Open Journal of Agricultural Biotechnology and Sustainable Development
Vol. 1, No. 1, June 2013, PP: 01 - 10
Available online at http://www.scitecpub.com/Journals.php

Research article

REVIEW ON COMMUNITY FOOD SECURITY AND EDIBLE INSECTS RESOURCES: BIODIVERSITY AND POLICY IMPLICATIONS FOR SAFEGUARDING HUMAN CONSUMPTION

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Abstract

The aim of this paper is to review the impact of climate change on food security with emphasis to alternative food resources such as edible insects in the Lake Victoria region. It goes further and outlines basic recommendations and policy issues for mitigation. There is increasing concerns that climate change is compromising achievement of the Millennium Development Goal activities. Climate change is affecting food security by influencing agricultural production, distribution and consumption pattern in many areas. The most affected nations are the developing countries such as Kenya whose efforts in poverty reduction have been reduced. Market forces and voluntary choices influence individual decisions about what food to eat and how to maintain good health under changing climate. Even though climate change indicators predict increase of land under crop production of third world, food production, distribution and consumption pattern of villagers remain evasive. Many African communities regularly eat edible insects. Climate change has seen such insects increase and the villagers are having a second look at entomophagy. However, the risks the villagers face is contamination by agrochemical pesticides. The government is thus called upon to oversee the wanton and indiscriminate use of the chemicals to safe guard the health of the villagers who practise entomophagy.

Key words: Entomophagy, Edible insects, Policy, Environment, Food Security

Introduction

The Food and Agriculture Organization (FAO) defines food security as a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO 2002; FAO 2006). In deed there is increasing concerns that climate change is undermining the achievement of a number of the Millennium Development Goal activities in achieving food security because of its impact on food production, distribution and consumption pattern. The most affected nations are the developing countries such as Kenya whose efforts in poverty reduction have been most reduced. Market forces and voluntary choices influence individual decisions about what food to eat and how to

maintain good health under changing climate. This paper therefore reviews the impact of climate change on food security with emphasis to alternative food resources such as edible insects in the Lake Victoria region. It goes further and outlines basic recommendations and policy issues for mitigation.

The Climate Change and its Impact

Like in other communities, climate change has impact on all major four elements of food security in Kenya: namely, the availability, access, stability and utilization, just as documented in the definition for food security. Climate change is affecting agriculture and food production in a complex way. It has impact on human health, livestock, livelihood assets, food production and distribution channels that ensures that the food is placed on consumers' table on time. Because it affects consumer purchasing power and market flow, it changes consumers' food consumption pattern. Many family members are experimenting with new foods and many other consumers are willing to consume new food items not familiar to them. The climate change also influences food safety and quality that go with it all (Schmidhuber and Tubiello, 2007). The basic dimension of the agricultural system to meet food demand includes the agro-climatic fundamentals of crop and pasture production and socio-economic and cultural factors that determine how farmers respond to market demands. Such a diverse demand calls for adoption of several production technologies many of which may not be safe for human and animal health. Food security and stability relates to individuals risks and uncertainty to access relevant resources for adequate food in the home. And of course the aspect of access entitles consumers to safe commodities over which a person can establish some reasonable health standard. As mentioned above, utilization embraces food safety and quality aspects of nutrition which determines health of the consumers. As families make efforts to diversify their diet, unprecedented risks and uncertainties originating from the use of agrochemical technology diminish their choices of food. Unhealthy consumer cannot ascertain food security for the whole family. Climate change is indeed posed to influence food security in many aspects of national security. It is not remote to say that food items may be there, but they are unavailable due to producers' practises.

