

*Full Length Research Paper*

# Climate change and the abundance of edible insects in the Lake Victoria Region

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Global warming is adversely affecting the earth's climate and its profound effects are virtually on all ecosystem. Every living animal will be affected in one way or another by climatic changes and insects being an integral biotic component of nearly all ecosystems are not an exemption. However, the various ways by which change will occur is yet to be determined by scientists. Insects being an integral biotic component of nearly all ecosystems will be affected by the change in a variety of ways not yet determined by scientists. This partial review and empirical observation paper discusses how edible lake flies in Lake Victoria and termites in the lake region are responding to climate change and how they are likely to impact on entomophagy and gastrophagy as part of food chain among the riparian communities. The dynamics of the insect population have been observed by several households that collect the insects for domestic purposes. The focus is given to the lake flies (Ephemeroptera and Diptera), termites (Isoptera) and formicidae ants (Hymenoptera) which form part of livestock and human feed. Several factors of climate change are identified and discussed in relation to how they influence insect abundance. Ability to respond successfully to challenges requiring a lot of collaboration across different fields of study is solicited. It requires understanding of all stakeholders, how they will be affected by climate change and strategic adaptive measures open to all. Analysis of impact on humans' livelihoods with specific focus on developing countries is discussed. The interrelationship in the metamorphosis of entomology and entomophagy in food production in the region is proposed.

**Key words:** Lake flies, termites, climate change, edible insects, entomophagy.

## INTRODUCTION

There is increasing evidence that the earth's climate is undergoing change largely due to human activities. It is estimated that the global climate change will have profound impacts on virtually all ecosystems. Insects being an integral biotic component of nearly all ecosystems will be affected by the change in a variety of ways not yet determined by scientists. Studies point out that insect population is likely to increase with the changing climate (Saunders, 2008). Given that Lake Victoria basin is inhabited by the greatest diversity of insects, the climate change is set to influence both plants and insects alike. Insects have a unique symbiotic relationship with plant life (Fleshman, 2007). Plants and insects that may not adapt to new changes will have to give way to the survivors and these survivors will have to re-group at

different suitable habitats. Lake Victoria is the second largest fresh water lake and supports the largest fresh water fishery in the world. Over the past 75 years, the lake has become eutrophic due to deforestation, increased agriculture and urbanization, (Verschen et al., 2002). The climate change is already having an impact on the food security of the large population of persons within the Lake Victoria basin.

Entomophagy studies in several parts of the world indicate that consumption of insects is gaining ground not only in rural Africa but in many parts of the western societies (Huis, 2002; Huis, 2003; Saunder, 2008; Banjo et al., 2006; Ayieko et al., 2010). With the realization of the pending food shortage particularly in developing countries, the consumption of insects is sure to increase (Meyer-Rochow, 2009). As such, global climate change and the increasing food insecurity in many parts of the developing world may put insects on the menu for many families in many communities. This will particularly be

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so with the reduction in supply of conventional food items such as fish, meat, poultry or plant produce of which production is fast spiralling down with the climate change. Data and information on climate change show that agriculture and fisheries sectors are also being affected to a significant degree thereby influencing the already constrained food situation in Africa (Fleshman, 2006; Saunder, 2008). Although effects of climate change will be far from uniform around the world, the lake region is likely to be more vulnerable because of its biodiversity and the size of the population of people living in the area. Furthermore, the climate change is also having an impact of fisheries in the lake. The shift in the ecosystem due to climatic change is changing the resource base of fishery with far reaching consequences for local livelihoods. This change in the ecosystem of Lake Victoria is creating new opportunities in the livelihoods of the people around the lake. Many are attracted to take up fishing and related activities as observed in most fish landing beaches in Kenya. Climate change that has been observed to enhance the abundance of the insects is thus of an added advantage.

This paper therefore discusses how the edible lakeflies in Lake Victoria and the elate termites in the region are responding to climate change and how it is likely to impact on entomophagy and gastrophagy as part of food security among the riparian communities. The focus is given to the lake flies (Ephemeroptera and Diptera), and termites (Isoptera) and formicid ants (order Hymenoptera) which are normally collected within the lake region for domestic purposes such as feeding family members and poultry because of their unique food value. Other species are in use for traditional medicine and witchcraft (Ayieko and Oriaro, 2008; Banjo et al., 2006; Huis, 2002; Huis, 2003).

