# Characterisation of Anopheles Mosquitoes breeding habitats in lowland rice fields in Uganda

Nanfumba David[1]; Tenywa,M.M[2].; Okui,O.[3]; Majaliwa,M.J.G.[2]; Wasige,J.E.[2]; Lufafa,A.[2]; Musiime,O.[2]

1. National Agricultural Research Organisation, Buginyanya Zonal Agriculturel Research and Development Institute, P.O.Box 1356.Mbale-Uganda, nanfumbada@yahoo.com, nanfumbada@agric.mak.ac.ug
2. Makerere University, College of Agricultural and Environment Sciences, P.O.Box 7062, Kampala-Uganda
3. Makerere University, Institute of Public Health, P.O.Box 7062, Kampala-Uganda

Abstract: Malaria, the number one killer disease in sub-Saharan Africa, is closely linked with lowland rice cropping systems. In this cropping system, parts of the irrigated/flooded lowland rice fields act as breeding grounds for the anopheles mosquito – the malaria vector. In Uganda, source control of this vector, is almost limited to removal of stagnant water, a strategy not realistic in paddy rice growing areas. Source control of this vector in paddy rice growing areas requires a comprehensive understanding of the bio-physical factors that influence its breeding/multiplication activity. There however exists an information gap of breeding habitats' bio-physical properties influencing breeding of this vector in the lowland rice cropping systems. This research aimed at identifying bio-physical properties influencing the anopheles mosquitoes (AM) breeding in lowland land rice fields. The research was conducted in Nankoma, Nabukalu and Buluguyi sub counties in Bugiri district, a district classified by Ministry of Agriculture, as a lowland rice growing area in Eastern Uganda. Data was collected every after 25days for a period of 12 months covering 2 rice growing seasons. Shallow skim dipping method was used to sample the anopheles mosquito larvae (AML) from breeding habitats. Number of AML dip$^{-1}$ was used as a proxy for suitability of breeding conditions for the mosquitoes. Water from the habitats was characterised for water temperature, pH, oxygen content, electro conductivity, water depth, turbidity and number of other organisms. Also recorded for suspected habitats with rice still standing in the field was; the rice height (cm), density (hillm$^{-2}$) and number of tillers. Pearson correlations results between variables and number of anopheles larvae dip$^{-1}$ were 0.17, 0.437, 0.193, -0.357, -0.393, -0.329, 0.356, and -0.329 for water depth, turbidity, temperature, paddy density, paddy height, oxygen content, electro-conductivity and number of rice tillers respectively, significant at $p<0.05$. Stepwise regression analysis indicated that turbidity, water electro conductivity, rice height, water depth, water temperature, number of other organisms and rice density, significantly ($p<0.05$) explained the number of AMs in a given habitat. This research is fundamental in guiding malaria vector-source control in paddy rice growing systems in Uganda and sub-Saharan Africa as a whole.

[**Nanfumba David; Tenywa,M.M.; Okui,O.; Majaliwa,M.J.G.; Wasige, J.E.; Lufafa, A.; Musiime,O.** Characterisation of Anopheles Mosquitoes breeding habitats in lowland rice fields in Uganda. Nature and Science 2011;9(6):44-57]. (ISSN: 1545-0740). http://www.sciencepub.net.

Key words; Malaria, paddy rice field, Anopheles mosquitoes, Anopheles Mosquito Larvae, breeding habitats, biophysical properties

## 1.0 INTRODUCTION

The Anopheles Mosquito (AMs) is known to transmit malaria, the number one killer disease in Uganda, and sub-saharan Africa. In Uganda, the disease kills 300 people per day(MOH, 2003). Like in other crops, this disease negatively affects paddy rice yields and production through its contribution to farm labour loss (MAAIF, 2000). The labour loss results into late, inadequate or total failure by farmers to carry out the necessary paddy rice production activities which in turn leads to failure of farmers to attain the optimum yields Ha$^{-1}$. Yet the vectors of this disease are known to breed from the paddy rice fields.

With disease's vector breeding in water, Malaria is particularly important in paddy rice cropping systems where water used for rice irrigation doubles as breeding ground for the anopheles mosquito. Different researchers have documented paddy rice fields as potential breeding grounds for malaria transmitting/spreading mosquitoes (Wim van der Hoek et al., 2002). In Kenya, there was a 70-fold increase in the population of adult An. gambiae caught biting man on the Ahero irrigation scheme compared with an area of undisturbed settled agriculture (Surtees et al., 1970). The irrigation carried out in the paddy rice fields lead to a stabilization of previously unstable numbers of malaria cases in the area (MAAIF, 2000). However in Kenya, an irrigated paddy rice area was found to have a much higher prevalence of malaria than a cotton area 20-km away (Coosemans 1985). Indeed the disease has been reported to be more serious in areas of relatively stable malaria transmission (WHO/UNICEF, 2003).

Control of the breeding of AM requires clear knowledge of the factors influencing the vector's breeding habit. Accurate information concerning the factors influencing the breeding of malaria transmitting mosquitoes on the paddy rice field, is key to effect targeted malaria vector source control efforts (MOLG, 2001). Unfortunately, there is inadequate research based data on which the malaria source control programme can be based in paddy rice growing systems in Uganda and sub-saharan Africa. This makes malaria vector source control by the relevant authorities in paddy rice growing systems almost impossible. Many cases, these efforts are limited to removal of stagnant water. As a result, malaria vector control in paddy rice field is never considered as an option. This research therefore aimed at identifying and characterising the AM breeding habitats in the paddy rice fields.

## 2.0 MATERIALS AND METHODS

### 2.1 Location

The study was carried out in Bugiri district located in south Eastern part of Uganda located between longitudes 34º 00'E -33º 30' E and latitudes 1º 00'N – 0º 45' N (MWLE, 1998). The district falls in Southern Eastern Agro ecological zone of Uganda, and drains into the Lake Victoria and Kyoga catchments (NARO, 2002).

