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Review

Could Earthworms Reduce the Spread of Tick-borne Diseases like Lyme Disease?

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ABSTRACT

Tick-borne diseases are a global problem. Currently there are no vaccines available for Lyme disease. Climate change is allowing the spread of these diseases as suitable habitats are expanding into areas previously unavailable to *Ixodes scapularis*. Stopping the introduction of the ticks into an area is a preferred approach, but once they are established, methods of interruption of the life cycle of the ticks becomes an option. On small areas such as homesteads, planting of certain plants which are deterrents to the ticks, or removing the litter layer, are possible. In woodlands and ecotones, the introduction of anecic or epigeic earthworms are a possible solution be removing the litter layer essential for the overwintering nymphal stage. There are limiting problems and issues with this approach which could make this impracticable.

Keywords: Blacklegged ticks; *Ixodes scapularis*; Earthworms; Lyme disease; Control

Classification: Kingdom Animalia (Animals); Phylum Arthropoda (Arthropods); Subphylum Chelicerata (Chelicerates); Class Arachnida (Arachnids); Subclass Acari (Mites and Ticks); Superorder Parasitiformes; Order Ixodida (Ticks); Family Ixodidae (Hard Ticks); Genus *Ixodes*; Species *scapularis* (Black-legged Tick)

Introduction

I don't know if it was my premed training, my research work with Tall Timbers Research Station, and their work on controlled burning, or a short research project at the Cary Institute of Ecosystem Studies with Dr. Richard Ostfelt and one of his students, but I have thought about this issue for a number of years. This approach might be what today is called "thinking outside the box"[1]. But first it is necessary to discuss Lyme disease, its spread and the black legged tick (*Ixodes scapularis* Say, 1821), also known as the deer tick and bear tick[2], and its life cycle.

As well as Lyme disease, other tick-borne diseases are transmitted by *Ixodes scapularis* e.g., *Borrelia mayonii*[3](which cause Lyme disease), *Anaplasma phagocytophilum*[4,5] (anaplasmosis), *B. miyamotoi*[6] (hard tick relapsing fever, htrf), *Ehrlichia muris eauclairensis* 1995[7] (ehrlichiosis), *Babesia microti*[8] (babesiosis), and Powassan virus (Powassan virus disease) are emerging as diseases locally found within Canada[7]. Tick-born encephalitis[9], although not currently in North America, and limited to and spreading within Asia and Europe, is mentioned it here due to climate change and international travel. In the future, it could become an issue here[10]. Fortunately, there is an effective vaccination (TicoVac, FSME-Immun). This paper will concentrate on Lyme disease (*Borrelia burgdorferi* Johnson et al. 1984 emend[11].).

Lyme Disease

Found in over 80 countries, Lyme disease is a global problem[12] (**Figure 1**). My interest and experience are primarily in North America and particularly in Canada.

Figure 1: Global distribution of Lyme disease [■] (This image is licenced under creative commons attribution)

Lyme disease is a bacterial spirochete infection caused by *Borrelia burgdorferi*, and is transmitted to humans through the bite of an infectious blacklegged tick, *Ixodes scapularis*. This is the most common vector-borne disease in North America, with an estimated 300,000 cases annually in the United States alone[13]. In 1975, Lyme disease was first recognized in North America, when it was described as juvenile rheumatoid arthritis cases in several Connecticut towns as a result of farmland reforestation[14,7]. After the initial description of Lyme disease in the early 1980s, the blacklegged tick was identified as the vector of *B. burgdorferi* in New York[15,16]. Lyme disease is found throughout eastern North America, including southern portions of Canada, wherever blacklegged ticks are present.

