

Environmental medicine aspects of chronic ill health due to Lyme disease and co-infections

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Fleas

Great fleas have little fleas upon their backs to bite
'em,

And little fleas have lesser fleas, and so ad infinitum.

And the great fleas themselves, in turn, have greater
fleas to go on;

While these again have greater still, and greater still,
and so on.

Pathogens

- A pathogen is defined as an organism causing disease in its host.
- About one in a billion microbial species is a human pathogen.
- It has been estimated that there are one trillion microbial species on Earth.

Balloux F, van Dorp L. Q&A: What are pathogens, and what have they done to and for us? BMC Biol. 2017;15:91.

Infectious diseases

- A comprehensive literature review identifies 1415 species of infectious organism known to be pathogenic to humans.¹
- Of the catalogued pathogen species that infect humans, 538 are bacteria, 317 are fungi, 287 are helminths, 208 are viruses, and 57 are protozoa.²
- Pathogens shared with wild or domestic animals cause more than 60% of infectious diseases in man.³
- 175 pathogenic species are associated with diseases considered to be 'emerging'.¹

1. Taylor LH, Latham SM, Woolhouse ME. Risk factors for human disease emergence. *Phil Trans R Soc Land B Biol Sci.* 2001;356:983-9.
2. Woolhouse MEJ. Where do emerging pathogens come from? *Microbe Magazine*, November 2006.
3. Karesh WB, Dobson A, Lloyd-Smith JO, Lubroth J, Dixon MA, Bennett M, et al. Ecology of zoonosis: natural and unnatural histories. *Lancet.* 2012;380:1936-45.

Infectious diseases (cont.)

- The World Health Organization (WHO) defines zoonoses as “diseases or infections which are naturally transmitted between vertebrate animals and humans.”¹
- For hundreds of human pathogen species, an animal reservoir is an important feature of their biology.¹
- The most striking feature of such animal reservoirs is their diversity.¹
- Reservoirs include birds and mammals, including domestic animals.
- The transmission route for bacterial disease is often zoonotic, though some bacterial infections are from direct or indirect contact.

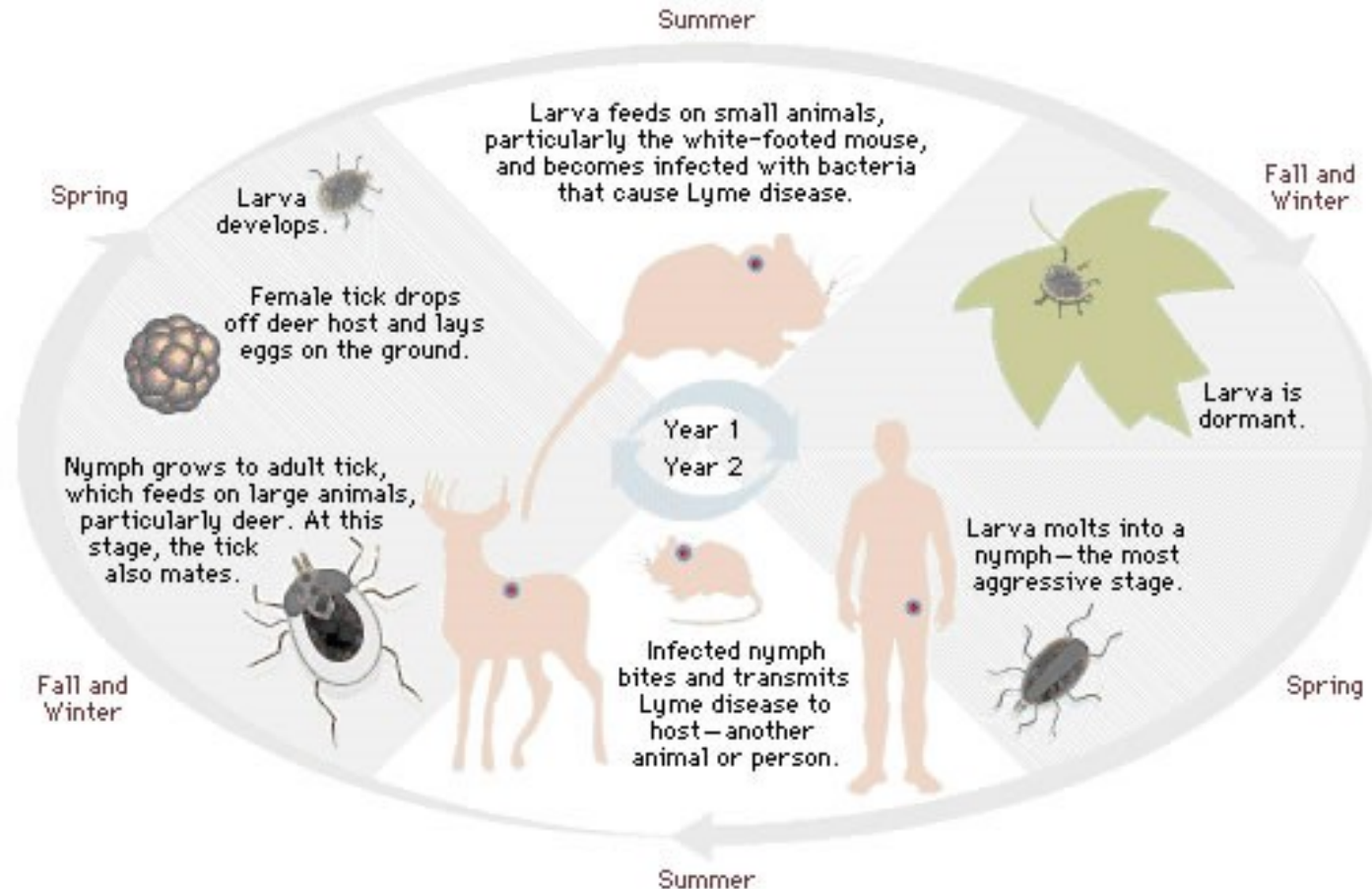
1. Woolhouse MEJ. *Where do emerging pathogens come from?* *Microbe Magazine*, November 2006.

2. Taylor LH, Latham SM, Woolhouse ME. *Risk factors for human disease emergence.* *Phil Trans R Soc Land B Biol Sci.* 2001;356:983-9.

Lyme borreliosis

- This is the most complex of zoonoses because it has many hosts and a carrier.
- It is a spirochaete that must survive very complex environmental conditions.

