Assessing awareness of tree pests and pathogens amongst tree professionals: A pan-European perspective

Abstract

Tree professionals play an important role in protecting forests against invasive pests. Their awareness of pests and knowledge of how they spread is likely to be a key component of effective detection, eradication and management measures, but very little is known about awareness levels of this stakeholder group. To address this important evidence gap, a questionnaire survey of tree professionals was carried out across nine European countries. Results from 392 tree professionals show relatively low levels of self-reported awareness for a number of pests and pathogens. Levels of awareness rise with increasing age as well as frequency of visits to forests. Awareness also appeared higher where pests were present in the respondent's country. There was a high level of support for purchasing plant material from accredited sources. Barriers to changing behaviours include financial and resource pressures but also the perceived behaviour of others. Tree professionals utilise multiple sources to gain information about tree pests but the internet was the most popular. A considerable amount of pest information is already available online and this study recommends that different approaches to raising awareness be trialled, including the use of experienced tree professionals as knowledge brokers and exploring new ways of using digital technologies as a learning tool. (205 words)

Key words: biosecurity; forest pests; survey, awareness, professionals; Europe

1. Introduction

Pests and diseases (hereafter, referred to as 'pests' where possible) pose significant threats to European trees and forests (Brasier 2008; Kenis and Branco 2010; Webber 2010). Tree professionals, i.e. individuals whose livelihood involves trees, often represent the first line of defence against their introduction and spread, as they occupy key positions along supply chains and pathways. Their actions, such as inspections surveillance, buying plants, and silviculture and forest planning are vital to the future biosecurity of trees and forests. In this context it would be reasonable to expect tree professionals to have high levels of awareness of pests and diseases. However, with continual change in this area of knowledge, increasing numbers of new pest and disease establishments and the growing complexity of pathways (Pautasso 2013; Stenlid et al 2011; Eschen et al 2015a), levels of awareness amongst professionals may be less than ideal.

Awareness is an important dimension of managing the spread of pests because much spread is unintentional: occurring without the knowledge of those responsible. More positively, increased awareness is likely to improve surveillance and pest monitoring, at the same time as increasing outbreak preparedness. A lack of awareness of plant biosecurity practices and risks amongst forestry, horticulture and conservation sector stakeholders is commonly suggested (Webber 2010; Dehnen-Schmutz et al. 2010), and Marzano et al (2015) emphasise that raising awareness amongst these stakeholders is essential for future biosecurity. Studies on awareness of tree pests generally are rare and very little work has been done around awareness of forestry-related professionals (Hathaway et al 2003; Hurley et al 2012). A comprehensive review of the literature on stakeholder awareness relating to tree health identified only eight studies focused directly on tree pests (Marzano et al 2015). Seven of these looked at awareness of beetle pests while one study looked at the Sirex woodwasp (*Sirex noctilio*). Of these seven, only three looked at awareness amongst tree professionals, which included foresters, aboriculturalists and horticulturalists (Hathaway et al 2003; Hurley et al 2012; Molnar et al 2003). These few studies suggest that tree professionals have general awareness of the tree pest issue, but less of the specific knowledge needed for identifying symptoms of disease or infestation. Additional literature shows that there are low levels of awareness of invasive species in general amongst other groups of tree professionals (see Marzano et al 2015). This paper therefore seeks to contribute knowledge to fill the significant gap in understanding of levels of awareness amongst these stakeholders.

As the scale and complexity of tree health issues increases, so too does the number and range of tree professionals involved. Biosecurity measures to prevent the introduction or mitigate the spread of tree pests have received substantial policy attention recently as the extent and scale of new and emerging pests have intensified (Webber, 2010; Liebhold et al. 2012; Eschen et al. 2015a, Freer-Smith and Webber 2015). There is considerable evidence showing the key pathways for introductions and spread include trade using wood packaging (Brockerhoff et al. 2006; Haack et al. 2010, 2014) and trade in live plants (Kenis et al. 2007; Liebhold et al. 2012; Hantula et al 2014) - which itself includes practices such as 'ex-importing', that is moving growing stock from one country to another to benefit from better growing conditions before being returned to the country of origin (Brasier 2008). The use of wood for fuel has also been shown to be an important pathway (Poland et al 1998; Muirhead et al 2006). Whilst these pathways clearly involve many stakeholders beyond the forestry, arboricultural and horticultural sectors, the number and breadth of tree professionals involved in them is substantial.

