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RESEARCH ARTICLE

ECTOPARASITES OF SMALL MAMMALS: ECOLOGY, INFECTION AND MANAGEMENT IN THE CHANGING WORLD

*Zeyede Teshome and Teklay Girmay

Department of Biology, Adigrat University, P. O. Box, 50, Adigrat, Ethiopia

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ABSTRACT

Small mammals are one of the most successful and diverse groups of mammals which inhabit a wide range of habitats in different area of the world, and most of them are rodents. Small mammals with their arthropod ectoparasites which live near to human's inhabitation play a significant role in the transmission of diseases to humans and domestic animals. The transmission of pathogens to humans is influenced by climatic variability such as, flooding, change in rainfall pattern and increase in temperature which may cause small mammals with their ectoparasites of disease vectors to be displaced from their natural habitats. As a result, bring them into closer contact with humans and domestic animals which increase potential zoonotic disease transmission. Moreover, climate change may also result changes in human lifestyles, such as an increase in outdoor activities which increase human-wildlife contact leading to potential human exposure for pathogens and their vectors in the small mammals reservoirs. Therefore, identifying the type and extent of vector distributions of public health concern in response to climate change will enable us to deploy better and more accurate management strategies against zoonotic disease spread.

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INTRODUCTION

Small mammals are one of the most successful and diverse group of mammals which occupy different types of habitats and most of them are rodents. Rodents which live near to human inhabitations play a significant role in the transmission of diseases to humans and animals. These rodents also play a significant role as pests in the agriculture and cause economic losses (Paramasvaran, 2009). Though, rodents are helping to maintain the ecosystem by being the most important herbivores in almost any ecosystem, they also are the important reservoirs of viral, rickettsial and bacterial pathogens that cause diseases in humans and livestock. Rodent-borne diseases in humans include plague, typhus, spotted fever, Hantavirus and Lyme disease and those diseases that are transmitted by arthropod vectors that infect rodents (Woodhouse *et al.,* 2001). The arthropod ectoparasites of rodents are important vectors of pathogenic microorganisms and parasitic zoonoses, like babesiosis, plague and others (Paramasvaran, 2009). Arthropod ectoparasites show a wide range of forms of association with their hosts, including obligate to facultative, permanent to intermittent, and superficial to subcutaneous. The salivary and faecal antigens produced by ectoparasites can stimulate immune responses. In some individuals they may cause hypersensitivity. Some ectoparasites are also vectors of protozoa, bacteria, viruses, cestodes and nematodes. The behaviour of ectoparasites also may cause such harm as disturbances, increasing levels of behaviour, such as rubbing, and leading to reduced grazing ability in animals (Van den Broek *et al.,* 2003).

Ectoparasites, such as mites, flea and ticks, which live in permanent association with their hosts are usually small and highly susceptible to factors such as desiccation and have relatively low mobility. The risks associated with living without their host and finding another food are adequately high for these animals excessive virulence leading to the death of the host might result in their own death and failures in reproduction. Therefore, these ectoparasites are generally obligate host-specific specialists and cause minimal damage or in some cases existing as commensals. Ectoparasites abundance and activity may be affected by a wide range of abiotic factors such as climate change that directly affects the host and the environment in which occupied by them (Wall, 2007). Ectoparasites are found everywhere and cause a lot of damage and in most cases cannot be permanently eradicated.

Corresponding author: Zeyede Teshome
Department of Biology, Adigrat University, P. O. Box, 50, Adigrat, Ethiopia

That is why they must usually be managed at a local scale with chemical control like insecticides. However, the growth in resistance, the slow rate of development of new actives with environmental and health concerns associated with the continued use of some of the existing neurotoxin insecticides suggest that more sophisticated approaches to their management need to be identified. These approaches are good for ectoparasites populations to be maintained at normal levels and conserve the compounds that remain available. Generally the development of integrated approaches in which cascades of management strategy and parasiticides are may be the most appropriate means for achieving this purpose (Wall, 2007). Therefore this paper is aimed to review the ecology and the public health significance of ectoparasites of small mammals and summarize some of the novel approaches used to their management.

