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BMC Public Health

RESEARCH

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Lyme borreliosis risk perceptions, disease knowledge, and training among at-risk groups

R. Walsh[1,2], M. Gormally[1], C. Williams[3] and Caitríona Carlin[1*]

Abstract

Background Lyme borreliosis (LB) is the most common tick-borne disease in Europe. Although there are indicators that disease risk is higher in the west of Ireland than other areas of Ireland, regional incidence data to confirm this, and to drive effective risk communication is sparse. Professions (e.g. farming, forestry) or recreational activities (e.g. hiking, trail running) that require spending time in tick habitats increase the risk of exposure. The present study is designed to provide baseline information on the perceptions, knowledge, and training of at-risk groups in Ireland relating to LB.

Methods The study used an online questionnaire to gather data on perceived risk, disease-related knowledge, and the receipt of training by at-risk individuals ($n = 443$) in Ireland. Data were analysed using IBM SPSS Statistics version 29.0.1.0.

Results The study found a median perceived risk of 3/5 (i.e. moderate). There was no difference geographically in perceived risk, despite regional differences in environmental risk factors and cumulative neuroborreliosis rates. The majority (77%) of respondents identified woodlands/scrub as habitats carrying highest LB risk. Fewer than half (48%) of respondents mentioned or described the pathognomonic erythema migrans rash when asked to describe symptoms of LB, and 37% listed erythema migrans plus at least one flu-like symptom. As respondents' perception of risk increased, so did their ability to identify woodland/scrub as risk habitats, and early LB symptoms. However, when asked to rate the amount of training they had received on a 5-point scale (1 indicates no training and 5 indicates maximum training) respondents in at-risk professions indicated a minimal amount of training (median = 2/5) on tick bite and LB prevention, and people engaging in leisure activities gave a response which indicated no training (median = 1/5). Greater levels of training were associated with greater proportions of respondents indicating woodland/scrub habitats as high-risk habitats ($p = 0.003$, $T = 8.876$), and describing erythema migrans as a LB symptom ($p = 0.08$, $T = 7.007$).

Conclusions These findings identify the need for more robust risk communication in Ireland, more training for at-risk groups, and the use of targeted awareness campaigns to address knowledge gaps. The implications of the study findings for international research are also discussed.

Keywords Lyme borreliosis$_1$, Lyme disease$_2$, Awareness$_3$, Risk perceptions$_4$, Disease knowledge$_5$

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Introduction

Lyme borreliosis (LB), caused by the spirochaete *Borrelia burgdorferi sensu lato*, is the most common tick-borne disease in Europe [1]. The incidence of LB varies between regions and countries of Europe, with an average population-weighted European disease incidence of 22.05/100,000 person-years [2].

Disease in humans occurs in three stages [3, 4]. Early LB is characterized by flu-like symptoms and a characteristic erythema migrans lesion in 70 to 95% of cases. Erythema migrans is defined as an expanding rash of over 5 cm in diameter, with or without central clearing [4]. Early disseminated infection may produce a range of symptoms depending on the *B. burgdorferi* genotype present and the system affected. Late disseminated disease is characterized by symptoms such as Lyme arthritis and acrodermatitis chronicum atrophicans [3, 4]. Of note, disseminated infection may result in Lyme neuroborreliosis, which is defined by involvement of the central or peripheral nervous system [3]. The reporting of cases of neuroborreliosis is mandatory within the European Union [5]. In some jurisdictions across Europe this is the only centralized reporting system in place, while in other countries there is still no routine centralised reporting system [6].

At the individual level, two important factors with respect to LB transmission risk and ultimately illness risk include; (a) human behaviour and awareness in relation to the ability to identify and mitigate environmental risks [7, 8], (b) the ability to identify symptoms of the disease and to access prompt treatment [9]. Certain groups of individuals, e.g. those who work in an outdoor setting or use the outdoors regularly for recreational purposes, are considered to be more at risk than others [8, 10, 11], with woodland habitats posing the highest risk of LB [12] to such individuals. These include professional outdoor workers such as foresters, farmers, local government workers, outdoor guides, wildlife management/surveyors [13], and recreationists, which includes people who engage in leisure activities outdoors, such as hikers, trail runners, mountain bikers [14] etc. A recent Irish report indicates that 60% surveyed individuals now visit a woodland more regularly than they did before the pandemic, and that 75% of individuals wish to have more woodlands in their area [15]. As such, it is particularly important that such groups are aware of their risk, so that they can employ disease mitigation strategies such as the wearing of protective clothing (long sleeves, trousers tucked into socks), performing a self-check for ticks upon return from the outdoor setting, and the prompt and correct removal of any ticks that are found [5, 10, 13]. It is also important that people who are at increased risk are able to identify early symptoms of infection and to access early treatment, which is vital to ensure complete recovery and avoid the development of further symptoms [16, 17]. Most (70–95%) early LB cases are marked by the pathognomonic erythema migrans lesion [2, 4], and at-risk individuals who can recognise this lesion are enabled to seek medical treatment [9]. To increase disease knowledge and awareness levels, awareness campaigns are regularly run in various jurisdictions across Europe to remind the public of the risks of LB in outdoor settings [5].

While various jurisdictions employ different levels of surveillance to quantify the risk of LB in an area, there is currently no active or passive surveillance of tick bite risk in Ireland [18]. Neuroborreliosis alone is reportable under Irish guidelines, with a reported incidence of 0.3 per 100,000 population per annum in 2020 and of 0.08 per 100,000 in 2021 (2022 figures are not available at the time of writing) [19]. This is in comparison with an average incidence of 0.46 per 100,000 across the European Union in 2020 and 0.39/100,000 in 2021 [20]. While data on seropositivity for LB is not collected at national level, a single-centre study published in 2018 [21] analysed blood samples received by a hospital laboratory in the West of Ireland. The study estimated an average LB incidence in the west of Ireland of 2 per 100,000 per year, based on laboratory-confirmed cases, during the study period of 2010–2014, a figure which was below the European average but above the 25th centile [2]. Of note, the incidence varied widely between localities within the catchment area of the laboratory, with the incidence in the Connemara region (43/100,000 per year) being above the 75th centile for Europe [2]. Without national data of this kind, it is difficult to make an assertion on the true incidence of LB in Ireland.