We focus on Europe as it provides an important regulatory and trade context for plant health and biosecurity for tree professionals in member states and beyond in continental Europe

(MacLeod et al 2010; Maye et al 2012; Eschen et al 2015b) – and brings with it substantial interdependence and connectivity between these key stakeholders. Plants and plant products imported into European Union (EU) member states are required to have a phytosanitary certificate issued by the exporting country – indicating that certain standards, such as phytosanitary inspections, have been met (Jones and MacLeod 2013). Most plants and plant products are given a 'plant passport' following this initial inspections and are then allowed to be moved freely within the EU. Evidence suggests that the volume of trade combined with limited inspection capacities impedes the effective interception of pests at points of entry (Liebhold et al. 2012; Eschen et al. 2015a). Balancing trade requirements across Europe with effective phytosanitary measures is a complex challenge (Stenlid et al 2011). Despite the high levels of regulatory coordination across Europe, especially within the EU, variation in phytosanitary behaviours (including the phytosanitary actions of tree professionals) are likely to emerge due to the varied resources, capabilities, and enforcement of legislation in each jurisdiction.

This study attempts to go some way to fill the evidence gap by surveying tree professionals from nine countries across Europe (Bulgaria, Croatia, Greece, Italy, Macedonia, Serbia, Sweden, Switzerland and the United Kingdom). The aim was to gauge the awareness levels of a range of tree pests and pathogens, knowledge of how they spread and the sources of information that they draw upon and willingness to undertake specific biosecurity actions. In the following sections we report on our survey design, implementation and the results of our analysis. We discuss our results in the context of the wider literature, noting the challenges of raising awareness amongst tree professionals when much scientific evidence is available.

2. Methods

Survey Design

We conducted a self-completion questionnaire survey of tree professionals (individuals with a current livelihood linked to trees or forests) across nine European countries. These countries were chosen because of the ready access to networks of tree professionals in each location afforded by participation in the EU Cost Action PERMIT (http://www.cost.eu/COST_Actions/fps/FP1002). Whilst this approach did not generate responses from every European state, it did provide insights from a broad geographical and socioeconomic range, and produced data relating to a number of common pest and disease threats. .

The survey was designed initially by social researchers at Forest Research, UK and subsequently iterated, tested and refined by the co-authors at collaborating institutions across Europe. This process generated a 'core' set of survey questions, and selection of tree pests to focus on, for all surveys wherever they were undertaken. The authors then translated this 'core' into locally relevant languages and added locally relevant content (e.g. the addition of specific tree pests present in the local environment). This co-ordinated, devolved model of survey design and implementation had both costs and benefits. It ensured considerable peer-review of the questions and the collection of a largely cross-comparable data-set, whilst allowing local flexibility and relevance. However, it also resulted in some disjointed data (e.g. some questions that required giving a ranking were answered differently because of differing local completion instructions) and limited opportunities to learn from innovation or lessons experienced by surveyors at the implementation stage in the varied locations.

Surveys consisted of around 20 questions (both open and closed format) and asked respondents to make judgements about their own level of knowledge of a range of tree pests, the importance of trees and forests, the effectiveness of biosecurity measures, and the likelihood of further pest introduction to their country. It also gathered data regarding the sources of pest information used, who they reported pests to, and respondent demographics.

Surveys were distributed, by hand and by email, via the professional social networks of the authors. Whilst this ‘snowball’ or ‘respondent-driven’ approach to sampling is particularly effective and common in qualitative research (Biernacki and Waldorf 1981), it is also used in survey and questionnaire work: including in forestry (e.g. Ananda and Herath 2003; Carvalho-Ribeiro and Lovett 2011; Wilmsen et al 2015). Its strengths are its efficiency and its capacity to reach ‘hidden’ or otherwise difficult to access social groups (e.g. when the research focus is on a sensitive issue) (Perez et al 2011). The approach works by exploiting existing social or professional connections and as such its most significant limitation is its potential to over-sample socially similar respondents and miss ‘isolates’. However, it was deemed a particularly appropriate approach to obtain data on tree professionals as they are poorly visible and disparate (i.e. they are widely distributed across stakeholder groups and organisations), yet they are well cohered and inter-linked as a professional social group (especially in relation to plant health). As respondent-driven sampling is a nonprobability method of sampling we make only very limited claims regarding representation of the wider tree professional population, instead restricting ourselves to drawing conclusions primarily about our respondents. In total, approximately 1,250 surveys were distributed across the nine countries, and 392 completed surveys returned, indicating an overall response rate of approximately 30%. Whilst there is no agreed standard minimum acceptable response rate for survey research and rates of 60% or higher are deemed strongest (Stevanov et al 2016), 20% is agreed by some to be an absolute minimum (Malhotra and Grover 1998). Our response rate is therefore satisfactory and comparable to several other survey-based studies in forestry (e.g. Gruchy et al 2011, 28.8%; Cai et al 2016, 32%). Figure 1 illustrates the number of responses from different countries, with the greatest number coming from Bulgaria and Switzerland.

