

Lyme Disease in Treeless Islands of Scotland

[Announcer] This program is presented by the Centers for Disease Control and Prevention.

[Sarah Gregory] Hello, I'm Sarah Gregory, and today I'm talking with Dr. Caroline Millins. She's a research fellow at the University of Liverpool. We'll be discussing Lyme disease in treeless islands of Scotland.

Welcome, Dr. Millins.

[Caroline Millins] Good morning, Sarah. Thanks very much for inviting me.

[Sarah Gregory] So, a lot of people are concerned about Lyme disease, so let's make sure of the facts. What is it and what causes it?

[Caroline Millins] So, Lyme disease is the most common vectorborne disease in the northern hemisphere. It's a bacterial infection which is transmitted to animals and humans through bites from blood-feeding ticks. And ticks become infected when they feed on infected hosts, such as small mammals or birds, which are reservoirs to this bacteria.

[Sarah Gregory] Are there different ticks that are Lyme carriers in different parts of the world?

[Caroline Millins] Yes, there are. There are different tick species which are important for transmitting the bacteria which causes Lyme disease in different areas. So in Europe, the main tick species is *Ixodes ricinus*. In the United States, it's a different species called *Ixodes scapularis*, which is the main tick vector in the northeastern and north-central U.S., and *Ixodes pacificus* on the Pacific coast. And they do have some similarities, though. They're all...they're different species of the same genus of tick, and they're all generalist species so they'll feed on a really wide variety of different wildlife species and will also bite humans. And the bacteria is maintained in a similar way by different reservoir hosts (mammals and birds), which play an important role in infecting ticks in the wildlife cycle. And also larger mammals are important in both areas. Usually deer are playing an important role in maintaining the tick population, but they don't actually infect the ticks with the bacteria.

[Sarah Gregory] So are there different infection rates for the different kinds of ticks?

[Caroline Millins] So that's a really interesting question. So, the infection rate can vary for lots of different reasons. It's a very complex ecological system which maintains infection in ticks. And it depends on the...the community of wildlife hosts; the reservoir competence of the different species of wildlife (so how they can infect ticks that feed on them); how different tick life stages (so there's 3 different stages of these different tick species; there's larvae, nymphs, and adults)...so how these different tick life stages are distributed amongst different hosts, and that can affect infection in the host and then how...how the host can infect ticks; and also the vector competence of the actual tick species in transmitting the bacteria to different hosts.

So in the UK, as a result of all these different factors we can see a wide range of infection rates within just the one tick species, from...varying from 0% (so no infected ticks) to up to around 20% infection rates. And sometimes these variations can be within quite a small, local area.

[Sarah Gregory] Is Lyme disease relatively new to the UK?

[Caroline Millins] So, cases have been recognized in the UK since about the 1980s and for over a century in Europe. But it's likely to have been present in ticks for much, much longer. So for example, studies of the Tyrolean Iceman (who was nicknamed Ötzi), was found in the Italian Alps within...in a glacier there, and he's estimated as 5,000 years old and studies have found sequences of part of the...the genome of the bacteria which causes Lyme disease within his remains.

[Sarah Gregory] Oh, I had no idea. What are the geographic locations that are known for Lyme disease in the UK?

[Caroline Millins] So, Lyme disease can be contracted anywhere in the UK. Areas of woodlands, heathland, urban parks and gardens, particularly where these gardens back onto areas of suitable habitat for wildlife and ticks, are all areas where people may encounter ticks and be bitten by infected ticks. Epidemiology studies suggest that Lyme disease cases are being reported from all regions of the UK, but certain areas have higher numbers of cases. And these are the Highlands of Scotland and some areas in the south and the southwest of England.

[Sarah Gregory] Is there a seasonality to increased risk for catching Lyme disease?

