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Factors Influencing the Prevalence and Distribution of Ticks and Tick- borne Pathogens among Domestic Animals in Malaysia

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Abstract – Changes in tick-vector densities and a resultant incidence of tick-borne diseases are caused mainly by human activities affecting the environmental ecosystem, especially in tropical countries. As one of the most important invertebrate arthropod vectors of disease transmission, ticks are susceptible to changes in their environment due to their sole dependence of all their life stages on prevailing environment. Upon completion of their lifecycle, ticks depend on the availability of hosts and other several factors related to their surroundings to survive. This review discusses the major factors that influence the prevalence and distribution of tick-borne diseases among domestic animals in Malaysia. It is highly imperative to understand the factors that lead to increase in tick-vector populations, infection intensity and hence the spatial distribution of ticks and tick-borne diseases in order to prevent their emergence and resurgence as well as to serve as a basis for effective control.

Keywords: Prevalence, distribution, ticks, tick-borne hemopathogens, domestic animals, Malaysia.

Introduction

Ticks are one of the most important invertebrate arthropod vectors for disease transmission to domestic and other wild animals. They are susceptible to changes in their environment due to their sole dependence of all their life stages on prevailing environment. Upon completion of their lifecycle, ticks depend on the availability of hosts and other several factors related to their surroundings to survive (Audy, 1956; Hoogstraal, Lim, Nadchatram, Anastos, 1972; Hoogstraal and Wassef, 1984; Hoogstraal and Wassef 1985a; Hoogstraal and Wassef, 1985b; Tanskul and Inlao, 1989; Petney, 1993; Irwin and Jefferies, 2004; Salman, 2012).

In the early 1980s, many unknown human diseases caused by tick-borne pathogens have emerged causing varying clinical signs ranging from cutaneous lesions, renal failure, respiratory insufficiency and central nervous system involvement (Zamri-Saad, Sharif, and Basri, 1988; Voinov and Votyakov, 1992; Schaffner and Standaert, 1996; Gubler, 1998; Dantas-Torres, Chomel, and Otranto, 2012; John et al., 2014). Some important peculiar elements that have led to the emergence of new or undiscovered diseases and the resurgence of the old quiescent ones are due to increased vector population densities brought about by ecological changes. Movements of travellers and their animals from one geographical location to the other have also brought about the spread of vector-borne etiologic agents from an endemic region to non-endemic ones (Wilson, 1995, Gratz, 1999, Irwin and

Jefferies, 2004; Watanabe, 2012) and may also have been caused due to a lack of more sensitive diagnostic methods compared to today's modern diagnostic techniques (Pitney, 1993; Salman, 2012). The presence of a suitable vector helps in transmission and establishment of disease but does not ensure that transmission will be established in an area in which an etiologic agent has been introduced. The climate, immune status, proportion of vertebrate animals and vector populations' densities, and presence of a suitable reservoir host, among other factors, usually influence the possibility of transmission to be established (Irwin and Jefferies, 2004; Salman, 2012). The availability of suitable tick-vector populations capable of transmitting infection is the most important factors that determine the establishment of infection in a new environment (Emmons, 1988). Even though the threat posed by emerging tick-borne diseases is serious, the resurgence of previously known diseases poses an even greater threat. Resurgence is usually caused by an increase in vector population densities as a result of alterations of the environmental factors (Piesman, 1987; Salman, 2012).

Strong evidence has suggested the effects of climate change on the vulnerability to hardcore poverty and public health issues in Malaysia, which necessitates national and international responses on the issue in the country (Begum and Pereira, 2009; Begum, Siwar, Abidin, & Pereira, 2011). In an attempt to ameliorate the issue of climate change in the country, the Malaysian government has put in place many initiatives which include promoting utilization of renewable energy, energy efficiencies in industries, housing and transport sectors and stringent emission standards (Jafar, Al-Amin, & Siwar, 2008; Begum, Pereira, Jaafar, & Al-Amin, 2009; Begum and Pereira, 2009; Begum et al., 2011). However, the bulk of the government plans on environmental issues has been geared more towards tackling the economic problems posed by environmental factors, such as climate change, changes in land use or ecological influence due to excessive Green House Gas emission and excessive deforestation on the economy, than public health related aspect.

