THE PUBLIC HEALTH RISKS OF LYME DISEASE IN BRECKLAND, U.K.: AN INVESTIGATION OF ENVIRONMENTAL AND SOCIAL FACTORS

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Abstract—This paper considers the public health risks of Lyme disease, a borrelial infection transmitted to humans chiefly by nymphal *Ixodes* ticks. A study undertaken in the Breckland area of East Anglia, U.K., combined analysis of the spatial and temporal factors affecting tick activity at recreational sites with a survey of current levels of disease awareness among visitors to these locations. Significant relationships were found between densities of questing ticks and vegetation type, relative humidity and temperature. More than two thirds of the general public visiting the sites were aware ticks could carry diseases, but only 13% recognized an unfed nymph, and under half knew that Lyme disease could be contracted from tick bites. Such results need to be taken into account when formulating public health and education measures.

Key words—Lyme disease, *Borrelia burgdorferi*, *Ixodes ricinus*, Breckland, risk assessment

INTRODUCTION

This paper presents initial results from an investigation of public health risks posed by Lyme disease (LD). The illness is tick-vectored and our study examines both environmental influences on disease vector activity and social factors affecting tick–human interaction such as public awareness. While a similar approach has been used in disease ecology research (Verhasselt, 1990), this is usually applied in tropical areas, where human–vector contacts are frequent and infection levels high. In the case of LD however, there is a complex transmission cycle and rates of vector infectivity can vary appreciably from place to place (Ginsberg, 1993). With the exception of some outdoor workers, most human exposure to ticks occurs during recreational activities chosen by the individual (Rees et al., 1995).

TRANSMISSION AND SYMPTOMS OF LYME DISEASE

Essentially an enzootic phenomenon, Lyme disease is a borrelial infection transmitted chiefly by ixodid ticks. In 1975 at Lyme, Connecticut, U.S.A., a cluster of cases of an apparently new infectious tick-borne disease occurred, the main symptoms being juvenile rheumatoid arthritis and a skin rash called an erythema migrans (EM) (Steere, 1989). Erythema migrans have been widespread in Europe since at least 1909 (Burgdorfer, 1993) and are associated with bites from the tick *Ixodes ricinus* (*I. ricinus*) (Steere, 1989). In 1982 Burgdorfer and Barbour isolated from *Ixodes* tick species in the U.S.A. a previously unrecognized spirochaete which became known as *Borrelia burgdorferi* (*B. burgdorferi*) (Burgdorfer, 1993). Examination of tissues from LD patients revealed that antibodies to *B. burgdorferi* were present. European *I. ricinus* and tissues from European patients with EM were also positive for *B. burgdorferi* (Steere, 1989). The term Lyme disease, or Lyme borreliosis, was introduced to describe various states of infection with *B. burgdorferi*.

Although LD has been described as a newly emerging infectious disease (Schrag and Wiener, 1995), analyses of museum specimens of ticks and mammals have shown that the infection was present in North America and Europe by the 1890s (Matuschka et al., 1995). The widespread geographic distribution of the pathogen in reservoir animal hosts and several tick species suggests that current disease incidence results from the dynamic interplay of tick–host interactions, natural and anthropogenic environmental changes (Korch, 1994).

