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Biodiversity of Insect Vectors and Parasites: Prospects and Challenges in the 21st Century

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Abstract

This paper examines diversity of insect vectors and parasites/vector-borne diseases also the successes and challenges in vector control in the 21st century and the way forward suggested. The generally accepted insect biodiversity is estimated to be 5.5 million worldwide with only about 1.5 million described. Generally, four insect orders: Coloeptera, Lepidopera, Hymenoptera and Odonata have been well studied and broadly described. Majority of insect species are known to be beneficial to man and the environment however, insect vectors which are fewer have been identified as causes of morbidity. Mosquitoes which are hematophagous insect vectors are known to be the leading vector for human infectious agents. Insecticides majorly dichloro-diphenyl-trichloroethane (DDT) were therefore used for the control of insect vectors. This succeeded only for a short while in the 19th century due to insect vector resistance and the widely condemned ecological disadvantages. This led to the development of safer and more effective insecticides such as the pyrethriods although also plagued with the tendencies of insect vector resistance. However, it has been strongly indicated that there are links between drivers of global biodiversity modification and vector-borne diseases. This is identified as the strongest reason for control programs that are all encompassing, engaging different fields and institutions, communities and individuals. The Integrated Vector Management (IVM) is therefore, advocated as the way forward for control of insect vector in the 21st century. It is encouraged to be practised putting the basic principles of biodiversity conservation which are ensuring biological diversity, ecological integrity and resilience in proper perspective.

Keywords: Diversity, vector-borne diseases, Insecticides, Control of insect vector, vector resistance.

INTRODUCTION

Biological diversity also referred to as biodiversity has been defined as the variety of life, in all of its many manifestations (Gaston, 2010; Sodhi and Erhlich, 2010). Wilson (1988) have also defined biodiversity as the variety of life at every hierarchical level and spatial scale of biological organisations such as genes within populations, populations within species, species within communities, communities within landscapes, landscapes within biomes, and biomes within the biosphere. Convention on Biological Diversity (CBD) has further elaborately defined biodiversity as variability

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among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD, 1992). The World Resource Institute (WRI) estimated that the total number of species on earth was about 14 million, of which only about 13 percent have been scientifically described (Figure 1) (WRI, 1995).

Furthermore, about 26,000 plants and 5,400 animals that have been described are threatened with extinction. However, the United Nations (UN) recently reported even higher rates of extinction of species; up to 1 million species of plants and animals are reported to be threatened with extinction (UN, 2019). According to UN (2019), the current global estimate of plant and animal species is 8 million including 5.5 million insects. The current status of some taxa is further elucidated in Table 1.

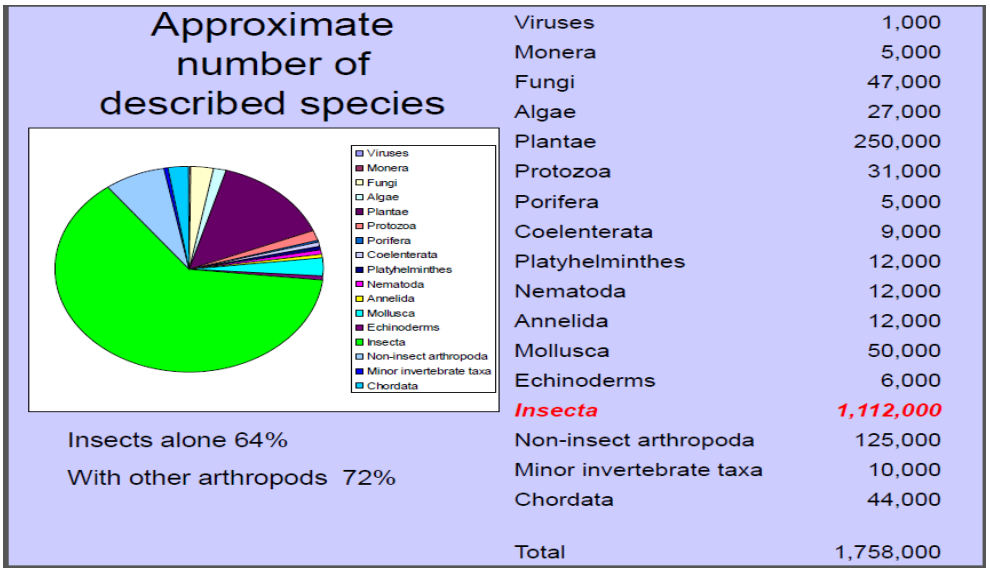

Figure 1: Approximate number of described species (Adapted from Matu, 2017)

Table 1: Species, Populations and variety of animals and their current status

S/N	Group	Current status
1	Vertebrates:	
	Reef forming corals, sharks and sea mammals.	About 33% are threatened with extinction.
	Amphibians.	More than 40% are threatened with extinction.
	Domesticated breed of birds	3.5% were extinct by 2016.
	Domesticated breed of mammals	About 10% were extinct by 2016 with at least 1000more threatened
2	Insects	About 10% are threatened with extinction

Adapted from UN (2019).