Ectoparasites of small mammals and climate change concerns

Recent studies suggest that tropical hosts and parasites might be impacted by increasing temperatures as those at higher latitudes regardless of the slight increases in tropical temperatures (Deutsch, 2008). Because tropical climates are less variable and tropical organisms are adapted to almost same temperature ranges than are temperate and arctic species which are more sensitive to slight climate changes (Deutsch, 2008). And also because of metabolic rate increases when temperature increases and organisms in the tropics adapted to a greater change in metabolism with increasing temperature than organisms in temperate and Polar Regions (Dillon, 2010). Actually when we see both recent global warming and the relationship between metabolic rate and temperature, organisms in tropical and northern temperate zones are experiencing the largest increase in metabolic rates. Thus, they are being impacted most by climate change (Rohr *et al.,* 2011). In addition to this, ectoparasites may also be related to habitat selection by the host and as a result when habitats are disturbed and the composition of the small mammal community changes, ectoparasites may be transfer to different hosts near to their microhabitat. And also, the occurrence of ectoparasites living on more than one host species may be related to the behavior, intra and interspecific relationship of hosts and with the microhabitats used by the host (Thanee *et al.,* 2009).

There is an obvious paradox in literature that focuses about climate change and disease relationships that explain climate change will reduce biodiversity including parasite diversity (Dobson, 2008). In fact, parasites might be more sensitive to secondary extinctions than might non-parasitic species. This loss of parasite diversity may contradict with the belief that climate change will generally increase diseases (Lafferty and Kuris, 2009). So in order to solve this paradox, we must understand the parasite declines caused by climate change and the dilution effect that explains in the way that biodiversity generally reduces wildlife and human diseases (Rohr *et al.,* 2011). Therefore this controversy surrounding climate change and disease interactions needs further research; for example the study on the tick borne zoonotic Lyme disease shows that reduction of wildlife biodiversity increases the risk of infection to humans (Thomas and Renaud, 2005).

For example, anthropogenic disturbance favors several conditions favorable for flea-borne disease spread in which it causes higher infestation levels, greater flea abundance and greater host utilization. And also, it facilitates greater flea exchange and higher flea infestation levels because of its effect on diversity which may favor generalist host and vectors (Thanee *et al.,* 2009). Disturbed habitats may also play an important role in facilitating the range expansion of vectors because of climate change or global warming. Those regions that are already damaged are mostly affected by the negative consequences of such expansion of vectors whereas range expansions may be more limited in areas less affected by disturbance. This is due to the presence of natural checks and balances which reduce the conditions that promote flea exchange from one host to another (Friggens and Beier, 2010). Therefore, climate change will generally increase contact between humans and wildlife diseases because of the conditions that promote ectoparasites expansion on small mammals. They occupy variety of natural habitats and they move toward human settlements due to climate change or global warming that cause the disturbance or loss of their wild natural habitats.

Parasite ecology

Little attention is given for the role of parasites in ecology or ecosystem function, because they have low biomass, low visibility and small direct roles in energy and material flows in natural ecosystems (Thomas and Renaud, 2005). However, they have significant indirect roles in ecosystem properties, by controlling dominant host species, top-down control and maintaining the diversity of lower trophic levels. Moreover, they have a great role by shifting from parasitic to mutualistic interactions with their hosts and by making limiting nutrients to have more or less efficient recycling pathways (Thomas and Renaud, 2005). Nowadays, the potential importance of parasites and disease emphasize both direct and indirect effects in ecosystems even though indirect effects have received increasing attention in community ecology (Thomas and Renaud, 2005).