### THE EDIBLE INSECTS IN THE LAKE VICTORIA BASIN

Chaoborid and Chironomid larvae had been reported to be the most common insect larvae in Lake Victoria in the 1950s (Macdonald, 1956). Birds, human and many aquatic organisms feed on these lake flies. Of similar significance are the mayflies which traditional medicine practitioners have indicated to be of unique uses (Ayieko and Oriaro, 2008) and both bird and fish species feed on. In the 1980s, the lake's food web changed from a complex fauna with many species to a simplified food web dominated by three fish species (tilapia, *Oreochromis niloticus*, the Nile perch, *Lates niloticus* and a cyprinid, *Rastrineobolus argetea*) and one shrimp, *Ciridina niloticu* (Barel et al., 1985; Gouds et al., 2005).

This increased biomass of shrimps and lakeflies in the Lake Victoria region could be attributed to increased eutrophication and this provides additional feed for the Nile perch and other species in the lake region. The elate termites are important as human and poultry feed

(Ayieko, 2007; Ayieko and Oriaro, 2008). Grasshoppers are equally a delicacy, hence are used for human feeding. These insects form part of the food chain in the lake ecosystem that provides valuable food nutrients such as protein, vitamins and essential minerals in animal nutritional requirement. These are nutrients which are normally found to be lacking in poor communities within the lake region (Ayieko, 2007; Banjo et al., 2005). Insects are not only important for human nutrition, but also for other aquatic organisms in the lake which help to maintain the riparian ecosystem. However, with the changes in the benthic macrofauna community of the lake, the dynamics of the population and distribution of these insects may change.

### DYNAMICS OF THE EDIBLE INSECT POPULATION IN THE VILLAGES

The dynamics of the insect population have been observed by several households that collect the insects for home consumption. A total of 11 different groups of villagers surrounding the lake on the Kenyan side have reported an increase in insects. These households have collected lake flies and elate termite for a long period of time. (Ayieko, 2007; Ayieko and Oriaro, 2008). The villagers noted that lately there have been plenty of elate termites and edible lake flies. The edible lake flies are commonly referred to as "sam" by the locals living along the lake. Field observations indicated that there is a gradual increase in the observed abundance and frequency of swarming of the lake flies and elate termites relative to 5 to 10 years back. Based on our observations and that of the residents of Lake Victoria region, it was confirmed that the edible insects are more available than before. The lake flies and the elate termites have exhibited a prolonged period of emergence than residents had expected as a result of protracted period of rainfall. A case in point is the period between March and November, 2008 and 2009 when the villagers of the lake region collected edible insects throughout the season. Similarly, 12th and 13th May 2009 villagers in Kisumu East and West and Vihiga districts (in western Kenya) experienced a heavy emergence of elate termites which was fairly distinct from the normal swarming. In a normal situation, these insects would be collected from the onset of rains in March till early May only, but 2009 season yielded a surprisingly abundance of edible insects in the region.

### CLIMATE CHANGE AND EDIBLE INSECT POPULATION

Several factors of climate change have been identified to influence reproduction of insects. Dunn and Crutchfield (2006), Heegaard et al. (2006), Both et al. (2006),

Bale et al. (2002), Hunter (2001), Landsberg and Stafford, 1992) briefly outlined some of the factors that influence insect population. Weather conditions precipitated by climate change favour the increased emergence of insects. Moisture and temperature play a significant role in insect ecology. Climate change influence insect population by influencing benthic fauna and its biodiversity that supports the insects.

In East Africa, particularly in Uganda, the long-horned grasshopper, Orthoptera *Raspolia nitidula* Scopoli is a delicacy when in season. This insect is highly associated with forests (Owen, 1973) which are not yet affected by the current climate change. However, its emergence and swarming is highly dependent on the onset of the rain season which is currently unpredictable due to climate change. Nevertheless, this could affect it indirectly because it feeds on the seasonal lush growth of forest trees (Wellington and Trimble, 1984; Martinat, 1987). The unpredicted seasonal changes could affect the temporal distribution of the emergence and the quantity thereof. Insects have been reported to be sensitive to temperature increases and are known to be more active in higher temperatures (Schindler, 1980; Both et al., 2006; Dunn and Crutchfield, 2006; Heergaard et al., 2006). Patrick Durst, the FAO's Senior Forestry Officer, comment in an interview with Media Global on February 2008, that there is an expectation that if the climate change is warming, there will in fact be more insects. Indeed the observed increase in temperatures with the current climate change has favoured increased reproduction of the many other insects as observed by Dunn and Crutchfield (2006).

Several pointers confirm increased emergence of lake flies and elate termites among other insects of economic importance in the country side. For example, several termite mounds that have been known to yield only one swarm of elate termites annually are realizing more than one or two emergence in a year. Other termite mounds that had been dormant or giving just a few elates for several years are back in high production. Villagers are also witnessing emergence of elate termites in new places, indicating increased under the ground activities of the termites. Most likely this could be as a result of high temperatures on the physiology of the developing juveniles causing them to develop faster than the usual rate of development (Taylor, 1981). Studies have indicated that high temperatures also stimulate high fecundity in female insects consequently giving rise to a large number of individuals at emergence (Rattle, 1985).