Data Analysis

Along with the generation of descriptive statistical information, a number of statistical tests were conducted using SPSS (v19, IBM) to assess inter-relationships between key variables. The degree of association between nominal row and column factors within a cross-table (e.g. respondent's country and degree of awareness) was assessed using Phi statistics, a measure of association based on chi-square. Associations between ordinal data (e.g. age or visit frequency and degree of awareness) were assessed using gamma tests.

Five prominent and widespread tree pests were selected to form the 'core' survey, about which all respondents were asked. In addition, several locally relevant pests were chosen and added by local surveyors. Survey respondents were thus asked to report their level of knowledge of between five and twelve pests, depending on the country in which they were surveyed. To strengthen the analysis of these self-reported levels of knowledge we created a Median Degree of Awareness (MDA) measure using these values. This assigned the median value of the range of levels of knowledge reported by each respondent, to that respondent.

The survey included a number of open questions which generated qualitative data in the form of short textual responses. This data was collated and an open coding strategy was used to identify key themes. Codes are a useful mechanism for sorting through descriptive data and grouping responses (Robson 2002). For this article we focused on two questions with the first exploring barriers to changing behaviours that have a negative impact on tree health. Answers largely coalesced around legislation, lack of awareness and financial constraints. The second question focussed on information and here we documented the preferred formats for information provision but also the types of information respondents felt they needed. In the

Results section below, selected qualitative data is presented to illustrate the prominent themes. Data is labelled with individual respondents, following ISO standard coding to identify the country within which the respondent was surveyed.

3. Results

Our survey generated data from 392 tree professionals from nine European countries, of generally middle-age groups (Figure 1). 57.4% of the respondents worked in forestry (*n*=225). Other professions included agronomists, landscape architects, horticulturalists, conservationists and researchers. 38% of our respondents were female (*n*=149). Unsurprisingly given the nature of the sample, the vast majority of respondents (79.6%, *n*=312) considered trees and forests as 'very important' overall and were very familiar with forests, with nearly half the respondents (47%) visiting forests 'several times per week' (Figure 2). Their importance as wildlife habitat rated most highly amongst a suite of ecosystem services proposed in the survey: 75%, *n*=294, answered 'strongly agree' when asked whether forests are 'an important place for wildlife'.

INSERT FIGURE 1 AND 2

3.1. Levels of pest and disease knowledge amongst tree professionals

Respondents were asked to assess their own level of knowledge and awareness of tree pests and diseases on a four-point scale. Results (Table 1) reveal what can at best be described as modest levels of knowledge and awareness amongst this stakeholder group. Whilst at an overall level there is a little variation between invertebrate pests and pathogens, levels of knowledge and awareness of chestnut blight (*Cryphonectria parasitica*) are highest, and are lowest in relation to Emerald ash borer (*Agrilus planipennis*). In general only one-quarter or less of these professionals feel they ‘know a lot’ about these pests. A significant proportion of respondents (including more than one-third for Emerald ash borer) say that have ‘never heard of’ these pests and diseases. Our MDA measure suggests that overall just over half (51.4%) of these professional respondents report they have either ‘never heard of’ or ‘have heard of but know nothing about’ the tree pests that were listed.