The most common vector-borne diseases, such as Lyme disease, are transmitted by ticks (Hainesa *et al.,* 2006). Recent studies show that tick populations are increasing so that climate change may increase tick numbers and caused widespread tick-borne diseases. Mostly ticks inhabit woodlands and meadows with hosts such as deer, rodents, other small mammals and birds (Thomas and Renaud, 2005). The impact of most ticks on human health are less in urban environments but increasingly they occur closer to home where a moist microhabitat is provided by high grass, gardens and rough forest edges (Hainesa *et al.,* 2006). The diversification of flea assemblages is also associated with climate change (Krasnov, 2005). The specificity of ectoparasites may also be related to microhabitat selection by the hosts. As a result, when habitats are disturbed and the composition of the small mammal community changes, ectoparasites may inhabit different hosts near their microhabitats and may move to closer to human and their livestock (Thanee *et al.,* 2009).

The occurrence of a particular ectoparasites species living on more than one host species may also be related to the behavior, intra and interspecific relationships and with the microhabitats utilized by the host (Bettencourt, 2003). Ectoparasites that parasitize a large number of small mammal species is common with ticks suggested that these ectoparasites usually occupy a particular habitat and as a result tend to parasite a wide range of hosts living in that particular habitat. For example, in many species of ticks exchange among hosts is common (Bettencourt, 2003). When comparing remote and urban area, most study showed that trends of diversity consistent with ecosystem simplification and flea host use became more generalized as disturbance increased (Friggens and Beier, 2010). Specifically, the proportion of generalist flea species and the average number and proportion of host species infested by each flea species increased with increasing disturbance. Clearly anthropogenic activity can potentially increase disease risk through changes in flea host utilization patterns (Thanee *et al*., 2009). In general, it is better to emphasize on both the direct and indirect effects of ectoparasites on the ecosystems as a whole and on the potential importance of parasites in zoonotic disease transmission in relation to climate change. Climate change is a major factor for the disturbance of natural habitats which cause changes in the composition of the small mammals' community. As result, ectoparasites may inhabit different hosts near their microhabitats and may move to closer to human inhabitation and their livestock which facilitate zoonotic disease transmission.

Infection mechanisms

Small mammals are among the most ubiquitous and important components of terrestrial ecosystems and now coexist with a diverse array of parasites that play key roles in the transmission and maintenance of parasitic diseases. The current climate change and global warming will impact on rodents by causing habitat shifts and their interaction with humans. This suggests that temperature is the major factor influencing the reproductive potential of rodents and that this reproductive potential is increased during the warmer months or during rainy seasons which intern increases risk of infection to human and animal (Hainesa *et al.,* 2006). Other climatic factors such as precipitation can increase rodent populations and urban rodents can be infected with a wide range of pathogens such as *Salmonella*, which causes Salmonellosis infection, and typhoid fever, which is a life-threatening illness of human. In addition to this, the transmission of pathogens to humans is also influenced by climatic factors, such as flooding, which may cause rodents to be displaced from their habitats. As a result, bring them into even closer contact with humans and increasing the likelihood of disease transmission. Changes in the climate may also result in changes in human lifestyles such as an increase in outdoor activities. This in turn affects rodent populations more where more food is available (Thomson *et al.,* 2010). Anthropogenic disturbance is also associated with conditions conducive to increased transmission of flea-borne diseases in that most measures of flea infestation intensified with increasing disturbance or peaked at intermediate levels of disturbance. Therefore, future trends of habitat and climate change will probably favor the spread of flea-borne disease.

An infected flea is more likely to attempt to feed and thereby infect a greater number of host species than an uninfected flea (Friggens and Beier, 2010). Thus, flea-borne disease spread is a function of the characteristics of the flea communities and these characteristics in turn, are influenced by host availability and microclimate preferences (Blagburn and Dryden, 2009). It is generally accepted that increased anthropogenic activity leads to decreased ecosystem heterogeneity and stability which increases disease transmission. In particular, changes in diversity can have many consequences for flea community structure with direct implications for disease spread. First, ecosystem simplification can favor host species that are natural reservoirs or good intermediate hosts for zoonotic disease (Keesing *et al.,* 2006). Commonly, these host species are habitat generalists that benefit from disturbance-related declines in abundance of habitat specialists (Keesing *et al.,* 2006). In addition, these generalist host species often carry more diverse flea communities and higher flea loads both of which are associated with increased disease transmission. Second, increases in the densities of generalist host species favors transmission of vectors and their pathogens.