### 2.2 Climate and Vegetation

The district receives a mean annual rainfall of approximately 1250 mm (NEMA, 1997). It receives mainly conventional rainfall with two peaks every year occurring between April-May and September-November (NEMA, 1997). The annual mean temperature ranges from 21$^o$C to 23.6 $^o$C. The soils are predominantly ferralitic (NEMA, 1997). As far as vegetation is concerned, the southern part of Bugiri district has generally got forest and Savannah mosaic type of vegetation (NEMA, 1997). The part bordering the lake has thicket mosaic while that above the shores has moist thickets of forests in addition to the mosaic (NEMA, 1997). The northern part has got mainly Savannah type of vegetation. The altitude of the district ranges from 1150 m to 1200 m. The southern part it is 1200 m while the northern part is 1150 m (Ollier et al, 1969). Therefore, the district is generally sloping northwards.

### 2.3 Data Collection

Three (3) Sub counties; Nankoma, Nabukalu and Bulegeni, which predominantly have paddy rice cropping system were randomly selected. From each of the 3, a multi stage sampling technique was used to select farmers' fields from which water and anopheles mosquito larvae (AML) were sampled(Mettrick, 1993). Visual classification of the paddy rice fields, into potential anopheles mosquito breeding habitats, was carried out basing on the observable field physical conditions and presence of water. The water samples and mosquito counts were taken every 3.5weeks (approximately 25 days) for 12 months. Care was taken when approaching the suspected breeding site. At the site a 2-3 minutes pause was allowed before taking the dip to allow the mosquitoe larvae to freely move to the water-air interface suspected breeding site. Every classified potential habitat was confirmed to be one with the observation of at least one larva.

From the identified breeding habitats, Anopheles mosquito larval counts were taken and water biophysical physical variables measured. The AMLs were identified by their unique characteristic of lying flat on the water surface (Claudia, 2005; Sunish, 1992). AML samples were taken using the shallow skim dipping method with a white plastic standard pint-size dipper of 450ml capacity (Claudia, 2005, Sunish, 2001). This method, is particularly recommended for AML sampling (Claudia, 2005, Sunish, 2001; Claudia 1995). In this method, the leading edge of the dipper, tipped about 45 degrees, an inch below the surface of the water was moved, quickly but gently, along a straight line. In cases where the larvae escaped to the lower end of the water body, water was re-sampled after 30 seconds, a time when all larvae are expected to swim back to the surface. Four dips were taken at each of the classified potential breeding habitat in the field (Claudia, 2005; Sunish, 2001). The AML per sample were counted. The mosquito density expressed as breeding index, BI (Claudia, 2005) was computed as follow:

$$BI = TLP/(ND * BP)$$

Where
BI= breeding index
TLP = Total number of larvae
ND= Number of dips
BP= Number of breeding places

At the sampling point, water temperature, water depth, rice height, density, number of tillers and number of other organisms were measured. Water samples were carried in 100 mls bottles from each of the breeding habitat kept in an insulated container with temperatures kept low (0-10 $^{o}$C). The water was allowed to rise to room temperature before measuring its bio-physical properties in the laboratory. This water was analysed for Oxygen content, Electro conductivity, turbidity and pH using the multi-probe method (Majaliwa, 2005). Water temperature was measured using a clinical thermometer. Water depth was measured using a meter rule, placing it vertical in the water with the lower end just touching the soil. Paddy height was measured using a meter ruler by stretching and holding the last upper most leaf's tip against the ruler as shown in figure 3 below.

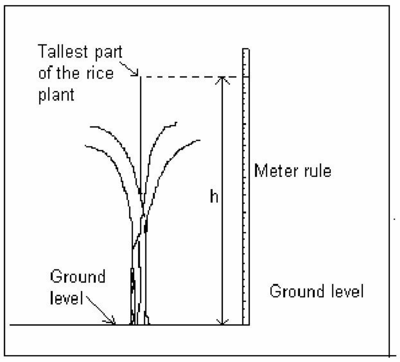


**Figure 1 indicating how the height of the paddy rice plants was measured**

Paddy density was measured using a 1m$^2$ quadrant placed at the point of AML sample collection. A count of the number of rice hills present at the sampling point was taken and recorded. Turbidity was measured using an electro-spectrophotometer at 400nm

**3.3 Data Analysis**

A multiple regression analysis was performed using the Genstat statistical package to produce a model that explains the prevalence of AML in the paddy rice fields, breeding habitats.

$Y = c + b_1*X_1^{1} + b_2*X_2^{2} + \ldots\ldots\ldots b_2Xn^{n}$

Y; Dependent variable (AML prevalence)

c; constant (intercept)

X; Independent variables

b; β coefficients of independent variables 1,2,3……n, respectively

Regression analysis both linear and exponential (quadratic) were conducted for each dependent variable and the number of AML to establish the models that explain the abundance of AML in the habitat.

**4.0 RESULTS**

**4.1. Characterization of the Mosquito Breeding Habitat**

Correlation results (see Table 1) indicated that there is a significantly high positive correlation ($p<0.05$) between the number of AML and water depth, turbidity, temperature and electro conductivity. On the other hand, significantly high negative correlations ($p<0.05$) with water oxygen content, rice height and density were recorded. These results suggest that water depth, turbidity, temperature, electro-conductivity and oxygen content together with rice density and height significantly influence the breeding of AMs in the paddy rice fields' breeding habitats.

Stepwise regression analysis results (Table 2) produced a model/function

$N=-10.42+19.0a+0.0176e-0.182h+0.538d+0.529t-0.256n-0.124b$

Where:

N: Number of AML

e: electro conductivity

h: Rice height

d: Water depth

t: temperature

a: turbidity

b: Rice density

n: Number of other organisms

This is an indication that electro-conductivity, rice height, water depth, temperature, turbidity, rice density and number of other organisms are the most important bio-physical properties in influencing the number AML in a given habitat. The model had a relatively strong linear relationship (R= 0.535) with the number of AML in the paddy rice field habitats and it explained only 28.6% of the total variation (See Table 8 in appendix). Analysis of variance of the regression model indicated that the 7 properties significantly ($p<0.05$) explained the number of AML in the breeding habitats (See table 7 in the appendix).