Lyme disease life cycle



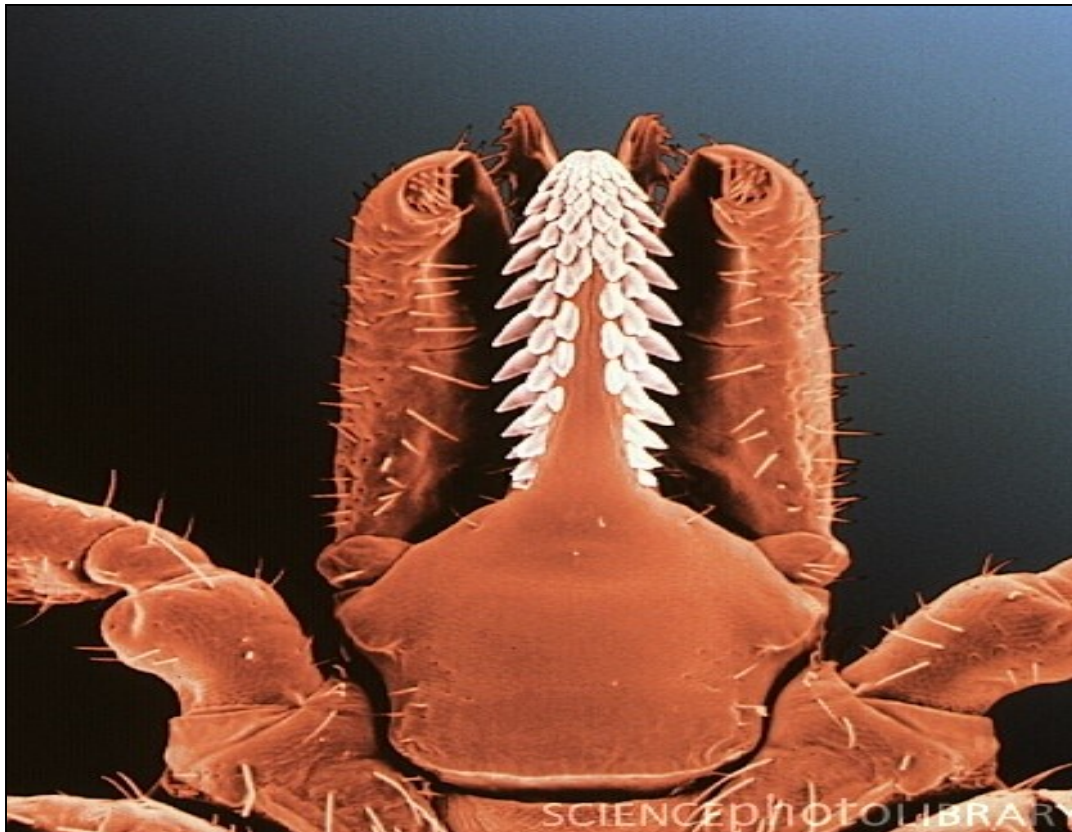
Lyme disease diagnosis and treatment. [Cited 2019 Nov 8]. Available from: <https://www.ssequineclinic.com/veterinary-services/lyme-disease-diagnosis-treatment/>

Tick forms



[Cited 2011 April 8]. Available from: <http://medent.usyd.edu.au/photos/tickst.jpg>

Tick (mouthpart)



Lyme disease tick. Head and mouthparts of the female Deer Tick *Ixodes scapularis* (previously *Ixodes dammini*). It transmits Lyme disease to humans. At centre is the barbed, skin-piercing, blood-sucking mouthpart; at lower centre is the head.

[Cited 2011 Mar 24]. Taken from: from www.sciencephoto.com/images/download_lo_res.h...

Life cycle of the tick

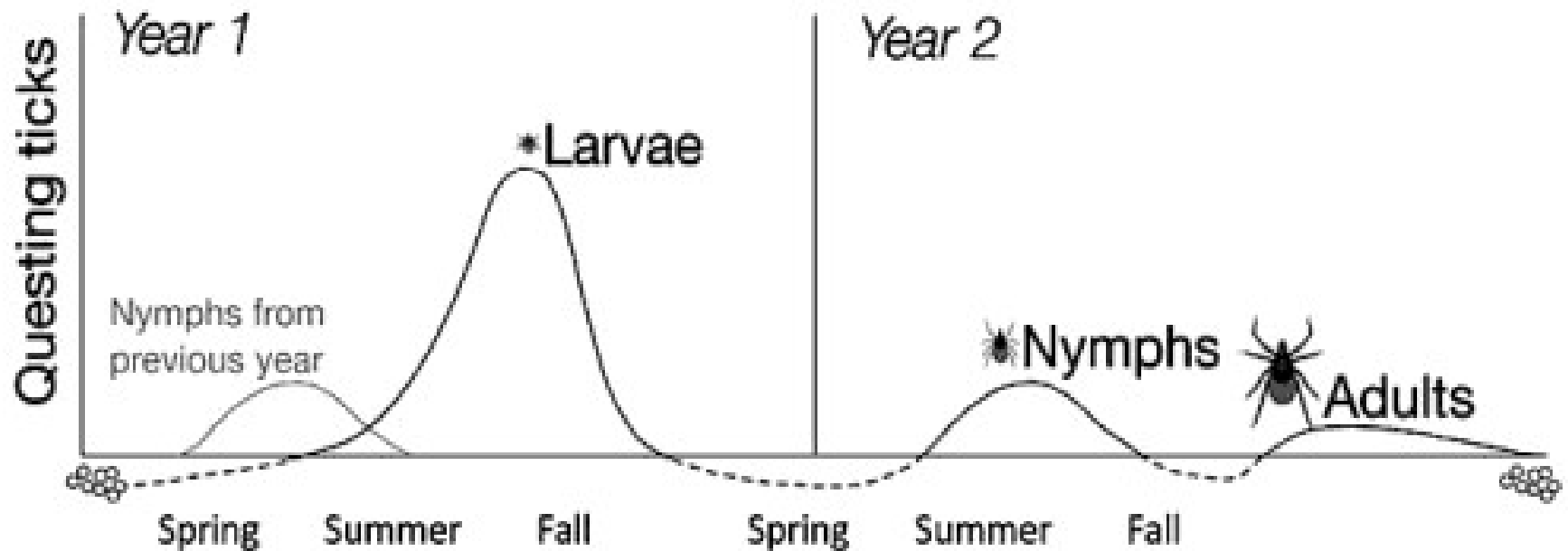
- In the course of a meal, the ticks can acquire *Borrelia* from an infected host.
- Ticks usually have only one meal annually. Therefore the nymphs will transmit the infection to the adults, which will be infected.
- The adults themselves can pass their infection transovarially (via the eggs) to the larvae and the nymphs that emerge subsequently will be infected already.
- They, when they bite, can transmit an infection.

Life cycle of the tick (cont.)

- To understand the epidemiology, one has to know about the life of the tick.
- The adult tick lays eggs anywhere in grass or leaves.
- The first immature stage (larvae) have only six legs.
- These larvae must find and attach themselves to a host (a small mammal) in order to get a blood meal.
- After obtaining this blood meal, they usually drop to the ground, shed their skin and emerge as eight-legged nymphs.