Third, disturbance can also favor generalist vector species which are important determinants for the spread of zoonotic disease among wildlife populations due to their tendency to feed from a variety of taxa (Molyneux, 2003). For this reason, increased abundance of generalist vectors is strongly associated with increased parasite transmission and incidence of disease outbreaks in both human and wildlife population (Molyneux 2003). And also, bacterial, viral or parasitic diseases are transmitted to humans and animals by the bite of infected ticks (Friggens and Beier, 2010). The families Ixodidae and Argasidae contain many bloodsucking species that are important pests of man and wild mammals. They probably exceed all other arthropods in the number and variety of disease agents they transmit and many of the tick-borne diseases are zoonotic (Hainesa *et al.,* 2006). Small mammals are important in the maintenance and transmission of many zoonotic pathogens with increasing urbanization and the resulting emergence of tick-borne zoonotic diseases (Hainesa *et al.,* 2006). In case of Africa, poor housing and overcrowding of small mammal results in closer contact and makes it easier for these ectoparasites to bite humans and their livestock.

The socioeconomic conditions also favoring rodent infestation continue to persist in many rural and urban areas (Omudu and Ati, 2010). In conclusion, the effects of climate change on health are likely to be predominantly negative and its impact is most heavily on low-income countries like African countries where ability to acclimatize this condition is weakest. And climate change may affect health through a range of pathways; as a result of increased floods and droughts, changes in the distribution of vector-borne diseases, and effects on the risk of disasters and malnutrition. Consequently, the overall stability of effects on health is expected to be negative and populations in low-income countries are likely to be mostly vulnerable to the adverse effects of climate change (Hainesa *et al.,* 2006). Therefore, the ecological perspective of human health suggests that the foundations of long term good health lies within the persistent stability and performance of the living world or life support systems.

Why ectoparasites management?

Nowadays there is an important change in ecology, climate and human behavior that favor the development of pests (Thomson *et al.,* 2010). Climate change is particularly relevant because it is expected to alter not only the natural environment but also the urban environment as a result of changes in land use, temperatures increase, change in precipitation patterns, higher sea levels and more extreme weather condition such as flooding will become more frequent and will impact pest populations. These changes need to be carefully assessed the potential threat of pests to public and environmental health. Therefore, the development of pest and pest-related disease management is the most appropriate methods used to protect public health (Thomson *et al.,* 2010). Identifying the type and extent of vector response to habitat change will also enable better and more accurate management strategies for anthropogenic disease spread (Friggens and Beier, 2010). For non-isolated populations complete eradication is not a practical, sustainable or economically viable option and the persistent pressure of immigration results in rapid breakdown within control areas.

Furthermore, without central coordination, the limited and geographically inconsistent manner in which insecticides and endectocides are used by individual farmer's results a best temporary local control and necessitates more frequent repeated application (Wall, 2007). Current management strategy for many ectoparasites is repeated treatment rather than eradication. This has deep implications for the approaches that can be used sustainably for ectoparasites management. Until the end of the 19th century pest and parasite control depends almost entirely on relatively inefficient but low cost management practices such as pasture hygiene, pasture rotation, crutching, digging, clipping and the use of natural plant derived insecticides, sulphur, dusts, oils and highly toxic heavy metals (Wall, 2007). Then following the development of synthetic neurotoxins in the 1940s the relatively low cost, ease of application, speed and efficiency of insecticides rapidly propelled them towards being main methods applied against ectoparasites (Eisler *et al.,* 2003).