[Caroline Millins] Yes, there is. So, the tick which transmits Lyme disease in the UK and Europe is seasonal in its activity pattern. The main tick activity period is between March and October, and within this the peak of the nymphal life stage activity (so this is the...the middle life stage, this tick's about the size of a sesame seed), it's thought to be the most important life stage for transmitting Lyme disease to people and it has a peak of activity generally in the spring. So this would be the period we would consider as the highest hazard, so, the highest number of infected ticks present in the environment. But the...the risk period really depends on how the environmental conditions influence the tick activity, but also how people are using those habitats and coming into contact with ticks. And in recent years there's also reports of tick activity during the winter months, which is interesting and important to point out. It's much lower levels of activity, but good for people to know that they might also come into contact with ticks during the winter months.

[Sarah Gregory] I heard that recently, with another podcast on Lyme disease we did for in the U.S. here, I just...that just astounds me. I mean, at least with mosquitoes they... they go away in the winter, you can count on that.

[Caroline Millins] Yes, yes. There seems to be a link with warmer, milder winters and increased frequency of...of tick activity. So, it...it's probably got a climate influence there.

[Sarah Gregory] So how many people get Lyme disease in the UK every year?

[Caroline Millins] So there are approximately 2,000 cases of Lyme disease in the UK annually. And around 2–300 of these are diagnosed in Scotland.

[Sarah Gregory] Supposedly, Lyme infection creates a target-like rash at the site of the bite. Is this a reliable way to tell if you have Lyme disease? Or does it change with the kind of tick? And does it manifest differently in different parts of the world, say Scotland versus the U.S.?

[Caroline Millins] So I'll...I'll just start that reply to...to that question by saying I'm...I'm not a medical practitioner and I don't study clinical aspects of Lyme disease. But I can tell you that Lyme disease most commonly presents as a spreading rash around the bite area or elsewhere on

the body, which is known as an erythema migrans rash (or target rash). And this is considered to be a reliable method of diagnosis of Lyme disease. According to Public Health England, in the UK, around a third of cases of Lyme disease...people don't notice a rash and they may also present with fever, headache, or neurological symptoms. So, there is some overlap between the clinical presentations which is seen in Europe and the U.S. The target rash is seen in the U.S., and as well, people report fever, joint swelling, and neurological symptoms.

It's worth mentioning there's some evidence that different genus species of the bacteria (which are present in Europe and the United States) are thought to be associated with different clinical presentation. And within the US, some strains are thought to cause more severe symptoms compared to others. It's a really interesting area of research, but it's something that's always incredibly challenging to...to work on because it's relatively rare that we actually get the...the species or the strain of bacteria which causes Lyme disease in a clinical patient.

[Sarah Gregory] As you mentioned, the Highlands of Scotland have the highest incidence of ticks in the UK. But now cases are being found on treeless Scottish islands. Tell us what's going on?

[Caroline Millins] So the...the highlands of Scotland have the...the highest incidence of Lyme disease cases in the UK, and that's been highlighted in several epidemiology studies. We don't fully understand the reasons for this. It's probably a combination of the habitat for wildlife and tick hosts, as well as people's activity patterns and their exposure to ticks. And...so the...the issue with Lyme disease cases on treeless islands in Scotland came to my attention, my colleague at the University of Glasgow (Dr. Roman Biek) in 2017, and this was at a national Lyme disease meeting where we met Isabell MacInnes, who is a public health nurse working for NHS Western Isles. And she shared concerns from public health and also from the local community about really high numbers of cases (approximately 40 times the national average) which had been reported over the last decade. The Western Isles are treeless. So from an ecological perspective, this is really quite unusual. Typically in Europe and North America we associate woodland habitat as having the most suitable conditions for wildlife hosts and tick populations, and also having the highest risk for human cases of Lyme disease.

And Isabell went on to explain that cases had increased over the last decade, and...and the distribution was different between different islands. So, some islands had very high numbers of cases while others had much lower numbers of cases, similar to what we saw on the mainland. And this is really intriguing from an ecological and public health perspective. Superficially, the habitats and the climate of these islands look very similar. So what was going on that was different that was causing high numbers of cases of Lyme disease on some islands compared to others? And...and it was also an area that...where they were reporting Lyme disease emergence that we wouldn't typically associate with Lyme disease and tick...tick populations and infected ticks. There was a really high level of engagement from local stakeholders and the community to understand the reasons for emergence and what they could do to reduce this.

[Sarah Gregory] Why did you decide to investigate these trends in the first place?