Research work reveals that changes in temperature and precipitation associated with continued emissions of greenhouse gases may bring changes in land suitability and crop yields. In particular, the Intergovernmental Panel on Climate Change (IPCC) has considered four families of socio-economic development and associated emission scenarios, known as Special Report on Emissions Scenarios (IPCC, 2000; and 2007). The Special Report on Emissions Scenarios (SRES) assumes the highest projected population growth and is thus associated to the highest food demand. It is not a surprise that the group suggests that in temperate latitudes, higher temperatures are expected to bring predominantly benefits to agriculture. However, the consumers and producers activities interact to make the produce evasive. According to Schmidhuber and Tubiello (2007) another important change for agriculture is the increase in atmospheric carbon dioxide (CO_2) concentrations. The report says that higher CO_2 concentrations have a positive effect on many crops, enhancing biomass accumulation and final yield. Other changes are to be observed in land suitability, potential yields, and agricultural production on the current suite of crops and cultivars available today. Therefore, these estimates implicitly include adaptation using available management techniques to make food available for all the households. Fischer, Shah, and van Velthuizen (2002) shows that total land and total prime land would remain virtually unchanged. The main question remains: will productivity be sustainable at all levels? The expected regional shifts, with a considerable increase in suitable cropland at higher latitudes have already shown indications of invasion of several insects which are also looking for alternative survival lash land (Ayieko et al. 2010b). It is indeed a welcome idea that the pronounced shifts within the quality of cropland are predicted in developing countries where consumption of edible insects is not a new alternative to obtaining food for families.

It is now common knowledge that when climate fluctuations become pronounced and widespread, droughts and floods become severe and frequent as often experienced in many parts of Kenya. In semiarid areas, droughts can dramatically reduce crop yields and livestock numbers and productivity as has been witnessed in Kenya. How strongly these impacts will be felt will crucially depend on whether such fluctuations can be countered by investments in irrigation, better storage facilities, or higher food imports. In addition, a policy on environment that fosters safe use of forest products such as edible insects, wild plants and other mini-livestock, investments in transportation and communications will enable and promote access to exchange of food ideas to help address these challenges.

In third world nations, agriculture is not only a source of the food items but also a source of income. Anything affecting food production, affect the community source of income security. In a nation such as Kenya where agricultural production is synonymous to trade, the crucial issue for food security is not whether food is available but whether the monetary and non-monetary resources at the disposal of the population are sufficient to allow everyone access to safe and adequate quantities of food. Climate change adaptation should therefore go hand in hand with relevant mitigation

measures to soften its impact on peasant farmers who are likely to be subjected to unhealthy food items in the villages due to unsafe production technology.

Often food security in context of national consideration is discussed in the context of crop and animal production. Studies on the impact of climate change indicate that all forms of lives are subject to change. Some will be negatively affected while other will gain. It is thus the prerogative of scientist to stay vigilant to effectively identify humans' best option for survival. One least considered source of food, yet has demonstrated significant potentials for human feeding in the wake of climate change is edible insects as discussed below.

Entomophagy in the Food Chain

More than 2.5 billion people in Africa and Asia, eating insects is a common dietary practice and collecting edible insects for human and livestock feeding is a potential income generating activity for many women and youth in the rural areas (FAO 2010). Edible insects are confirmed highly nutritious and entomophagy is thus rooting its rightful position in the world food chain in many communities. The practice is progressing from a formerly thought position of a 'backward practice' to a 'healthy eating option' and is globally embraced. Because of being undervalued in the world food order, production and harvesting of edible insects has suffered lack of improved technology. Thanks to the current endeavours of FAO in promoting edible insect as forest resources. Researchers are now making commendable efforts to support insect farming for human consumption. Often many edible insects regarded as crop pests are nutritionally more valuable than the actual crop the peasant farmers try to protect. In such situations, farmers, therefore could be encouraged to farm insects as alternative to crops production.

In Kenya, almost all the edible insects are traditionally collected from their habitat in the forests using traditional methods. As a matter of facts, some insects would offer better food option if not contaminated by agrichemicals. In such a case the villagers would see edible insects as a healthy alternative harvest from their land and not simply as pests that need to be destroyed. The biodiversity would also benefit from unnecessary insecticides which pose the risk of pollution. Acceptance of insects as important food source in the wake of climate change would be significant in food security not only of the riparian community of the lake region, but the whole lake basin and parts of the coastal region where entomophagy is practised.

One most seasonally collected edible insect in western Kenya is termites. (Ayieko 2007, Ayieko et al. 2010a). Different species of termites are a delicacy in almost all the communities within the lake basin. Different species of termites emerge at different seasons and time of the day.