However, in recent years the human health and environmental contamination associated with the use of some of the older neurotoxin compounds, such as the organ chlorines, organo phosphates and pyrethroids has seen concerned their gradual withdrawal and restriction in some areas of the world (Eisler *et al.,* 2003). This has been counter balanced by the development of new actives, such as the phenylpyrrazoles, chloro-nicotinyl insecticides, semicarbazones and the use of compounds such as the insect growth inhibitors and their derivatives (Eisler *et al.,* 2003). On the other hand, the development of new actives and the beginning of a novel product is rare (Geary *et al.,* 2004). The concern surrounding this issue is sensitized by the rapid development and spread of insecticide resistance (Bates, 2004). Widespread insecticide resistance now exists in most major groups of ectoparasites and clearly, a major very important thing is now the need to conserve existing actives and use them in such a way that they are retained for effective use when necessary (Rust, 2005). The need to reduce the rate of development of resistance and to minimize the environmental contamination that may result from repeated application of some classes of compound suggests that more sophisticated approaches to the management of parasites and the use of parasiticides are required (Rust, 2005). Community-wide rodents control strategies with strong emphasis on community participation needs to be employed to prevent the increase of rodent population. However, further epidemiological and zoonotic investigations needs to be conducted in order to determine the role of household rodents in the lifecycle of emerging new infections in Africa (Omudu and Ati, 2010).

Ectoparasites management: the new approaches

Successful management of rodent problems depends upon correct identification of the rodent species involved and obtaining information on the biology, ecology and behavior in domestic ecological situation (Omudu and Ati, 2010). Preservation and conservation of functional and diverse ecosystems may be an effective strategy for limiting zoonotic disease spread by controlling the expansion of ectoparasites in wild habitats and their transfer to human settlement due to their small mammal hosts like rodents (Peter *et al.,* 2005). In the development of approaches which allow effective management of ectoparasites populations which minimize non-target effects and preserve the availability of our existing parasiticides and it is essential to develop the use of integrated programmes. In such away, a cascade of management tactics may bring effective action to be used in appropriate conditions (Peter *et al.,* 2005).

The adoption of such approaches, however, will require substantive changes in the thinking about parasites and wide ranges of new tools are becoming available to assist in this goal. These include molecular techniques, which are providing powerful new insights into diagnosis and re-interpretation of parasite taxonomy and epidemiology (Wall *et al.,* 2002). Particularly the use of satellite images are allowing a more comprehensive understanding of climatic constraints limiting spatial distribution or botanical repellents the use of resistant or resilient strains of livestock and a fuller understanding of the effects of better nutrition may also have important contributions. In addition to this, the ectoparasites control such as biological control and the identification and the possibility of selective treatment of susceptible individuals may be good approaches for control of ectoparasites expansion (Wall *et al.,* 2002).

Biological control

Biological control is the use of naturally occurring biological pathogens, such as nematodes, bacteria, fungi and viruses, which is particularly interesting approach to ectoparasites management. For example, the common bacterium, *Bacillus thuringiensis* has been used on sheep in small-scale field tests for the prevention of blowfly strike, lice of poultry, sheep body lice and buffalo fly (Gough *et al.,* 2002). However, so far the use of *B. thuringiensis* has not achieved a wider field application. The use of fungal pathogens for the control of agricultural insect pests has been widely considered. However, only a small number of studies have considered their use against arthropod ectoparasites (Gough *et al.,* 2002). Previous work had shown that the fungal pathogen *Metarhizium anisopliae* can infect ticks on livestock, giving mortality in experimental trials of 30 and 37% for *Rhipicephalus appendiculatus* and *Amblyomma variegatum*, respectively but in field experiments, *M. anisopliae* was shown to induce mortalities of 83% in *R. appendiculatus* which were naturally infesting Zebu cattle (Kaaya *et al.,* 1996). Also biocontrol deliberate introduction or augmentation of biological agents such as pathogens, parasites and predators to control arthropod ectoparasites and further researches are recommended to develop a more wide-ranging account of ectoparasites in different locations and habitats which can improve knowledge regarding host-parasite relationships, biology and ecology for developing better control strategies in changing world (Madinah, 2011).

