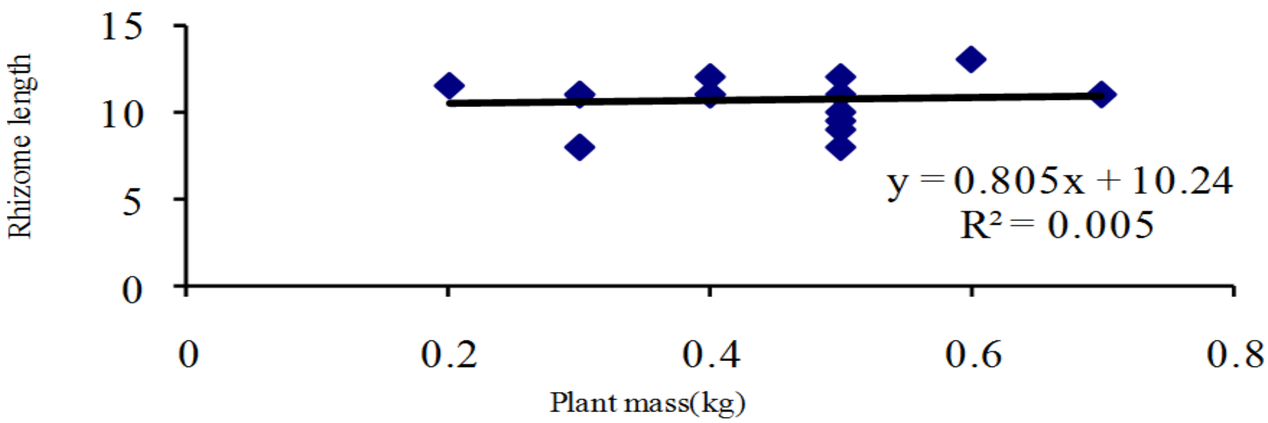

Figure-6. Correlation of plant mass with rhizome length at Dunga beach Kisumu

Source: Opande [5].

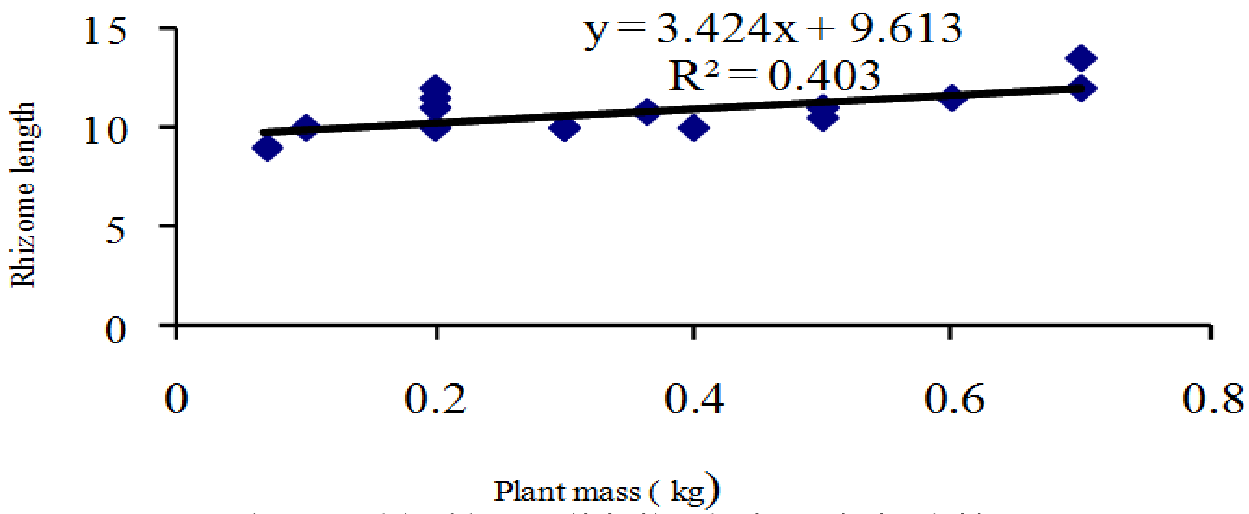

Figure-7. Correlation of plant mass with the rhizome length at Kusa beach Nyakach bay

Source: Opande [5].