This confirms that the variables above acting together do influence number of the AML found in a given habitat in the paddy rice field. This result therefore suggests that they (variables) are together pertinent in influencing the breeding of these malaria-transmitting mosquitoes in the paddy rice growing system. Turbidity, water electro conductivity, water depth, temperature positively influence the larvae. On the other hand, rice height, number of other organisms and rice density negatively influence the number of AML. Basing on t values, in this function turbidity is the most influential factor while paddy rice density is the least. Having got the highest t value, the result suggest turbidity to be the most influential bio-physical property on the anopheles mosquito breeding while rice density is the least.

**4.2 Effect of rice density on AML in the Paddy ice field**

Linear regression indicated that the number of AML decreases with increase in paddy rice density and completely disappears at 70 hills $m^{-2}$ ($R^2$=0.127, n=90, $p<0.05$). Quadratic curve linear regression results, however, revealed that the number of AML first decreases with increase in paddy rice density and later increase with increase in density with a minimum at 69 hills $m^{-1}$ ($R^2$=0.4965, n=90, $p<0.05$). Quadratic function intercepts the x-axis at 84.52 and 52.65 and its minimum occurs at 68.58 hills $m^{-2}$. This suggests that the least favorable rice densities for mosquito breeding ranges from 53 - 85 hillsm$^{-2}$ with 69hillsm$^{-2}$ being the least favorable density. ANOVA of the linear model and quadratic models indicated a significant explanation of the anopheles larvae by the model (Sig. F=0.0005 and 0.0000 respectively, $p<0.05$) (See table 9 and 10 in Appendix).

Linear model is N = 16.501-0.243b

Quadratic equation is N=26.699-0.823b+0.006b$^2$

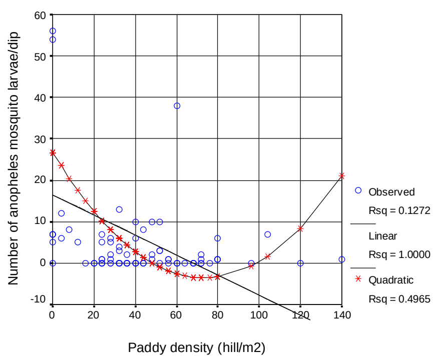


**Figure 2 . Breeding rate of AMs with changing rice density**

**4.3 Effect of Water Depth on AM Breeding Rate**

Linear regression analysis indicated that the number of AML generally increase with the increase in the depth of the water ($R^2$= 0.0289, n=353, $p<0.05$). However, quadratic curve linear regression analysis revealed that the number of AML first increases at a decreasing rate with increasing depth up to 9 cm beyond which it decreases with further increase in depth ($R^2$=0.4711, n=353, $p<0.05$). It gives a down ward concave curve. The number of larvae increase at a decreasing rate from 0cm to 8cm, is constant between 8 and10cm and starts decreasing at an increasing rate beyond 10cm. The curve further indicates absence of larvae in water beyond 18cm. Analysis of variance of both linear and quadratic curve-linear regression models indicated that they both explained well the change in the number of AML in a given habitat (Sig. F=0.0013 and 0.0000 respectively, $p<0.05$) (See table 11 and 12 in Appendix). The quadratic function intercepts the x-axis at -0.08 and 17.95 and its maximum occur at 8.94 cm. This suggests that the AMs breed in water with depth ranging from 0 to 17.95cm. It also suggests that 8.94 is the most favorable water depth for mosquito breeding.

Linear equation is N=2.997+0.697d

Quadratic equation is N= 0.19+2.449d-0.137d$^2$

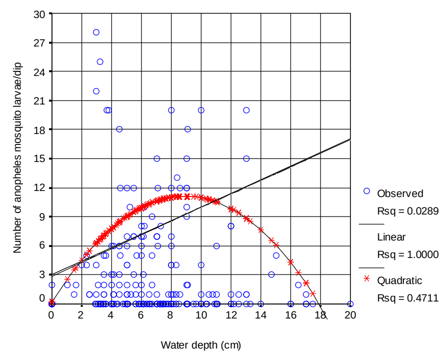


**Figure 3 . Breeding rate with changing water depth in the paddy rice field**

**4.4. Effect of Water Turbidity on AMLs in the Paddy Rice Fields**

Linear regression analysis indicated that the number of AML increase with the increase in turbidity ($R^2$=0.191, n=186, $p<0.05$). Quadratic regression analysis indicates an increasing number of AML at an increasing rate with an increasing turbidity ($R^2$=0.965, n=186, $p<0.05$). ANOVA of both the linear and quadratic regression analysis indicate that both models significantly explain the number of AML in the habitat (Sig. F 0.0000 and 0.0000 respectively, $p<0.05$) (See table 13 and 14 in Appendix). The curve intercepts the x-axis at -0.24 and -1.57 and has a minimum at -0.91. This suggests that mosquitoes breed least in water with very low turbidity close to zero.

Linear model is N=0.53+21a

Quadratic model is N=2.42+11.63a+6.41a$^2$

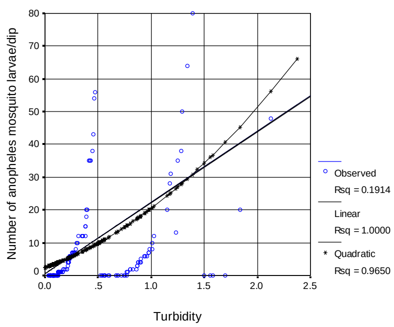


**Figure 4 . Number of AML with changing water turbidity**

**4.5 Effect of Water Temperature on AML in the paddy rice fields**

Linear regression analysis indicated an increase in the number of larvae with the increase in temperature ($R^2$=0.0373, $p<0.05$, n=247). Curve linear regression analysis indicates that the number of larvae increase at an increasing rate with increasing water temperature between 23 and 39 $^oC$ ($R^2$= 0.7037, $p<0.05$, n=247). ANOVA for both linear and quadratic regression (with Sig. F of 0.0022 and 0.0013, respectively, $p<0.05$) indicated a significant influence of temperature on the number of larvae in a given habitat (See table 15 and 16 in Appendix). The quadratic function intercepts the x-axis at 20.3$^o$C and -1.4$^o$C and its minimum occur when temperature is 9.4$^o$C. This suggests that the AMs' least favorable water temperature for breeding lies between -1.4 and 20.3$^o$C. They also indicate that the AMs cease to breed at temperature higher than 39.0$^o$C. It also suggests that the least favorable temperature to breeding is 9.4$^o$C.

