The leading edge of the geographic distribution of *Ixodes scapularis* (Acari: Ixodidae)

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Dear Editor,

A recent paper by Hahn et al. (2016) modeled and mapped the geographic distribution of the tick *Ixodes scapularis* Say, the primary vector of several pathogens in eastern North America. Because their results indicated an unexpectedly small distributional area for the species, we (Peterson and Raghavan 2017) developed a partial reanalysis and showed that the model-predicted distributional extent depended to a large degree on methods for thresholding models into binary results. Hahn et al. (2017) then responded to our critique. Here, we present a brief further response, with the aim of clarifying the aims of the overall exercise.

Although Hahn et al. (2016) presented some methodological variations and focused on differences between the two modeling protocols, our model predictions were closely similar to theirs when we followed their assumptions about thresholding. As a

result, we do not believe that the difference has to do with methodology, but rather with conceptual framework and interpretation.

Hahn et al. (2017) stated that their purpose had been "... to better define the leading edge of the tick's ongoing geographic expansion." We assert that they have not made the appropriate assumptions to this end: that is, they accepted greater omission error, which reduced the area identified as suitable to the very conservative, "rimming" distributional estimate that they had originally reported. If the primary purpose is to define the "leading edge" of the species' distribution, a more liberal, lower threshold would be in order.

It is important to note that this issue is not simply one of different thresholding assumptions including more or less area within model predictions. If large-scale differences exist in abundances (or at least in the sampling and reporting) of tick populations in marginal regions, these marginal regions (or marginally sampled regions) are systematically removed by the higher thresholds that Hahn et al. (2017) advocate. That is, assumptions and choices regarding thresholds on model predictions must be established based on conceptual frameworks, rather than on convenience (Peterson et al. 2011).

The definition of a fundamental ecological niche is an inclusive set of conditions under which the species is able to maintain populations without immigrational subsidy (Peterson et al. 2011). Clearly, the center of abundance of this species is not at the western edge of its distribution, but just as clearly, the species' distribution extends much farther west than the model predictions that Hahn et al. (2016) presented would indicate (see numerous records in Eisen et al. 2016). The distribution of abundance of

the species across this distributional area is of course interesting and relevant, and can be examined via other classes of models in distributional ecology (Martínez-Meyer et al. 2012). However, the “leading edge” of the distribution of *I. scapularis* is at a longitude of about 98°W, rather than much farther to the east; this broader range is reflected in the transmission of pathogens and cases of canine and human Lyme disease in many regions (Bacon et al. 2008) that were indicated by the Hahn et al. (2016) models as unsuitable (compare panels A and B in their Figure 3). Over the years, *I. scapularis* has been collected consistently as far west as central Kansas, both by flag/dragging methods and from sentinel species (e.g., white tailed deer) by us and other researchers, albeit in small numbers; appropriate models aimed at locating the leading edge of the distribution of the species should include these areas, as the tick is certainly present and important in public health and policy-making there. Although we two are based in Kansas, this discord between presence of the tick and transmission of *Borrellia* versus the Hahn et al. (2016) model results has broad, sweeping public health implications: the “leading edge” of the distribution of the species is in the central United States, and the distribution of this tick species covers much of the eastern United States.

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