[Caroline Millins] So, following this initial meeting Isabell introduced us to the community and stakeholders. These were represented by the local deer management group, which included crofters, local landowners, estates (these were the main deer estates, Stòras Uist and the North Uist estates), veterinary surgeons (including Graham Charlesworth), and local government

agencies including public health (NHS Western Isles) and conservation and land management, represented by Scottish National Heritage (now Nature Scot) and particularly Johanne Ferguson and Des Thompson. And we found that there was concern within the community about problems with ticks and Lyme disease and...and the community asked us to investigate the environmental factors associated with infection risk and which species of Lyme disease bacteria were present in ticks, and longer term which interventions could be considered to reduce risk.

[Sarah Gregory] What kind of surveillance is used to track Lyme in the UK?

[Caroline Millins] Lyme disease surveillance in the UK is based on laboratory-confirmed cases. These are cases where blood samples are submitted for serological testing and interpreted with the clinical history and presentation. This means that we miss information on cases which are diagnosed on the basis of clinical symptoms alone, for example the...the cases of target rashes or erythema migrans we just talked about. Most of these cases will be treated in primary care without additional testing. So, surveillance based on serological cases in the UK has found that in England and Wales there are around 2 cases per 100,000, Scotland around 5 cases, the Highlands up to 50 cases per 100,000, and in some treeless islands in the Western Isles, over 100 cases per 100,000 have been reported.

And because of the heightened concern in the Western Isles, Isabell MacInnes (the public health nurse I just introduced) collected additional information on the diagnosis of Lyme disease from erythema migrans rashes in primary care records. And this shows the same pattern as the serologically-confirmed cases. So some islands had a very high number of cases, and others had a much lower number.

[Sarah Gregory] Why don't you give us the highlights of your study, now?

[Caroline Millins] So what we found was that islands which had a high number of cases of Lyme disease also had a higher rate of infection in the ticks. And people on these islands were also more likely to be bitten by ticks. Most people were being bitten by ticks close to their home and often in their garden, and there was a perception that increased numbers of ticks and proximity of ticks to people's homes was related to increased numbers of deer and deer coming closer to people's homes.

[Sarah Gregory] What methods did you use to carry out your study?

[Caroline Millins] So there were two main parts to this study. There was an environmental or ecological side to the study. We didn't know very much about tick abundance and infection rates in ticks in these different treeless habitats. And we also had a...a survey component to understand the social and behavioral factors which influence people's tick bite exposure rate.

So in...in the ecological part, we sampled a large number of sites from the main habitat types that we thought would support tick populations. So, this is different types of grassland as well as moorland, bogs and peatland, and people's gardens. And we designed this in a way that we could look at tick numbers and infection rates between different habitats and also between different islands. And the way that we collect ticks in the field is by dragging a one-meter woolen blanket across the vegetation along a measured distance, and ticks latch on to the blanket as if they were latching on to a passing host. We were able to pick them off and count them and place them into tubes to transport and take them back to the lab. And we also collect data on the...the habitat and

the vegetation type and other factors like temperature and humidity, which can also affect tick numbers and activity. And all of the ticks we've collected we take back to the lab and test them for the bacteria which causes Lyme disease.

In the...the survey part that I mentioned, we distributed a survey across all the residents of the Western Isles. And we were really interested in more information on where people were bitten and...and the risk factors for tick bite exposure. And we also assessed people's knowledge and attitudes towards ticks and measures people took to prevent tick bites. And we also gathered these community perceptions on which environmental factors may have changed over time that might be related to the emergence of problems that they were seeing.

[Sarah Gregory] What did you find from your study?

[Caroline Millins] So in the ecological part of the survey, we found that the infection rate was significantly higher on islands with high numbers of cases of Lyme disease. Around 6% of ticks were infected compared to <1% on islands with lower numbers of cases. And when we analyzed the genus species of the bacteria causing Lyme disease that was present in the ticks, we found that this was almost entirely one species and this species is associated with small mammals, but not with birds. This was quite a surprise. We only find this species of Lyme disease bacteria on islands which have high numbers of cases of Lyme disease, and it appears to be completely absent from other islands. It's a really interesting finding, it makes studying the host involved much simpler as we can narrow this down to just a few potential species. And it's also very different to what we see on the mainland, where typically if we sample from a large number of sites we would see more of a mixture of different genus species that are present in Europe. So, there are three main genus species of bacteria which cause Lyme disease in Europe: one which is associated with rodents and small mammals, one associated with birds, and one which can infect both birds and small mammals, which you also have in the U.S.