Linear model is $N= -14+0.83t$

Quadratic model is $N= -0.99-0.66t+0.035t^2$

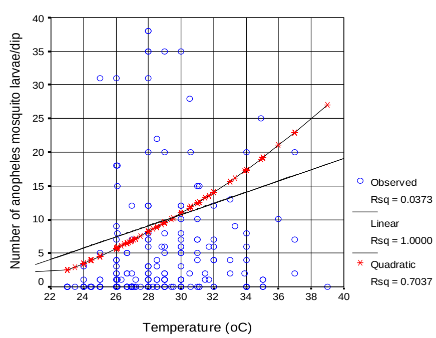


**Figure 5 . Number of AML with changing temperature**

**4.6. Effect the Paddy Rice Height on AML in the paddy rice fields**

The Linear regression analysis indicated that number of AML generally decrease with the increase in the paddy rice height ($R^2$=0.154, n=89, $p<0.05$). Quadratic Curve linear regression indicate an upward facing curve showing decreasing number of larvae in the early stages of rice growth and increases in the late stages of rice growth ($R^2$=0.5537, n= 89, $p<0.05$). The relationship indicate that the number of AML decrease at a decreasing rate from 0-60cm of paddy height. The quadratic function intercepts the X axis at 75.7 and 54.72 with a minimum at 65.21, -0.77 suggesting that the least favorable rice height for mosquito breeding is between 75.7 and 54.72 cm with 65.21cm being the least favourable. The number then increases at an increasing rate there after from 80cm to 110cm of paddy rice height. ANOVA of the linear and quadratic regression model indicated that they significantly explain the number of anopheles larvae in the habitat (F Sig. 0.0001 and 0.0000 respectively, $p<0.05$) (See table 17 and 18 in Appendix).

Linear model is $N=18-0.24h$

Quadratic model is $N=29-0.913h+0.007h^2$

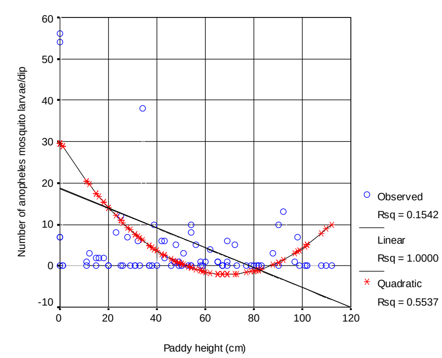


**Figure 6 . Number of AML with changing paddy rice height**

**4.7. Effect of Water Electro-conductivity on AML in paddy rice fields**

Linear regression analysis indicated that the number of AML increases almost linearly with the increase in the water electro conductivity ($R^2$=0.127, n=182, $p<0.05$). Quadratic regression results indicated that the number of larvae increase continuously from 0 larvae at 100us/cm to 28 larvae at 1600 us/cm ($R^2$=0.9910, n=182, $p<0.05$). The quadratic function intercepts the x axis at 7.77 and 5.48 suggesting that AMs breed least in water with oxygen content between 5.48 and 7.77 mg/l. The function has a minimum value at 6.63, -0.73

suggesting that the most un favorable water oxygen content for mosquito breeding is 6.63. ANOVA for both linear and curve linear regressions indicate that the water electro-conductivity do significantly explain the number of larvae in a given larvae (Sig. F 0.0000 and 0.0000 respectively, $p<0.05$) (See table 19 and 20 in Appendix).

Linear model is N=-2.243+0.022e

Quadratic model is $N=-3.932+0.29e-5.077e^2$

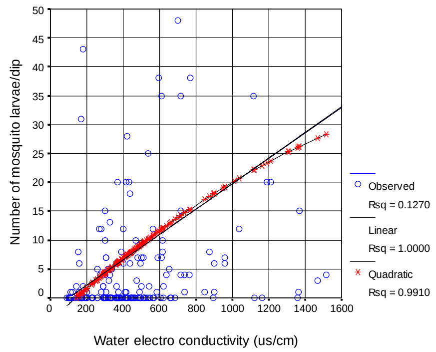


**Figure 7 . Number of AML with changing water electro-conductivity**

### 4.8 Effect of Water Oxygen Content on AML in the paddy rice fields

The linear regression indicated that the number of AML decrease with the increasing amount of oxygen content in the water ($R^2=0.108$, $p<0.05$, n=147). Quadratic regression analysis, like the linear, indicates that the number of larvae decreases with the increase in Oxygen content though at a decreasing rate (R=0.333, $R^2=0.111$, $p<0.05$, n=147). ANOVA of the linear and quadratic models indicated that they significantly explain the number of AML in the habitats (Sig. F=0.0000 and 0.0002 respectively, $p<0.05$) (See table 21 and 22 in Appendix).