The tick vectors of LD feed on a wide variety of mammals, birds and reptiles. Starting as an egg, the life cycle of *I. ricinus* includes three active stages during each of which it feeds only once (see Fig. 1). Spirochaetes are transmitted between host animals and ticks during feeding and also trans-stadially through the tick’s developmental stages (Anderson and Magnarelli, 1993). Studies of *I. ricinus* populations in Europe have found rates of infection with *B. burgdorferi* varying from 2% to over 40% (De Boer and Van Den Bogaard, 1993). Most of the life cycle, however, is spent fasting and the presence of suitable microhabitats (particularly in terms of...
temperature and relative humidity) is important for survival and development during these intervening stages (Sonenshine, 1993; Daniel and Dusábek, 1994). Vegetation cover affects such microclimatic variables and can also influence the living conditions of hosts (e.g. deer). Reafforestation in Europe and North America is one example of an anthropogenic change which has tended to increase suitable tick habitat, and has been identified as a factor contributing to current levels of *B. burgdorferi* infection in the environment and LD incidence in humans (Matuschka and Spielman, 1986; Spielman et al., 1993). Lyme disease is now a cause of considerable morbidity in the U.S.A. and Europe. It has also been reported from Australia, Asia and parts of Africa (Paleologo, 1992; Botha, 1993). In the U.S. it is the most common vector-borne disease with 13,083 cases in 1994 (MMWR, 1995). A general two stage pattern of the disease (Table 1) has been noted (Steere, 1989), but the symptoms actually experienced by individuals can vary greatly (Sigal, 1995). Some people only experience relatively mild flu-type symptoms and EM, while others find that *B. burgdorferi* disseminates and migrates into many of their physiological systems causing long-term debilitating illness such as fatigue and neuropsychiatric disorders (Waniek et al., 1995). Some symptoms of chronic LD are the focus of controversial debate within the medical community (Barbour and Fish, 1993). It has been argued that LD has become a convenient diagnosis for sufferers of unexplained fatigue syndromes which can be subject to social stigma if there is no obvious cause (Sigal, 1995).
While details of the underlying physical causes of chronic LD are unclear, links have been made between psychological stress and development of chronic symptoms (Soloman et al., 1995).

With such a wide range of symptoms early diagnosis of LD can be difficult, particularly since people may be unaware that they have been bitten by a tick or have visited an endemic area. Limited clinical awareness can result in cases being missed (Guy et al., 1993) and laboratory diagnostic methods vary in their efficiency (Magnarelli, 1995). Antibiotic treatment during the early stages of infection can provide a successful cure, but some individuals with chronic symptoms do not respond to antibiotics (Steere, 1989). The reasons for this are unclear and no alternative biomedical solutions have been found to date.

**PUBLIC HEALTH RISKS OF LYME DISEASE IN BRECKLAND**

There are currently some 200 confirmed cases of LD per year in the U.K. (O’Connell, 1995; Rees et al., 1995), one of the main endemic areas being the Breckland region of East Anglia (see Fig. 2). Following forest clearance beginning in the Late Neolithic, this area was characterized by a series of sandy heaths or “brecks” until the early 20th century. The dry environment would have been generally unfavourable for ticks, but many sheep and rabbits grazed on the heaths and it is feasible that residual *I. ricinus* populations survived in some areas. Since 1920, however, the Breckland landscape has changed considerably and over 20,000 hectares of commercial pine forest plantation have been established (Thetford Forest). The forest now also

![Fig. 2. The location of the study area.](image-url)
provides an important facility for outdoor recreation and leisure, attracting over 1.5 million visitors a year. Deer are numerous and large tick populations in Thetford Forest compared with nearby heaths were noted during the 1960s (Barnett, 1965). The first confirmed case of EM in Breckland was recorded in 1968 and there have since been positive tests for *B. burgdorferi* in ticks and many other species of wildlife (Craine, 1994; Craine *et al.*, 1995).

Recent discussions of the potential risk of LD tend to focus on the types of habitats in which host seeking (or questing) ticks may be encountered (Falco and Fish, 1989; Kitron *et al.*, 1992; Glass *et al.*, 1995; Fish, 1995). However, there is a need to consider the role of social factors as well, such as individuals’ awareness of ticks, which affect the possibilities of infection and disease outcome. Unlike many other tick-borne diseases where a bite from an infected tick results in disease transmission, estimates suggest that only 2–3% of people bitten by ticks will go on to develop LD (Fish, 1995). Availability of information, individual reaction to this and clinician awareness are consequently as much a part of the disease risk as the presence of ticks themselves. Our assessment of the public health risks posed by LD therefore sought to investigate both environmental influences on tick activity, and levels of disease awareness among the public, at selected recreational sites within the Breckland region.

