Disease ecology of ticks and wildlife: One Health and wildlife management perspectives

Summary of Doctoral Thesis

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The involvement of wildlife as tick hosts has been suspected in the outbreak of tick-borne diseases. However, the ecology among host-parasites, such as the quantitative evaluation of tick infestation to wildlife host and its association to the tick dispersion. In particular, the landscape and fauna of the Kanto region have changed dramatically since the Meiji era, when the number of wildlife decreased drastically, and since World War II, when their distribution expanded.

Recently, overabundance of wildlife such as wild boar, raccoon, and deer caused by anthropogenic environmental changes is expected to have an ecological impact on ticks, and elucidating these mechanisms is expected to control human exposure to ticks and prevent tick-borne diseases.

This paper aims to clarify how ecosystem management can contribute to the control of ticks and tick-borne diseases, which will become increasingly important in the future. 2) the host-parasite relationship between host wildlife and ticks, and 3) the relationship between the antibody status of host wildlife and tick habitat distribution. Elucidation of the ecological relationship between ticks and the background factors of pathogen distribution by ticks carried by wildlife in wildlife that inhabit human habitats is expected to provide useful knowledge for ecosystem management for tick-borne diseases and vector control.

1. Prediction of potential distribution of ticks in the western Kanto region

The analysis was conducted in an area of 90 x 180 km, including the Kanto Plain, where urban areas and farmlands spread out from the subalpine and mountainous zones of the Kanto Mountains through hilly areas. The background information used in the analysis included land use status, forest continuity, elevation, and meteorological data extracted from satellite images, as well as distributional data of the potential wildlife hosts, Japanese deer (*Cervus nippon*), Japanese wild boar (*Sus sucrofa leucomystax*), raccoon (*Procyon lotor*), raccoon dogs (*Nyctereutes procyonoides*), and masked palm civets (*Paguma larvata*) (Here after, civet). Tick collection were conducted at 134 sites in the target area using the flagging method and 16 tick species were collected. The potential distributions of nine tick species were estimated from the habitat modulus obtained by the Maximum Entropy (MaxEnt) model.

Results indicated that forest connectivity contributed 18.6-51.1% for seven tick species, followed by raccoon habitat distribution as an important contributor (7.3-19.1%) for six tick species. The predicted potential distributions of the ticks from the model showed that the moderate habitat for several tick species is distributed in the lower mountains, to the hills of the Kanto Mountains. In addition, ticks were found to be distributed in isolated green areas in urban region where green areas existed within a radius of 2 km and where wildlife were distributed, indicating that medium and large size wildlife that became Urban Wildlife contributed to tick distributions.

2. Host-parasite relationship between host wildlife and ticks

The study further evaluated the tick spreading ability of raccoons, raccoon dogs, and civets which are thought to have overlapping ecological niches of raccoons that indicated as an important contributor of the models. In Kanagawa Prefecture, 97.4% of parasitic ticks in raccoons were *Haemaphysalis flava*, indicating a strong host-parasite relationship and that raccoons influence the density and dominance of *H. flava*. On the other hand, in the Miura Peninsula, Kanagawa Prefecture, where the intensity of tick infestation was significantly lower in the civet, indicating that the civet is a host with an ecological function as an Ecological Trap that reduces the number of tick bites by feeding on ticks during grooming behavior (p<0.05). On the contrary, raccoons were considered to have a role as Ecological Booster with high tick spreading ability.

The host selectivity indicated by the Marcum method in Gunma Prefecture showed that raccoons and raccoon dogs were significantly more suitable as the host of various ticks than civets (p<0.05). For the three species of medium-sized carnivores known as Urban Wildlife, we found that the civet was the most unsuitable host for ticks. In addition, raccoons use forest-edge environments and urban areas relatively more frequent than raccoon dogs which prefer forest and forest-edge environment. Thus, raccoons were thought to be the most susceptible wildlife that transfer ticks into human dwellings.