In Canada, *I. scapularis* distribution is limited primarily to the southern portions of Manitoba and eastward to Nova Scotia[17,18] (**Figure 2**). In the early 1970s, the first population of blacklegged ticks in Canada was identified at Long Point Provincial Park, in Norfolk County, Ontario, along the northern shore of Lake Erie[19]. Beginning in the mid-1990s and through the 2000s, additional established populations of blacklegged ticks were located along the northern shores of Lake Erie, Lake Ontario, southwest Ontario. Urban-suburban Blacklegged tick surveillance also covered Ontario parks[20-23]. Cases have been reported as far east as Newfoundland and Labrador Since 1988, the majority of human cases of Lyme disease reported in Ontario have originated from southern Ontario, especially in areas of southeastern Ontario where blacklegged tick populations are expanding (**Figure 3**). There is another vector of Lyme disease in the western US (*Ixodes pacificus* Cooley and Kohls, 1943[25]), it has a rather limited range now, but predictions are that it will increase. It has not been reported in Canada[26].

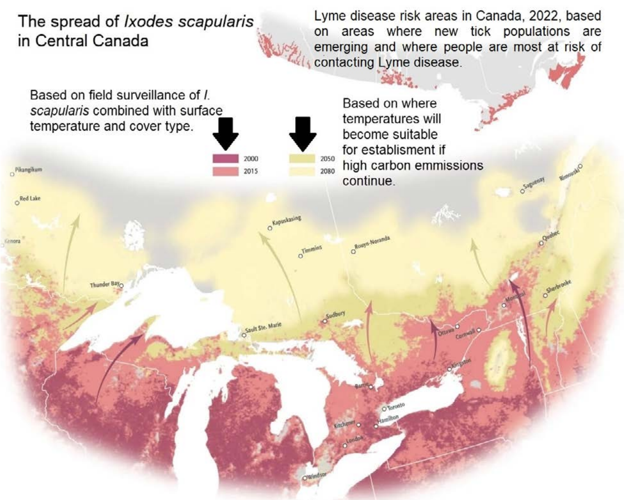

Figure 2. The spread of *Ixodes scapularis* in central Canada; Eastern Canada Risk 2000–2015 (modified from: earthobservatory.nasa.gov/images/148482/mapping-the-spread-of-lyme-disease; future scenario, climateatlas.ca/ lyme-disease-under-climate-change.

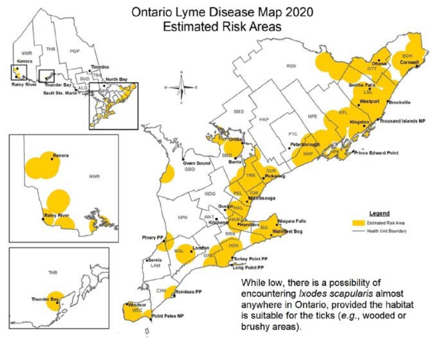

Figure 3. Location of Lyme Disease in Ontario in 2020 (modified from: Public Health Ontario, risk across areas, 2023 [■])

A model-based prediction by Leighton et al.[27] suggested that the range of the *I. scapularis* tick will expand into Canada by 46 km/year over the next decades, with warming climatic temperatures as the main reason for the increased speed of spread.

Many environmental factors are responsible for the expansion of blacklegged ticks in Ontario and other provinces. The major reason for this spread is climate change, specifically the increase in the mean annual degree days above 0°C[22,28]. Other factors that contribute to blacklegged tick expansion include land use changes (i.e., farmland to forest; encroaching human populations; forest fragmentation) and changes in the tick hosts' range (i.e., white-footed mouse *Peromyscus leucopus*, white-tailed deer *Odocoileus virginianus*). All tick surveillance indicators suggest that the current geographic range of blacklegged tick populations is expanding in southern Ontario and will likely continue to do so, as available habitats permit[24].