Fig 1: Picking termites by the garden in the afternoon

To collect termites, villagers simply lay-wait the insects and collect them one by one as they emerge from their habitats in the wild when they are in season (Figure 1). The figure shows a woman picking termites that suddenly started swarming as she was passing on a foot path early afternoon. Often the insects may emerge unannounced in the bush. When such an emergence of the edible insects occurs, the locals simply help themselves without a prior plan as the woman in the figure did. Like most other edible insects, termites have been collected for many decades by means of traditional technology because of the less importance previously attached to Entomophagy. This constrain is slowly changing with the efforts of FAO and other development supporters in the region.

The most popular species of termites are *Macrotermes subhylinus and Macrotemes bellicosus* (locally known as *Agoro and Sisi* respectively). The plump fat species, *Macrotermes subhylinus,* normally swarm at night and can be collected using light traps. However, due to the dangers involved in going out in the bush for insect collection, the villagers wait till morning before they can go to pick the insects that are burrowing underground to form new colonies. Villagers normally search for Agoro termites in the morning after the swarm (Figure 2).

Fig 2: Picking termites in the morning

In the day break after the emergence of Agoro, school children also spend a lot of time in the morning hours picking the most sought after species, Agoro. Figure 3 shows pupils from a local school searching for the burrowing insects on the road side. The collection makes an important and nutritious meal of the day. The teachers cannot contain children in classroom on such a day as this!

As mentioned earlier, 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 is affected by the change in a variety of ways not yet fully determined by scientists. Studies point out that insect population is likely to increase with the changing climate (Saunders, 2008; Ayieko et al 2010b). Given that Lake Victoria basin is inhabited by the greatest diversity of insects and plants, the climate change is set to adversely influence the ecosystem. Insects have a unique symbiotic relationship with plant life (Fleshman, 2007). Nature has that plants and insects that may not adapt to new changes always have to give way to the survivors, and the survivors re-group at different suitable habitats for new colonies - invaders.

Entomophagy studies indicate that consumption of insects is gaining ground not only in rural Africa but in many parts of the western societies as well (Huis, 2002; Huis, 2003; Saunder, 2008; Banjo et al., 2006; Ayieko et al., 2010b). With the realization of the pending food shortage particularly in developing countries, increasing entomophagy is an available option (Meyer-Rochow, 2009). Global climate change and the increasing food insecurity in many countries will put insects on the menu of many people. This will particularly be so given 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 new world

economic dispensation. Data 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, 2007; Saunder, 2008). Although the 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.

Fig 3: School children picking termites in the morning

Complementarities of Edible Insects and Lake Food Resources

The climate change is also having an impact of fisheries in the lake. The observed lake flies in the Lake Victoria partly 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 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 alternatives to earning income and business opportunities in the livelihoods of the people around the lake. As the fish yield in the lake reduces, alternative fish feed will be sought to sustain production by the fish farmers. The most promising base for the livestock feed is insects which are found in plenty in the lake region. Several insect species may be explored for livestock feed development in the region.

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 niloticus* (Barel et al., 1985). This increased biomass of shrimps and lake flies in the Lake Victoria region was attributed to increased eutrophication and provided additional feed for the Nile perch and other species in the lake region. The change in the biodiversity of the lake greatly influenced the food chain of the riparian community of the lake region. Proximate analysis of the dried lake flies shows that the flies have a crude protein of 72% on dry weight basis and this is higher than that of *Rastrineobola argentea and Haplochromines* (59%), the most common source of protein in livestock (Tamale et al 2010). The lake flies are rich in macro and micro elements crucial in the growth of the fish.

Nutritional value of edible insects

The value of insects as a food item is undisputed. Almost all edible insects are a significant source of short chain polyunsaturated fatty acids, iron, calcium and vitamin B complex. They are also rich in protein and the amino-acids composition of which are better than of grains and legumes. The crude fat content of only 10% in the dried lake flies is ideal for fish feed and 47.63% is also good for human consumption (Table 1).

Table 1: Proximate Analysis and Crude fibre of Termites and Lake Flies

Analysis	Termites	Sun-dried Lake flies
Moisture content (%)	58.32	11.6
Crude Protein (%)	45.85	72.00
Crude fat (%)	47.63	10.10
Crude fibre (%)	2.85	-

Source: *Ayieko, MA (2007). Nutritional Value of Selected Species of Reproductive Isoptera and Ephemeroptera Within the ASAL of Lake Victoria Basin. Journal of Discovery and Innovation, Vol 19(2), 126-130.*

Tables 2 and 3 demonstrate the good source of minerals and vitamins which are critical for both human and livestock health.