**METHODS**

Six popular recreational sites were selected for study. Each had a predominant vegetation cover of either pine forest (two sites), heath (two sites), mixed woodland or deciduous woodland. At each site footpaths were divided into a series of 25 metre sections and vegetation along both edges was dragged for questing ticks once a month between May and November 1995. The drags were undertaken using a “tick sweep” with a 1 m² woollen blanket (incorporating lead weights sewn to the hem) attached to an aluminium frame based on the design by Carroll and Schmidtmann (1992). Questing ticks will adhere to such a dragged blanket and this technique has been found to be the most reliable and efficient means of evaluating questing tick densities (Falco and Fish, 1989).

A total of 104 sections were surveyed each month and during five months parallel drags at 5 m, 15 m, and 25 m from the path edges were undertaken at selected sections within four sites to assess questing tick densities in the surrounding vegetation. During each drag the blanket was inspected for ticks at the middle and end of the 25 m section, the numbers of adults and nymphs recorded, and the ticks placed back on the vegetation. Temperature and relative humidity (RH) were measured at ground and 1 m levels when each section was dragged using a HANNA hand-held thermohygrometer.

To evaluate levels of public knowledge regarding ticks or LD a pilot questionnaire survey was carried out at two of the recreational sites (High Lodge Forest Centre and Brandon Country Park) in
October 1995. Most of the questions took a multiple choice format, with respondents asked to select an answer from a list shown on a card. One of the questions concerned recognition of ticks and for this a box of specimens was compiled and a hand lens supplied to the interviewees to help them with identification. Other subjects covered by the questionnaire included frequency of visits to the sites, activities undertaken at them, knowledge of diseases transmitted by ticks, and past experience of tick bites. A randomly selected sample of 54 visitors were questioned on a face-to-face basis at the two sites, with the interviews being conducted at a variety of times on both weekdays and at weekends.

RESULTS

Environmental influences on tick activity

Mean densities of questing ticks on the path edge sections in each month between May and November 1995 are shown in Fig. 3. Tick activity was highest in May and June, but this general pattern masks the variability found locally between the 25 m sections, and as can be seen in Fig. 4 for adults and Fig. 5 for nymphs, the standard errors of the mean densities are often quite large. The data were non-normally distributed, and the totals ranged from 0 to 142 ticks per 25 m section. Results from the parallel drags revealed that ticks were clustered at the path edges, with few being found at 5 or 15 m. Although there were slightly higher densities at 25 m away, these were still much lower than those at the path edges.

Differences in questing activity were observed in terms of the dominant vegetation at each site, although this contrast was stronger in some months than others (see Fig. 6). A Kruskal Wallis analysis of variance revealed a significant difference between vegetation types with respect to tick densities ($P < 0.05$). Tick activity was generally greatest in areas of pine forest and least on heaths.

Microclimate factors were also influential and Kruskal Wallis analysis of variance indicated significant differences ($P < 0.05$) in densities between temperature and RH categories using measurements at both ground and 1m levels. Tick activity was greatest when temperatures were between 10$^\circ$C and 25$^\circ$C, and lower outside this range. Figure 7 shows mean tick numbers in relation to RH recorded at ground-level (where the ticks were actually questing) and suggests that densities were generally lower in drier conditions, particularly after the seasonal peak in May and June.

Public knowledge of ticks and their role as vectors of disease

Questionnaire respondents were asked to identify ticks from a box of specimens. Table 2 summarizes the results obtained and reveals some poor levels of
recognition. Although 67% of the 54 respondents recognized a gravid female, very few were able identify unfed ticks, and only seven people thought that the nymph was a tick. Nymphs are thought to be the main vector to humans as they can easily go undetected, probably explaining why many LD patients do not recall a tick bite (Rees et al., 1995). As ticks often crawl over the host for several hours before attachment, it would be desirable for people to recognize unfed ticks as removal at this stage is easier and there is no risk of infection.