Blacklegged Tick (Figure 4)

Figure 4. Adult *Ixodes scapularis* Say, 1821 also known as the blacklegged, deer or bear tick (Illustration by Iza Valle/Can Geo)

Blacklegged tick populations can occur sporadically over a wide geographic range in Canada, due to larvae and nymphs readily attaching themselves to migratory birds[29]. These birds help transport blacklegged ticks from areas in the US and Canada to different areas across Canada and create the possibility of infectious tick bites almost anywhere in Ontario. The risk of Lyme disease is usually greater in tick-established areas because of a greater probability of bites from infectious ticks compared to areas where blacklegged ticks are not established[30]. Ogden et al[31] have prepared risk maps for public health use now for identifying current and possible future areas of risk for *I. scapularis* ticks and, by inference, possible current or future Lyme disease risk.

Though you can find these ticks in a wide range of habitats, they can adapt to any number of different areas, but they often prefer areas with warm temperatures and humid climates. Their favourite type of habitat is the edge of a clearing, where a line of forest meets a lawn or a meadow. They most often utilize low shrubs and leaf litter. Generally, tick populations tend to be higher in elevation, in wooded and grassy areas where the hosts they feed on live and roam. One misconception is that the ticks live on their hosts. Ticks are not as mobile as people think. They do not jump, fly, or drop from trees; instead, they only crawl and climb. They can, however, get transported to new areas while feeding on their hosts[28]. There are significant data to show that domestic pets, dogs and cats), substantially contribute to the spread of ticks and tick-borne bacterial pathogens into the home[32].

Adult black-legged ticks are in fact most active from fall to spring, often after the first frost. In the Northeastern United States and Canada, populations of these adult ticks start growing in early October and will remain active as long as the temperature remains above freezing and the ground doesn't freeze or become covered in snow.

Ixodes scapularis has a 2-year life cycle, containing three stages: larva, nymph, and adult (**Figure 5**). The tick must take a blood meal at each stage before maturing to the next. The tick females latch onto a host and drink its blood for 4B5 days. When the tick has consumed a blood meal, its abdomen is a light grayish-blue colour. The tick itself is naturally black when unfed[31]. Deer (*Odocoileus* spp.) are the preferred host of the adult tick, but it is also known to feed on small rodents such as mice (*Apodemus* spp.), etc. After the female is engorged, she drops off and overwinters in the leaf litter of the forest floor. The following spring, the female lays several hundred to a few thousand eggs in clusters[33]. Transmission of *Borrelia burgdorferi* between life stages in common. There is contrary opinion regarding transmission. Rollend et al[34]. based on their study, believe there is strong evidence that transovarial transmission is not by *B. burgdofferi* but the antigenically and phylogenetic relative *B. miyamotoi*. Because of the tick's genetics, it is a successful vector of *Borrelia* by limiting the proliferation of the spirochaeta[35].

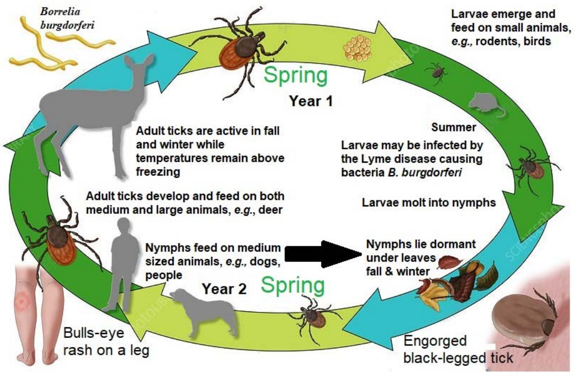

Figure 5: Life cycle of the tick *Ixodes scapularis* (➡ stage where life cycle could be broken by the action of earthworms) (modified from: Monica Schroeder/Science Source/Science Photo Library; Model release not required, Property release not required).

Like other ticks, *I. scapularis* is hardy. It can be active after a hard frost, as daytime temperatures can warm it enough to keep it actively searching for a host. In the spring, it can be one of the first invertebrates to become active. The ticks can be quite numerous and seemingly gregarious.