Biodiversity has continued to decline (Brooks *et al*., 2006) especially over the past four decades (Butchart *et al.,* 2010). Predictions of global change impacts on biodiversity show continuing, and in many cases, accelerating species extinction, loss of natural habitats, and changes in the distribution and abundance of species and biomes over the 21st century (Leadley *et al.,* 2010). The implication of these loses is that many plants and animals, including many potentially valuable species are on the fast track to extinction, hence, lost of their ecosystem functions. Similarly, biodiversity in Nigeria is highly threatened due to factors such as land use changes from agriculture and overgrazing, over exploitation of natural resources, introduction of invasive species and environmental pollution. The causal factors to this continual degradation of biodiversity in Nigeria have been categorised into: high population growth rate, poverty, policy and legislation constraints. Other categories are poor land use planning, governance and transparency, socio-cultural characteristics, food and trade connections and effect of climate change (CBD, 2015). According to the International Union for the Conservation of Nature (IUCN) Red list 2013, Nigeria has a total of 309 threatened species in the following taxonomic categories: Mammals (26), Birds (19), Reptiles (8), Amphibians (13), Fishes (60), Molluscs (1), other Invertebrates (14) and Plants (168), (CBD, 2015).

From the foregoing, it is clear that insects have the highest diversity among all animal groups hence to make insect biodiversity a subject matter of national and international discourse is very proper. Their contributions ecologically, economically, medically and otherwise through their roles as keystone organisms, ecosystem engineers, pollinators, parasitoids, and agents of disease are excellent topics which can generate information very key to insect conservation. A critical aspect of insect conservation, however, is the need for people to change their perceptions of insects as a whole from harmful or dirty to one of a pivotal part of the maintenance of ecosystem form and function (Hawksworth, 2011). This discussion therefore, briefly considers insect biodiversity and prospects/challenges of insect – vector management in the 21st century in relation to biodiversity generally.

Insect Biodiversity

Arthropods form an important part of the world's biomass and they contribute significantly to biodiversity richness and morbidity. For these reasons, arthropods are considered essential for life on earth (Takken, 2008). The Class Insecta is vast in numbers of species in comparison to other living organisms and insects are still a frontier in scientific exploration. Although, the exact number of insect species are not known, the question "How many species are there?" has been the bases for many biodiversity studies (Stork, 2007). Estimates of up to 30 million extant species have been proposed, although excellent arguments have been made for lower estimates of between 5 to 15 million (Stork, 2018).

Generally, only about 1.5 million insects have been described (Figure 1) out of the estimated 5.5 million insect biodiversity (Briggs, 2014; Stork, 2018). And about 80–95% is estimated and yet to be collected, named and described; most of them suggested being in the tropics (Stork, 2007). According to a report by the IUCN Species Survival Commission, about 80% of the world's species are invertebrates and about 20% of them are threatened with extinction. Furthermore, that of the world's terrestrial invertebrates, about 90% is insects (Brigs, 2014). Four orders of insects: Coloeptera, Lepidoptera, Hymenoptera and Odonata have

been studied and extensively described (Figure 2), (Solis, 1999; Stork 1997).