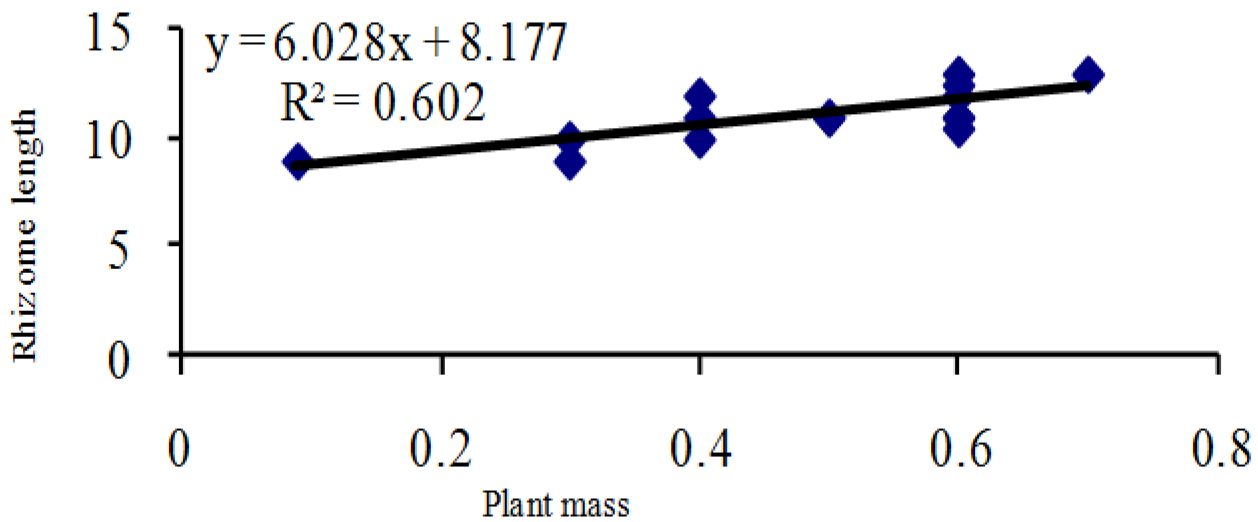

Figure-8. Correlation of the p.m and the rh-l of plants collected from Kobala beach, Nyakch bay

Source: Opande [5].

Biomass density varied between 2.5 kg/m² to and 15 kg/m², from the different areas from which these measurements were taken. While the population density varied from as low as 0 plants/m² in open waters to as high as 150 plants/m² in densely populated parts. No accurate estimator of plant population could be obtained using data of Biomass density. When population density was correlated to biomass density (Fig-9). A scatter diagram for biomass and population densities showed that there actually existed a relationship between the biomass density and the population density as evidenced by the least square equation produced when these two variables were correlated. The least square equation thus produced was r^2 = 0.9202, further reinforces the inference that a relationship does exists between these two variables. It seems that this equation if further analyzed could form a basis from which sample water hyacinth populations in the Winam gulf can be estimated. Though a more accurate estimator of water hyacinth population densities based on standing biomass density and plant length/petiole length was observed [4].

Connectivity was determined when the plant mat and the mesh wire placed on the weed carpet was found to support an average weight of about 12.6 kg (table 8.1), before all the entangled stolons and petioles below it were disconnected. Water hyacinth carpets were found to be able to support an average weight of about 11.74 kg (table-8.2), which is equivalent to a force of 115.05N. The average mat buoyancy of the water hyacinth mats in the Winam-gulf based on the averages obtained was therefore 265.09Pa. These observations further

Table-1. Showing observation sites, wet weight, biomass density and population density

Site of observation	Wet Weight (kg)	Biomass density (kg/m^2)	Pop density ($Plants/m^2$)
Dunga beach	47.35	2.5	99
Kisumu pier	52	5.5	109
Kusa	60.5	7.5	120
Kobala	65.5	8.3	133
Kendu bay	71.5	10	156
Average	**59.37**	**6.76**	**123.4**

Source: Opande [5].

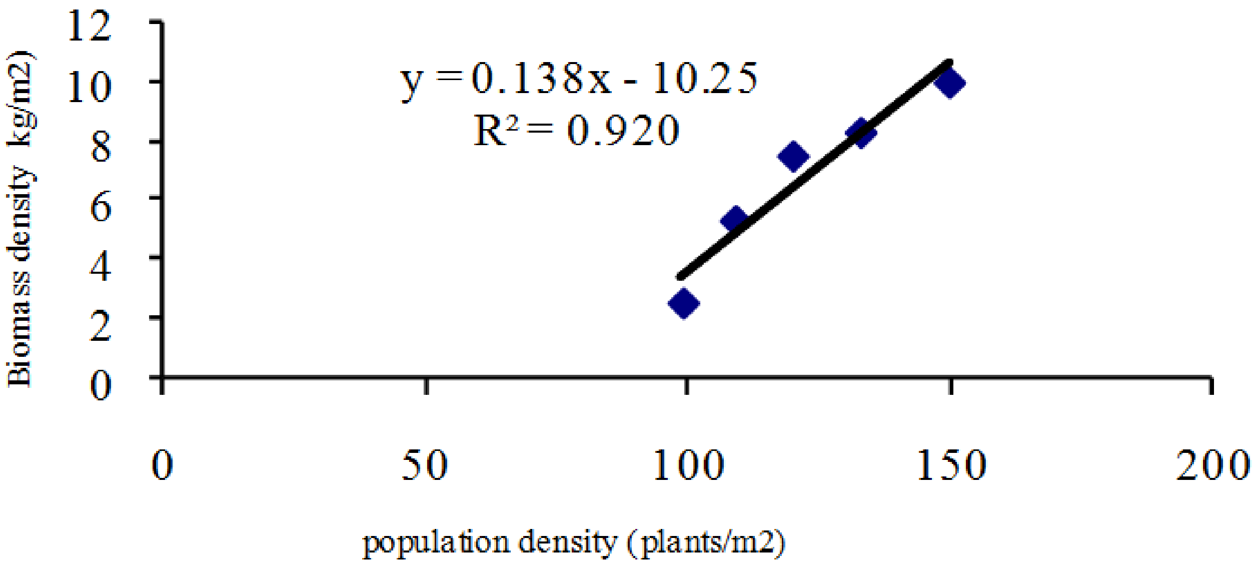

Figure-9. Correlation between population density biomass density.