Discussion

There is currently no vaccine available for Lyme disease. Clinical trials of new vaccines for Lyme disease are currently underway. Valneva and Pfizer have developed a Lyme disease vaccine candidate, VLA15, that is currently in Phase 3 human trials. VLA15 is a multivalent, protein subunit vaccine that targets the outer surface protein A (OspA) of *Borrelia*. This vaccine is designed to protect people against North American and European strains of the Lyme disease bacterium[36]. This is good news for those who have sustained bites from infected ticks.

But could there be actions taken to reduce the spread of ticks and their range?

Transovarial transmission in Lyme disease complicates their epidemiology. This is where the disease agent is transferred from female ticks to her eggs so ticks immediately after emergence from the egg are infective. Larval and nymphal tick stages play important roles in maintaining the disease cycle[34].

They tend to flourish more in warm, humid climates, because they require a certain amount of moisture in the air to undergo metamorphosis, and low temperatures inhibit their development of eggs to larvae. The occurrence of ticks and tick-borne illnesses in humans is increasing. Tick populations are spreading into new areas, due in part to the warming temperatures of climate change[37]. Climate warming and other environmental changes have contributed to the expansion of the range of several tick species into higher latitudes in North America. As temperatures increase in Canada, the environment becomes more suitable for ticks and the season suitable for tick activity lengthens, so tick-borne diseases are likely to become more common in Canada[38]. Because of the tick's genetics, it is a successful vector of *Borrelia* by limiting the proliferation of the spirochaeta[35].

Several plants act as tick repellents. If you want ticks to avoid your home, have these plants in your garden or along the periphery of your yard. Here are some of the more common plants used to repel ticks: Catnip (*Nepeta cataria* L., 1753[39]), Chrysanthemum (*Tanacetum cinerariifolium* Sch. Bip.), Eucalyptus (*Eucalyptus* spp.) Garlic (*Allium sativum* L., 1753[39]), Geranium (*Geranium* spp.), Lavender (*Lavandula spica* L., 1753[39]), Lemongrass (*Cymbopogon* spp.), Marigold (*Tagetes* spp.), Pennyroyal (*Mentha pulegium* L., 1753[39]), Rosemary (*Salvia rosmarinus* Spenner, 1835[32]), Rue (*Ruta graveolens* L., 1753[39]), Sage (*Salvia officinalis* L., 1753[40]) and Wormwood (*Artemesia absinthium* L., 1753[39])[41,42].

The association of earthworms and medicine is not new[43-45,29]. From the life cycle diagram (**Figure 5**), the stage where it can be disrupted is when the nymphs require a leaf litter to over-winter, e.g., suitable habitat with higher humidity and lower temperatures within the leaf litter, as well as protection from exposure over winter. If the litter is removed, this stage will not survive our current winters. One study indicated that removal of leaf litter (detritus and dead leaves) led to a 72%--100% reduction in ticks[46]. There is a literature reference which recommends the removal of dead leaves from your property[18]. This works for residential property, but what about woodlands and ecotones that are too large and impractical for individuals. Certain earthworms could solve this problem, particularly anecic and epigeic species which consume leaf litter e.g., *Aporrectodea longa* (Ude, 1885[47]), *Lumbricus terrestris* L., 1758[48], *Dendrobaena octaedra*, (Savigny, 1826[49]) and *Dendrodrilus rubidus* (Savigny, 1826[49]) (**Figure 6**).

Figure 6: Forest floor and plant community at base of trees before (A) and after (B) European earthworm invasion in a sugar maple-dominated forest (Chippewa National Forest, photo by Dave Hansen, University of Minnesota).