NIAID [Cited 2011 Mar 24]. Taken from: www.niaid.nih.gov/topics/lymedisease/research/pages/cause.aspx

Life cycle of the tick (cont.)



Ostfeld R. *Lyme disease: the ecology of a complex system*. Oxford: Oxford University Press; 2011. p23.

Life cycle of the tick (cont.)

- The promulgation of the *Borrelia* can be either from the bite of a nymph or from the bite of an adult tick.
- Changes in the host community ecology contribute to the emergence of infectious diseases.
- The attribution to the increase in deer population that has been going on for the past 100 years is not entirely correct because although deer do serve as a host for adult ticks, transmission of the *B. burgdorferi* pathogen occurs during the nymphal stage of tick development.

Life cycle of the tick (cont.)

- The smaller mammals carrying the nymphs may be more important in *B. burgdorferi* transmission.
- Ostfeld et al. have identified that there are more ticks carrying the *Borrelia* organism in small mammals than in the deer.¹

Ostfeld R. Lyme disease: the ecology of a complex system. Oxford: Oxford University Press; 2011. p64.

Effect of climate change on vector-borne disease risk in the UK

- During the early part of the 21st century, an unprecedented change in the status of vector-borne disease in Europe occurred.
- Tick-borne diseases, such as Lyme disease, continue to increase.
- Intercontinental air travel and global shipping transport create new opportunities for invasive vectors and pathogens.
- Changes in vector distributions are being driven by climatic changes and changes in land use, infrastructure, and the environment.

Medlock JM, Leach SA. Effect of climate change on vector-borne disease risk in the UK. Lancet infect Dis. 2015;15:721-30.

Assessment of the Public Health threats posed by vector-borne disease in the UK

- For tick-borne diseases, data on the changing distribution of the Lyme borreliosis tick vector, *Ixodes ricinus*, has recently been published.
- There has been an increase in the numbers of reported human cases of Lyme disease.
- Surveillance data and pertinent research on vector-borne disease in the UK highlights the need [to monitor] our native mosquito and tick fauna and expand surveillance for invasive species.
- Maintaining surveillance capacity to ensure accurate and timely disease risk management to help mitigate the UK's changing emerging infectious disease risks, especially in a time of climatic and environmental change and increasing global connectivity.

Medlock JM, Hansford KM, Vaux AGC, Cull B, Gillingham E, Leach S. Assessment of the Public Health threats posed by vector-borne disease in the United Kingdom (UK). *Int J Environ Res Public Health*. 2018;15:2145.

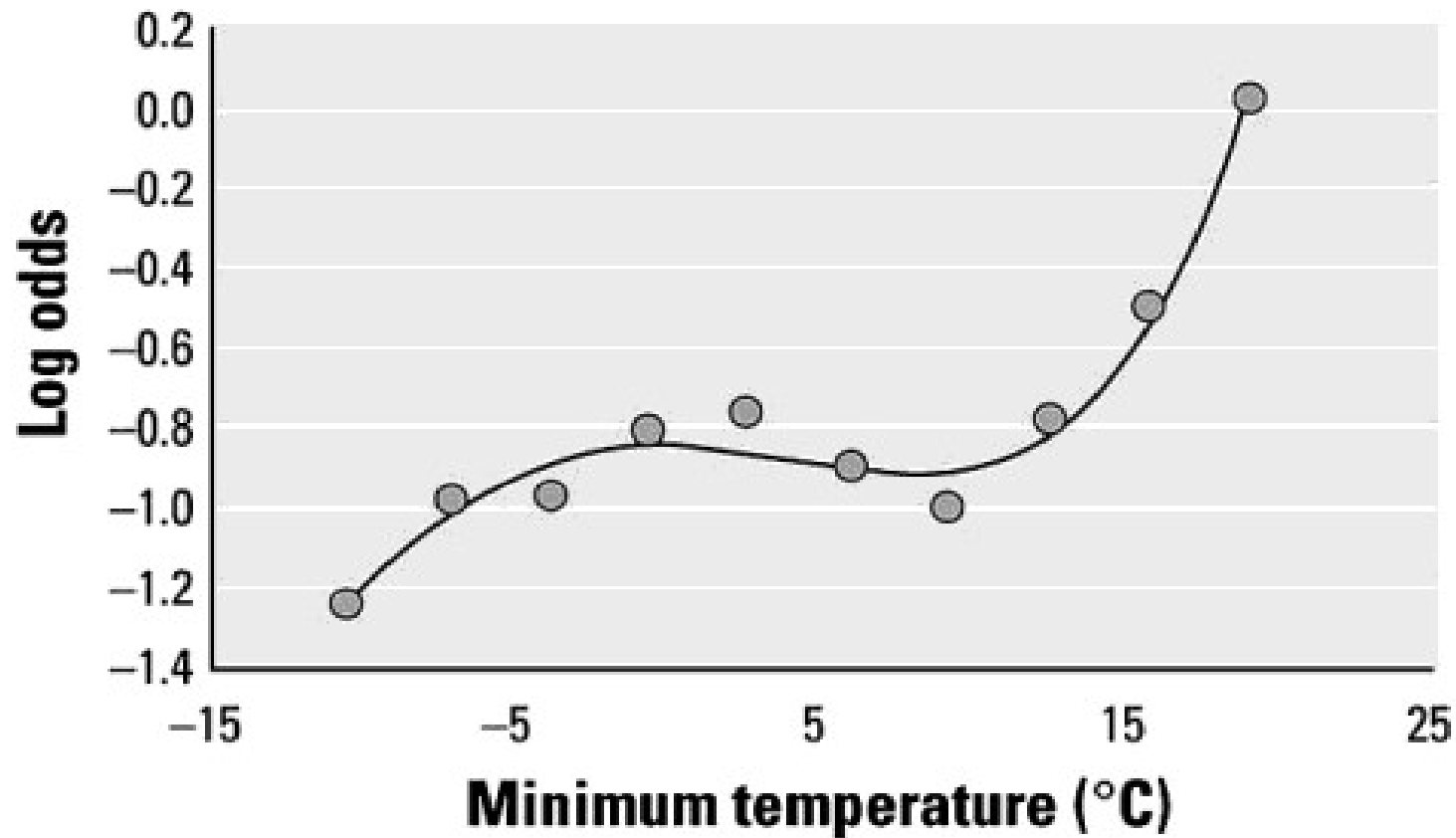
Distribution of ticks in Great Britain

Factors potentially influencing tick distribution:

- Climate change
- Increased movement between countries of people
- Companion animals

Smith FD, Ballantyne R, Morgan ER, Wall R. Prevalence, distribution and risk associated with tick infestation of dogs in Great Britain. Med Vet Entomol. 2011;25:377-84.

Climatic influence



Ostfeld R. *Lyme disease: the ecology of a complex system*. Oxford: Oxford University Press; 2011. p64.