Previous studies have indicated that, when the public are aware of the incidence of LB in an area, they are more likely to adopt risk-mitigation behaviours [22, 23], and that a person's disease knowledge and level of perceived risk determines their risk-mitigation behaviours [5]. However, even in endemic areas, adoption of risk mitigation behaviours is often low [7, 24]. Recent research has assessed the knowledge of LB and mitigation behaviours amongst 76 farmers in Ireland by means of a survey [25]. While 98.5% of respondents had heard of 'Lyme disease', only 43% displayed 'adequate' disease knowledge – which was defined as answering 5 of 6 questions relating to basic knowledge about ticks and LB correctly [25]. This contrasts with a similar study conducted with woodland owners in Maine (USA), which is a highly endemic area, wherein 7 of the 9 knowledge assessment questions were answered correctly by a majority of the study population (69.5% or above) [26]. Aside from the abovementioned study [25], to the authors' knowledge, no research has been published to date on the risk perceptions or knowledge of LB in at-risk groups in Ireland.

In the wider literature, there is evidence to show that those who have access to information around LB are more likely to be aware of their risk of LB [11]. A study which compared risk perceptions in a region of Canada where LB is relatively new, to a region of Switzerland where LB has been endemic for many years, found the number of respondents in Canada who perceived their risk to be high was half that of Switzerland [27]. Of note, the impact of any prior training on LB risk prevention upon study participants was not assessed. Furthermore, in France, following a national LB awareness campaign, there was an increase following the campaign in the proportion of survey respondents who felt they were well informed on the topic of LB (29% in 2016 to 41% in 2019) and who took measures to prevent illness from tick bites, such as checking for ticks and tick removal after exposure (47% in 2016 to 54% in 2019) [28].

The use of measures to prevent tick-bites is a popular question for LB knowledge and awareness studies [7, 25–30]. However, European studies rarely report on the objective ability of at-risk individuals to recognise the symptoms of LB. A Polish study which elicited such insight observed that 58.9% of the studied population in an endemic area of Poland could identify erythema migrans, while 25% incorrectly identified an illustration of a tick [29]. Similarly, a North American study which surveyed hikers on the Appalachian Trail (USA), used photographs of the erythema migrans rash to assess hikers' ability to recognise this LB symptom. They found that only 54% of this at-risk group in a disease risk area were able to identify this pathognomonic symptom [9]. Another study, conducted on at-risk individuals in Canada ($n = 137$), asked respondents to describe symptoms of LB. 11.7% described a rash or erythema migrans, and only 35.8% described a rash/erythema migrans plus flu like symptoms [8]. This outcome warrants further investigation and indicates that there are potentially at-risk groups in other regions amongst whom there is a deficit in the ability to recognise and act upon disease symptoms. In general, more studies which objectively measure respondent's LB disease knowledge are needed.

Given the current lack of data on LB demographics in Ireland, and gaps in the literature pertaining to the study of disease perceptions, knowledge and awareness, this study aimed to collect and analyse data on the risk perceptions, disease-related knowledge, and training levels relating to LB amongst at-risk groups in Ireland. This study sought to create a unique but easily replicable questionnaire that could be used to gather data on a range of different at-risk groups such that the group with the most pressing needs could be identified. Furthermore, the study aimed to employ a methodology whereby data on risk perceptions, awareness of environmental risks, knowledge of disease symptoms, and access to training could all be gathered simultaneously from each respondent. The results of this study will contribute to a roadmap for developing strategies to reduce disease incidence nationally, and can be used to inform further international research on LB awareness and knowledge.

Materials and methods

A knowledge and attitudes questionnaire was developed for this study. Two versions of the same questionnaire were rolled out - one for those who use the outdoors regularly for recreation, and one for those who work outdoors, with the same questions appearing in both versions, but with the wording varying slightly depending on whether respondents were asked about their profession vs. their recreational activity (Additional File 1). The questionnaire was fully anonymised, and distributed via the online survey platform SurveyMonkey.

Questionnaire development

The questionnaire contained 15 questions, broken into three question types:

1. Demographic information, relating to respondent age and gender and information on type, location (county, province), experience (i.e. years active) and duration and frequency of risk activity (i.e. number of hours per week and times per year activity was undertaken).
2. Assessment of respondents' perception regarding the level of risk of LB they associated with their work or leisure activity, and their opinions on the training they have received (if any) on LB. Questions of this type used a five point Likert scale (ranging from 1 to 5, with 1 equating to 'none' and 5 to 'very high'). Respondents were asked to rate the risk associated with their activity, and (separately) with the location they most often carried out their activity. Location-based answers were analysed at county and province level. An open-response field was also provided to allow respondents to include information on the type of training (if any) they had received. The responses in this field were analysed for common themes and grouped accordingly for data interpretation.
3. Assessment of respondent's knowledge on LB risk. One question gave a standard list of habitats found in Ireland [31] and asked the respondent to select which habitat(s) carry the highest risk of LB. Another asked respondents to describe symptoms of LB, with space for an open-format answer. These answers were then analysed for early key LB symptoms as described on the public information website of Ireland's national health service (Health Service Executive, (HSE)) [32].

All questions are given in Additional File 1.

Both questionnaires received ethical approval from the National University of Ireland, Galway (now University of Galway) ethics committee.

Distribution methods and timescale

Both versions of the questionnaire were rolled out at the same time, over a period of 18 months between 27/11/2020 and 15/07/2022. The questionnaire was made available to respondents via emailed links to the SurveyMonkey platform, where responses could be inputted online. All respondents gave their informed consent before proceeding with the questionnaire. The questionnaire was disseminated to professionals who work in outdoor settings by contacting ecological/engineering consultancy agencies, local authorities, web sites and interest groups for farmers, etc. The questionnaire was disseminated to recreationists via societies and groups such as mountaineering clubs, mountain biking clubs, trail running clubs, gardening societies, etc. Care was taken to ensure that a broad range of groups from various regions of Ireland were contacted, using the publicly available contact email address of 150 national recreational or professional groups, employers, or regional employers, agencies, or groups (see Additional File Table 2.1–2.2 for breakdown of groups to whom invitations to participate were sent).

Analysis

Questionnaire responses were analysed via IBM SPSS Statistics version 29.0.1.0. Respondents were given an open text box such that they could describe their profession or recreation type in their own words. The responses were then grouped based on how they self-described. An open-text response format was also used to allow respondents to describe the training they had received on LB, and responses to this question were also hand-analysed and grouped thematically. Similarly, respondents were asked to use their own words to describe symptoms of LB. These responses were then analysed and coded as dichotomous variables to identify whether respondents had mentioned key symptoms of early LB [32]. Any mention of a rash was noted and coded as one dichotomous variable. A second dichotomous variable was coded to indicate use of the exact term "erythema migrans", "bullseye", "target", or any description of a circular or ringlike rash. Answers were also analysed to identify whether respondents had listed any flu-like symptoms as described by the Health Service Executive (HSE) on their LB information website page [32]. These flu-like symptoms include one or a combination of fever, muscle pains, headache, and fatigue. Any wording relating to any one of these symptoms was coded as a further dichotomous variable.