INSERT TABLE 1

Results of the Phi statistical tests suggest that reported levels of knowledge are not uniformly distributed across the European countries included in this survey. The relative proportion of respondents reporting specific levels of knowledge varies significantly between countries, both for MDA and for each pest. Patterns in the variation of knowledge levels are not identifiable from the statistical tests, however some meaningful observations can be noted. Table 2 reports the proportions of respondents in each country reporting ‘some’ or ‘a lot of’ knowledge about the core pests. There is substantial variation within both columns (pest) and rows (country) exhibited in this table. Having said this, a loose pattern can be seen linking pest presence in a country (indicated by bold text in Table 2) to higher levels of awareness. This appears to be the case for a number of countries including Bulgaria, Sweden, Macedonia and Italy, yet the UK reports very low levels of knowledge even for present pests. Seven of the ten highest reported levels of knowledge relate to present pests, whilst six of the ten lowest reported levels relate to absent pests.

INSERT TABLE 2

MDA was tested against a number of demographic variables for the respondents. No significant variation was observed in relation to gender (p=0.122) nor overall level of importance attached to trees and forests (p=0.451). Nor were there significant associations between MDA and the level of importance individuals attached to trees, woods and forests for economic (p=0.617) or wildlife habitat (p=0.607) reasons. There were significant associations between MDA and the age of respondents (p=0.001) and the frequency with which they visit forests (p=0.001). Reported level of knowledge and awareness rises with age and frequency of visit.

The vast majority of respondents believe that further introductions of tree pests and diseases are likely, with over 93% agreeing or strongly agreeing. Respondents were asked to identify pathways that could potentially introduce pests and diseases into their country. Two insect pests and two pathogens were enquired about across seven or more countries. The results are summarised in Table 3.

INSERT TABLE 3

A substantial proportion of respondents gave no answer to these questions. Imported wood was considered the most common pathway for the insect pests (ALB and EAB), with imported live plants the most likely for pathogens. Overall these two pathways were judged the most likely introduction routes for pests. Natural dispersal was judged a more likely means of spread for the pathogens (both of which are already present in Europe) than the insect pests, although a quarter of respondents judged natural spread of EAB to be a potential pathway.

3.2. Attitudes towards biosecurity behaviours

The vast majority of respondents (85.7%) indicated that they had or would purchase plant material only from accredited sources where biosecurity measures are put into place to monitor for, and prevent, pest and disease outbreaks. Just less than two-thirds (63.8%) said they would not buy imported plants. Although they form only a small sub-sample, this proportion was about the same (60.0%) for landscape architects, a key sub-group of stakeholders often implicated in biosecurity risk. Only 19.9% of the respondents said that they currently clean footwear or vehicle / bike tyres when visiting the countryside to help prevent the spread of tree pests. However a further 29.3% said they may in the future.

Respondents were asked an open question on what factors might prevent them from changing their behaviour to reduce biosecurity risk. A number of answers pointed to a lack of financial resources (e.g. “Lack of funding that could support the application of necessary measures" (GR17); “Increase employees and resources at the borders” (IT3)). Another respondent highlighted a “fear of going bankrupt” (CH7) as a factor. Further issues included a lack of information or knowledge (e.g. “Inability of the foresters to conduct inspections; lack of scientifically trained personnel at customs” (GR7), "Insufficient information" (CH78)), the amount of effort required to make changes (e.g. “very labour intensive measures and changes” (CH78)) and perceptions about the behaviours of others (e.g. “indifferent citizens” (GR 11); “If most people behave properly I would join them” (SE13)). Lack of coordination between relevant agencies at the national and local level was also considered an impediment to changing behaviour (e.g. “Failing coordination during control efforts” (CH49); "Lack of means and cooperation with the related agencies” (GR19)).

Some respondents answered this question by identifying the factors that they felt would support biosecure behaviour. In this respect, a common response was education and information provision. This related particularly to how behaviours can contribute to the introduction and spread of pests and diseases, and included some reflective insights about professionals' own behaviour:

> “Information and knowledge about threats, which I do not have now” (RS42)

> “Insight that my behaviour may lead to damages and is a risk” (SE18)
>
> “If my behaviour will spread pests/diseases into my region/country I would avoid this behaviour” (SE28)

Concerns about increasing knowledge were sometimes associated with a call for stricter legislation and controls. For example,

> “Legislation strictly to be applied and education of the whole population from early childhood” (RS10);
>
> “Phytosanitary control, education of phytosanitary inspection” (RS23).