Linear model is N=20.6-4.334o

Quadratic model is $N=23.68-7.368o+0.556o^2$

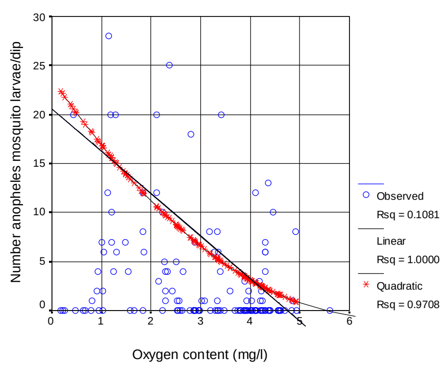


**Figure 8 . Number of AML with the changing water oxygen content**

### 4.9 Effect of Water pH on AML in Paddy Rice Fields

A linear regression indicated that the number of AML generally decreases as pH increases ($R^2=0.005$, n=176, $p<0.05$). Quadratic regression results indicated that the number of larvae a down ward concave curve that start at pH 6.75 to pH 7 when it reaches maximum. There after, the number of larvae decrease at an increasing rate and finally reaches 0 at 8.75 ($R^2=0.6734$, n= 176, $p<0.05$). The curve intercepts the X axis at 4.53 and 8.95 suggesting that mosquito do not breed in water with pH below and above 4.53 and 8.95 respectively. The function's maximum is at 6.74, 9.21 suggesting 6.74 to be the most favorable pH at which mosquitoes breed. ANOVA indicated that the linear and quadratic models do not significantly explain the number of AML in the habitats (Sig. F=0.359 and 0.5399, respectively, $p<0.05$) (See table 23 and 24 in Appendix).

Linear model is N=26.026-2.503p

Quadratic model is $N=-76.61+25.471p-1.894p^2$

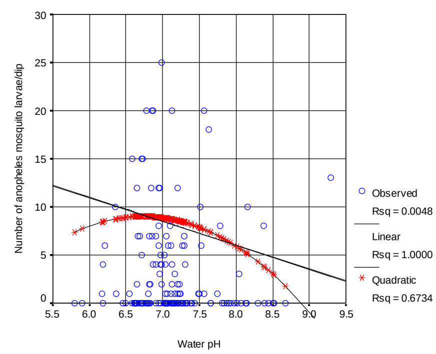


**Figure 9 . Number of AML with changing water depth**

### 4.10 Effect of Number of Other Organisms on AML in Paddy Rice Fields

A linear regression analysis indicated that the number of AML increase with the increase in the number of other organisms particularly tadpoles ($R^2=0.009$, n=48, $p<0.05$). Quadratic regression analysis indicated increasing number of larvae with the increasing number of other organisms ($R^2=0.9966$, n= 48, $p<0.05$). The quadratic function/ model suggest that the AML will always exist together with other organisms as the curve does not intercept the x axis. ANOVA of the linear and quadratic regressions model indicated that the number of other organisms do not significantly explain the number of anopheles larvae in the paddy rice fields (Sig. F=0.5212 and 0.8153 respectively, $p<0.05$) (See table 25 and 26 in Appendix).

Linear model is N=4.38+0.211n

Quadratic model is $N=4.44+0.164n+0.003n^2$

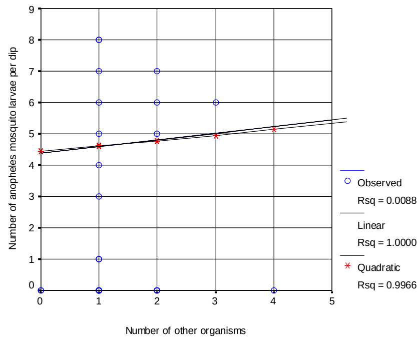


**Figure 10 . Number of AML changes with changing number of other water organisms**

### 4.11 Effect of Number of Tillers on AML in paddy rice field

Linear regression analysis indicated that the number of larvae found in a given site generally decrease with increase in the number of tillers ($R^2$= 0.00609, $p<0.05$, n=40). Quadratic curve-linear regression analysis indicated a decreasing number of larvae with increasing larvae populations at the beginning and an increasing number with increasing number of tillers with the minimum occurring at 25 tillers ($R^2$=0.2185, $p<0.05$, n=40). ANOVA of the linear and the Quadratic regression analysis indicated that they do not significantly explain the number of larvae in the habitat (Sig. F=0.6277 and 0.5845, respectively, $p<0.05$) (See table 27 and 28 in Appendix).

Linear model is N=4.103-0.024g

Quadratic model is $N=4.77-0.263g+0.005g^2$

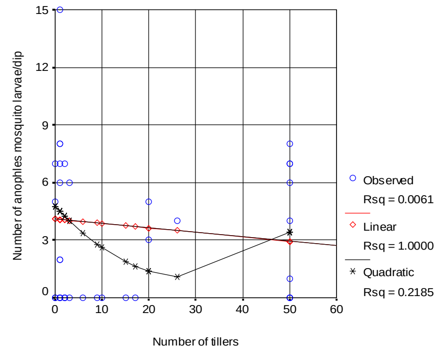


**Figure 11 . Number of AML with changing number of paddy rice tillers**

## 5.0 Discussion

### 5.1 Effect of Water Depth on AML in paddy rice field

The number of AML was found to increase generally with increasing depth though quadratic regression indicated increase and a decrease with a maximum number of larvae occurring at 9cm. This result partly agrees with the (Verse P, 2006) which indicated that the mosquito prefer to breed in water with the depth below 91.5cm (3feet) (T2 Quarterly Newsletter, 2006, University of Florida). The initial increase is probably explained by the increasing electro conductivity which shows a significant positive correlation with the water depth (Pearson Correlation= 0.162, p=0.05). The decrease beyond 9 cm is due to the fact that the deep water, which occur in the wet seasons due to heavy rains, is usually flowing and highly mobile, a characteristic that is not preferred by the anopheles mosquito for breeding. In deep water also were found the mosquito larvae predators such as fish which negatively impacts on the anopheles larvae number. Low depth also associated with high temperature, a factor has already been seen to favour anopheles mosquito breeding.

### 5.5 Effect of the water electro conductivity on AML in the paddy rice field

Results indicated that the AMs prefer breeding in water with high electro-conductivity basing on correlation (Pearson Correlation=0.356, $p<0.05$) and both the linear and quadratic regression. This may be explained by the higher number of micro-organisms in such water on which the mosquito larvae feed. The salts in the water act as nutrients that support growth of algae and other microscopic plants and organisms on which the mosquito larvae depend for food. This result suggests that fertilizer application in paddy rice fields may result into increased malaria cases in the paddy rice growing season. Dissolving of the applied fertilizers may lead to increase in the number of salts in the water resulting into higher electro-conductivity therefore making the fields more favorable for mosquito breeding.