Table 2: Mineral Composition of Edible Termites and Lake Flies

Minerals (mg/100gm)	Termites	Sun dried lake flies
Calcium	22.0	25.55
Magnesium	42.63	32.01
Potassium	259.6	126.96
Sodium	123.6	77.35
Phosphorous	182.3	70.54
Iron	11.52	100.40
Zinc	10.23	5.62
Manganese	3.29	21.98
Copper	1.70	69.65

Source: *Ayieko, MA (2007). Nutritional Value of Selected Species of Reproductive Isoptera and Ephemeroptera Within the ASAL of Lake Victoria Basin. Journal of Discovery and Innovation, Vol 19(2), 126-130.*

Table 3: Vitamins Composition in Edible Termites and Lake Flies

Vitamins	Termites	Sun dried Lake flies
Retinol (μg/g)	2.41	0.19
α-Tocopherol (μg/g)	62.41	25.42
Niacin (mg/100g)	1.07	3.35
Riboflavin (mg/100g)	3.39	4.40
Ascorbic acid (mg/100g)	0.59	0.04
Folic acid (mg/100g)	0.18	0.14
Pyridoxine (mg/100g)	0.27	Traces
Thiamine (mg/100g)	1.98	Traces

Source: *Ayieko, et al. (2009). Value adding on edible insects for production of livestock feed formulae and entomophagy in the Lake Victoria basin. Annual Report*

Insects have a high food conversion rate, emit less greenhouse gases than conventional livestock and can be reared on organic waste (FAO 2010). The elate termites are important as human and poultry feed (Ayieko, 2007; Ayieko and Oriaro, 2008). 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 as reflected in the tables above. 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 are threatened.

Climate change and insects population

Several factors of climate change have been identified to influence reproduction of insects. Researchers have identified some of the factors that influence insect population (Dunn and Crutchfield, 2006; Heegaard et al. 2006; Both et al. 2006; Bale et al. 2002; Hunter 2001; Landsberg and Stafford 1992). Weather conditions precipitated by climate change favour the increased emergence of insects as 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.

Insects tend to be sensitive to temperature increases and are known to be more active in higher temperatures (Schindler, 1980; Fleming, 1995; Both et al., 2006; Dunn and Cutchfield, 2006; Heergaard et al., 2006). Patrick Durst, the FAO's Senior Forestry Officer, commented 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. Several pointers confirm increased emergence of lake flies (Chaoboridae and Chironomidae) and edible termites (*Isoptera Macrotermes***)** among other insects of economic importance. For example, several termite mounds are realizing more than one or two emergence per year. Studies have indicated that high temperatures also stimulate high fecundity in female insects consequently giving rise to larger swarms (Rattle, 1985). 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 lakes.

Recommendation and Policy Implication

Based on the above discussed issues ranging from food security, climate change and the use of edible insects, policy implications to safeguard consumption of edible insects is necessary. Elevating entomophagy from a mere subject of interest to mainstream strategy for rural development will require multifaceted effort put together or held in place with a sound food policy. There is no doubt that managing the impact of climate change requires globally consorted efforts. Individual national synergy in management of edible insects is paramount to promoting safety and food security in many ways. A key aspect in promotion of economic use of edible insects is controlled use of pesticides in areas where the villagers collect insects for human consumption. The use of organophosphorus insecticides in controlling crop pests may be harmful to insect collectors. Although harvesting insects may be less effective than the use of pesticides, it generates additional source of food item in the home, it reduces cost of chemical runoff and contamination in the village. Government's deliberate efforts in capturing the opportunity to integrate edible insects into food production system will reduce the current wanton destruction of native biodiversity. However currently there is lack of scientific information that can reinforce the above sentiments for policy makers, hence there is need for strategic research approaches with these objectives.