The...the second part of the research where we used the survey to ask how often people were exposed to tick bites, we found that on islands where there was higher Lyme disease cases, there was a significant...significantly higher frequency of tick bites. Most of these tick bites happened close to people's homes, including many bites in gardens. And we found a similar density of infected ticks in people's gardens as in the surrounding habitats, suggesting that ticks were being spread from these surrounding habitats probably with wildlife hosts into people's gardens.

And then lastly when we asked people about their perceptions of what had changed to understand the underlying driver of emergence, we found that residents on islands with high numbers of cases were reporting increasing problems with ticks, and many of them suggested that changing deer distribution and presence of deer near homes was a potential factor.

[Sarah Gregory] What do you consider the most important aspect of your study?

[Caroline Millins] So, a really important part of this work for me was working closely with the community and local stakeholders, and ensuring that our research study really addressed their questions. We've been able to provide answers to their questions on what the infection rate is in ticks and how this varied between different habitats and different islands, and also the genospecies causing the majority of infections, which settled many preliminary conversations about which wildlife species may be involved and infecting the ticks. So we know now that it's one of a few species of small mammals. We still don't know why some islands have relatively

low infection rate and others have a high infection rate. So, whether this is differences in the...the community of small mammals present on these islands or whether the bacteria may have been introduced to some islands and not others, that's the question for future research. And we're continuing to work closely with the community to provide evidence for them on how to manage Lyme disease with two PhD studentships. One is looking at understanding the contributions of wildlife hosts in maintaining ticks, and also which host...which reservoir hosts are...are responsible for infecting ticks. And the other is looking at how deer habitat use relates to tick distribution.

The other important aspect of this study that I'd like to highlight was integrating between the ecological factors (which determine how many infected ticks are in the environment) with how people become exposed to tick bites. Both of these aspects contribute to Lyme disease cases which are collected by surveillance, and we really need to understand both aspects to understand differences in case numbers. And that's if we're assuming that awareness and diagnosis is similar, which in our study I think we can assume that.

[Sarah Gregory] What were the biggest challenges to doing this study?

[Caroline Millins] So, the Western Isles are quite remote. Even from Glasgow in Scotland where I was based when I started this study, it's an 8-hour journey by road and ferry. I was initially quite anxious about having graduate students work in a more remote environment than I was used to. But here the support that we received from the community and stakeholders was really incredible. In particular, I'd like to mention Isabell MacInnes (who works for NHS Western Isles), Graham Charlesworth (who's a local vet), and Johanne Ferguson (who works for Nature Scot) who all are also co-authors on the study. They really welcomed all of the graduate students who were involved in the work as well as myself, Roman Biek and Lucy Gilbert from University of Glasgow. They invited us for dinner on many occasions, and spread the news of our work through their networks and...and really helped for our research to run smoothly. I'm really grateful to them for this and for their continued interest and support of our research.

[Sarah Gregory] That's what makes scientific investigation wonderful is partnerships and cooperation like that.

[Caroline Millins] Yes.

[Sarah Gregory] How would you like to see your findings used going forward?

[Caroline Millins] So, there are several future directions leading on from this work, which we are developing with stakeholders in the community. So as I mentioned, we've identified that small mammals are very important in infecting ticks. And as part of one of the PhD studentships, we're looking at understanding which hosts are important as reservoir hosts and the question of whether there's differences in the host community among different islands, or if the...the bacteria may have been introduced to some islands and not others.

We're also studying how deer and livestock contribute to maintaining tick populations. This research will help inform the community on possible ways to manage Lyme disease in the future by managing deer populations and/or tick treatment of livestock. And finding ways to manage people's risk in gardens is something we'd like to work on with communities and with public health, especially working together with Isabell MacInnes.