British tick species carrying *Borrelia burgdorferi sensu lato* (Lyme borreliosis)

Species	Common name	Preferred host	Bite risk to humans	General habitat	UK distribution
Argas (Argas) reflexus	Pigeon tick	Pigeons, swallows, swifts, crows and chickens	Will attach to humans in close proximity to infested bird colonies	Primarily where pigeons roost, eg Kings College, Cambridge	Mostly South East England
Dermacentor (Dermacentor) reticulatus	Ornate cow tick/Marsh tick	Domestic and wild animals, eg dogs, horses, cattle, foxes, hares and hedgehogs	Will attach to Humans particularly in close proximity to cattle	Grasslands, pastures and woodlands	South West England and Wales
Haemaphysalis punctata	Red sheep tick/Coastal red tick	Mainly sheep, cattle, small mammals and birds	Will attach to humans	Widely differing environments	South East England, West coast of Wales, North Wales
Ixodes (Exopalgiger) trianguliceps	Vole tick/Shrew tick	Principally small rodents but also foxes and mustelids	Attachment to Humans occasionally occurs	The burrows or nests of its hosts but larvae quest for hosts in plant litter	Widely distributed UK wide

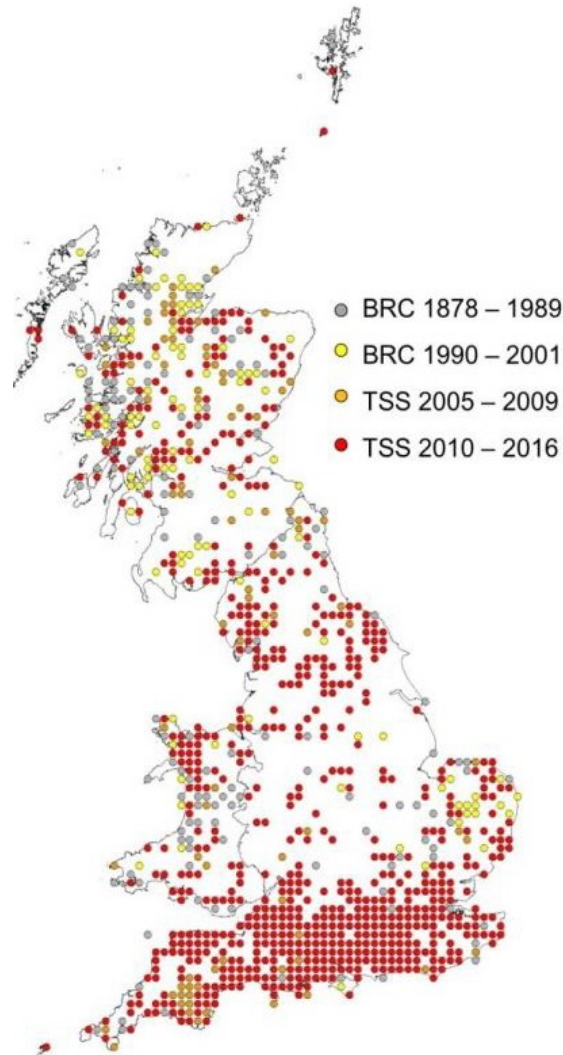
[Cited 2011 May 25]. Taken from: www.bada-uk.org

British tick species carrying *Borrelia burgdorferi* sensu lato (Lyme borreliosis)

Species	Common name	Preferred host	Bite risk to humans	General habitat	UK distribution
Ixodes (Ceratiixodes) uriae	Seabird tick	Primarily colonial seabirds, occasionally other birds	Actively quests for hosts. Will readily bite humans visiting bird colonies.	Found in and around the nests, burrows and cracks in stone.	Coastal regions UK wide
Ixodes (Ixodes) hexagonus	Hedgehog tick	Hedgehogs, foxes, mustelids, dogs, cats, rodents and occasional birds	Frequently attaches to humans	On the host or in the next. Present in suburban/urban areas.	The whole of the UK but commonest in South East England
Ixodes (Ixodes) ricinus	Sheep tick/Castor bean tick/Wood tick	Wild and domestic small-large mammals, birds and reptiles	Frequently attaches to humans	Grassland, moorland, heathland and woodland. Found in suburban/urban areas.	Widely distributed UK wide

[Cited 2011 May 25]. Taken from: www.bada-uk.org

Distribution of *Ixodes ricinus* ticks in Great Britain



Medlock JM, Hansford KM, Vaux AGC, Cull B, Gillingham E, Leach S. Assessment of the Public Health Threats Posed by Vector-Borne Disease in the United Kingdom (UK). *Int J Environ Res Public Health*. 2018;15:2145.

Lyme distribution

For tick-borne diseases, data on the changing distribution of the Lyme Borreliosis tick vector, *Ixodes ricinus*, has recently been published, at a time when there has been an increase in the numbers of reported human cases of Lyme disease.

Medlock JM, Hansford KM, Vaux AGC, Cull B, Gillingham E, Leach S. Assessment of the Public Health Threats Posed by Vector-Borne Disease in the United Kingdom (UK). Int J Environ Res Public Health. 2018;15;2145.

Lyme distribution (cont.)



Health
Protection
Scotland



Lyme Disease, Scotland, Annual Totals
as at 28 July 2016

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015*
<i>Borrelia</i> (total) (Lyme Disease) ¹	171	230	285	228	308	229	207	176	224	200
<i>Borrelia burgdorferi</i>	171	230	285	228	308	229	207	176	223	200
<i>Borrelia</i> species	0	0	0	0	0	0	0	0	1	0

¹ includes *Borrelia burgdorferi* and *Borrelia* species

Data source: Health Protection Scotland

*2015 data remain provisional

Lyme disease, Scotland, annual totals as at 28 July 2016. [Cited 2019 Nov 8]. Available from:
https://hpspubsrepo.blob.core.windows.net/hps-website/nss/1761/documents/1_lyme-disease.pdf