The three major factors that modify the properties in the transmission and infection intensity of tick-borne diseases worldwide are climate change, changes in land use or ecological influence and movements of animals through importation of exotic and wildlife species, migratory birds and movement of domestic animals (Gratz, 1999; Robson and Allen, 2000; Gubler, Reiter, Ebi, Yap Nasci and Patz 2001; Cumming and Van-Vuuren, 2006; Ergönül, 2006; Nijhof et al., 2007; Tack, Madder, and Verheyen, 2010; Molin et al., 2011; Salman 2012; Madder and Pascucci, 2012; Low et al., 2014). These factors have been known to influence the prevalence and proliferation of both the tick vectors and the pathogens they transmit by modifying the survival and fecundity rate of the ticks, time of the year and level of tick activity; specifically the blood sucking rate and time taken for a complete lifecycle of the tick-borne pathogens within the ticks (Gratz, 1999; Salman 2012).

Interactions among these three factors are important for forecasting how the prevalence and distribution of ticks and tick-borne diseases may appear in an area. Risk assessments should focus on looking for combinations of factors that may directly or indirectly affect these three factors. A risk assessment module can be proposed based on these factors and a framework designed for this purpose could be used to screen for the emergence of unexpected disease events (Gale, Drew, Phipps, David, & Wooldridge, 2009).

Although the significance of ticks and tick-borne diseases has been documented in domestic animals worldwide, there is a lack of information regarding factors influencing the prevalence and distribution of ticks and tick-borne diseases. This preliminary review aims at identifying factors which could influence the prevalence and distribution of ticks and tick-borne diseases among domestic animals in Malaysia. These factors include climate change, changes in land use or ecological influences and movement of animals through importation of exotic and wildlife species, migratory birds and movement of domestic animals.

Climate

Climate is one of the most influential factors that affect the prevalence, infection intensity and distribution of ticks infesting domestic animals worldwide. It tends to affect the geographical distribution of tick-borne diseases, while changes in weather, such as temperature, rainfall and humidity, influence disease transmission dynamics, hence the timing and intensity of outbreaks (Epstein et al., 1998; Gubler, 1998; CIESIN Thematic Guide, 2007; Begum et al., 2011; Dantas-Torres et al., 2011). The Malaysian climatic condition is characterized by a steady temperature, relatively high humidity and copious rainfall, where winds are generally light. Located near the equator, it is least expected to experience a full day with completely clear sky even during periods of severe drought. On the other hand, it is also rare to have a stretch of a few days with completely no sunshine except during the northeast monsoon seasons (Lim and Samah, 2004; Begum et al., 2011).

Climate also has a direct and indirect influence on tick survival, infection intensity and spatial distribution. Gray et al., (2009) report on the direct influence of climate changes on the survival of ticks and some empirical proofs have been obtained that show how climate may be one of the major causes for shaping the prevalence rates of some tick-borne diseases such as *Borrelia burgdoferi* around the world (Estrada-Pena et al., 2011). However, studies on their spatial distribution show no significant influence of climate when comparing disease sites (Estrada-Pena et al., 2011). Climate change and variation in length of seasons also affect directly tick survival, activity and development (Gubler et al., 2001). This situation is similar to that earlier reported for the Malaysian climate in which the seasonal wind flow patterns, coupled with the topographic features of the areas, determine the rainfall distribution patterns all over the country. During the northeast monsoon season, exposed areas, such as the east coast of Peninsular Malaysia, Western Sarawak and the northeast coast of Sabah, experience heavy rain while inland areas or areas covered by mountains experience less impact (Lim and Samah, 2004; Varikoden, Samah, & Babu, 2010; Varikoden et al., 2011). As reported by Begum et al., (2011), climate change has produced adverse effects on Malaysia as a country, making it highly vulnerable to public health issues and human settlements. The constant increase in temperatures and dryness experienced in Malaysia over the past few decades, coupled with a resultant decrease in the length of wet spell due to carbon emission from industries and urbanization factors such as housing and transport (Jamaludin, Suhaila, Wan Zin, & Jemain, 2008), has led to an extreme weather and climate variability. Although there is scant information regarding the vulnerability of ticks and tick-borne diseases in Malaysia, the above scenario will also affect the lifecycle of tick vector and the transmission cycle of tick-borne diseases among domestic animals.

Temperature can also influence the growth of a tick vector by altering their bite rates as well as their population dynamics, and the rate in which they visit their final hosts. This shows that a shift in temperature can alter the length of disease transmission season (Gubler et al., 2001, Jamaludin et al., 2008). An examination of the Malaysian evaporation data shows that the cloudy or rainy months are the months with lower evaporation rates while the dry months are the months with higher rates. Among all the factors affecting the rate of evaporation, cloudiness and temperature are two of the most important ones in Malaysia, which are, however, inter-related (Lim and Samah, 2004; Begum et al., 2011).