Just over 70% of respondents were aware that ticks could be disease carriers and these people were asked which diseases they thought were carried by ticks. The results are shown in Table 3 and indicate that 60.5% of this subset knew that ticks were vectors of LD. Such a finding nevertheless implies that only 23 of the 53 respondents (42.6%) knew that ticks were associated with LD. Two other tick-borne diseases, H.G.E (Human Granulocytic Ehrlichiosis) and Q-fever were included as there has been some media attention following deaths from H.G.E. in the U.S., and one suspected tick-borne death from Q-fever in England. Some gender differences in awareness were also observed with, for example, 82% of males knowing that ticks could carry diseases compared to 58% of females ($P < 0.05$ using a chi-squared test).

Fig. 6. Mean tick densities by month and dominant vegetation type.

Fig. 7. Mean tick densities by month and relative humidity at ground level.
Lyme disease in the U.K. 725

Table 2. Ability of visitors to identify a tick

<table>
<thead>
<tr>
<th>Creature</th>
<th>Number of respondents who identified it as a tick</th>
<th>Percentage of respondents who identified it as a tick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravid female <em>Ixodes ricinus</em></td>
<td>36</td>
<td>66.7</td>
</tr>
<tr>
<td>Unfed female <em>Ixodes ricinus</em></td>
<td>16</td>
<td>29.6</td>
</tr>
<tr>
<td>Nymph <em>Ixodes ricinus</em></td>
<td>7</td>
<td>13.0</td>
</tr>
<tr>
<td>Flea <em>Pulex species</em></td>
<td>9</td>
<td>16.7</td>
</tr>
<tr>
<td>Mosquito <em>Anopheles species</em></td>
<td>7</td>
<td>13.0</td>
</tr>
<tr>
<td>Lone <em>Pediculus humanus</em></td>
<td>10</td>
<td>18.5</td>
</tr>
</tbody>
</table>

Note: There were 54 respondents in the pilot questionnaire survey.

Preventive measures

No measures to avoid tick bites were taken by 67% of questionnaire respondents, but of those who did take precautions the methods usually consisted of not wearing shorts and tucking trousers into socks. Several people actively avoided bracken or areas where they thought ticks would be especially prevalent. One respondent who was frequently bitten reported trial use of a spray, but subsequently abandoned it as he found that soil and dust particles would stick to his legs when cycling through the forest, causing difficulty in spotting unattached ticks and resulting in a greater number of tick bites.

Questionnaire respondents were also asked to choose (from a range of options) a method for removing an attached tick. Just under 30% of the sample indicated that they would first cover the tick with a substance such as Vaseline, but this can cause the tick to regurgitate its gut contents into the host, increasing the likelihood of transmission (De Boer and Van Den Bogaard, 1993). Another third of the respondents said they would burn the tick out with a lighted cigarette, a method traditionally recommended for leeches. However, this is not advisable for tick removal as the feeding place is usually recommended for leeches. However, this is not advisable for tick removal as the feeding place is often on sensitive areas of the body and severe damage can be inflicted on the skin of the individual using a cigarette or match. The safest recommended method of removal is to use tweezers and 55.6% of the sample selected this alternative.

Table 3. Diseases that respondents thought were carried by ticks

<table>
<thead>
<tr>
<th>Disease</th>
<th>Number of respondents who thought the disease was carried by ticks</th>
<th>Valid percentage who thought the disease was carried by ticks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Granulocytic</td>
<td>5</td>
<td>13.2</td>
</tr>
<tr>
<td>Erlichiosis</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Legionnaires disease</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Lyme disease</td>
<td>23</td>
<td>60.5</td>
</tr>
<tr>
<td>Malaria</td>
<td>2</td>
<td>5.3</td>
</tr>
<tr>
<td>Q-fever</td>
<td>5</td>
<td>13.0</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>2</td>
<td>5.3</td>
</tr>
<tr>
<td>Weils disease</td>
<td>6</td>
<td>15.8</td>
</tr>
<tr>
<td>Subonic plague</td>
<td>3</td>
<td>7.9</td>
</tr>
</tbody>
</table>

*Sixteen of the 54 respondents (29.7%) did not know that ticks carried diseases. The valid percentage represents the proportion naming each disease of the 38 respondents who did know ticks could be disease carriers.