Source: Opande [5].

indicated that the average connectivity of all the water hyacinth mats studied in different parts of the gulf was found to be equal to 23.1Pa (N/m^2) kg. This value for average connectivity i.e. 23.1Pa (N/m^2) kg was reached when all the weight able to sustain entangled and disconnected carpets were measured and converted to Newton's per meter squared. The difference between the average of all the measurements of pressure obtained for connected and disconnected mats was considered as the average connectivity for the water hyacinth mats in the Winam gulf.

Connected water hyacinth mats covering an area of about 0.62m x 0.70m (0.434 m^2) of the Winam-gulf was thus able to sustain an average pressure of about 288.4 Pa (Pascal) before it could submerge. Any additional pressure would cause the connected carpet to sink.

The force in Newton that was being exerted on the weed carpet by the loads added on the mesh wire was calculated as the product of mass (kg) and acceleration due to gravity (m/s^2) or (Mass x 9.8) N. while the weight (W) needed to submerge the connected and disconnected carpet was calculated as the sum of the weight of mesh wire measuring 0.62m x 0.70m and that of the load added on to it until the carpet got submerged. All the readings were recorded in each case (Table-3) i.e. W = L + Me, where (W = weight needed to submerge mats covering an area of about 0.434 m^2. and L = The Load required to submerge connected mat (kg), while Me = mesh weight (kg)).

Table-2. Showing Pa_1, Pa_2 and Connectivity of water hyacinth mats in different beaches of the Winam-gulf

Observation Point.	Pa_1	Pa_2	Mesh size (m^2)	Mesh weight (kg)	Connectivity (Pa)
Kisumu-pier	287.9	259.7	0.62 x 0.70	1.4644	**28.9**
Dunga-beach	304.8	282.2	0.62 x 0.70	1.4644	**19.6**
Kobala-beach	270.9	246.1	0.62 x 0.70	1.4644	**24.8**
Kusa-beach	282.2	252.9	0.62 x 0.70	1.4644	**29.3**
Kendu-bay	295.8	284.5	0.62 x 0.70	1.4644	**11.3**
Average	**288.4**	**265.1**	**0.434 m^2**	**1.4644**	**23.1**

Source: Opande [5].

The mat buoyancy (Pa_2) measured as the pressure (Pa) that was required to submerge the mat after disconnection by physically cutting them using a scissors. An average value of 265.1 Pascal was obtained as the mat buoyancy value when all the 5 values obtained from the different areas of the Winam gulf were added to obtain a total which was then divided by 5 to get the average mat buoyancy for the Winam gulf

When all the connecting stolons and leaves were fully disconnected from the floating carpets with dimensions of 0.62m x 0.70m, which was the total area below the mess wire, it was notable that they submerged only when the weight added on exceeded an average weight of 11.74 kg (Table-3)**.** Therefore the average mat buoyancy for an area of 0.62m x 0.70m of the Winam gulf was equal to 265.1 Pa.

Table-3. Weights W_1 and W_2 and the difference between them.

Observation point	Weight kg (W_1)	Weight kg (W_2)	(W_1-W_2)
Kisumu-pier	12.75	11.50	1.25
Dunga-beach	13.5	12.5	1.00
Kobala-beach	12.0	10.9	1.10
Kusa-beach	12.5	11.2	1.30
Kendu-bay	13.1	12.6	1.50
Average	**12.6**	**11.74**	**1.23**

Source: Opande [5].

4. CONCLUSIONS AND RECOMMENDATIONS

This study is one of very few studies which have investigated the carpet characteristics of the water hyacinth in the Winam gulf and L. Victoria as a whole. We were thus able to determine the Connectivity, mat buoyancy, biomass density and population density measurements on portions of weed carpet. It is now clear from this study that a human being cannot walk or stand on a weed carpet in the Winam gulf (lake Victoria), because when all the connecting stolons and leaves are fully disconnected and they stand alone from the floating carpets with dimensions of 0.62m x 0.70m the total area below the mess wire, it was notable that they submerged only when the weight added on exceeded an average weight of 11.74 kg. Most healthy adult human beings have weights that are higher than 11.74 kg. A small animal on the other hand might be able to walk on these weed carpet so long as the animal weighs not more than 11.74 kg. We wish to conclude that;

- The Winam gulf of lake Victoria has a serious water hyacinth infestation problem

- There is an urgent need to conduct research to find possible long time self-sustaining control methods.
- A harvester machine may be deployed for use in a mechanical removal exercise in the lake because penetration of the weed carpet is possible.
- Only animals that weigh less than 11.74 kg can float on the weed carpet.

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