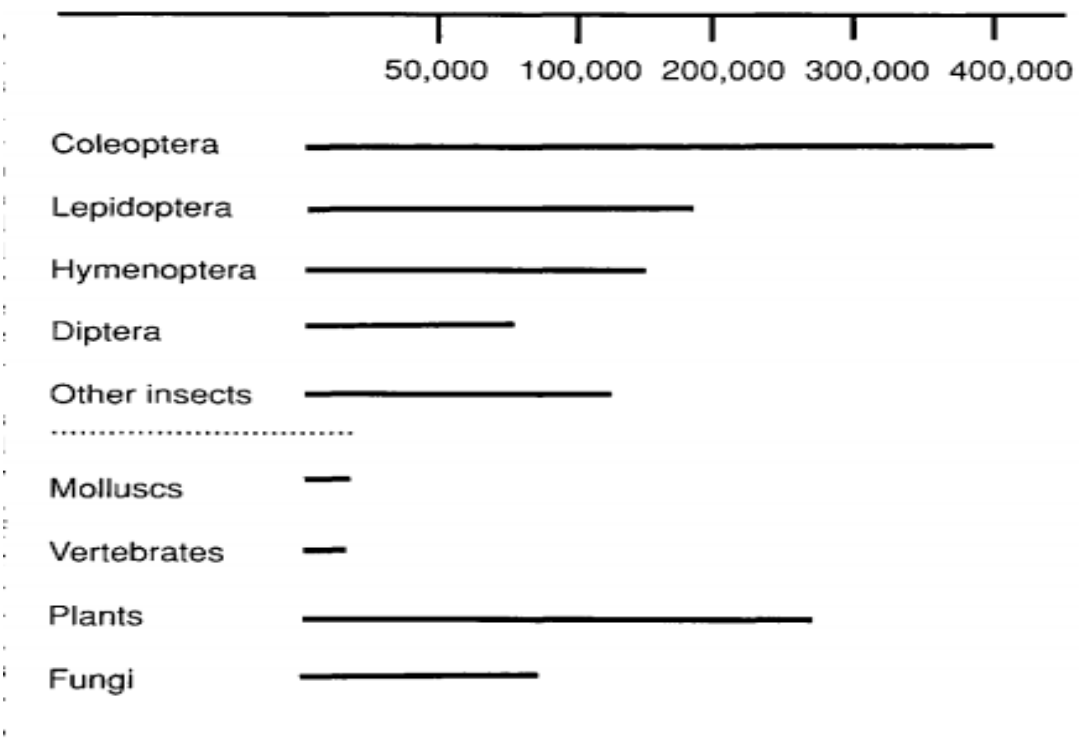

Figure 2: Approximate number of species described for some group of organisms (Modified from Stork, 1997)

Many insects have complex biologies with beneficial traits, such as the honeybee, which is responsible for the fertilisation of many plant species and, in the process, produces honey and wax which are important commodities for mankind. Another example is parasitic wasps, which act as effective natural enemies of herbivorous pests in forestry and agriculture. In the same light, ants are often a forgotten group of beneficial insects that have an important role in the food web in a wide range of ecosystems. Many times, however, bees and ants are viewed as harmful because of their painful stings (Takken, 2008); also mosquitoes and flies are known carriers of disease pathogens (Nwoke, 2015). In this way, these insects enter the world of public health. The more valid point of discuss may then not be how many insects there are but how do humans perceive their biological and ecological patterns that results from selective pressures on the organisms? This may become the key to understanding and, ultimately, surviving in our environment (Silos, 1999).

Biodiversity of Insect Vectors and Parasites: Prospects in the 21st Century

A vector is an animal that transmits a disease to other organisms. An insect that transmits a disease is known as an insect vector, and the disease it transmits is referred to as a vector-borne disease (Purcell and Almeida, 2005;

Wilson *et al*., 2017). It is worthy of note that vector- borne diseases have been reported to account for about 17% of infectious diseases globally (WHO, 2017). Insects can act as mechanical vectors, meaning that an insect can carry an organism but the insect may not be essential to the organism's life cycle, such as when house flies carry organisms on the outside of their bodies that cause diarrhoea in people. Insects can also serve as obligatory hosts where the disease-causing organism must undergo development before being transmitted as in the case with malaria parasites.

Vector-borne transmission of disease can take place when the parasite enters the host through the saliva of the insect during a blood meal (for example malaria and dengue) or from parasites in the faeces of the insect that defecates immediately after a blood meal (for example, Chagas disease), (Meyer, 2003). Parasites transmitted by insects often circulate in the blood of the host, with the parasite residing in and damaging organs or other parts of the body. This comparatively small, but very important group of insects, however, have become infamous because of their status as vectors carrying pathogens and parasites. A few of which are well known because of the history of their epidemiology are listed in Table 2.