Previously, government suggested that measures to control population of deer and wild boar are expected to reduce the risk of tick-borne diseases, but it is not known whether measures limited to these two wildlife will actuary reduces the risk of tick bites and disease emergences. In this study, we focused on the introduction and eradication of large-size wildlife. The study suggested the anthropogenically introduced sika deer in Nii-jima Island, the Izu Islands may have introduced *H. megaspinosa* and increased the density of *H. cornigera* and *H. longicornis*. On the other hand, we could not confirm the presence of *H. cornigera*, and *H. longicornis* on Jini-jima Island, a neighboring island where introduced sika deer were eradicated, and the tick density was extremely low compared to Nii-jima Island (p<0.05). Ticks collected Shikine-jima Island, another neighboring island where did not experienced sika deer introduction, were limited to the *H. flava* and *Ixodes turdus*, and tick densities were comparable to those of Jinai-jima Island. This suggests that in an island environment where is almost no immigration and emigration of terrestrial wildlife, the loss of a species of wildlife that function as major hosts has a significant impact on tick densities, sometimes resulting in a significant decrease in tick densities as seen on Jinai-jima.

Furthermore, wild boars, which are introduced to the Miura Peninsula in Kanagawa Prefecture, may have brought *Amblyomma testudinarium* and *H. hystricis* to this area, and this may have contributed to the increase in the density of *A. testudinarium* (Nymph: rs=0.92, p<0.05; Larva: rs=0.94, p<0.05). Infestation of *A. testudinarium* and *H. hystricis* were also observed on raccoons, civets, and Pallas's squisrel (*Callosciurus erythraeus*), which have been distributed in the same area as exotic species for several decades. In addition, this study indicated that changes in the tick fauna in the environment and on wildlife took three to seven years to be detected by scientific surveys.

This also suggests that population control of single species of wildlife can drastically reduce ticks in an isolated environment However, the environment holds multispecific fauna of host wildlife, the monospecific wildlife management will not be able to reduce the density of the ticks significantly. This result suggests that the monitoring of the habitat distribution of wildlife and ticks should be conducted in parallel, at least every three years.

3. Relationship between sero-prevalence of KAMV antibodies in raccoons and habitat suitability of ticks

Raccoons that showed high tick spreading ability were surveyed for serum antibodies by indirect ELISA using Kabuto mountain uukuvirus-like virus (KAMV) as a model pathogen. Serum or meat juice samples from raccoons captured in Kanagawa, Tokyo, Saitama, and Gunma Prefectures showed that raccoons possessed KAMV antibodies. The *H. flava* distribution threshold calculated by the MaxEnt model was HflLog=0.279. Areas above this threshold had an average of 34.2% of KAMV antibodies, while areas below 0.279 had an average of 7.9%. Based on the odds ratio, the probability of KAMV antibody possession was relatively 4.39 times higher in raccoons distributed in the area above HflLog=0.279.

Furthermore, a statistical model was developed by performing logistic regression using the antibody prevalence and the moderate habitat of the *H. flava*. From the obtained regression equation, we mapped the distribution of the probability of KAMV antibody possession in the raccoon distribution area, and used it as a risk map when raccoons were reservoirs of KAMV. In this example, we used KAMV as a model pathogen to calculate the probability of raccoons possessing antibodies, and we were able to estimate the western and southern parts of the Tama region and the Miura Peninsula as areas with high probability of possessing antibodies. It is expected this model can be used as the tool for searching vector candidates and reservoir wildlife candidates.

4. Recommendations from this study

This study has shown that ticks are transferred from wildlife to wildlife from mountainous areas to hilly areas and urban areas. In particular, it was found that the expansion of tick distribution into human dwellings by Urban Wildlife is already in progress. The fact that Urban Wildlife such as raccoons, raccoon dogs, and civets frequently use urban region suggests that prevention of the spread of ticks will not be able to accomplished by monospecific wildlife management of large-size wildlife. It is known that raccoons frequently use areas where green spaces and urban areas are adjacent to each other, indicating that raccoons have a significant impact on the spread of ticks in human living areas as Ecological Boosters and spreading many tick species. These results suggest that raccoons, which may be a factor in tick exposure to humans and domestic animals, are a wildlife species that must be addressed as a priority.

The WHO explains that it is important to conduct a uniform survey method over a wide area for vector control. However, the current implementation of surveys on wildlife and ticks in Japan is often led by prefectural and local governments, and the survey and evaluation methods are not consistent. The results of this paper also support the WHO's recommendation that wildlife and tick surveys should be conducted regularly in a uniform manner in order to predict tick habitat distribution, which is useful for vector control.

In recent years, urban development that incorporates the natural environment has been promoted in response to the need to conserve biodiversity. Such urban development has the potential to create more opportunities for wildlife to enter the city. In order to achieve a balance between the natural environment and preventive medicine, it is necessary to monitor and manage wildlife that pose a risk, and it is essential to take an approach that creates an environment that prevents encounters with ticks in the natural environment used by people.