Moisture availability and variability have also been shown to be a major determinant of insect habitats. In the recent past, weather conditions have kept termite mounds moist much longer in certain areas than in other years. This has also encouraged high reproduction in the termites and this has resulted in large populations of elates warming to form or founding new colonies. Swarming and migration in insects can also be triggered by changes in ambient temperature (Rabb and

Kennedy, 1979). Insects also respond to change in their thermal environment through migration, adaptation, or evolution (Dunn and Crutchfield, 2006). As such, the insects are able to adopt faster and widely spread to other areas to survive the climate changes, thereby increasing their availability to human consumers and other predators such as birds and fish in the lake region.

## INSECT HARVESTING AND CLIMATE CHANGE

Patrick Durst has also commented during the interview with Media-global that when crops fail due to adverse weather changes such as draught and flooding, most insects will survive the harsh conditions relative to other food sources such as plants (Saunders, 2008) because they tend to be hardy to such conditions. Polyphagous insects often utilize alternative food plants in times of scarcity because they can access and consume other suitable plant among the remaining plants that can survive dry conditions. Thus, polyphagous edible insects can be harvested sustainably for domestic consumption and be incorporated into the family diet requirement as sources of protein. This observation is therefore an encouragement to collection of edible insects for domestic use during such a time as this of climate change. Saunders (2008) suggested that commercialization and marketing of edible insects could create money-making opportunities and add key nutrients to the diet of many vulnerable populations. Saunders notes that given the rapidity with which many edible insects are able to reproduce imply that most insects do not have any real problems or threat to extinction. Edible insects are thus an ideal mini livestock. For example, lake flies are not likely to compete with other food production due to their natural habitat and choice of feeding habitat at the lake bottom because the lake flies nymphs inhabit the bottom of the lake. Whereas high ambient temperatures negatively impact on agricultural production on land, the same increases reproduction of edible insects which is an advantage for entomophagy (Coviella and Trumble, 1999). This increases in the frequency of emergence of insects as the developmental time for each generation becomes gradually shorter and shorter. The spatial distribution of elate termites in arid and semi-arid areas is likely to be improved by moisture availability and warmer temperatures which accompany climate change.

The major constraint in consumption of edible insects has been sustainability in supply. However, with careful considerations, the observed increased frequency of emergence of edible insect populations should promote the supply side economy of entomophagy.

## WATER QUALITY AND AQUATIC EDIBLE INSECTS

As alluded to, human activities have heavily contributed

towards the current climate change and global warming through their indiscriminate release of greenhouse gases. The emission of carbon gases which heavily contributes to the greenhouse gases which affects the PH of water. The high temperature also has an effect on dissolved oxygen in water. This in turn affects oxygen availability for both plants and insects that use water from the lake as their habitat (Elzinger, 1997). For example, the author explains that lake flies such as stoneflies and mayflies need plenty of dissolved oxygen in the water. Inadequate oxygen has negative impact on insect population. Population of mayflies has been reduced in certain areas of Lake Victoria due to pollution (Muli and Mavuti, 2001). These researchers noted changes in the lake ecosystem and that there is spatial distribution of the fauna attributed to the industrial effluence discharged from the lake catchments. Kisumu town (the Winam gulf) has witnessed reduced swarming of lakeflies within the past several years due to water pollution by the industrial effluence. The benthic macrofauna community of Winam gulf indicate changes from an Oligochaeta and Insecta classes of invertebrates dominated community to the present one now dominated by Phyla Mollusca and Oligochaeta due to pollution. Such changes have, even further reduced emergence of mayflies in certain areas of the lake.

Insects are well suited for use in environmental impact assessment because they respond to environmental perturbation in characteristic fashion, (Rosenberg et al., 1986) and the condition of the waters often can be monitored to a certain degree, through observing characteristics of some aquatic insect species. Certain species of insects can be used as bio-indicators of the status of the environmental conditions such as toxicity, bioaccumulation and bioavailability of environmental contaminants (Walton, 1989). As stated above, studies show that the presence of some edible aquatic insects in the lake can be used to monitor the environmental quality of the water (Schindler, 1980; Muli and Mavuti, 2001). Elzinger (1997) reported that stonefly nymphs require high concentration of dissolved oxygen and relatively pure waters. Their presence with a high diversity of other aquatic species indicates a measure of clean water quality. On the other hand, the presence of some chironomid larvae only indicated water pollution. Despite the above observations some villagers still, unknowingly, harvest the insects for domestic purposes.