Changes in weather patterns may also influence the risks of tick-bites to humans by modifying the human behavior to the change in seasonality of certain recreational activities such as hikings, huntings, as well as berry and mush-room pickings (Madder and Pascucci 2013). The effects of land and sea breezes on the general wind flow patterns in Malaysia as a maritime country are marked more so especially during days with clear skies. Sea breezes of 10 to 15 knots often develop and rise to several tens of kilometers inland usually on bright sunny afternoons. However, the opposite occurs with land breezes of weaker strength developing over coastal areas during the nights (Lim and Samah, 2004).

The indirect effects of climate change are caused as a result of the modification of the ecosystem which will in turn alter the tick life cycle, tick survival and host abundance. This phenomenon is highly complicated; for example, the influence of climate on the vegetation cover of a particular environment may influence the number of infected ticks. Hence, dense humid vegetation may be beneficial to the survival of some tick species and to a subsequent rise in tick abundance as well. Such vegetation cover may also be beneficial to the pathogen-reservoir hosts as in the case of rodents (Madder and Pascucci, 2013). It may also help in the increase and abundance of reservoir hosts which maintain the survival and proliferation of tick vectors (Jaenson, Eisen, Petersson, & Lindgren, 2012). Other indirect influence of some vegetations on rodent abundance helps in increasing the number of ticks in areas as seen in the case of *Borrelia*-infected *Ixodes* ticks (Ogden et al., 2005) and *R. sanguineus* (Gray, Dantas-Torres, Estrada-Peña, & Levin, 2013). Here, it is very important to understand that the indication of which tick-borne diseases that may emerge in Malaysia as a result of changes in climate could be gained by considering those ticks and tick-borne diseases that are emerging or are established in neighboring countries such as Thailand, Indonesia and other countries in the Southeast Asian region and other parts of the world that have similar terrain and climate to that of Malaysia. Examples that illustrate this approach include the emergence of *Anaplasma platys, Babesia canis*, *Ehrlichia canis* and *Hepatozoon canis* from dogs in both Malaysia (Rajamanickam, Wiesenhutter, Zin, & Hamid, 1985; Watanabe, 2012; Mokhtar et al 2013, Nazari et al., 2013; Chandrawathani et al., 2014; Koh, Panchadcharam, & Tay, 2015) and Thailand (Suksawat et al, 2001a, Suksawat et al, 2001b; Criado-Fornelio et al, 2007; Ariyawutthiphan et al, 2008; Pinyoowong et al, 2008).

As in the above phenomena, the Malaysian climate is also characterized by copious rainfall experienced in most parts of the country thereby providing a lush vegetation cover that will consequently increase and extend the breeding season of rodents in the area and a resultant increase in tick density. The rise in host rodent population will also affect the density of ticks in the country with a resultant rise in tick and tick-borne diseases transmission to other domestic animals (Tack et al., 2010). The magnitude of the effect of climate change on the reservoir, vector and pathogen in a geographical region such as that of Malaysia may be a result of the compounding interactive effects of many parameters associated with the ecosystem and biodiversity, socioeconomic, human (such as migration and settlement, land use and culture), immunity and animal population (Begum et al., 2011).

Changes in land use
Human-induced changes in land use are one of the most common factors that predispose men and animals to a wide range of ticks and tick-borne infectious disease (Pats et al., 2000). Changes in land use include agricultural encroachments, wetland modifications, and expansions of urban environments, deforestations for the purpose of road constructions and dam buildings, irrigations, coastal zone degradations, mining, and other human related activities. Effects of these changes in turn cause a range of factors that influence the increase in the emergence of infectious diseases and their vectors (Patz, Olson, Uejio, & Gibbs, 2008). These are important factors that are complex in nature and are only understood for a few diseases in Malaysia. For example, expansion and changes in agricultural practices are intimately associated with the emergence of the *Nipah* virus in Malaysia (Chua et al., 1999; Lam and Chua, 2002). Another example include flash floods experienced in some coastal parts of Peninsular Malaysia which will stop all human activities in those areas for long time. During this period, the population of vectors and rodents might increase and, when the land becomes accessible again, animals, including humans, might be exposed to tick-borne pathogens. Other related reports from other parts of the world include Ergönül (2006), where, usually, humans get infected with vector-borne pathogens from wild or domestic animals; more so when intruding a habitat where pathogens exist. Barbour and Fish (1993) state that the reversal of deforestation (reforestation) have led to the emergence of tick-borne disease such as *Lyme borreliosis* in northwestern United States.