[Sarah Gregory] And...and what further studies would you like to see done on the spread of Lyme disease?

[Caroline Millins] Well, I can think of three main areas. Firstly, the finding that tick numbers and infection rates can be similar in treeless habitats to woodland areas is striking, and suggests that further studies are needed. We suspect that the microclimate, particularly the humidity in the Western Isles, may play a role in increasing tick survival. And it would be very interesting to compare this with studies in treeless habitats in other locations. A large proportion of the Highlands region in Scotland, for example, is covered by grassland and moorland, and...and perhaps this also contributes to the relatively high numbers of cases that are reported there compared to elsewhere in Scotland and the UK.

Secondly, ticks and tickborne pathogens are very sensitive to changes in the environment. As we have very many land use changes planned as part of government policy such as reforestation, urban greening, foecimate change mitigation and human well-being, as well as biodiversity plans all occurring in the context of a changing climate, I think we really need to have studies which evaluate how risks from ticks and tickborne pathogens will change along with changing habitats, areas for hosts and how people will come into contact with...with tick vectors.

And thirdly, I think there's a need for more joined up studies which link between the ecology of the vectors and the pathogens, how people are exposed to tick bites, and clinical presentations of Lyme disease in people so we can understand connections from the hazard from ticks in the environment where people are exposed and identify if there are particular clinical presentations associated with different strains of the bacteria.

[Sarah Gregory] What is public health doing to protect people from Lyme disease in the UK?

[Caroline Millins] So, awareness and prevention of tick bites are the main ways public health promotes to reduce the risk of Lyme disease in the UK. And there's also been some epidemiology studies to try and understand who is most at risk in the UK and which areas of the UK are most at risk.

[Sarah Gregory] As Lyme disease spreads (and appears to be spreading more), how can we best protect ourselves from getting it?

[Caroline Millins] So, the best way to prevent getting Lyme disease is to be aware of the risks when you visit areas where ticks are found and take sensible precautions. So these include things like keeping to footpaths and avoiding long grass when you're out walking, wearing appropriate clothing such as long sleeves, tops and trousers tucked into your socks, using insect repellent on exposed skin and on your clothes, and being careful to check yourself for any ticks which are attached to you after you've been in tick habitats and removing these appropriately and seeking medical advice if you develop any of the symptoms that are related to Lyme disease that we mentioned earlier. So, flu-like symptoms or a headache or...or a rash around the site of the tick bite or...or elsewhere.

[Sarah Gregory] Tell us about your area of work and what you enjoy most about it. I know you are particularly interested in One Health. Tell us what that means and why it's important.

[Caroline Millins] So, I'm a veterinarian. I've been incredibly lucky to have a very broad career in clinical practice and later specializing in wildlife disease ecology and epidemiology. I find the

ecology of wildlife disease fascinating, and understanding the drivers of emergence of disease a very relevant and necessary area of work. And I like the One Health approach as a multidisciplinary approach to investigate complex health problems. It integrates between human, animal, and environmental health, but also acknowledges the social, economic, and political context which is really critical to designing successful interventions.

[Sarah Gregory] I always like to ask authors a question about their lives, at this point. And just the other day I heard an interview with Dr. Fauci and he was asked this, so I'm going to ask you. Do you have a favorite streaming show you watch now that we're at home and what's your favorite snack to go with it?

[Caroline Millins] So I have to admit, during the pandemic I have been watching quite a lot of shows, more than usual. We're in our third lockdown here in the UK. I enjoyed the Queen's Gambit and I'm working my way through the American series at the moment. And sometimes I'll treat myself to a glass of red wine and some dark chocolate while I'm watching.

[Sarah Gregory] Ah, perfect. Well thank you for taking the time to talk with me today, Dr. Millins.

[Caroline Millins] Thank you very much, Sarah. It's been a pleasure.

[Sarah Gregory] And thanks for joining me out there. You can read the February 2021 article, Emergence of Lyme Disease on Treeless Islands, Scotland, United Kingdom, online at [cdc.gov/eid](https://www.cdc.gov/eid).

I'm Sarah Gregory for *Emerging Infectious Diseases*.

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