Past experiences of tick parasitism

A quarter of respondents said they had been bitten by ticks, although 75% of these encounters were at locations other than the six Breckland study sites. Claims to have been bitten by a tick did not, however, entirely correspond with the ability of respondents to recognize a tick. Two of the people who said they had been bitten by a tick before were unable to correctly identify even an engorged tick and, more generally, previous contact did not appear to help in the recognition of unfed ticks. In addition, two thirds of those bitten said they would take no preventive measures against future bites.

DISCUSSION

Results from the program of blanket drugs support the view that no single factor can explain fully the distribution of a tick species (Sonenshine, 1993) and suggest that significant variables include vegetation cover, RH and temperature. The observed seasonal pattern of tick activity was slightly different from that recorded during a previous study in Thetford Forest (Craine et al., 1995) and it seems likely that the unusually hot weather in July and August 1995 had an adverse effect on tick populations. Nevertheless, a feature of the results is that appreciable numbers of questing ticks were collected when the RH was below the 75% level that is often considered critical for the longer-term survival of *I. ricinus* (Rudolph and Knüll, 1979). This may be because RH can fluctuate considerably in many natural environments. Ticks are thus able to quest in unfavourable conditions and recover body moisture later when RH rises.

The observed variations in *Ixodes* densities between broad categories of vegetation accord well with previous studies (Sonenshine, 1993; Lord, 1995). Some substantial contrasts in tick activity between sections at the same site were found and consequently the actual vegetation that ticks were questing in is currently being classified according to the plant communities of the National Vegetation Classification (Rodwell, 1992). A further series of blanket drags are planned for spring and early summer in 1996, and this additional data should help to disentangle the influences of seasonality, vegetation and microclimate on questing tick densities in Breckland.

From a public health perspective, the preliminary results on tick activity have two main implications. Firstly, that ticks are active in a wider range of climatic conditions than might be anticipated and, secondly, that the areas of pine forest which attract the greatest numbers of visitors also correspond to the locations with higher tick densities. At all sites, moreover, tick densities were highest along the path edges. However, further investigations are needed to determine if activities engaged in by visitors...
affect the likelihood of tick contact. This should include details of the locations within sites frequented by visitors, as some venture no further than the car park.

Leaflets and posters giving advice on ticks and LD are available at several recreational sites in Breckland, but the results of the pilot questionnaire survey suggest that current levels of knowledge are generally poor. The risk of contracting LD is difficult to assess given the paucity of data on current prevalence and a number of uncertainties; in particular, there is no clear relationship between infection and the development of symptoms. Physical and mental factors affecting individuals’ immune systems can be important, as are risk perceptions. How individuals perceive the risk of LD will affect whether they take preventative measures when in tick infested areas, and anxiety levels can influence disease outcome (Sigal, 1995; Soloman et al., 1995).

Risk perception is often related to the subjective construction of dread factors (British Medical Association, 1990) concerning particular health risks, even if the statistical evidence suggests a low disease incidence. Given the odious evocations of ticks in popular culture, such as Süsskind’s character “Grenouille” (Süsskind, 1987) and the horror film Ticks (Randall, 1994), it is possible that this dread combined with medical ambiguity could contribute to an accentuated perception of risk. Indeed LD has been likened to AIDS in its catastrophic effects on public health (Spilman et al., 1993; Paleologo, 1992), despite the relatively low incidence and non-mortal nature of symptoms.

Several aspects of awareness and risk perception among the general public in Breckland require further investigation. Although the majority of people questioned took no measures to prevent tick bites, it needs to be appreciated that only 43% of respondents were even aware that ticks could transmit the LD pathogen. Public health and education measures clearly need to recognize such limited levels of knowledge. It also appears important to determine if there are any factors associated with variations in awareness and the extent to which perceptions of risk alter with increased knowledge of LD. A more extensive questionnaire survey planned for 1996 will hopefully provide insights into these issues.

REFERENCES