Table 2: Insect vector and parasite diversity and their diseases

Insect (vector)	**Insect order/Family/Genus**	**Parasite**	**Disease**
Assassin or kissing bugs	Hemipterans, Reduviidae, genera *Triatoma* and *Rho dnius*	*Trypanosomacruzi*	Chagas disease
Human lice (*Pediculushumanus* and *P. capitus*)	Phthiraptera,Pediculidae, *Pediculus species*	*Borellia recurrentis* *Rickettsia prowazeki* *Rickettsia Quintana*	Epidemic relapsing fever Epidemic typhus Trench fever
Horse flies	Diptera,Tabanidae,	*Pasteurella tularensis* *Bacillus anthracis*	Tularaemia anthrax
Horse flies	Diptera, Tabanidae	*Loa loa*	Loiasis
Blackflies	Diptera, Simulidae,*Simulium*	*Onchocerca volvulus*	*Onchocercaisis – river blindness*
Phlebotomine sand flies	Diptera,Psychodidae, *Phlebotomus*	*Bartonellabacilliformis* *Leishmania* species	Carrion's disease Leishmaniasis
Biting midges or Punkies	Diptera,Ceratopogonidae,	Vector of parasitic roundworms in several genera, including *Acanthocheilonema, Dipetalonema, Mansonella*, and *Onchocerca*.	
Tsetse flies	Diptera, Glossidae, *Glossina*	*Trypanosoma brucei gambiense*, *Trypanosoma brucei rhodesiense*	Trypanosomiasis (Sleeping sicknes)
Rat fleas	Siphonaptera, Pulicidae, *Xenopsylla cheopis*	*Pasturellapestis*	Bubonic plague
Mosquitoes	Diptera, Culicidae, *Anopheles*	*Plasmodium* species	Malaria fever
Mosquitoes	Diptera, Culicidae, *Aedesa egypti*	Yellow fever virus	Yellow fever
Mosquitoes	Diptera, Culicidae, *Aedesa egypti*	Dengue virus	Dengue fever
Mosquitoes	Diptera, Culicidae, *Culex, Mansonia and Anopheles species*	Wuchereria bancrofti and Brugia malayi	Filariasis

Adapted from Meyer, 2003.

Steady successes have been recorded in the control of insect vector – borne diseases worldwide within the past decades (IVCC, 2019). With continues multi-stakeholder cooperation, much more can be achieved given the advancements in vector control techniques in the 21st century (Nwoke, 2015; Aju-Ameh *et al.,* 2018). It is known that among insect vector biodiversity, the hematophagous insect vectors, mosquitoes are the leading vector for human infectious agents (Álvarez-Hernández and S-Rivera, 2017). The *Anopheles gambiae* complex has been particularly indicted for possessing threats to human life in Nigeria and the whole of sub-Saharan Africa (Aju-Ameh *et al.,* 2017). The introduction of DDT (dichloro-diphenyl-trichloroethane) in 1943 therefore, gave immediate success in the control of mosquitoes. This led to reduction in malaria infection globally; but these successes were soon short lived as a result of insect - vector resurgence due to resistance developed by the vectors to the insecticides (Mafuyai, 2014; IVCC, 2019). This necessitated the development of other insecticides such as the Pyrethriods which are used as indoor residual sprays (WHO, 2012). Insect vectors are in a sort of evolutionary arm race with new insecticides (Krebs and Davies, 1993) this is very likely as resistance to pyrethriods have also been reported (Oxborough, 2015, Cook *et al.*, 2018), hence, new and inexorable ones need to be developed.

Massive mobilisations for the usage and the actual use of long-lasting insecticidal mosquito nets (LLIN) have been attained in a number of African countries (Nwoke, 2015). For example between 2012 and 2014, a cumulative total of 427 million LLINs were supplied for use in sub-Saharan Africa, mostly free of charge through mass distribution campaigns (Oxborough, 2015). The rapid scale up of LLIN distribution has resulted in an estimated 49% (44–54 %) of households in sub-Saharan Africa owning at least one insecticide treated net (ITN) in 2013 compared with only 3% in 2004 (Oxborough, 2015). As a result substantial reduction in the prevalence of malaria has been recorded even in areas were disease was highly endemic (Nwoke, 2015). Although, reports have also shown that there was no significant reduction in global malaria cases between 2015 and 2017 (WHO, 2018).