Mann-Whitney U and Kruskal-Wallis tests were used to test for differences between groups (e.g. differences between professions, gender) when the dependent variable was ordinal (answers pertaining to Likert ranking e.g. perceived risk). Where differences were found using the Kruskal-Wallis test, a post-hoc analysis was undertaken using the Dunn's test with Bonferroni adjustment. A series of Cochrane Armitage tests were run to identify any correlation between ordinal factors such as age bracket, and the frequency of outdoor activity, and ordinal dependent variables, such as respondents' level of perceived risk associated with their activity or geographic area. The Pearson Chi-Square test was used to test whether there was a difference between groups in their ability to identify risk habitats and symptoms of LB (dichotomous outcomes). In all cases, a p-value of 0.05 or lower was considered significant.

Results

Description of population surveyed

A total of 443 respondents completed the questionnaires including 166 (37%) outdoor professionals and 277 (63%) recreationists (see Table 1 for profession/recreational activity breakdown). The questionnaires took an average of 11 min to complete. A breakdown of all respondents (recreationist and outdoor-professionals) by age and by location can be found in Additional File Tables 2.3–2.4 and Fig. 2.1. Overall, almost 52% and just over 43% of respondents identified as female and male respectively

Table 1 Profession or recreational activity of all respondents

Profession	Percentage	Recreational activity	Percentage
Ecologist	56	Birdwatching or Wildlife Photography	8
Educator	8	Climbing	10
Engineer or other scientist	15	Gardening/Farming	11
Environmental Scientist	10	Hiking	156
Farmer	15	Mountain Biking	15
Forester	47	Orienteering	24
Other Profession*	15	Trail running/running	25
		Walking	11
		Other Hobby*	17

*More information on these groups can be found in Additional File 2.5-2.6

with the remaining respondents either identifying as "other" (< 0.5%) or giving no answer (< 5%).

Perception of risk of LB

Perception of risk of LB in respondents' profession/ recreational activity

Overall, there was a median perceived risk of 3 (medium risk), with no difference between the professionals and recreationists (median = 3 for both, $p = 0.052$, z=−1.942, Mann–Whitney U test). 6.7% and 27.4% of professionals chose a risk ranking of 1 and 2 respectively, versus 9.4% and 33.0% of recreationists. The professions with the highest perceived risk of LB were foresters (median risk rating = 4 ($n = 47$)). There were differences between professionals in their perceived risk ($p = 0.025$, $\chi^2(3) = 14.486$, Kruskal–Wallis test) with foresters perceiving a greater risk than the 'other' professionals group (median risk rating = 2.5, $n = 14$, $p = 0.028$, Additional File 2.7). Trail runners or runners (median = 4 ($n = 25$)), orienteers (median = 4 ($n = 24$)), and hikers (median = 3 ($n = 156$)) had the highest perceived risk of all recreationists. The lowest perceived risk was amongst birdwatchers/wildlife photographers (median = 2 ($n = 8$)). However, post-hoc comparisons between recreationist groups with adjustment for multiple testing did not reach significance (see Additional File 2.8). The associations between age, gender, years of experience (i.e. years active at the reported hobby/profession), frequency of outdoor activity, and risk perceptions are summarised in Table 2. There was an inverse relationship between respondent age and the risk they perceived to be associated with their recreational activity/profession, with increasing age band being associated with decreased perceived risk ($p = 0.005$, T=−2.776, Cochrane Armitage test of trends).

Geography and risk perception

Overall, respondents (professionals and recreationists combined) did not differ by geography in their perceived risk of LB. This was the case when geographic data were analysed at province level ($p = 0.536$, $\chi^2(3) = 3.130$, Kruskal-Wallis test), and when data were compared at county level ($p = 0.460$, $\chi^2(3) = 25.041$, Kruskal-Wallis test) (See Additional File Fig. 2.2). It was also the case when analysed in terms of counties in the west, east, or midlands of Ireland (i.e. counties with a coastline bordering the Atlantic Ocean vs. the Irish Sea vs. non-coastal) ($p = 0.627$, $\chi^2(3) = 0.933$, Kruskal-Wallis test). This remained the case when answers from professionals and recreationists were analysed separately at county level ($p = 0.24$ T = 26.280, and $p = 0.363$ $\chi^2(3) = 22.643$ respectively, Kruskal-Wallis test).

Table 2 Respondent demographics and risk perceptions

Variable	T	*p*-value
Age bracket	−2.78	0.005 (Somer's D test)
Years of experience	0.017	0.986 (Somer's D test)
Frequency of outdoor activity	0.980	0.327 (Somer's D test)
Gender	6.307	0.098 (Kruskal-Wallis test)

Assessment of disease-related knowledge

Assessment of habitat-specific risk

Seventy-seven percent of respondents identified woodland and scrub habitats as LB risk habitats, (82% of professionals and 74% of recreationists). This was followed by the selection (both groups combined) of grasslands & marshes (73%), heathlands (62%), bogs & fens (49%), areas near rivers/lakes/swamps (32%), cultivated areas gardens and parks (13%), rocky areas (5%), coastal areas (3%), and any other areas (9%) (Fig. 1). There was a difference between professional groups who selected woodland/scrub habitats as risk habitats, with the percentage of foresters (96%) being higher than the percentage of farmers (53%) who selected this answer ($p = 0.009$, T = 17.154, Pearson Chi-Square test and post-hoc Z-test with Bonferroni correction). There was no difference between recreationist groups who selected woodlands/scrub, ($p = 0.115$, T = 13.034, Pearson Chi-Square test).

There was no association between age ($p = 0.094$, T = 10.808, Cochrane Armitage test of trends), years of experience ($p = 0.977$, T = 0.807 Cochrane Armitage test of trends), or frequency of outdoor activity ($p = 0.421$, T = 3.891, Cochrane Armitage test of trends) and whether or not respondents selected woodland/scrub as risk habitats. There was an association between perceived risk and ability to identify woodland/scrub as risk habitats for LB ($p < 0.001$, T = 21.386, Cochrane Armitage test of trends).

Objective and perceived familiarity with symptoms of LB

Objective familiarity with symptoms of LB Of the 383 respondents who answered this question, 65% described any sort of rash, 48% named or described the erythema migrans lesion, 60% described fatigue, 55% mentioned any flu-like symptom other than fatigue. 37% of respondents mentioned erythema migrans as well as any flu-like symptom.