**5.6 Effect of water oxygen content on AML in paddy rice field**

The number of AML were found to significantly decrease with the Oxygen content as indicated by the negative correlation (Pearson Correlation = -0.329, $p<0.05$). Both linear and quadratic regression analysis come to the same conclusion, ($R^2$=0.108, $p<0.05$, n=147) and (R=0.333, $R^2$=0.111, $p<0.05$, n=147), respectively. These results can be explained by the high number of larvae predators that prevail in water with high oxygen content. The AML stand higher chances of surviving to maturity in the low oxygen content water that is not preferred by their predators thus explaining the negative relation ship between oxygen content and number of AML.

**5.7 Effect of water pH on AML in paddy rice field**

The numbers of AML were found to decrease with the increase in the pH as indicated by the correlation results (Pearson Correlation= 0.069) and the linear and quadratic regression analysis ($R^2$=0.005, n=176, $p<0.05$) and ($R^2$=0.6734, n= 176, $p<0.05$), respectively. These results suggest AMs prefer breeding in water of pH between 6.5 and 7. Adjusting the paddy rice field water pH outside this range leads to decreasing number of anopheles larvae breeding in the habitat. Conceivably then liming in the paddy rice fields leading to high pH levels beyond 7 decreases the number of anopheles mosquito breeding in them.

**5.8 Effect of other organisms on AML in paddy rice field**

Generally, there was a positive correlation between the number of other organisms and the (Pearson Correlation=0.094, $p<0.05$) though not significant. Linear and quadratic regression analysis also indicated weak relation ships between other organisms and the number of AML ($R^2$=0.009, n=48, $p<0.05$) and ($R^2$=0.9966, n= 48, $p<0.05$), respectively. The increase in the number of AML with the number increasing number of other organisms in the habitat is explained by the protective aspect of the habitats to both the larvae and the organisms from their common prime predators in the paddy rice field water mainly the fish. The habitats offer protection to the organisms and the larvae from the predators thus leading to increasing numbers of both.

**5.9 Effect of the water turbidity on AML in paddy rice field**

Significant positive correlation between the AML and turbidity together with the significant linear and quadratic relation ship as indicated by the regression results ($R^2$=0.191, n=186, $p<0.05$) and ($R^2$=0.965, n=186, $p<0.05$), respectively. This relationship is likely to be due to the presence of suspended organic particulates that make water less transparent. In cases of presence of the rice straws, the high turbidity results from the rotting materials. The high numbers of AML in highly turbid water could be explained by the availability of food, suspended organic solids, on which the larvae depend. The turbidity is also claimed to offer protection to the mosquito larvae from their predators. This is a confirmation that the number of AML is influenced by the turbidity of the water in a given habitat.

**5.10 Effect of paddy density on AML in paddy rice field**

Correlation analysis indicated a significantly high negative relationship between the density of larvae and the paddy density (hill/$m^2$) (Pearson's correlation= -0.437, $p<0.05$). The initial high number of larvae in the field at low density is explained by the hatching eggs that existed in large number during the land preparation stage. Another reason for the decreasing number of larvae with increasing density could be the obstruction of mature AMs' flights to the stagnant water beneath the paddy rice canopy. The denser the canopy the less easy it is for mosquitoes to access the water for breeding. The increasing number of larval counts beyond the rice density of 70 hills is yet to be explained. These results suggest that the number of mosquitoes breeding in the recommended rice density of 50-60 hills per $m^2$ is low.

**5.11 Effect of Paddy rice Height on AML in paddy rice fields**

Results indicated a significantly high negative correlation between the number of AML and the paddy rice height (Pearson's correlation= -0.393, $p<0.05$). Regression analysis, however, produced a significantly high regression suggesting the dependency of the anopheles larvae on the paddy rice height. The presence of larvae in the field is dependent on the availability of water in the rice field at a given time. The high number of larvae at 0 heights (before planting) is due to the tilling effect on the larva presence. The initial decrease in the number of larvae with height can explained by the generally decreasing amount of water after planting as regulated by the farmers after planting. The low number of larvae between 50 and 90cm of rice height is due to the absence of water in the field at the time the rice achieves this height. The number only builds up during the late stages of rice growth when the farmers supply the rice with more water reportedly to facilitate the tussling process.

### 5.12 Effect of water temperature on AML in paddy rice fields

The number of AML were generally found to increase with increasing temperature with a significant positive correlation (Pearson's correlation= 0.193 $p<0.05$). This confirms that the AML prefer to breed in water that has got high temperatures. The mosquitoes prefer higher temperature for breeding because it shortens the time of the life cycle which it spends in water thus standing more chances of completing the cycle before the water dries out. The linear and quadratic analysis does not give the low and high temperature limits at which breeding for the mosquitoes ceases. The highest temperature however recorded was $38^oC$.

### 5.13 Effect of Number of Tillers on AML in paddy rice field

There was generally a high negative correlation between the larvae and the number of larvae (Pearson's correlation= -0.078, $p<0.05$). The negative correlation relationship, though not significant, may be resulting from the obstruction of adult female mosquitoes' flights during the time of searching for breeding habitats.

## 5.0 Conclusions and recommendations

### 5.1 Conclusion

The number of AML in a given habitat cannot be attributed to a single factor only. The different biophysical factors, particularly rice height and density and water turbidity, electro conductivity, depth, temperature and number of other organisms, are collectively responsible for influencing the suitability of a habitat for breeding of AMs.