Targeting susceptible individuals

It is a well-recognized feature of many host-parasite systems that the parasite population is distributed within the host population in dispersed or clumped manner. As a result, the majority of hosts carry relatively few parasites while a small number of heavily infected hosts carry high parasite burdens comprising the majority of the parasite population (Blagburn and Dryden, 2009). Such distributions have been observed for almost all parasite taxa. The presence of highly aggregated parasite burdens may result in increased density-dependent effects on parasite size, fecundity and survival and may increase the probability of parasite-induced host mortality and at high degrees of parasite aggregation, selective control of only a few highly infested individuals will be needed to achieve effective reduction of the parasite population (Barger, 1985). Generally synthetic neurotoxin insecticides have provided over 50 years of effective parasite control; they are highly effective, easy to apply and relatively inexpensive (Wall, 2007). However, their obvious advantages, resulted in a degree of satisfaction in the way they were used, leading to ongoing problems of resistance and concerns over environmental contamination and effects on human health and to preserve the availability of those compounds that remain. It is important to develop parasite management programmes which have a multiplicity of techniques into which insecticide use can be integrated wisely because, integrated control may help to reduce the frequency of insecticide treatment and preserve refugia. Therefore, it helps to delay the development of resistance. However, to allow this development better information is required about the effects of ectoparasites on animal welfare and productivity especially when at relatively low abundance and further research is also now needed to develop the range cost-effective and environmentally compatible approaches that will be available (Wall, 2007).

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REFERENCES

Barger, I.A. 1985. The statistical distribution of Trichostrongylid nematodes in grazing lambs. *International Journal of Parasitology,* 15: 645-649.

Bates, P. 2004. Therapies for ectoparasiticism in sheep. *In Practice,* 26: 538-547.

Bittencourt, B.E.C. and Rocha, F.D. 2003. Host-ectoparasites Specificity in a Small Mammal Community in an Area of Atlantic Rain Forest (Ilha Grande, State of Rio de Janeiro), Southeastern Brazil. *Memórias do Instituto Oswaldo Cruz,* 98(6): 793-798.

Blagburn, L.B. and Dryden, W.M. 2009. Biology, Treatment, and Control of Flea and Tick Infestations. *Veternarian Clinic of Small Animals,* 39: 1173-1200.

Deutsch, C.A. 2008. Impacts of climate warming on terrestrial ectotherms across latitude. Proceedings of the National Academy of Sciences of the United States of America, 105: 6668-6672.

Dillon, M.E. 2010. Global metabolic impacts of recent climate warming. *Nation,* 467: 704-707.

Dobson, A. 2008. Homage to Linnaeus: how many parasites? How many hosts? Proceedings of the National Academy of Sciences of the United States of America, 105: 11482-11489.

Eisler, M.C., Torr, S.J., Coleman, P.G., Machila, N. and Morton, J. F. 2003. Integrated control of vector-borne diseases of livestock pyrethroids: panacea or poison? *Trends in Parasitology,* 19: 341-345.

Friggens, M.M. and Beier, P. 2010. Anthropogenic disturbance and the risk of flea-borne disease transmission. *Acta oecologica-international journal of ecology,* 164: 809-820.

Geary, T.G., Conder, G.A. and Bishop, B. 2004. The changing landscape of antiparasitic drug discovery for veterinary medicine. *Trends in Parasitology,* 20: 449-455.

Gough, J.M., Akhurst, R.J., Ellar, D.J., Kemp, D.H. and Wijffels, G.L. 2002. New isolates of Bacillus thuringiensis for control of livestock ectoparasites. *Biological Control,* 23: 179-189.

Hainesa, R.S., Kovatsa, D.C. and Lendrumb, C.C. 2006. Climate change and human health: Impacts, vulnerability and public health. *Public Health*, 120: 585-596.

Jones, K.E. 2008. Global trends in emerging infectious diseases. *Nation*, 451: 990-994.