There was no association between profession ($p = 0.577$, T = 4.746, Chi Square test) or recreational activity type ($p = 0.946$, T = 2.807, Chi Square test) and ability to describe erythema migrans as well as any flu-like symptom relating to early LB. There was an association between increasing age band and respondents' ability to mention erythema migrans and flu-like symptoms ($p = 0.005$, T = 20.504, Cochrane Armitage test of trends). The same was not true of respondents' level of experience ($p = 0.860$, T = 1.919, Cochrane Armitage test of trends) or frequency of outdoor activity ($p = 0.077$, T = 8.420, Cochrane Armitage test of trends). There was a positive association between respondents' perceived risk level

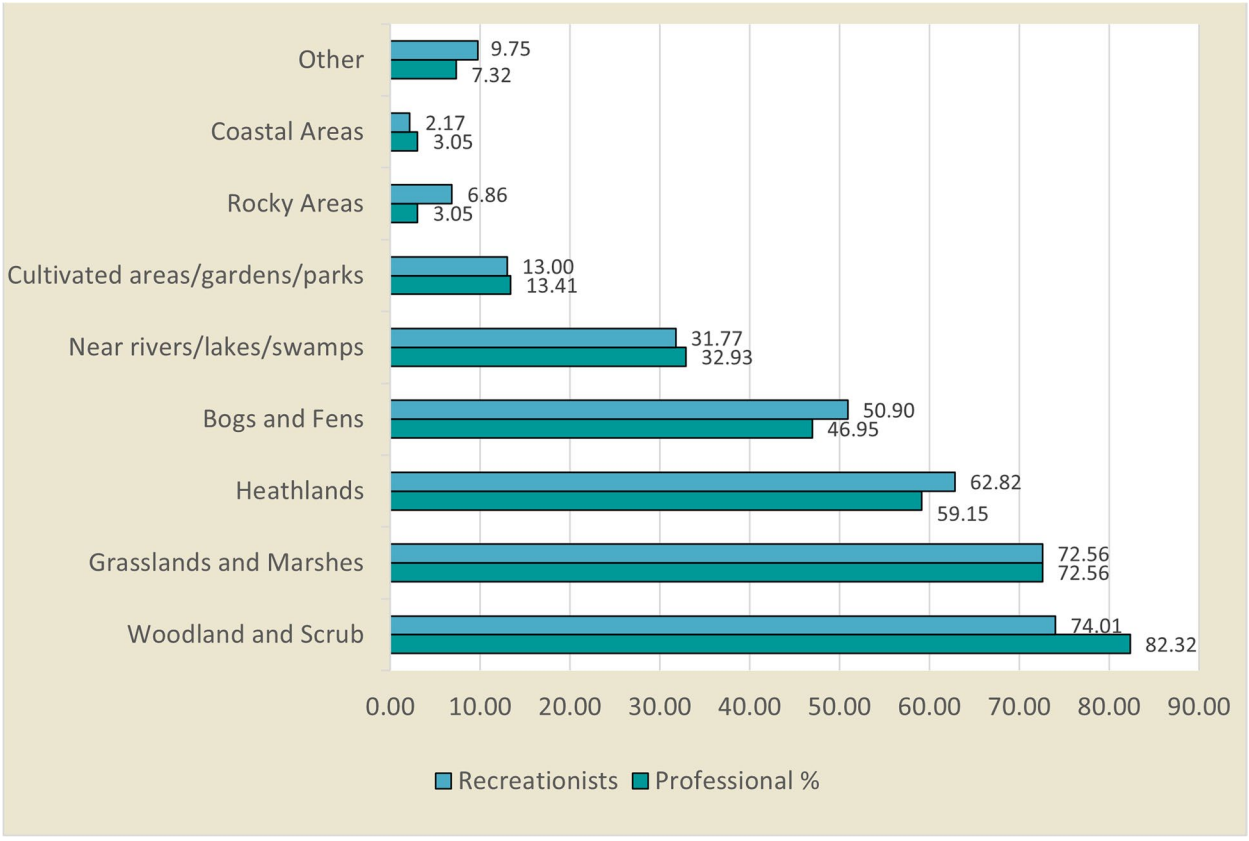

Fig. 1 Percentage of respondents who identified each habitat type as a risk area for Lyme borreliosis ($n = 441$). The percentage of respondents who identified each habitat type from a list of habitats in Ireland are broken down by professionals vs. recreationists

and their ability to describe erythema migrans plus any flu-like symptoms as LB symptoms ($p = 0.003$, T = 9.087).

Perceived familiarity with symptoms of LB When asked to rank their familiarity with the symptoms of LB, the median response was a ranking of 3 ($n = 425$), indicating moderate familiarity. There was no difference between professionals (median ranking = 3, $n = 158$) vs. recreationists (median ranking = 3, $n = 267$) in the ranking given ($p = 0.286$, z = −1.068, Mann Whitney U test), and there was no difference between groups of professionals or recreationists in their ranking of their familiarity with LB symptoms ($p = 0.386$, $\chi^2(3) = 6.343$, and $p = 0.376$, $\chi^2(3) = 8.616$ respectively, Kruskal Wallis test).

In terms of the relationship between perceived and objective familiarity with LB, there was a relationship between increasing self-reported familiarity and (a) ability to mention a rash ($p < 0.001$, T = 25.129), (b) ability to mention or describe erythema migrans ($p < 0.001$, T = 26.693), (c) description of flu-like symptoms excluding fatigue ($p < 0.001$, T = 37.941), and (c) ability to mention a rash plus any flu-like symptom ($p < 0.001$, T = 38.224).

Level, type, and impact of training

Level of training and type of training

When asked to rank the level of training they had received on prevention of tick bites and LB, respondents ($n = 425$) gave an overall median rank of 1. Recreationists gave a median rank of 1, while professionals gave a different median rank of 2 ($p = 0.032$, Mann-Whitney U Test).

Of the professionals who ranked their training, there was no difference between groups ($p = 0.124$, $\chi^2(3) = 10.004$, Kruskal-Wallis test,). Recreationists' perceptions of their training also did not differ between groups. The percentage of respondents in each group who selected each training rank is given in Fig. 2.

When training ranking was compared against geographic location, there was no difference ($p = 0.158$, $\chi^2(3) = 32.010$ for county, $p = 0.220$ $\chi^2(3) = 5.727$ for province, $p = 0.210$ $\chi^2(3) = 3.118$ for counties in the west, east, or midlands of Ireland, Kruskal Wallis test). This indicates that the location of a person within Ireland did not affect their ability to access training on LB risk awareness.