There is a dire need for the government to put in place a policy to identify and protect genetic resources of forest food species such as less known edible insects and their traditional knowledge base in Kenya. Feasibility studies to assess the potentials for product development of little known food items from edible insects are necessary. Regulatory government agencies may be called upon to facilitate identification for protection of those insects that are being heavily sought after than others. Conditions under which the specific circumstances arise should be analysed in order to place rules and regulations to monitor and control the habitat. The ecological impact analysis and consequences of long tern insect use and insect exploitation in their natural environment can only be done by effective government policies. Analysis of the biodiversity under scientific scrutiny may reveal the ecological balance that may be harmed by removal of certain highly sought after species. On the other hand, exploitation of species more desired by locals as food insects may cause unknown consequences to the environment. These are issues that can be carefully examined and effective policy be put in place to guard the biodiversity.

Programs such as insect tissue culture for genetic improvement can only be undertaken by government after realization of the value of the insects to food security of a community. Tissue culture has potential for promoting insect farming. If insect farming is undertaken, insect diseases and insect pest need to be given attention, not only in the view of the acceptability of the insect product by human consumers, but also in regard to the economic financial viability of such insects breeding facilities.

Conclusion

Until ethno-entomology becomes recognized as a serious field of research with inputs from wide range of discipline, the above entomophagy concerns may not be adequately addressed as an important source of food item for community. Enhancing the acceptance of entomophagy in practice and as a scientific discipline will be an important first step in promoting insects as food in Kenya. Policy paper will first raise awareness on the importance and underutilized resources, then embark on a nationwide baseline information study on edible insects before claiming control of key food resources for its population.

Food security is multifaceted. Availability, access, stability and utilization aspects all work together to bring about physically and socially healthy individuals to ensure economic stability of a nation. It is expected that the climate change will have both positive and negative impacts on both crops and animals that communities look up to for wealth creation. The status of food security of the marginal areas around the Lake Victoria will depend on how scientists interpret and manage the climate change information. Ability to respond successfully to challenges as a result of climate changes requires multidisciplinary approach. 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 country specific food sources is critical. Understanding the interrelationship in the metamorphosis of entomology and entomophagy in food production in the region is paramount in interpreting and managing climate changes and outcome.

Acknowledgement

We wish to thank VICRES and RPSUD for financial support and all those who contributed their expertise or were involved in the projects at different stages.

References

[1] Ayieko MA (2007). Nutritional value of selected species of reproductive isopteran and ephemeroptera within the ASAL of Lake Victoria basin. Discovery. Innovation. **19**(2): 126-130.

[2] Ayieko MA, Oriaro V (2008). Consumption, indigenous knowledge and cultural values of the lakefly species within the Lake Victoria region, Afri. J. Environ. Sci. Technol., **2(**10): 282-286.

[3] Ayieko MA, Oriaro V, Nyanmbuga IA (2010a). Processed products of termites and lake flies: Improving entomophagy for food security within the Lake Victoria region, Afr. J. Food. Agric. Nut. Devel., **10**(2): 2085-2098.

[4] Ayieko MA, Ndonga MFO, Tamale A (2010b). Climate change and the abundance of edible insects in the Lake Victoria region. Journal of Cell and Animal Biology **4**(7): 112-118.

[5] Bale JS, Masters GJ, Hodkinson ID, Awmack C, Bezemer TM, Brown VK, Butterfield JA, Buse JC, Coulson J, Farrar JEG, Good R, Harrington S, Hartley TH, Jones RL, Lindroth MC, Press I, Symrnioudis AD,

[6] Banjo AD, Lawal OA, Sngonuga EA (2006). The nutritional value of fourteen species of edible insects in Southern Nigeria. Afr. J. Biotechnol., **5**(3): 298-301.

[7] Barel CDN, Dorit R, Greenwood PH, Fryer G, Hughes N, Kawanabe PBN, McConel HRH (1985). Destruction of fisheries in African lakes. Nat., p. 315.

[8] Both C, Bouwhuis S, Lessells CM, Visser ME (2006). Climate change and population decline in a long distance migratory birds, Nat., 441: 81-83.

[9] Dunn D, Crutchfield JP (2006). Insects, Trees, and Climate: The bioacoustic ecology of deforestation and entomogenic climate change. Santa Fe Institute Working paper New Mexico, 06: 12-30.