Movements of animals
Movements of animals can influence greatly the spatial distributions of ticks infesting domestic animals in three ways namely through the following:

a) Migratory birds
b) Importations of exotic and wildlife species
c) Movements of domestic animals

Migratory birds
The spread in distributions of tick species by migratory birds have been reported in different parts of the world (Albanese, Smiraglia, and Lavagnino, 1971; Papadopoulos, Morel, & Aeschlimann, 1996; Jaenson et al., 1994; Molin et al., 2011). The dispersal of ticks by the birds may be restricted to a short distance after their breeding flights. However, during their migratory flights, they travel over a long distance covering thousands of kilometres. Some species of birds have been known to have travelled from Europe to Africa, through Asia (Hoogstraal, Kaiser, Traylor, Guindy, & Gaber, 1963).

With its rich bio-diversity, Malaysia has more than 742 species of birds belonging to 85 families, comprising of both resident and migratory species, and is among seventeen diverse countries with 70% of the world's species (Robson and Allen, 2000). Although the introduction and spread of tick species by migratory birds are yet to be fully documented here in Malaysia, the potential for such occurrence may not be unexpected. However, recent studies conducted in Bangi situated in Peninsular Malaysia reveal that *Haemophysalis* spp. were the common tick vectors of the Red jungle fowls in the area (Konto et al., 2015). Studies have shown that *Haemophysalis* spp. have been reported to be transmitting many tick-borne pathogens to both domestic and wild animals (Yadav et al., 2011; John et al., 2014; Mourya, Yadav, & Patil, 2014). As stated earlier, *Haemophysalis wellingtoni* was the major tick species found on birds from a study conducted in Bangi (Konto et al., 2015); however, no information has been found as yet regarding the pathogens being transmitted by this tick vector (*Haemophysalis* sp) in the area. However, with Malaysia's rich biodiversity in both resident and migratory birds as described by Robson and Allen (2000), the potential for disease transmission by this tick species may not be ruled out.

Importations of exotic and wildlife species
The ability of a pathogen and its vector to spread among humans and other animal populations worldwide has been highly related to the general mode of wildlife trade, coupled with the expansion of regional and international transportation routes (Karesh, 2005). Some exotic ticks and tick-borne pathogens have been introduced into other countries through domestic animal trades and importations of exotic animals (Burridge, 2001; Salman, 2012). Tick species are usually introduced into a country through reptiles (especially snakes and monitor lizards), trade animals (livestock), amphibians, such as tortoises, and other domestic and wild animals (Jongejan, 2001; Nijhof et al., 2007). Similar examples include the introduction of *Amblyomma* species into the American Mainland through the importation of tick infested African reptiles; so also the introduction of *Amblyomma* species into Poland through tick infested pythons and monitor lizards from the same African country (Nowak, 2010) and the risk of introducing cowdriosis into America through the importation of tick (*Amblyomma variegatum*) infested livestock and other wild ungulates from the Caribbean island and Africa respectively (Burridge, Simmons, Peter, & Mahan, 2002).

Pathogens transmitted, originating from wildlife, may have negative impacts on live stocks while, at the same time, threaten the native wildlife and ecosystems of the new habitat. In Malaysia, the link between an illegal wildlife trade and diseases of wildlife origin, however, remains contested as being an unrealized threat. Indeed, little is known about the extent to which illegally imported wildlife may carry harmful diseases in Malaysia.

Movements of domestic animals
Movements of humans and their animals as nomads, movements of agricultural products from one location to the other, inadvertent movements of wildlife populations and movements for trade are among the major portals of tick-borne infectious diseases emerging worldwide (Hoogstraal, 1985). Most tick species have the capacity to adapt and establish themselves in a new environment with typical examples of such tick vectors as *Rhipicephalus sanguineus,* widely known as the ''brown dog tick'' or ''kennel tick'' (Estrada-Pena et al., 2004, Dantas-Torres, 2010). *Rhipicephalus (Boophilus)*

microplus, also known as the ‘‘Pan-tropical blue tick’, is also considered as one of the most important vectors for the transmission of many livestock pathogens worldwide, due to its cosmopolitan nature (Coetzer and Tustin, 2004). This tick species (*Boophilus Rhipicephalus microplus*) originated from the Asian region and has been known to transmit the disease pathogen known as *Babesia*, causing a disease referred to as red water in domestic animals (Hoogstraal, 1956; Temeyer et al., 2004; Low et al., 2014). Babesiosis, clinically an important disease of domestic animals, was spread to Australia through cattle trade from South Africa, Latin America, Mexico and the United States (Hoogstraal, 1956; Temeyer et al., 2004). Also, the prevalence of *R. (Boophilus) microplus* has not been previously reported in West Africa until recently, through the importation of cattle by Ivory Coast and the Benin Republic (Madder, Thys, Geysen, Baudoux, & Horak, 2007; Madder, Thys, Achi, Touré, & De Deken, 2011). The high adaptability potential of ticks and uncontrolled animal trades and movements influence highly the spread and distribution of ticks and tick-borne pathogens across different parts of the world.