Of those who specified a non-zero level of training, 183 answered the question on training type, and a further 5 respondents then specified in the open format box that they had in fact received no formal training, bringing

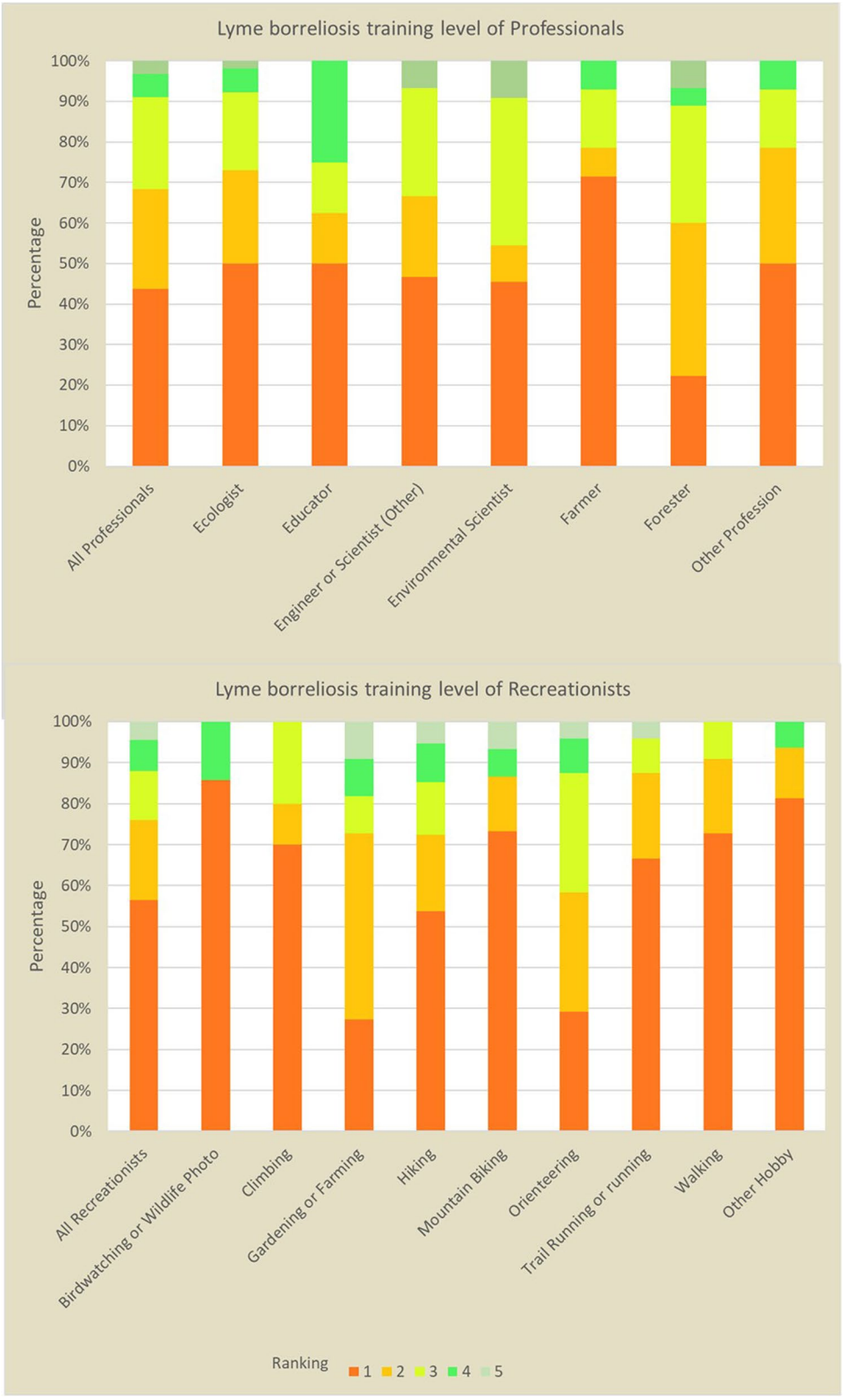

Fig. 2 Lyme borreliosis training level of respondents ($n = 425$). Self-reported level of training broken down by profession and by recreational activity type, showing the percentage of respondents in each group who selected each training rank. A ranking of 1 indicates no training, and 5 indicates in-depth training

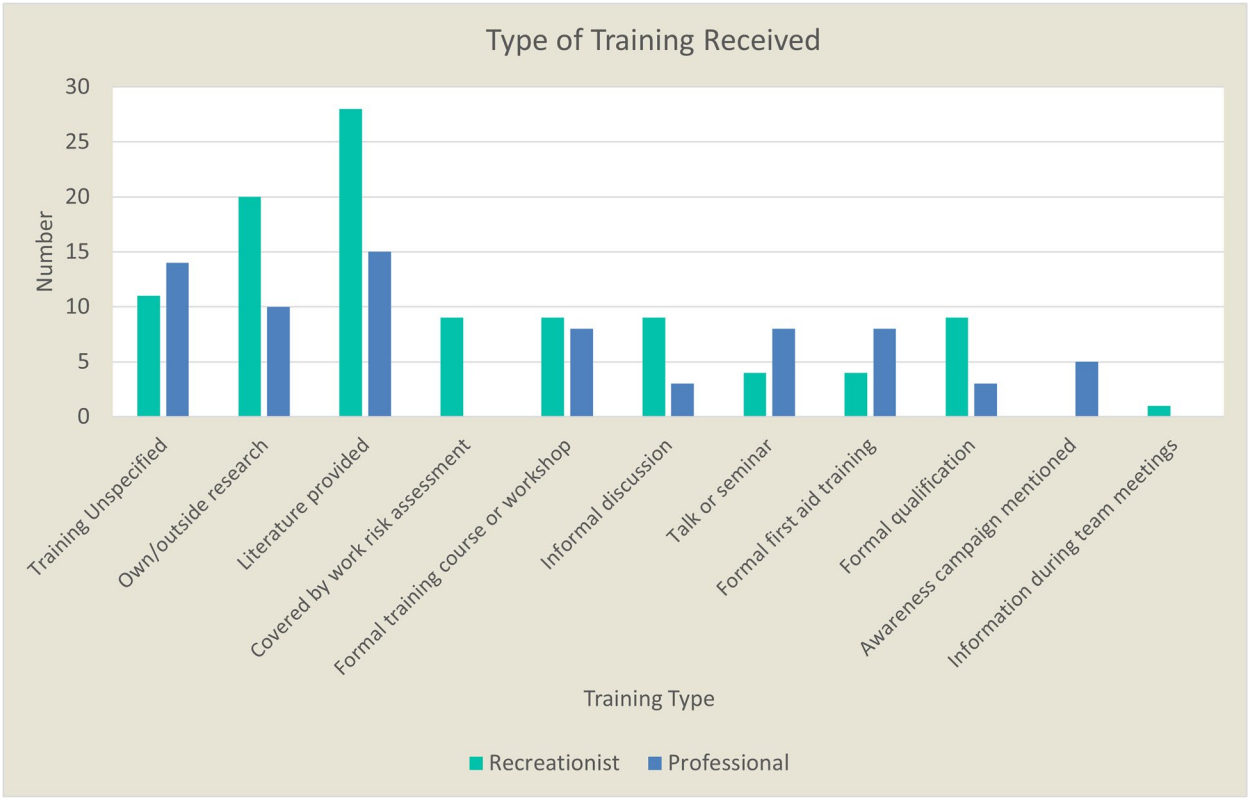

Fig. 3 Type of training indicated by professionals ($n=74$) and recreationists ($n=104$) who had received some form of training on LB (total $n=178$)