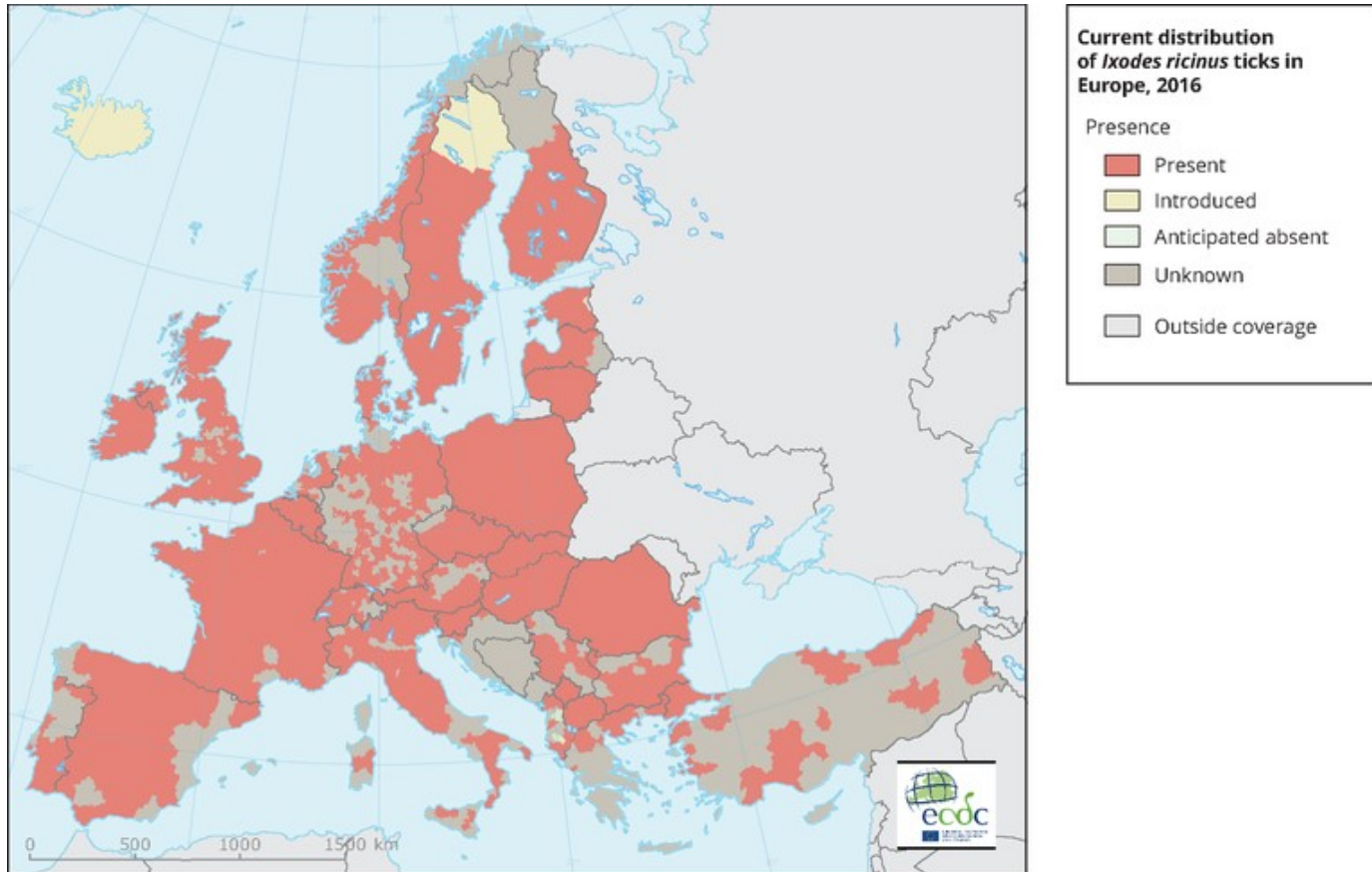
Lyme distribution (cont.)

Lyme disease epidemiology and surveillance

Years	Total laboratory confirmed cases	Mean annual rate per 100,000 population
2007	797	1.46
2008	813	1.52
2009	863	1.59
2010	905	1.64
2011	959	1.73
2012	1040	1.84
2013	936	1.64
2014	856	1.49
2015	1060	1.83
2016	1134	1.94
2017	1579	2.70

Lyme disease epidemiology and surveillance. 2018 [Cited 2019 Nov 8]. Available from: <https://www.gov.uk/government/publications/lyme-borreliosis-epidemiology/lyme-borreliosis-epidemiology-and-surveillance#annual-totals-and-rates>

Lyme distribution (cont.)



Current European distribution of *Ixodus ricinus* tics. 2016 [Cited 2019 Nov 8]. Available from: <https://www.eea.europa.eu/data-and-maps/figures/european-distribution-of-borrelia-burgdorferi-1>

Lyme distribution (cont.)

- Changes in climate have affected the emergence, distribution, and abundance of *Ixodes ricinus* in the UK.¹
- The risk for tick borne disease has increased.²
- Co-infestation of tick larvae and nymphs occurs in small mammals in UK woodland.³

1. Medlock JM, Hansford KM, Vaux AGC, Cull B, Gillingham E, Leach S. Assessment of the Public Health threats posed by vector-borne disease in the United Kingdom (UK). *Int J Environ Res Public Health*. 2018;15:2145.
2. Medlock JM, Leach SA. Effect of climate change on vector-borne disease risk in the UK. *Lancet infect Dis*. 2015;15:721-30.
3. B Vaux AGC, Ottowell LJ, Gillingham EL, Medlock JM. Tick infestation of small mammals in an English woodland. *J Vector Ecol*. 2017;42:74-83.

Lyme distribution (cont.)

- Ixodes ricinus ticks are the causative agent of human granulocytic anaplasmosis.
- Human cases in Europe are not frequent, although they may be underestimated due to their nonspecific flu-like symptoms.
- More recently, evidence of Rickettsia helvetica and Borrelia miyamotoi infection in I. ricinus in the UK has been reported.
- Potential changes in the distribution of two other, non-Ixodes tick species with disease vector potential have been detected: Dermacentor reticulatus (cow tick) and Haemaphysalis punctata.









Medlock JM, Hansford KM, Vaux AGC, Cull B, Gillingham E, Leach S. Assessment of the Public Health threats posted by vector-borne disease in the United Kingdom (UK). Int J Environ Res Public Health. 2018;15:2145.

Lyme distribution (cont.)

- There are established populations of *D. reticulatus* in three main areas of England and Wales: along the West Wales coast from Harlech to Borth, on the North and South Devon coasts, and coastal grassland at Bolt Tail, with a third focus in Essex, in both coastal grassland and urban parks.
- The detection of *Rickettsia raoultii* in the UK populations of *D. reticulatus* is a potential public health threat.
- The red sheep tick, *Haemaphysalis punctata*, has been reported to occur in England for over the last 100 years.
- humans presenting with *H. punctata* bites are also being reported to have Lyme Borreliosis.

Medlock JM, Hansford KM, Vaux AGC, Cull B, Gillingham E, Leach S. Assessment of the Public Health threats posed by vector-borne disease in the United Kingdom (UK). Int J Environ Res Public Health. 2018;15:2145.