The preferred habitat of the tick is woodland or woodland transitional zones where the vegetative cover is deciduous trees and not conifers. This is also the same tree cover preferred by earthworms. The leaf palatability index for earthworms was first reported by Reynolds[50] and ranked 16 genera: *Robinia* (Locust) >> *Populus* (Poplar)> *Ulmus* (Elm) >> *Acer* (Maple) = *Liriodendron* (Tulip poplar) = *Fraxinus* (Ash)= *Tilia* (Basswood) = *Betula* (Birch)> *Quercus* (Oak) = *Fagus* (Beech) < *Abies* (Fir) = *Larix* (Tamarack) = *Picea* (Spruce) = *Pinus* (Pine) = *Thuja* (Cedar) = *Tsuga* (Hemlock). Ticks are adapted for specific habitats [31], and as forest-dwelling species do not thrive in fields with minimal shrub cover or in grasslands[51]. Vegetation cover is important for most tick species so that forest community composition is a strong predictor of tick presence[4]. *Ixodes scapularis* density increases with the depth of the litter layer[52], which varies with plant litter quality and differs among plant species[53]. Decomposers, including earthworms, can also reduce litter layer thickness and affect tick populations by limiting soil refugia[54].

Abiotic factors including slope aspect, hydrology, and soil texture affect the habitat quality of ticks[55], thereby influencing both tick survival and behaviour[56]. In the humid continental climate of the North Central United States, *I. scapularis* (Say) (Acari: Ixodidae) is generally associated with forests on well-drained sandy soils and is not found in inundated areas[55]. Harsh weather conditions are a major driver for tick mortality, and these effects vary by life stage and species[57].

Conclusion

Can earthworms reduce the spread of tick-borne diseases - theoretically yes, but there are practical problems or issues.

1. Aside from personal property, having enough worms in forests and ecotones would require mass rearing of the best European species that reduce the litter layer. Currently, this has not been done on a commercial scale for anecic and epigeic species.

2. In recent decades, 16 species of Asian earthworms have made their way to the continent, and they have scientists particularly concerned. Originally from Korea and Japan, these pheretimoid earthworms are commonly known as "jumping worms," "snake worms," or "crazy worms" - named for their distinctive thrashing when disturbed. They are ravaging soils throughout the U.S., and have crossed the border into Canada. The first Canadian records were by Reynolds[58] and subsequently by Reynolds' colleagues[59,60,61].

These jumping worms pose an even greater threat than their European predecessors. Jumping worms have many of the same effects, except that they grow larger, recycle nutrients even faster and exist in dense colonies, sometimes numbering more than 100 individuals/m^2 of soil. Even more concerning is the fact they are parthenogenetic and a single introduction of one worm can produce an exploding population.

Jumping worms are known to quickly churn the top layer of soil, turning it into something that resembles coffee grounds from all the worm droppings and completely destroy the litter layer. There is no way of removing them from an area once they invade as every single worm would need to be removed. The best approach would be to restrict their introduction.

3. Climate change can have a significant effect on organisms above and below the soil surface in terrestrial ecosystems[62]. I have noticed a change in the earthworm diversity in North America during the past 50 years. In the mid to late 1960's, the Oriental pheretimoid species (*Amynthas*, *Metaphire* and *Polypheretima* spp.) were limited in natural habitats to the southeastern United States, particularly south of Tennessee[63,64]. A change in climate permits a rapid increase in their range due to their parthenogenetic reproduction. In the past 50 years, they have spread into the midwestern and the northeastern American soils[65,58]. I may not live to see it happen, but as the soils in Canada warm, if precipitation in the form of increased rain, and vegetation diversifies, one day earthworms will become a major component of the soil fauna in the Canadian far north[66].

4. Scientists and naturalists who have an interest in ground nesting species (e.g. mourning dove (*Zenaida maccroura* L., 1758[48]) and ruffed grouse (*Bonasa umbellus* L., 1766)[67] will strongly object to any attempt to reduce the litter layer and ground cover.

5. Any change in the natural plant or animal species composition in an area can have major consequences. I am not suggesting the introduction of invasive species into new habitats. There are a number of ways without human assistance that earthworms can move into new areas, e.g., transportation by birds and mammals, and soils and debris moving downstream during flooding[68-81].

Even though earthworms could disrupt the life cycle of the tick vectors, it will probably be decades before the change in climate and the spread of litter destroying earthworms will have any effect on the proliferation of tick-born diseases.

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