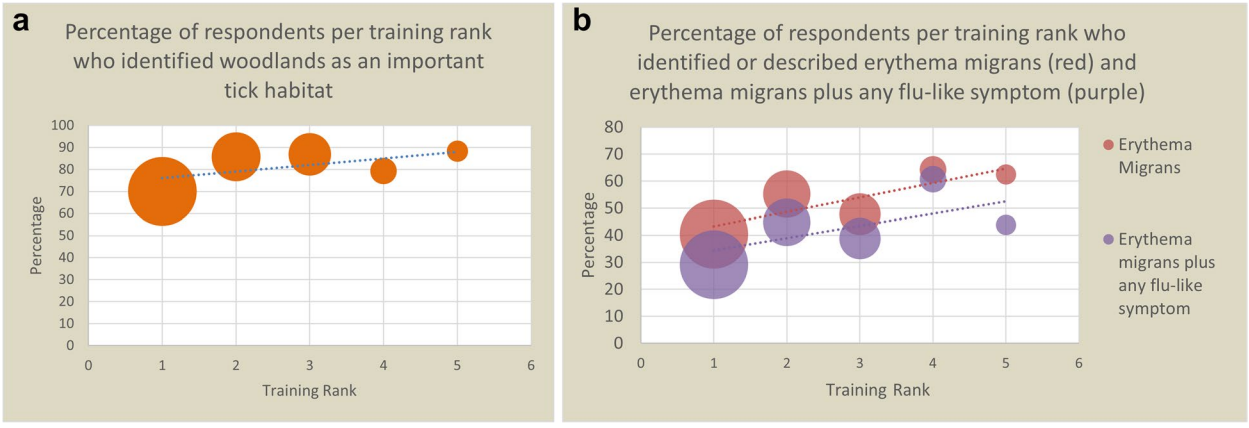

Fig. 4 Percentage of respondents per training rank who identified woodlands as an important tick habitat ($n=425$, professionals = 158, recreationists = 267), or who identified or described erythema migrans and flu-like symptoms ($n=380$, professionals = 149, recreationists = 231). The size of the bubbles indicates the number of participants who selected each training rank, indicating that most participants ranked their training as 1 (no training at all) and only very few ranked their training as 4 or 5, indicating a high level of training

the responses to this question to 178. Figure 3 shows the breakdown of training types reported.

There was a positive association between respondents' reported level of training and their ability to select woodland/scrub habitats as carrying LB risk ($p=0.003$, T = 8.876 Cochrane Armitage test of trends, Fig. 4) i.e. the proportion of those identifying woodland/scrub as risk habitats increased as reported training level increased. There was also a positive association between respondents' reported level of training and their ability to mention/describe the erythema migrans rash ($p=0.009$, T = 6.802, Cochrane Armitage test of trends, Fig. 4). There was a similar positive relationship between level of training and ability to mention erythema migrans plus any flu-like symptom ($p=0.003$, T = 8.729, Cochrane Armitage test of trends, Fig. 4). Finally, there was also an

association between respondents' reported level of training and their self-reported level of disease familiarity ($p = < 0.001$, T = 7.003 Somers D).

Discussion

LB disease risk occurs when recreational or occupational activities bring an individual into areas where they are exposed to infected ticks [2, 8]. Effective risk mitigation by an individual depends on disease awareness and the perception of there being a risk to oneself [8, 22]. Knowledge pertaining to the disease, and level of disease-related concern are also factors determining the uptake of risk mitigation behaviours [5]. However, the literature has indicated several knowledge gaps relating to tick ecology and LB amongst at-risk individuals in some endemic areas [26]. Understanding the attitudes and behaviours of people towards LB risk is of crucial importance to designing awareness campaigns and national strategies to reduce LB rates. This has been illustrated previously by a US study which showed that the only factor that was associated with high compliance with personal risk mitigation strategies was the perception of a significant prevalence of disease in the respondent's area [33]. However, even in areas with high LB incidence, almost half of respondents in the aforementioned study did not take any risk mitigation measures. Similarly, in northern Italy, risk mitigation methods are infrequently adopted, despite an increase in LB incidence in the region [7]. It is imperative that information on the risk of LB be communicated to at-risk individuals so that they can make informed decisions regarding LB risk and take action accordingly.

The present study found that the overall perception of risk amongst the study population was 3 on a scale of 1 to 5, which translates to a perception of moderate risk. There was an inverse relationship between respondent age bracket and their perception of the risk associated with their profession or recreational activity. This is in contrast with previous research in France, Canada, and Switzerland [27, 28, 30]. Furthermore, a study in Italy found no association between age and the probability of undertaking bite mitigation measures [7]. As such, the reason behind this finding warrants further investigation, as it may influence future awareness campaigns. Nonetheless, overall, as respondents' perception of risk increased, so too did their ability to identify woodland/scrub as risk habitats, and to mention early LB symptoms. Previous research in Canada and Switzerland has also indicated that there is a relationship between an increased level of disease-related knowledge and higher levels of perceived risk amongst the study population [27].

It is notable that geography seemed to have no bearing on respondents' perception of risk – respondents from no one geographical area (County) of Ireland perceived the risk in their area to be higher than any other. This is despite the fact that the west coast of Ireland has a higher probability of tick presence than other areas of Ireland [12] (Fig. 5). Moreover, the 7 year cumulative incidence of neuroborreliosis also indicates a higher incidence in the west and southwest of Ireland compared with the east [34] (Fig. 5). A previous study in Canada found that perceived risk did vary geographically with disease risk levels in Québec [30]. The contrasting outcome in the current study points to the need for more targeted risk communication in Ireland.