### 5.2 Recommendations

1. The farmers should carry the rice straws away from the rice fields to a raised ground where it is free from water. This will reduce its contribution to mosquito breeding and therefore malaria epidemic in the rice growing system.
2. Researchers especially the soil scientist should find the best way of decomposing the rice straws so that they can be applied back in the rice fields to reduce the nutrient depletion which would occur if it were to be carried away from the field.
3. The farmers should plant their rice targeting a density of 60-80 hills/$m^2$ at which mosquito breeding is at the minimum.
4. During irrigation, farmers should target the water depth of either less than 1cm or above 18 cm at which breeding is minimal.
5. The farmers should employ the Alternet Wet/Dry Irrigation (AWDI) (Wim van der Hoek 2002) where water is intermittently released into the rice fields, left for less than Seven days and released. This method was not only proved to be water saving but also prevents the anopheles mosquito breeding by breaking the cycle.


## 6.0 ACHNOWLEDGEMENT

**Rockefeller Foundation** and **Regional Universities Forum for Capacity Building (RUFORU)** for funding this research

**Bugiri District Local Government** for the at-most cooperation accorded during the study

**Bugiri District Farmers** who allowed the research to be undertaken on their rice plots


## REFERENCES:


**Audibert M, Mathonnat J, Henry M. C., 2003**. Malaria and property accumulation in rice production systems in the Savannah zone of Cote d'Ivoire. Tropical Medicine and International Health. Volume 8 No 5. Pp 471-483.

**Claudia M, 2005.** Guidelines for larval mosquito surveillance. USACHPPM readiness thruogh health.

**Claudia M 1992**. The biology of anopheles quadrimaculatus say. In: Proceedings of the Seventy-Ninth Annual Meeting of the New Jersey Mosquito Control Association, Inc. 1992. Pp 136-144.

**Claudia M, 1995.** Seven ways to a Successful Dipping Career. American Mosquito Association. Wing Beats (6)4: 23-24

**Claudia, M, 1989.** Guidelines for larval Surveillance. In: Proceedings of the 76th meeting. New Jersey mosquito control Association: 46-55

**Coosemans M H**, **1985**. Comparison of malarial endemicity in a rice-growing area and a cotton-growing area of the Rusizi Plain, Burundi.

**Majaliwa G.J.M, 2005.** Soil and nutrient losses from major agricultural land use types and the associated pollution loading in selected Lake Victoria micro-catchement.

**Mettrick H, 1993.** Development Oriented Research in Agriculture

**Ministry of Agriculture Animal Industry and Fisheries, 2000**. The Plan for Modernisation of Agriculture (PMA)

**Ministry of Agriculture Animal Industry and Fisheries, 2000**. Policy statement for the ministry of agriculture, animal industry and fisheries. VOTE 010/142. Budget financial year 2004/2005.

**Ministry of Local Government Uganda, 2001.** Local government development program; Operation manual for local government

**Ministry of Water lands and Environment,** 1**962**. Atlas of Uganda. Department of lands and survey

**Ministry Of Health, 2003.** Statistical Abstract-working paper 2002.

**NEMA, 2001.** State of the Environment report for Uganda 2000/ 2001.
**NEMA, 1997.** District state of environment report-Iganga.
**Ollier, C .D, Lawrance C. J, Beckett P. H, and Webster R. 1969**. Terrain classification and data storage. Uganda lands systems. MEXE report No. 959
**Sunish and Reuben 2001.** Factors influencing the abundance of encephalitis vectors in rice fields in India-I. Abiotic. Center for research in medical entomology, China chokkikulam-India. Medical and Veterinary Entomology (2001) 15, 381-392.
**Surtees G, Simpson D.I.H and Bowen E.T.W, 1970.** Rice field development and arbovirus epidemiology, Kano Plain, Kenya. Transactions of the Royal Society of Tropical Medicine and Hygiene 64:511-518.
**Victor T. J. and Reuben R 2001**. Effects of organic and inorganic fertilizers on mosquito populations in rice fields of south India. Institute of Vector control and Zoonoses, Hosur, Tamil Nadu state, India. 2000 Blackwell Science Ltd, Medical and Veterinary Entomology, 14, 361+368
**WHO/UNICEF 2003.** The African Malaria Report. WHO/CDS/MAL/2003.1093
**Wim Van der Hoek, Sakthivadivel R, Renshaw M, Birley H. and Konradsen F. 2002.** Alternate wet/dry irrigation in rice cultivation; A practical way to save water and control malaria and Japanese Encephalitis

**APPENDIX**

**Table 1 Results of correlation between the number of the AML dip$^{-1}$ and the explanatory environmental variables**

| | | Water depth | Turbidity | Temperature | Paddy density | Paddy height | Number of tillers | Number of other organisms | Oxygen content | ph | Water EC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of larvae | Pearson Correlation | 0.170 | 0.437 | 0.193 | -0.357 | -0.393 | -0.078 | 0.094 | -0.329 | -0.069 | 0.356 |
| | Sig. (2-tailed) | 0.001 | 0.000 | 0.002 | 0.000 | 0.000 | 0.628 | 0.521 | 0.000 | 0.359 | 0.000 |
| | N | 355 | 187 | 248 | 92 | 89 | 41 | 49 | 148 | 177 | 183 |

**Table 2 The stepwise regression model coefficients**

| Factor | β | t value | Sig. |
|---|---|---|---|
| Constant | -10.42 | -1.759 | 0.079 |
| Turbidity | 19.00 | 9.733 | 0 |
| Water Electro conductivity | 1.762E-02 | 5.73 | 0.000 |
| Paddy height | -0.182 | -4.333 | 0.000 |
| Water depth | 0.538 | 3.67 | 0.000 |
| Temperature | 0.529 | 3.307 | 0.001 |
| Number of other organisms | -0.256 | -2.628 | 0.009 |
| Paddy density | -0.124 | -2.625 | 0.009 |

a Dependent Variable: Number of larvae

**Table 3 ANOVA table for the stepwise regression analysis model**

| | Sum of squares | d.f | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 32840.501 | 7 | 4691.5 | 32.995 | 0.000 |
| Residual | 82042.953 | 577 | 142.189 | | |
| Total | 114883.45 | 584 | | | |

g Predictors: (Constant), turbidity, water EC, paddy height, water depth, temperature, number of other organisms, paddy density

h dependent variable: number of larvae

**Table 4 indicating the Stepwise regression Model Summary**

| Model | R | R square |
|---|---|---|
| 1 | 0.391 | 0.153 |
| 2 | 0.458 | 0.21 |
| 3 | 0.485 | 0.235 |
| 4 | 0.506 | 0.256 |
| 5 | 0.52 | 0.271 |
| 6 | 0.527 | 0.277 |
| 7 | 0.535 | 0.286 |