Boophilus microplus, on the other hand, was introduced into Malaysia probably from the Indian sub-region (Hoogstraal, 1985) as it is the most significant vector of Babesia parasites of domestic cattle and buffalos in Southeast Asia as a whole. It has also been found to be a vector for the transmission of *Babesia bigemina*, *Theileria orientalis* and *Anaplasma marginale* infections in cattle. *Haemaphysalis bispinosa* has been reported to be introduced into Malaysia from cattle trade (Hoogstraal et al., 1969) and is also responsible for the transmission of *Babesia* sp. to cattle, *Babesia mortasi* to sheep and *Babesia gibsoni* to dogs. *Rhipicephalus sanguineus* is also responsible for the transmission of *Babesia canis, B. gibsoni*, *Ehrlichia canis* and *Hepatozoon canis* to dogs in this region as well as other parts of the world (Rajamanickam et al., 1985; Mokhtar et al., 2013; Chandrawathani et al., 2014; Konto, Biu, Ahmed, Mbaya, & Luka 2014a; Konto, Biu, Ahmed, & Charles, 2014b). The genus *Haemaphysalis* has been widely distributed in the whole of Southeast Asia (Hoogstraal, 1971) and affected about half of the species found there. Some of these species, for example *Haemaphysalis doenitzi*, attach commonly to birds which are potentially migratory, hence increasing the possibility of transferring disease agents from one area to another (Hoogstraal and Wassef, 1973). Other species, such as *Haemaphysalis bispinosa*, *Haemaphysalis bandicota* and *Haemaphysalis rusae*, have been introduced to areas outside of their natural distribution, presumably by human activities (Hoogstraal, Lim, and Anastos, 1969; Hoogstraal and Wassef, 1973; Hoogstraal and Wassef, 1981).

Table 1: Tick-borne pathogens of domestic animals in Malaysia

Pathogen	Host(s)	Distribution	Reference
Anaplasma spp.	cattle, buffalo, sheep, dog	Perak, Selangor, Kuala Lumpur	Chandrawathani et al., 2014; Mokhtar et al., 2013, Koh et al., 2015
Babesia argentina	cattle	Malaysia	Ramamanickam, 1977
Babesia bigemina	cattle, buffaloes	Malaysia	Mohan, 1968; Chandrawathani et al., 2014
Babesia canis	cattle, buffalo, dog	Perak, Selangor	Chandrawathani et al., 2014; Rajamanickam et al., 1985
Babesia gibsoni	dogs	Malaysia	Purnell, 1981; Mokhtar et al., 2013; Chandrawathani et al., 2014
Coxiella burnetti	cattle, sheep, goat	Malaysia	Marchette, 1966
Dermatophilus congolensis	cattle	Malaysia	Zamri-Saad et al., 1988
Ehrlichia spp.	dogs	Perak, Kuala Lumpur	Chandrawathani et al., 2014; Nazari et al., 2013; Watanabe, 2012
Hepatozoon spp.	dogs	Selangor	Rajamanickam et al., 1984; Watanabe, 2012;
Theileria spp.	cattle, buffalo, deer, goat, sheep, horse	Perak	Chandrawathani et al., 2014

Conclusion

Climate change and changes in movements of domestic animals appear to have influenced significantly the prevalence and distribution of ticks and tick-borne pathogens in Malaysia. Ticks and tick-borne disease transmissions due to changes in land use and movements through migratory birds might also be a possibility as shown from this review. Ecological changes have brought about the emergence of previously unrecognized tick-borne diseases and the re-appearances of previously controlled ones that have been dormant for a relatively long time through an increase in the vector population densities. However, the emergence of some previously undetected diseases is perhaps due to a lack of better diagnostic methods compared to today's modern diagnostic techniques. The need for further research into the epidemiology of tick-borne infections using modern diagnostic techniques is imperative in order to determine new etiologic agents and understand the variability existing within species.

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