Scientists have shown how chironomids may act as a proxy for water quality and temperature (Heegard et al., 2006; Both et al., 2006). Studies show that fossils of chaoborids and chironomids are widely used by palaeolimnologists as indicators of past environmental changes, including past climatic changes. The Environmental Change Research Centre at the University College London (UCL) also observes in their web sites that the midges are sensitive indicators of environmental changes. Chironomid larvae preserved in the lake

sediments can be used to make quantitative reconstructions of palaeoenvironmental change. The role of these lake flies in studying the environmental changes cannot be overstated.

Water renewal rate also play a role in population of the insects in Lake Victoria since the productivity and trophic state of lakes is a balance between nutrient supplies and water renewal (Schindler, 2009), which cause washout of nutrients. For example, Schindler (1980) says that lakes in high rainfall areas have a faster water renewal than lakes in more arid climates. Schindler (2009) further comments that several paleoecological studies such as Lewis et al. (2001), Croley and Lewis (2006), McCormick (1990), Hari et al. (2006), Winder et al. (2009), Rood et al. (2005), Schindler and Donahue (2006), Rood et al. (2008) have all shown how slight changes in the balance between precipitation and evapotranspiration can dramatically change conditions in lakes. Of late, the lake region has experienced erratic high rainfalls, higher water run-off in rivers and uncontrollable water pathways causing flooding in several areas such as Budalangi and Nyando districts in Kenya. The sporadic high rainfall pattern within the lake region has brought about changes in the physico-chemical properties of the lake water. The change in physico-chemical properties that defines the chemistry and biology of the lake has significantly influenced the population of the lake flies at certain points. Climate change determines the temperatures in which various species and communities of fauna and flora survive and it controls the rates of chemical weathering and evaporation, which in turn determine chemical concentrations of minerals in the water (Schindler, 1980). Schindler records that the release of sulphur and nitrate oxides from the burning of fossil fuels and sulphur con-taining ores are major contributors to the acidification of soft waters. Wild fires during extended dry spells in the lake catchments areas such as the one of March 2009 in the Mau Forest of Kenya to some extent contributed to acidification of the lake waters. Emission of carbon gases from such activities on the Nandi hills and surrounding Mau forests only add to weather changes within the lake basin. Pickford (2006) has reminded us that the harvest of elate termites flourished in the Namibian savannah and coastal regions as evidenced by the presence of numerous termite mounds. But when a massive climate change occurred, millions of years ago all the mounds were buried by sand dunes. Thus, indicating that such extinctions of insects are also possible with climate change. It is indeed a wake-up call to experience the current abundance of insects with the present climate change.

## **POTENTIALS OF EDIBLE INSECTS FOR LIVESTOCK FEEDING**

The lack of appropriate livestock feeds at affordable

prices has greatly contributed to the slow pace of development in aquaculture and agriculture particularly in East Africa. Research on aquaculture has shown that the demand for fish is increasing at a rate of 2.5% per annum. This rate is expected to increase despite the declining fish supply from the lakes, a factor exacerbated by the growing processing plants targeting the export markets which is likely to be destroyed by human activities (Barel et al., 1985; Gouds et al., 2005).

Feed used in commercial livestock production must contain all essential nutrients at adequate levels to meet total nutritional requirements of livestock for normal growth and development. Fish are generally fed on diets containing 28 to 32% protein, while for most livestock feeds, 15 to 25% protein are generally used (Donald et al., 2002; Edwin et al., 1998). *Rastrineobola argentea* has been the major animal protein source for most livestock species that allows high protein digestibility with amino acid profile, which closely matches the fish and poultry dietary requirements. On the other hand, Haplochromines that would provide the necessary feed quality has other competing need that is, it is used as food for human and also as a medicament. This has left the nutritionist with no choice other than seek for alternative feed sources for the livestock. The use of lake flies and grasshoppers in the livestock diets can greatly boost the macro and micro minerals to help curb on the deficiency diseases which result from the lack of sodium, potassium, cobalt, iodine, iron, copper, manganese, zinc, selenium and vitamin E, which are rampart nutritional challenges in livestock feeding. Grazing animals rely on pasture for their nutrition. The trace element content in pasture is measured in parts per million (ppm). There should be at least 10 ppm of copper, but only 0.25 ppm of iodine, 0.10 ppm of cobalt and a mere 0.03 ppm of selenium is enough for animals to grow well. If the soil in which the pasture grows lacks these trace elements, feed supplement for the livestock is necessary for their growth. Farmers choose what to feed their livestock, especially cattle, based on availability and the cost of feeding. Cattle feeds tend to be bulky and costly such that farmers often do not take into consideration nutritional value of the feed. This has led to nutrition deficiencies, hence diseases in various livestock species. Among the most important malnutrition is nutrient intake deficiency of macro and micro nutrients. Such deficiencies often predispose the livestock to various types of ill health conditions broadly referred to as metabolic diseases because it affects the animal ability to convert food into energy and growth. Nutrient availability in edible insects has been shown to be adequate to provide part of essential source of vitamins and minerals. The lake flies, termites and grasshoppers which are found in abundance with climate change provide additional option of the essential macro and micro minerals in feed supplements. Studies show that the high food nutrients in grasshopper and lake flies which range between 62 and 66% may help