1 Predictors: (Constant), Turbidity
2 Predictors: (Constant), Turbidity, Electro Conductivity
3 Predictors: (Constant), Turbidity, Electro Conductivity, Paddy Height
4 Predictors: (Constant), Turbidity, Electro Conductivity, Paddy Height, Water Depth
5 Predictors: (Constant), Turbidity, Electro Conductivity, Paddy Height, Water Depth, Temperature
6 Predictors: (Constant), Turbidity, Electro Conductivity, Paddy Height, Water Depth, Temperature, Number of Other organisms
7 Predictors: (Constant), Turbidity, Electro Conductivity, Paddy Height, Water Depth, Temperature, Number Of Other organisms, Paddy Density

**Table 5 Analysis of variance of the linear regression of AML and paddy rice density**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 4017.33 | 1 | 4017.34 | 13.11065 | 0.0005 |
| Residual | 27577.54 | 90 | 306.42 | | |

**Table 6 Analysis of variance of the Quadratic regression of AML and paddy rice density**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 8078.13 | 2 | 4039.07 | 15.29 | 0.0000 |
| Residual | 23516.74 | 89 | 264.23 | | |

**Table 7 Analysis of variance of the linear regression of AML and water depth**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 3230.62 | 1 | 3230.62 | 10.49707 | 0.0013 |
| Residual | 108640.70 | 353 | 307.76 | | |

**Table 8 Analysis of variance of the Quadratic regression of AML and water depth**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 3230.62 | 2 | 3515.48 | 11.80316 | 0.0000 |
| Residual | 104840.37 | 352 | 297.84 | | |

**Table 9 Analysis of variance of the linear regression of AML and water turbidity**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 17621.77 | 1 | 17621.77 | 43.77844 | 0.0000 |
| Residual | 74466.50 | 185 | 402.52 | | |

**Table 10 Analysis of variance of the quadratic regression of AML and water turbidity**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 18241.74 | 2 | 9120.87 | 22.72606 | 0.0000 |
| Residual | 73846.52 | 184 | 401.34 | | |

**Table 11 Analysis of variance of the linear regression of AML and water temperature**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 3944.95 | 1 | 3944.95 | 9.53648 | 0.0022 |
| Residual | 101762.54 | 246 | 413.67 | | |

**Table 12 Analysis of variance of the quadratic regression of AML and water temperature**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 5606.28 | 2 | 2803.14 | 6.86075 | 0.0013 |
| Residual | 100101.21 | 245 | 408.5764 | | |

**Table 13 Analysis of variance table of the linear regression of AML and paddy rice height**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 4865.29 | 1 | 4865.29 | 15.86403 | 0.0001 |
| Residual | 26681.77 | 87 | 306.69 | | |

**Table 14 Analysis of variance table of the quadratic regression of AML and paddy rice height**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 8844.95 | 2 | 4422.47 | 16.75 | 0.0000 |
| Residual | 22702.11 | 86 | 263.98 | | |

**Table 15 Analysis of variance table of the linear regression of AML and water electro conductivity**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 7943.61 | 1 | 7943.61 | 26.32285 | 0.0000 |
| Residual | 54621.48 | 181 | 301.78 | | |

**Table 16 Analysis of variance table of the quadratic regression of AML and water electro conductivity**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 8016.04 | 2 | 4008.02 | 13.22559 | 0.0000 |
| Residual | 54549.04 | 180 | 303.05 | | |

**Table 17 Analysis of variance table of the linear regression of AML and water oxygen content**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 5194.65 | 1 | 5194.65 | 17.69802 | 0.0000 |
| Residual | 42853.35 | 146 | 293.52 | | |

**Table 18 Analysis of variance table of the quadratic regression of AML and water oxygen content**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 5347.09 | 2 | 2673.55 | 9.07859 | 0.0002 |
| Residual | 42700.91 | 145 | 294.49 | | |

**Table 19 Analysis of variance table of the linear regression of AML and water pH**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 298.17 | 1 | 298.17 | 0.84582 | 0.3590 |
| Residual | 61690.51 | 175 | 352.52 | | |

**Table 20 Analysis of variance table of the quadratic regression of AML and water pH**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 437.65 | 2 | 218.83 | 0.61860 | 0.5399 |
| Residual | 61551.03 | 174 | 353.74 | | |

**Table 21 Analysis of variance table of the linear regression of AML and number of other organisms**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 28.19 | 1 | 28.19 | 0.41776 | 0.5212 |
| Residual | 3171.81 | 47 | 67.49 | | |

**Table 22 Analysis of variance table of the linear regression of AML and number of other organisms**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 28.29 | 2 | 14.14 | 0.20514 | 0.8153 |
| Residual | 3171.71 | 46 | 68.95 | | |

**Table 23 Analysis of variance table of the linear regression of AML and number of tillers**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 9.28 | 1 | 9.28 | 0.23895 | 0.6277 |
| Residual | 1514.77 | 39 | 38.84 | | |

**Table 24 Analysis of variance table of the quadratic regression of AML and number of tillers**

| | Sum of Squares | d.f. | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 42.47 | 2 | 21.23 | 0.54461 | 0.5845 |
| Residual | 1481.58 | 38 | 38.99 | | |

**Table 25 Paired Samples Test between the normal expected yields and the yields acquired when affected by malaria during the paddy rice growing season**

| Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | t | d.f. | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|
| | | | Lower | Upper | | | |
| 1269.3 | 699.6 | 52.4 | 1165.9 | 1372.8 | 24.208 | 177 | 0.000 |

**Author information**
Mr. Nanfumba David
Nature and Science
Volume:
Issue:
Page number:
ISSN:

**02nd May 2011**