[10] Fleming RA, Volney WJA (1995). Effects of climate change on insect defoliator population processes in Canada's boreal forest: Some plausible scenarios. J. Water. Air, Soil. Poll., **82**(1-2): 445-454.

[11] Fleshman M (2007). Climate change: Africa gets ready. Planning how to deal with higher temperatures and shifting weather, Africa Renewal, United Nations, (website), **21**(2): 1-8.

[12] Fischer G, Shah M, van Velthuizen H (2002). Climate Change and AgriculturalVulnerability, A Special Report Prepared as a Contribution to the World Summit on Sustainable Development (International Institute for Applied Systems Analysis, Laxenburg, Austria).

[13] Food and Agriculture Organization (2002) The State of Food Insecurity in the World 2001 (Food and Agriculture Organization, Rome).

[14] Food and Agriculture Organization (2006). The State of Food Insecurity in the World 2006 (Food and Agriculture Organization, Rome).

[15] Food and Agriculture Organization (2010). Promoting the contribution of edible forest insects in assuring food security. Forestry Department Programme on Edible Insects; Forest Economy, Policy and Products Division; Information Flyer 6 pages, Rome

[16] Heegaard E, Lotter AF, Birks HJ (2006). Aquatic biota and detection of climate change: Are these consistent aquatic ecotones, J. Paleolimnol., **35**(3): 507-518.

[17] Huis van A (2002). Medicinal and stimulating properties ascribed to arthropods and their products in Sub-Saharan Africa. Insects in oral literature and traditions. Elizabeth Motte-Florac and Jacqueline M.C. Thomas, (Eds). Paris Louvai, Peeters-SELAF Ethnosciences, pp.367-382.

[18] Huis van A (2003). Insects as food in Sub-Saharan Africa. Insect Sci. Appl. **23**(3): 163-185.

[19] Hunter MD (2001). Effects of elevated atmospheric carbon dioxide on insect-plant interactions. *Ag.* For. Entomol. **3**: 153-159.

[20] Intergovernmental Panel on Climate Change (2000) Special Report on Emissions Scenarios, Summary for Policy Makers, Working Group III, International Panel on Climate Change (Cambridge Univ Press, Cambridge, UK).

[21] Intergovernmental Panel on Climate Change (2007) Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge Univ Press, Cambridge, UK), in press.

[22] Landsberg J, Stafford SM (1992). A functional scheme for predicting the outbreak potential of herbivorous insects under global atmospheric change. Aust. J. Bot., **40**: 565-577.

[23] Meyer-Rochow VB (2009). Entomophagy and its impact on culture of the world: The need for a multidciciplinary approach. Cultural impact of entomophagy and ethnoentomophagy. FAO- press Books, New York.

[24] Owen DF (1973). Man's environmental predicament: Introduction to human ecology in tropical Africa. London: Oxford University Press, pp. 132-136.

[25] Rattle HT (1985). Temperature and insect development. Environmental Physiology and Biochemistry of insects. (Hoffman KH Ed.), Springer- Varlag, Berlin, pp. 33-65.

[26] Saunders A (2008). FAO serves up edible insects as part of food security solution. *Mediaglobal*, (February, 2008), United Nations Secretariat, New York, FAO Rome.

[27] Schindler DW (1980). Aquatic ecosystems and global ecology. Fundermentals of aquatic ecology. 2nd Ed. (Barnes RSK, Mann KH, Eds.). Blackwell Science.

[28] Schmidhuber J and FN Tubiello (2007). Global food security under climate change. www.pnas.org/cgl/dol/10.1073/pnas.0701976104

[29] Tamale A, Sifuna TM, Glaston KM, Ayieko M, Ndonga, FO, and T. Otude (2010). Use of May flies (*Ephenoptera*) as total replacement of *Rastrineobola argentea* in diets of catfish (*Clarias gariepinus*) in Lake Victoria Basin. Africa Journal of Animal and Biomedical Sciences **5**(3): 99-105

[30] Verschen D, Thomas J, Hedy JK, Edington DN, Leavitt PR (2002). The chronology of human impact on Lake Victoria, East Afr. Proc. *R. Soc.* London, B 269.