Ticks and diseases transmitted

<p>American Dog Tick</p>  <ul style="list-style-type: none"> • Tularemia • Rocky Mountain Spotted Fever 	<p>Brown Dog Tick</p>  <ul style="list-style-type: none"> • Rocky Mountain Spotted Fever • Q Fever 	<p>Deer Tick</p>  <ul style="list-style-type: none"> • Lyme Disease 	<p>Cayenne Tick</p>  <ul style="list-style-type: none"> • Rocky Mountain Spotted Fever
<p>Lone Star Tick</p>  <ul style="list-style-type: none"> • Southern Tick Rash Illness (STARI) • Heartland Virus • Tularemia • Ehrlichiosis • Q Fever 	<p>Rocky Mountain Wood Tick</p>  <ul style="list-style-type: none"> • Colorado Tick Fever • Powassan Encephalitis • Rocky Mountain Spotted Fever 	<p><i>Ixodes</i> Ticks (Multiple Species)</p>  <ul style="list-style-type: none"> • Lyme Disease • Babesiosis • Powassan Encephalitis • Anaplasmosis (HGA) 	<p>Soft Ticks</p> <p>African Tick</p>  <ul style="list-style-type: none"> • Tick-Borne Relapsing Fever

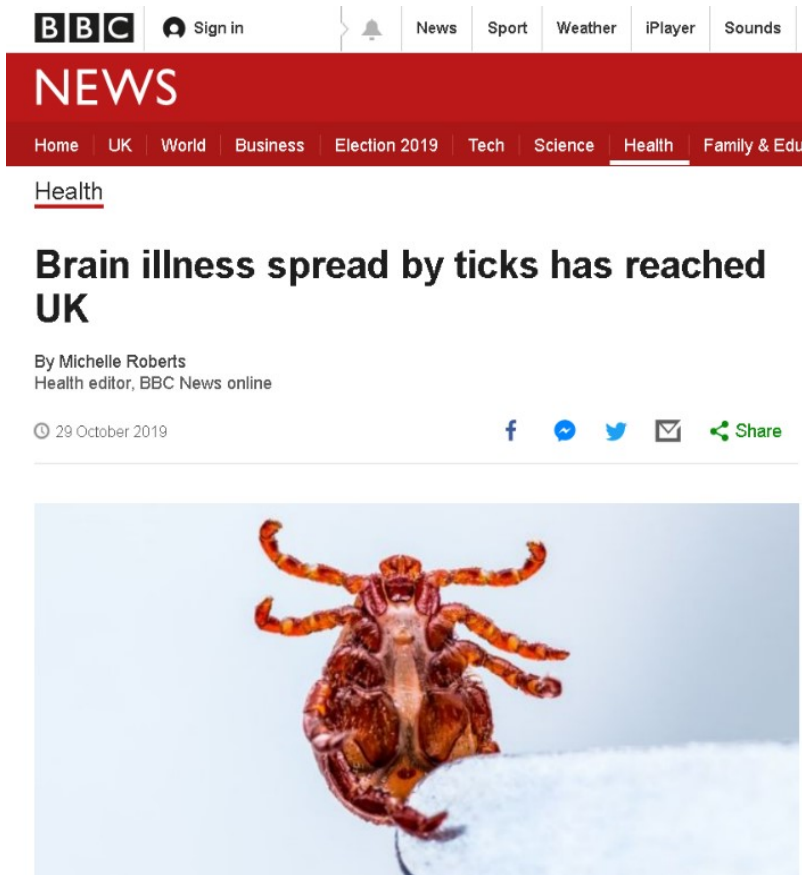
Davis CP. Ticks (tick bites). [Cited 2019 Nov 8]. Available from: <https://www.medicinenet.com/ticks/article.htm>

Tick-borne encephalitis virus in the UK

- Large-scale surveillance was conducted for the presence and prevalence of tick-borne encephalitis virus (TBEV) and louping ill virus (LIV) in sentinel animals and ticks in the UK.
- *Ixodes ricinus* tick species is the most abundant and widely distributed tick species in the UK and a known vector of Lyme borreliosis.
- Humans are incidental hosts for LIV, and infection has been reported in around 45 clinical cases during the past 85 years.

Holding M, Dowall SD, Medlock JM, Carter DP, Pullan ST, Lewis J, et al. Tick-borne encephalitis virus, United Kingdom. Emerg Infect Dis. 2020 [Cited 2019 Nov 8]. Available from: <https://doi.org/10.3201/eid2601.191085>

Lyme distribution – encephalitis



- An infectious disease that can harm the brain and is spread to people by tick bites has been identified in ticks in the UK for the first time.
- Public Health England (PHE) says it has confirmed cases of tick-borne encephalitis virus in ticks from two parts of England – Thetford Forest and an area on the Hampshire-Dorset border.
- PHE says the risk to people is still “very low”.
- It is monitoring the situation to check how common the infected ticks may be.

Roberts M. Brain illness spread by ticks has reached UK. 2019 [Cited 2019 Nov 8]. Available from: <https://www.bbc.co.uk/news/health-50206382>

Results of the Big Tick Project

The largest ever study of ticks in dogs in the UK

- Professor Richard Wall from the School of Biological Sciences at the University of Bristol, leads the Big Tick Project team.
- He said: "The work that we have carried out shows that ticks are very widely dispersed and illustrates that we appear to have had an increase in tick numbers across the country.
- "What we are most concerned about is the diseases that they carry. In this country, we have relatively low rates of the prevalence of these pathogens at the moment and, in contrast, in continental Europe they have much higher rates of disease. As there seems to be a rise in tick numbers, we need to be concerned and be aware of the potential for increasing problems."

University of Bristol. Results of the Big Tick Project – the largest ever study of ticks in dogs in the UK. 2016 [2019 Nov 8]. Available from: <http://www.bristol.ac.uk/news/2016/september/big-tick-project.html>

Preventing tick-borne disease through awareness



The largest study of ticks on dogs ever undertaken in the UK provided the science behind a successful and high profile campaign, endorsed by TV presenter and naturalist Chris Packham, to raise awareness of tick-borne diseases and how to protect against them.

Preventing tick-borne disease through awareness. [Cited 2019 Nov 7]. Available from:
<http://www.bristol.ac.uk/research/impact/preventing-tick-borne-disease/>

Essential oils as tick repellents on clothing

The results of this study suggest that 5% oregano and spearmint oils exhibit potential as natural clothing repellents, with an effective equivalence to 20% DEET.

Soutar O, Cohen F, Wall R. Essential oils as tick repellents on clothing. Exp Appl Acarol. 2019;79:209-19.

Other complications

- Can people develop meat allergies from tick bites?
- Yes, alpha-gal syndrome occurs when a tick bites a human and transmits a carbohydrate that it received while feeding on another mammal host.
- In some people, the alpha-gal carbohydrates trigger an immune system reaction when they eat red meat, which can be quite severe.
- There is no treatment for alpha-gal syndrome except avoiding red meat.

Lyme in urban areas

- The common blackbird and the European robin were the bird species most frequently infested with *I ricinus* ticks and had the highest prevalence of tick-borne pathogens.
- The continuous introduction of infected ticks by migratory birds to gardens and urban areas, which may otherwise not be able to sustain a viable tick population, may constitute an unrecognised zoonotic risk to humans.