In Italy there was a greater focus on borders (e.g. “More control at borders” (IT12); “Close some borders” (IT20)). Finally, some respondents indicated that trade practices and consumer buying habits needed to change. For example,

> “Only buy controlled exotic plant species” (SE4)
>
> “…imported plants should not be cheaper than locally produced plants” (CH9)
>
> “The trade of forest products that cannot be controlled”(GR11)

3.3. Sources of pest and disease information used by tree professionals and reporting behaviour

Our results indicate the majority of the professionals we sampled utilise multiple sources of information to gain knowledge about tree pests and diseases: usually 2 (20.6%) or 3 (26.2%) (mean = 2.87). The internet is the most frequently reported information source (70.9% of 358 valid responses) and is also by far the most common choice of those using only a single source of information (53.7% of those respondents). For those reporting that they do not use the internet (29.0%), no single alternative emerges from our results, although around half name newspapers and government organisations.

Our results also reveal the importance of education and training as a source of information with more than half (56.1%) of respondents identifying these. Other sources are government organisations (45.8%), trade journals (43.6%), professional organisations (33.2%) and newspapers (29.6%). Friends and family are only rarely (7.8%) drawn on by tree professionals for information about pests and diseases.

Respondents were asked to indicate who they would most likely report the discovery of a pest or disease to, by ranking a number of options. Unfortunately this question returned a high number (n=167) of invalid or missing responses, primarily because many respondents interpreted the question as requiring a weighting rather than ranking response. The results must thus be treated with caution. However, analysis of the valid responses (n= 225) revealed national government to be most likely first point of contact, with more than half (53.8%) of respondents choosing this option. Local authorities (11.6%) and conservation groups (12.0%) were the organisations next most likely to be the first point of contact. 13.8% of respondents felt that reporting to 'nobody' was the most likely option, although given the overall problem with interpreting this question, this figure may be artificially high.

When asked what information they would need in order to become more knowledgeable about tree pests and diseases, responses to this open question fell into two broad categories, focussed on content (type of information) and format. Respondents who interpreted the question as being about content were most interested in learning more about the biology of pest species and how they spread followed by prevention or control methods:

> "All relevant data on how to prevent introduction and spread of invasive species (biology of species, host plants, distribution, factors favouring its dispersal etc)". (HR11)

Other respondents requested alerts about potential new introductions. For those respondents who interpreted the question as being about the format in which to receive information, the highest response related to face-to-face contact through "lectures", "seminars" and "training" or "professional courses". The second highest response related to accessible online material with an emphasis on visual images of pests and diseases (e.g. "Open, national web page that will contain all the necessary information regarding pests and diseases" (GR12)). Email alerts were again thought to be use useful and were linked to requests for published materials, newsletters and fact sheets. Although there were few requests for peer reviewed publications, there was a concern that the information should come from "…competent specialists in plant diseases and pests" (RS10).

4. Discussion

Our survey suggests that awareness of pests is relatively modest amongst tree professionals. This finding corresponds with and expands upon the very limited current literature on stakeholder knowledge and awareness levels of tree pests (e.g. Hurley et al 2012; Hathaway et al 2002; see Marzano et al 2015). Given the potentially very significant roles that these particular stakeholders can and do play in plant biosecurity, this result should be of concern to policy makers and others. Arguably, increasing awareness of pest threats remains an area that urgently needs to be addressed, not only for current 'known' pests but also those which pose a future risk.

Awareness levels do vary in relation to the respondents' demographics. We found that knowledge and awareness rise with age and frequency of visit, suggesting that it increases with the professional's experience and the amount of time they spend 'in the field'. A few studies have explored the relationship between levels of awareness and demographic variables amongst residents (e.g. McFarlane et al 2006; Chang et al 2009), but rarely for tree professionals. One example is a survey of 240 forestry professionals in South Africa in relation to the Sirex woodwasp (*S. noctilio*). This study found that the key variables influencing high awareness levels were relevance of the pest to their job and perceptions on whether research on forest pests was important (Hurley et al 2012). Similarly to our study these authors also found that number of years' experience influenced exposure to information about tree pests and thus levels of awareness.

There was a mixed response to our question assessing knowledge of pathways of introduction and spread. A large proportion of respondents did not answer this question, which is perhaps an illustration of the scale of uncertainty and/or lack of knowledge regarding pathways. However, the professionals who did respond showed a reasonable understanding of pathways. In particular, imported wood was considered the most common pathway for the insect pests (as supported by Eyre et al 2013; Liebhold et al 2012; Cappaert et al 2005; Haack et al 2002), and imported live plants the most likely for pathogens, (as supported by Liebhold et al 2012, Haack et al 2010; Webber 2010). These two pathways were judged the most likely introduction routes for pests in general. It is important to note that it is rare for a pest introduction to be observed directly and therefore pathways of introduction can remain unclear (Kenis et al 2007). Although general pest sources (such as a nursery or industrial unit) can often be identified, it is less common for the specifics of an introduction, such as precise shipments, to be known. These results suggest pockets of good knowledge about pathways exist amongst our respondents, but that efforts need to be made to disseminate that knowledge more widely.