in alleviating the negative balance of herd health and improve udder health common in cattle. For example, studies done by Brand et al. (2001) on nutrition and clinical mastitis found that vitamin E, A and Beta carotene and selenium had positive effects on the health of cattle especially on the improvement of udder health. Supplementation of livestock feed can be obtained by adding selected insects which are made abundant with climate change.

## CONCLUSION AND RECOMMENDATIONS

The amounts and pattern of emergence of insects during the onset of rainy season has been influenced by the changes in the weather patterns. This paper described how the climate change is impacting on edible insects. Periodicity of emergence of the insects has been influenced by the unpredictability of the onset of the rain season and other weather activity on which the emergence of the insects depend on but these influences are yet to be explored. It is expected that the climate change will have both positive and negative impacts on collection and utilization of edible insects for human consumption and livestock feeds formulation. The status of food security of the marginal areas around the Lake Victoria will depend on how scientists interpret and manage the climate change outcomes.

Ability to respond successfully to challenges as a result of climate changes requires a lot of collaboration across different fields of study. It requires understanding on the part of stakeholders, how they will be affected by climate change, and strategic adaptive measures open to all. Analysis of the status and impact of insect population change on humans' livelihoods with specific focus on developing countries is critical. Specifically, understanding the interrelationship in the metamorphosis of entomology and entomophagy in food production in the region is paramount in interpreting and managing the climate changes outcome on the lakeflies and the elate termites in order to understand and adopt appropriate measures for utilization of these edible insects.

The reducing number of swarming aquatic insects in certain areas is attributed to environmental pollution as a result of the global warming. The balance of the insect population and other consequences are subject to studies. Therefore, this discussion extrapolates scientific reasoning for the increase based on recorded documents. The changes could be considered a wake-up call for researchers to pay closer attention to insect population (Fleming and Volney, 1995; Fleshman, 2007; Fraser, 2006). This could be an opportuned time for increased entomophagy as an available means for insect control and also improved food security when other sources of food items decrease.

The relationship between insects, plants and climate may elicit new kinds of behaviour yet to be determined. It

is interesting to note that researchers have tended to record potential climate change effects of insects on human and animal health (Petzoldt and Seaman, 2008; Marigi et al., 2005; Marigi and Wairoto, 2005). This is particularly so, due to threats of increased transmission of pathogens. Resulting dynamics of effects of climate change on insects and plants may not necessarily be due to any single player but to their interactions. In any case, it is not certain that such interaction will maintain ecosystem stability, or lead to biodiversity instability (Bredenh, 2008; Connor, 2008; Coviella and Trumble, 1999). This is an issue yet to be researched more for future effective management. The interrelationship between moisture and temperature and the insect population may create new insect dynamics in the tropics with widespread influence on riparian communities. New things do happen with change! For example, Dunn and Crutchfield (2006) say that due to climate change, pine beetles have been noted to do things which have not been recorded before. The insects are attacking younger trees and attacking timber in altitudes they have never been before. What the future holds for edible insects is unknown. Formal research may help to unearth even additional phenomena. Different environmental factors may influence the rates of change in the composition and activities within and among groups of insects (Harrington, 2005; Harrington et al., 2001; Harvel et al., 2002). Multi-disciplinary proxy studies comprising of several independent groups of the insects can be used to reconstruct past environmental conditions and the future sustainability of the edible insect fauna.

The role played by insects as source of feeds for livestock cannot be overstated. This will go a long way in providing livestock feed concentrate to some of the animals that now compete for the same sources of feed. The current abundance of insects may be such an opportunity presenting itself. In view of the above changes and the interdependence of many aquatic species, there is need to investigate the biology and ecology of the edible insects and their impacts in general on the benthic fauna. This could spell the beginning of insect farming for food security! The bottom line is how we interpret the increased population of the edible insects. Is it a boon or just a wake-up call not yet answered?

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