Two aspects of disease-related knowledge that are important for at-risk groups are the ability to identify where risk occurs (i.e. the source of risk), and to identify symptoms of LB [13]. 77% of respondents in the current study correctly identified woodland/scrub as amongst the habitats that carry the highest risk of LB. This finding is similar to that of a study conducted in France which used semi-structured interviews, drawings, and questionnaires to assess LB risk perceptions in central France [35]. The study found that those interviewed thought that forests were areas associated with LB risk, and 80% of respondents' drawings also showed other types of vegetation cover. This points, perhaps, to the need for awareness campaigns in Ireland to include reference to other common tick habitats as well as woodlands and scrub, particularly heathlands bogs and fens (as wetlands are especially abundant habitats in the Atlantic climate of Ireland), so that people are aware of the need to take mitigating action when undertaking work or leisure activities in these habitats also. The inclusion of photographs of typical habitats of each of the above types would be helpful. Of further note, our findings suggest that farmers need to be targeted with communications relating to woodland/scrub as risk habitats. This is particularly important given the recent and growing policy interest in agroforestry practices in Ireland [15]. Similarly, being able to identify early symptoms of LB is of crucial importance to the mitigation of disease severity in a given individual, as administration of early treatment for LB lowers the risk of developing further symptoms [17]. A lack of awareness of LB in the general public means that important early symptoms of the disease may be neglected [2]. While only 35% of respondents in the current study were unable to describe some sort of rash relating to early LB, more than half (52%) overall were unable to correctly mention or describe the pathognomonic erythema migrans rash, and 63% of respondents did not mention any flu-like symptom as well as erythema migrans. It is important that at-risk individuals be aware of the potential for LB to cause a spreading rash around the site of a tick bite, so that they can seek medical treatment where appropriate, thereby reducing the risk of the infection progressing to a systemic infection with more serious

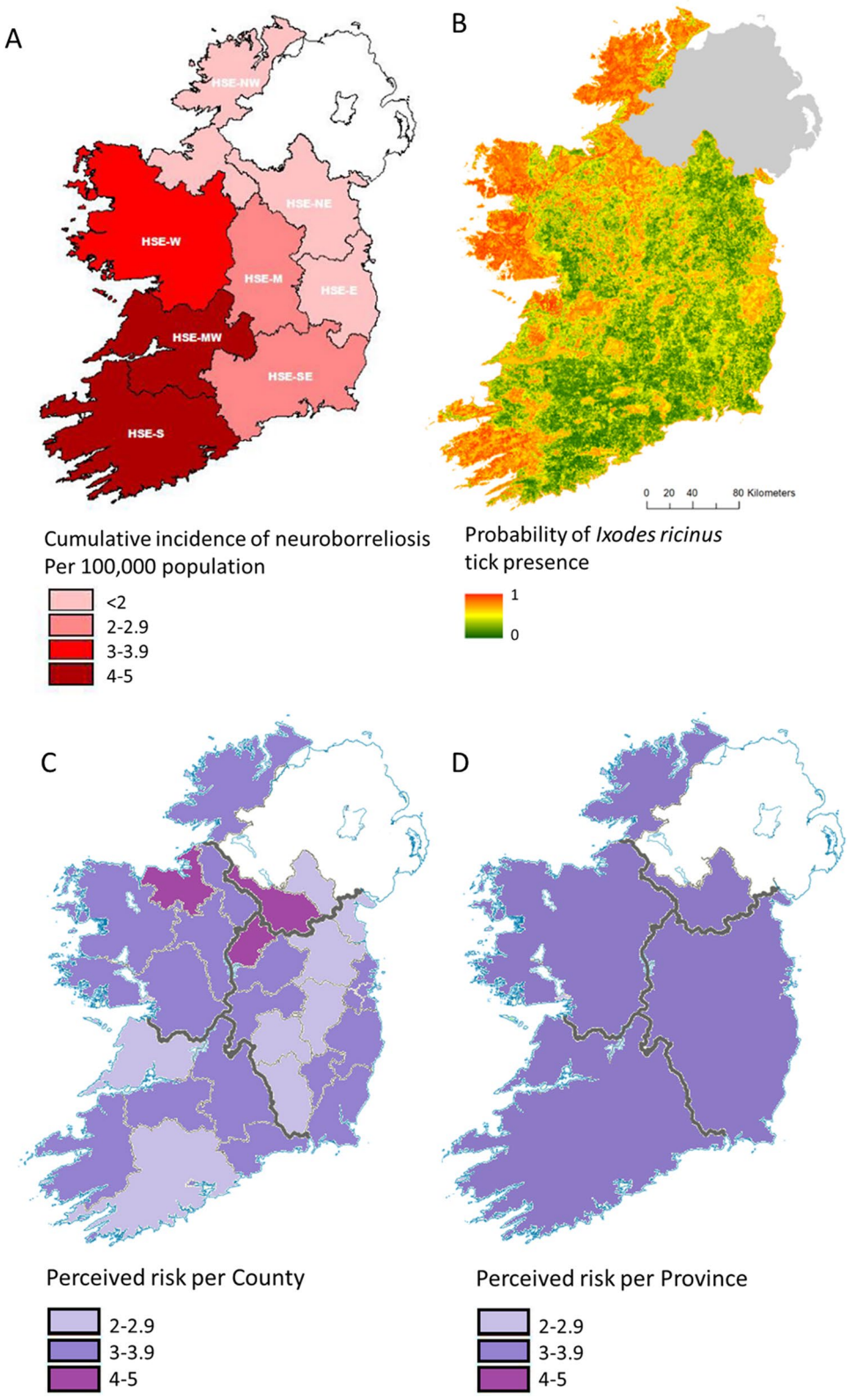

Fig. 5 Indicators of regional risk and perceived risk of Lyme borreliosis in Ireland. **A** regional 7-year cumulative incidence of neuroborreliosis 2012–2018 – figure from HPSC, broken down by regional health service area [34] and **B** Probability of Ixodes ricinus presence – figure from Zintl et al. [12], compared with **C** median perceived risk per county in Ireland as seen in the current study. There was no difference between counties in perceived risk of LB ($p = 0.460$, $\chi^2(3) = 25.041$, Kruskal-Wallis test). **D** Median perceived risk per province in Ireland. There was no difference between provinces in perceived risk of LB ($p = 0.536$, $\chi^2(3) = 3.130$, Kruskal-Wallis test).

symptoms [2]. Of note, it was possible for respondents to look up answers to these questions, or to potentially answer both the professional and recreationist versions of the survey, which was regarded as an unavoidable limitation of the study format. Nonetheless, the reported results reflected those of a survey of hikers of the Appalachian Trail in the United States of America, which found that 46% of hikers were unable to accurately recognise photographs of the erythema migrans rash [9]. Furthermore, in the present study, there was no relationship between respondents' frequency of outdoor activity and years of experience and their ability to describe symptoms correctly. This outcome, which was also seen in a study of outdoor workers in Québec [30], indicates that further outreach is necessary.