Effective vector transmission depends on each component in the vector-borne system (pathogen, vector and reservoir) but it also depends on the interactions of these components within their environment, which can affect them directly or indirectly (Álvarez-Hernández and S-Rivera, 2017). Therefore, besides all the vector control strategies used so far, a multifaceted control intervention such as the integrated vector management (IVM) assures to be the most reliable in achieving national and international goals in the coming years (Nwoke, 2015; Aju-Ameh *et al*., 2017; Niang *et al.,* 2018). This is in view of the limitations in earlier vector control intervention measures also the trend of environmental challenges in the 21st century which are majorly habitat modifications and climate change (Samways, 2005). IVM is characterised by the following:

1. Influencing local vector biology, disease transmission and morbidity
2. Use of a range of interventions, often combination and synergistically
3. Collaboration within the health sector and other public private sectors that impact on vectors
4. Engaging with local communities and other stakeholders

5. Giving consideration to Public health regulatory and legislative framework

Biodiversity of Vectors and Parasites: Challenges in the 21st Century

Impacts of habitat degradation and fragmentation, changes in land use, introduction of invasive species and climate change are obvious environmental challenges in the 21st century (Mwansat and Da'an, 2014). These footprints of man's activities are fast eroding the diversity of species on earth and these have dire consequence for man. For example the frequency and severity of infectious disease outbreaks in human, wildlife, and domesticated species are increasing (Sutherst, 2004; Pongsiri *et al.*, 2009; Civitello *et al.*, 2015, Vijayapushpam *et al.*, 2018). These concurrent patterns have prompted suggestions that biodiversity and the spread of diseases are linked. Therefore, global interactions and environmental/ climate change could indeed increase the risk of vector invasion and the spread of vector-borne diseases (Keesing *et al.*, 2010; Manguin and Boëte, 2011; Dobson and Auld, 2016), (Figure 3).

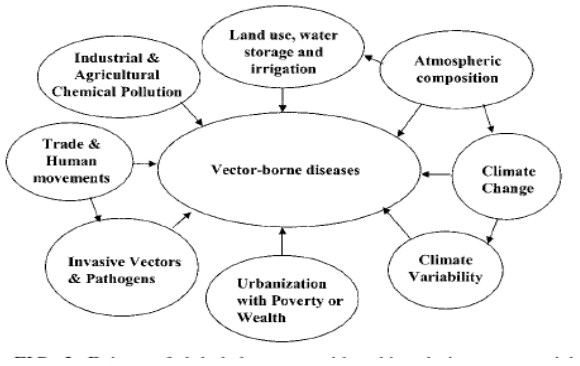

Figure 3: Drivers of global change considered in relation to potential changes in the status of vector-borne diseases (Adapted from Sutherst, 2004).

This is substantiated by the dilution effect hypothesis which posits that these patterns are causally related. Diverse host communities inhibit the spread of parasites via several mechanisms, such as by regulating populations of susceptible hosts or interfering with parasite transmission (Manguin and Boëte, 2011; Bowden and Drake, 2013; Dobson and Auld, 2016) (Figure 4).

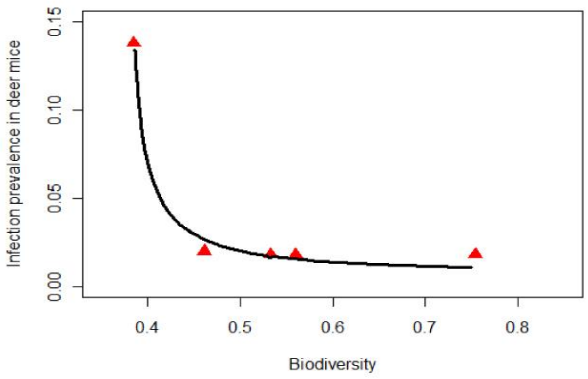

Figure 4: Evidence of dilution effect, shown by decline in prevalence of Sin Nombre virus in Deer mice with increasing biodiversity of surrounding community (Adapted from Bowden and Drake, 2013).

WAY FORWARD

It is important to remember that while some species of insects are vectors, majority are beneficial to people and the environment. Therefore the task of conserving and managing insect biodiversity should be taken as core by all, especially entomologists. Since it is very popular that there is an established link between biodiversity and diseases transmission, pathogens can be managed by sustainably managing biodiversity (Keesing *et al.*, 2010). A collective knowledge, innovative collaborative research programmes and national and

international initiatives are important steps to be taken and sustained. This will provide a hopeful perspective such that these diseases may be brought under control, or perhaps even be eradicated (Takken, 2008). Crucial to all successful action for biodiversity conservation, however, is awareness from the local community to national and international levels (Samways, 2005); this is the key for behavioural change in people that is much needed for success.

In conclusion, it is hereby recommended that integrated vector management (IVM) is the safest strategy so far for vector control. However, this should be consciously conducted in the light of the principles of conservation by maintaining:

i. the natural diversity found in living systems (biological diversity).
ii. the composition, structure, and function of these systems (ecological integrity) and
iii. their resiliency and ability to endure over time.

Doing these will ensure biodiversity and environmental sustainability.

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