Klitgaard K, Højgaard J, Isbrand A, Madsen JJ, Thorup K, Bødker R. Screening for multiple tick-borne pathogens in Ixodes ricinus ticks from birds in Denmark during spring and autumn migration seasons. Ticks Tick Borne Dis. 2019;10:546-52.

Lyme advice



Public Health
England

Protecting and improving
the nation's health

Travelling with or importing dogs?

Important information you need to know about ticks

Your dog may come into the UK with the brown dog tick which can transmit diseases to humans and animals. Unlike ticks in the UK, this species can also live indoors and infest houses.



The brown dog tick
(*Ixodes ricinus*)

Many dogs will travel without acquiring ticks but for those that do, you can help protect the health of your dog and yourself by:

- seeking advice about ticks from your vet prior to travelling with or importing dogs
- remaining vigilant by checking your dog and their bedding, yourself and your home for ticks once returning to the UK
- removing ticks found feeding on your dogs or yourself promptly and in a safe way using a tick removal tool or pointed tweezers
- contacting your veterinarian if your dog becomes unwell or your GP if you notice that you have been bitten by a tick or start to feel unwell
- seeking tick identification and pest control when necessary, should you suspect you have a tick infestation in your home

We are asking members of the public and veterinarians to remain vigilant for imported ticks on recently travelled or imported dogs. It would greatly enhance our understanding of tick importation risk if members of the public and veterinarians could **submit specimens to the PHE Tick Recording Scheme for identification**.

For more information contact **Tick@phe.gov.uk** or visit **www.gov.uk/tick-recording-scheme**

PHE publications gateway number: 2015173

Figure 7

Raising awareness of risks associated with native, and, in this case, non-native ticks.

Lyme organism

The life cycle of the Lyme organism in ticks

- **Tick:** *Ixodes scapularis*
- **TROSPA:** Tick Receptor For Outer Surface Protein A
 - Gut lining receptor links with an outer surface protein, OspA. TROSPA allows avoidance of elimination from the gut from the time it is ingested through the subsequent moult so that it can be injected into a new host at the next blood meal.

Lyme organism (cont.)

Three of the outer surface proteins, OspA, OspB and OspC, are expressed at different times through the bacterial life cycle.

Lyme organism (cont.)

Each *Borrelia burgdorferi* has:

- 1,500 gene sequences
- at least 132 functioning genes

This compares with the spirochaete agent of syphilis *Treponema pallidum*, which contains only 22 such genes.

Lyme organism (cont.)

- A *Borrelia spirochaete* contains 21 plasmids: 9 circular and 12 linear.
- A plasmid is “a circular, double-stranded unit of DNA that replicates within a cell independently of the chromosomal DNA and is most often found in bacteria”; it is used in recombinant DNA research to transfer genes between cells.
- It is also known as an “extrachromosomal element”. This is by far the largest number of plasmids found in any known bacterium.

Lyme organism (cont.)

The spirochaete enters human cells such as:

- fibroblasts
- synovial cells
- endothelial Cells
- macrophages

Lyme organism (cont.)

- In these cells the organism may become resistant to treatment because it has a camouflage protein produced by itself or absorbed from its host cell. It conceals itself with a bit of its own host.
- It can also alter its own shape from being a long, spirochaetal, spiral-shaped organism to a cyst form. The non-replicating cyst forms can be “resuscitated” by autocrine cytokine-like factors after lying dormant for months.

Lyme organism (cont.)

- Sometimes the cyst form is a blob-like structure inside the host cell and does not even have a cell wall.
- The organism has an evasion strategy similar to that used by tuberculosis and other agents, such as those that cause leprosy. This is a granulomatous reaction, a “walling off” of the organism, a calcified lesion.
- Change is induced in the host which affects the way it handles calcium in the body.

Types of forms of *Borrelia*

- In unfavourable conditions, the spirochaetes can transform into survival forms.
- They exist in three different growth stages – spherical and non-motile cysts, including tightly wound spirochaetes.
- They are resistant to almost every antibiotic.
- The others are L forms spheroplasts devoid of cell wall, insensitive to many antibiotics used in borreliosis (having effect on the cell wall).

Skotarczak B. Adaptation factors of Borrelia for host and vector. Ann Agric Environ Med. 2009;16:1-8.

Types of forms of *Borrelia* (cont.)

- Migration of spirochaetes from the tick's gut to its salivary glands during its sucking of the vertebrate's blood, then the penetration of the spirochaete to the vertebrate's tissues
- Bacteria recognising the environmental signals, which modulate the expression of fundamental genes that ensure success in adaptation

Chronic infections

- Biofilm (biofilm of the pleomorphic organisms hiding the *Borrelia* organism)
- Exopolysaccharide matrix
- Planktonic organisms
- Colonies of bacteria
- Bacteria can sense if their host is stressed, using channels to detect cortisol, adrenaline and noradrenaline and release powerful factors that help to take advantage of the host.

Biofilm

- Colonies of bacteria with biofilm are the source of many human infections, particularly those that often become chronic: borreliosis.
- The biofilm can upregulate drug resistance genes and trigger inflammatory and immune responses from within the exopolysaccharide matrix.
- The bacteria can sense if their host is stressed, using channels to detect cortisol, adrenaline and noradrenaline, and release powerful factors which help to take advantage of the host.

Host migration

- The geographic patterns of transmission opportunities of vector-borne zoonoses are determined by a complex interplay between the migration patterns of the host and the vector.
- Impact of host migration on spread of tick-borne zoonotic disease was examined:
 - limited geographic structuring between countries of *Borrelia garinii* and *Borrelia valaisiana* (birds) compared with those associated with *Borrelia afzelii* (small mammals)
 - higher migration rates in avian hosts than in small mammals

Vollmer SA, Bormane A, Dinnis RE, Seelig F, Dobson ADM, Aanensen DM, et al. Host migration impacts on the phylogeography of Lyme Borreliosis spirochaete species in Europe. Environ Microbiol. 2011;13:184-92.

Animal hosts

- The next ecological niche one needs to consider is the small animal hosts: often these are birds and small mammals including squirrels, hedgehogs, mice and rats.
- The larger hosts would be foxes, deer and pets (specifically dogs and cats).

Animal hosts (cont.)

- In the UK, the predators of small animals are carnivores such as foxes and badgers.
- Furthermore, in the UK, we need to keep the small animal population control in balance with ecological measures, and therefore to remove the large animals would be inappropriate. It follows that there should be no culling of badgers and no indiscriminate fox-hunting.
- It is almost impossible to control zoonoses in wildlife.
- Certainly they can be controlled more in our domestic animals through immunisation and through control of infectious disease in domestic animals.
- People are dead-end hosts.*

**Kilpatrick AM, Randolph SE. Drivers, dynamics, and control of emerging vector-borne zoonotic diseases. Lancet. 2012;380:1946-55.*

Animal hosts (cont.)