Kaaya, G.P., Mwangi, E. N. and Ouna, E.A. 1996. Prospects for biological control of livestock ticks, Rhipicephalus appendiculatus and Amblyomma variegatum, using the entomogenous fungi Beauveria bassiana and Metarhizium anisopliae. *Journal of Invertebrate Pathology,* 67: 15-20.

Keesing, F., Holt, R.D. and Ostfeld, R.S. 2006. Effects of species diversity on disease risk. *Ecological Letters,* 9: 485-49.

Krasnov, B.R., Jason, R., Rohr, Andrew, P., Dobson, Pieter, T.J. Johnson, A., Kilpatrick, M., Shenbrot, G.I., Khokhlova, I.S. and Poulin, R. 2005. Diversification of ectoparasites assemblages and climate: an example with fleas parasitic on small mammals. *Global Ecology and Biogeography,* 14: 167-175.

Lafferty, K.D. and Kuris, A.M. 2009. Parasites reduce food web robustness because they are sensitive to secondary extinction as illustrated by an invasive estuarine snail. *Philosophical transactions of the Royal Society B: Biological sciences,* 364: 1659-1663.

Madinah, A., Fatimah, A. Mariana, A. and Abdullah, M.T. 2011. Ectoparasites of Small Mammals in four localities of Wildlife reserves in Peninsular Malaysia. *Southeast Asian*

Journal of Tropical Medicine and Public Health, 42(4): 803-813.

Molyneux, D.H. 2003. Climate change and tropical disease: common themes in changing vector- borne disease scenarios. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* 97: 129-13.

Omudu, E.A. and Ati, T.T. 2010. A Survey of Rats Trapped in Residential Apartments and Their Ectoparasites in Makurdi, Nigeria. *Research Journal of Agriculture and Biological Science,* 6(2): 144-149.

Paramasvaran, S., Sani, R.A., Hassan, L., Krishnasamy, M., Jeffery, J., Oothuman, P., Salleh, I., Lim, K.H., Sumarni, M.G. and Santhana, R.L. 2009. Ectoparasite fauna of rodents and shrews from four habitats in Kuala Lumpur and the states of Selangor and Negeri Sembilan, Malaysia and its public health significance. *Tropical Bio Medicine,* 26(3): 303-311.

Peter, R.J., Van den Bossche, P., Penzhorn, B.L. and Sharp, B. 2005. Tick, fly and mosquito control lessons from the past, solutions for the future. *Veternary Parastology,* 132: 205-215.

Rohr, J.R., Andrew, P. D., Pieter, T.J., Johnson, A., Marm, K., Sara, H. P., Thomas, R. R., Diego, R. M. and Matthew, B. T. 2011. Frontiers in climate change–disease research. *Trends in Ecology and Evolution*, 26(6): 270-277.

Rust, M.K. 2005. Advances in the control of *Ctenocephalides felis* (cat flea) on cats and dogs. *Trends in Parasitology,* 21: 232-236.

Thanee, N., Kupittayanant, S. and Pinmongkholgul, S. 2009. Prevalence of Ectoparasites and Blood Parasites in Small Mammals at Sakaerat Environmental Research Station, Thailand. Thai Journal of Agricultural Science, 42(3): 149-158.

Thomas, F. Renaud, F. 2005. *Parasitism and Ecosystems*. Oxford University Press.

Thomson, L.J., Sarina, M. and Ary, A.H. 2010. Predicting the effects of climate change on natural enemies of agricultural pests. *Biological Control*, 52: 296-306.

Wall, R. 2007. Ectoparasites: Future challenges in a changing world. *Veternary Parasitology,* 148: 62-74.

Wall, R., Cruickshank, I., Smith, K.E., French, N.P. and Holme, A.S. 2002. Development and validation of a simulation model for sheep blowfly strike. *Medical and Veternary Entomology,* 16: 335-346

Woodhouse, M.E., Taylor, L.H. and Hayden, D.T. 2001. Population biology of multihost pathogens. *Science*, 292: 1109-1112

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