Of the different professions and recreational activity types, there was no difference in any group's ability to describe the symptoms of early LB, indicating that future training on symptom recognition needs to be distributed across all at-risk groups. There was a relationship between increased ability to describe early LB symptoms and increasing age bracket, though the same was not seen when respondent experience level or frequency of outdoor activity was analysed. This indicates that increased life experience, but not job/recreational activity experience, is associated with better LB symptom awareness. There was an association between self-rated familiarity and ability to describe symptoms of LB, indicating that respondents' beliefs about their familiarity with disease symptom were generally accurate. This outcome was similar to that of studies in Canada [8] and France [35]. Previous research has also indicated that having experienced a tick bite in the past is positively associated with the uptake of tick bite mitigation measures [7, 22], and thus, future research should now investigate whether such an experience has an impact on disease knowledge in at-risk groups in Ireland.

A critical outcome from the current study was the finding that, asked to rank the level of training they had received on prevention of tick bites and LB, 52% of respondents indicated that they had received 'no training'. Recreationists gave a median rank of one point, equating to no training, and professionals gave a median rank of two points, indicating minimal training. This is despite the Health and Safety Authority (the agency tasked with ensuring safety for the workforce in Ireland) advising that at-risk workers should receive training from their employer such that they know the symptoms and sources of infection of LB [13]. The low level of training reported in the current study is similar to that reported by St. Pierre et al. [8], which stated that only 20% of professionals and 6% of recreationists in the studied region of Canada had received training on LB. The current study asked what type of training respondents had received and conducting one's own research was a popular answer. This was a similar outcome to that seen in a study in Maine, wherein 53% of woodland owners had cited the internet as their mode of collecting information on LB, and in 45.5% of cases it was a family member or friend who had imparted information to them [26]. In the current study, where training was given, it was associated with increased disease knowledge on several counts: there was a positive relationship between respondents' level of training and their ability to identify woodlands and scrub as risk habitats, as well as to symptoms of early LB. Crucially, effective training on LB risk and symptom awareness needs to be rolled out more fully across the board to all professionals and recreationists in Ireland whose job or recreational activity puts them at increased risk of LB.

The authors note that the existing literature on LB risk often focusses on individuals' risk mitigation strategies, a fact that has also been recently pointed out by Urcuqui-Bustamante et al. [26]. Given the lack of insights into awareness of LB in Ireland, and into LB training in the wider literature, we have focused on this instead. Nevertheless, excluding bite prevention strategies remains a limitation of our study design, and future studies building on this pilot should be expanded to cover this area.

Of note, a 2019 report [5] prepared by The Health Protection Surveillance Centre (HPSC) indicated that international approaches to ensuring an adequate level of awareness of LB in the community were varied, but included school-based education programs, annual media campaigns, e-health initiatives (including the use of phone applications), citizen science studies, and the placing of signage at the entrance to risk habitats. The same report gave an overview of the present provisions by the HPSC to ensure awareness of LB in Ireland. These include factsheets for use by the general public on the prevention of tick bites, as well as factsheets for understanding and recognising LB, and explaining the process for serological testing for LB. These cover most of the knowledge gaps highlighted in the current study. While these factsheets are useful tools, the present study's findings regarding the low levels of training and gaps in disease knowledge amongst at-risk groups shows that such tools are not being used effectively to target at-risk groups. A concerted effort is needed at national level to encourage employers and recreational clubs/societies to provide training for employees/members, making use of the existing HPSC tools. For example, the availability of statistics around regional incidence of LB on different island areas of Scotland, has allowed policymakers to evaluate the need for targeted awareness campaigns to decrease incidence in the Outer Hebrides – a highly affected area [36]. The campaign involved the use of lesson plans and information packs for schools and

Table 3 Table of recommendations

Gap Identified	Significance	Recommendation
No difference geographically in perceived risk despite regional differences in environmental risk factors and cumulative neuroborreliosis rates in Ireland.	A lack of perceived risk translates to a lower likelihood of mitigation strategies being implemented by at-risk individuals.	Target known high-risk areas with awareness campaigns.
23% of respondents were unable to identify woodlands and scrub, 26% were unable to identify grassland, 38% were unable to identify heathland, and 51% were unable to identify bog as risk habitats.	Individuals failing to identify risk habitats will be less likely to take protective measures when entering such habitats.	Ensure that communication on risk habitats is included in future awareness campaigns, including images to help individuals recognise these habitats. Farmers should be amongst the first professional groups to be targeted.
Fewer than half (48%) of respondents mentioned or described the erythema migrans rash when asked to describe symptoms of LB, and only 37% listed a flu-like symptoms as well as erythema migrans.	Inability of at-risk individuals to identify symptoms of LB and seek help puts them at risk for disease progression and reduces the chance of complete recovery.	Future awareness campaigns should focus more heavily on symptoms and timeline of early LB, including rash description as well as other common symptoms.
52% of respondents overall indicated that they had received no training on LB.	There is a clear lack of training for at-risk groups.	The provision of training courses should be required by employers and registered clubs/societies.

nurseries, distribution of information to general practitioners (GPs), local businesses, and community halls, and information stalls at events, and resulted in an increase in presentations to GPs and hospitals with erythema migrans [36]. By contrast, such a targeted response would be difficult in Ireland as data on the regional incidence rates of LB are sparse (other than cumulative 7 year crude incidence data on neuroborreliosis) [34]. Therefore, in the absence of campaigns targeted towards higher-risk areas in Ireland, we suggest that the results of the current study can be used to target at-risk groups instead. Table 3 provides a list of recommendations that have been synthesised from the current study.

Conclusion

The data collected by this study provide novel information on awareness levels of LB in Ireland, and perceptions of the disease among at risk-groups. The results indicate important knowledge gaps amongst at-risk individuals relating to the symptoms of LB, affecting their potential ability to seek medical treatment. Furthermore, respondents reported a perception of moderate risk to themselves, but a markedly low level of training on LB, indicating that current training and awareness strategies must be improved. The study ultimately provides information which could guide the implementation of awareness campaigns. Any future awareness campaign on LB should target the groups identified in this study, and should ensure that communication on risk habitats and early symptoms of LB are included. This study provides baseline data against which the effectiveness of such an awareness campaign or other intervention aimed at increasing the level of LB awareness/knowledge can be measured. It also provides a methodology for the collection of granular data on perceptions and knowledge around LB amongst at-risk groups, that can be replicated by future research internationally.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions

R.W. – Conceptualisation, Data curation, Formal analysis, Funding Acquisition, Investigation, Methodology, Project Administration, WritingM.G. – Conceptualisation, Methodology, Funding Acquisition, SupervisionC.W. - Methodology, Formal Analysis, SupervisionC. C. - Conceptualisation, Methodology, Funding Acquisition, Validation, Supervision.

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Data availability

The dataset for this study can be obtained from the corresponding author on request.

Declarations

Ethics approval and consent to participate

Ethical approval of the experimental protocol presented in this paper was given by the University of Galway (formally National University of Ireland, Galway) ethics committee, reference number 20-Mar-14. Informed consent was obtained from all subjects.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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