Pathogens in fleas collected from cats and dogs: distribution and prevalence in the UK

This study reports a large-scale survey of pathogens in fleas collected from client-owned cats and dogs in the UK. Rising levels of pet ownership, climate change and globalisation are increasing the importance of a detailed understanding of the endemicity and prevalence of flea-borne pathogens.

Abdullah S, Helps C, Tasker S, Newbury H, Wall R. Pathogens in fleas collected from cats and dogs: distribution and prevalence in the UK. Parasit Vectors. 2019;12:71

Prevalence and distribution of ticks in dogs in Great Britain: 2011

A three-month review of dogs in 173 veterinary practices showed:

- of 3,534 dogs, 810 had at least one tick
- *Ixodes ricinus* (Linnaeus) (Acari: Ixodidae) was identified in 72.1% of cases
- *Ixodes hexagonus* Leach was identified in 21.7% of cases
- *Ixodes canisuga* Johnston was identified in 5.6% of cases
- five samples of *Dermacentor reticulatus* (Ixodidae) were also found
- 50% of the vets reported infested dogs

Smith FD, Ballantyne R, Morgan ER, Wall R. Prevalence, distribution and risk associated with tick infestation of dogs in Great Britain. *Med Vet Entomol.* 2011;25:377-84.

Game birds and small rodents

Ticks, rodents and pheasants were analyzed for spirochete infections.

- In questing *Ixodes ricinus* ticks:
 - genospecies of *Borrelia burgdorferi* sensu lato were detected
 - highest prevalences were found for *Borrelia garinii* and *Borrelia valaisiana*
 - *Borrelia burgdorferi* sensu stricto was rare
 - *Borrelia afzelii* not detected

Kurtenbach K, Peacey M, Rijpkema SG, Hoodless AN, Nuttall PA, Randolph SE, et al. Differential transmission of the genospecies of Borrelia burgdorferi sensu lato by game birds and small rodents in England. Appl Environ Microbiol. 1998;64:1169-74.

Sheep and grey squirrels

Sheep

- *Borrelia burgdorferi sensu lato* can be maintained by sheep in the virtual absence of alternative hosts.¹

Grey Squirrels

- Grey squirrels are important hosts of larvae and nymphs of *Ixodes ricinus* L.²
- Squirrels are quantitatively more important than small mammals as hosts for larval ticks from April until July, and overwhelmingly so for nymphal ticks throughout the year.³

1. Ogden NH, Nuttall PA, Randolph SE. Natural Lyme disease cycles maintained via sheep by co-feeding ticks. *Parasitology*. 1997;115:591-9.
2. Craine NG, Nuttall PA, Marriott AC, Randolph SE. Role of grey squirrels and pheasants in the transmission of *Borrelia burgdorferi sensu lato*, the Lyme disease spirochaete, in the UK. *Folia Parasitol (Praha)*. 1997;44:155-60.
3. Craine NG, Randolph SE, Nuttall PA. Seasonal variation in the role of grey squirrels as hosts of *Ixodes ricinus*, the tick vector of the Lyme disease spirochaete, in a British woodland. *Folia Parasitol (Praha)*. 1995;42:73-80.

Population of pets (UK 2017)

- In 2017, it is estimated that 44% of UK households had at least one pet. This is equivalent to 12 million households.
- The UK dog population was around 8.5 million. Approximately 24% of the UK households owned at least one dog.
- The UK cat population was around 8 million. Approximately 17% of the UK households owned at least one cat.

Population of foxes

- At the end of the winter, there are 258,000 adult foxes in Britain, of which 33,000 have been estimated to live in urban areas and 225,000 in rural areas. Each year approximately 425,000 cubs are born each spring.
- Estimated densities at the end of winter varied between 0.21 and 2.23 foxes per square kilometre.

Ticks and biting insects infected with the etiologic agent of Lyme disease, *Borrelia burgdorferi*

It is not just ticks that transmit *B. burgdorferi*; it is harboured by several species of arthropods, including mosquitoes, horse flies and deer flies.

- Luger SW. *Lyme disease transmitted by a biting fly. N Engl J Med* 1990;322:1752.
- Magnarelli LA and Anderson JF. *Ticks and biting insects infected with the etiologic agent of Lyme disease, Borrelia burgdorferi. J Clin Microbiol.* 1998;26:1482-6.

Polymerase chain reaction in diagnosis of *Borrelia burgdorferi* infections

- *Borrelia burgdorferi* sensu lato comprises three different human pathogenic genospecies:
 - *Borrelia burgdorferi* sensu stricto
 - *Borrelia garinii*
 - *Borrelia afzelli*
- *Borrelia garinii* is the principal agent of Lyme neuroborreliosis in Europe.

Lebech AM. Polymerase chain reaction in diagnosis of Borrelia burgdorferi infections and studies on taxonomic classification. APMIS Suppl. 2002;105:1-40.

Future risks and ways to address them

- A particular concern is the impact of globalization on the spread of infectious diseases.
- We need more effective communication and cooperation between those working in human and animal health.

Historical perspective: Willy Burgdorfer

- 1) *Borrelia* found in the ice man¹
- 2) In 1978 Dr Burgdorfer noticed movement between the cells and tissue of six ticks he dissected. The movement came from larvae that were developing into a parasite found in deer.²

In 1981, while testing more than 100 deer ticks, Dr Burgdorfer noticed, in two ticks, the same larvae-type movement he had observed in 1978.²

- 3) *Borrelia* is the fastest growing vector-borne disease in the UK, Europe and USA.³

1. Taken from: <http://ngm.nationalgeographic.com/2011/11/iceman-autopsy>

2. NIAID [Cited 2011 Mar 24]. Taken from: www.niaid.nih.gov/topics/lymedisease/research/pages/cause.aspx

3. What is Lyme disease? 2013. Taken from: <http://www.ticktalkireland.org/whatislyme.html>

Lyme disease groups



Lyme Disease UK



ILADS
International Lyme and
Associated Diseases Society



lymeresearchuk.org



Further resources

- **Royal College of General Practitioners:** Lyme disease toolkit
<https://www.rcgp.org.uk/clinical-and-research/resources/toolkits/lyme-disease-toolkit.aspx>
- **Public Health England:** ‘Be tick aware’ – Toolkit for raising awareness of the potential risk posed by ticks and tick-borne disease in England (2018)
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/694157/PHE_Tick_Awareness_Toolkit.PDF
- **Department of Health Reviews Facility:** Incidence and surveillance of Lyme disease: systematic review and policy mapping
<https://eppi.ioe.ac.uk/CMS/Portals/0/PDF%20reviews%20and%20summaries/Lyme%20disease%20surveillance%202017%20Lorenc.pdf>

Environmental medicine aspects of chronic ill health due to Lyme disease and co-infections

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