Reported awareness levels also appear to vary to some extent in relation to location. Although we don't have sufficient depth of data to explore these differences in detail it is notable that higher awareness levels are reported where a pest is present in the respondent's country. These findings identify perhaps two key areas for additional action alongside the maintenance of existing awareness levels. First, efforts should be made to increase knowledge of pests and diseases that are not yet present, but are likely to arrive in, certain locations. Such awareness would greatly enhance the capacity of tree professionals to fulfil an early warning surveillance role. Second, if experienced professionals have greater awareness levels and knowledge is unevenly distributed amongst them, consideration should be given to how their knowledge can best be communicated and disseminated amongst younger, less-experienced and less specialist colleagues.

It is interesting to note that respondents in our survey appeared to support changes to their own and others' plant buying practices, which may be a response to perceived limitations in current regulatory measures. In particular, buying plants from biosecure accredited sources was broadly supported. Although such systems are currently not widespread, there are some examples of codes of practice that have been collaboratively developed by industry, government or other stakeholders. These are primarily related to horticulture and invasive plants (e.g. Horticultural code of practice: helping to prevent the spread of invasive non-native species (Defra 2011); Nursery Industry Accreditation Scheme Australia (NIASA)). Brasier (2008) recommended that in order to enable consumers to make biosecure choices, plant retail establishments should provide labelling that highlights geographic origin and production method (see also Roy et al 2014). These newly emergent responses to biosecurity concerns that fit within neoliberal trade regimes extend tree health stakeholdership considerably, and emphasise the role of tree professionals as consumers and standard-setters.

The finding that only one-fifth of the survey's respondents said they would clean their footwear and equipment as part of their biosecurity practice is concerning. This may to some extent be explained by perceptions of low risk and/or the ineffectiveness of those actions. Our results are supported by Breukers et al (2009) who used 'The Pest Belief Framework' to understand how perceptions of phytosanitary risk influence decision-making in the plant production chain. Breukers et al. (2009) found that risk perception and its influence on attitudes as well as levels of knowledge were important factors in determining risk management behaviour, although they also noted the significance of support from others and the feasibility of proposed management actions in promoting biosecure behaviours.

Our study explored opinions on a number of government biosecurity measures such as border control, quarantine, monitoring and information provision. Given the widespread calls for more effective measures and evidence that highlights the severe challenges facing current controls and measures, it is perhaps surprising that two thirds of respondents, largely practitioners, indicated that their government's efforts in these areas were effective. There was, however, less confidence expressed in response to open questions on factors that might inhibit biosecurity. Here, there were calls for increased resources, greater coordination between relevant agencies, stricter control of trade, and even closing some borders. Much of this debate centres on the relationship between globalised trade and biosecurity. Plant health scientists frequently highlight the role of trade in the spread of pests and diseases, and suggest various responses including trade bans, greater regulation or novel policies to meet the costs of biological invasions (Brasier 2008; Webber 2010; Hantula et al 2014; Roy et al 2014). Greater exploration is needed of the feasibility of such calls or whether it is possible to work within existing regulations. For example, under the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement; WTO 1995) and the International Plant Protection Convention (FAO 1997), a country may prohibit entry of a commodity only if in the course of a pest risk analysis no phytosanitary measures are identified that would ensure an acceptable level of risk (Eschen et al. 2015b). There are inevitably tensions when plant health regulations appear as a sub-component of WTO rules (SPS Agreement - https://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm), which have the overarching objective of promoting free trade (Roy et al 2014; Potter 2013). The aim of the SPS Agreement is to stipulate phytosanitary measures without unnecessarily impeding trade. In practice this means that measures are based on scientific evidence (Eschen et al 2015b). There is the added difficulty of pests entering countries that were previously unknown or not considered to be harmful before establishment due to the unpredictability of impacts following new interactions between introduced pests and host (Eschen et al 2015b; Freer-Smith and Webber 2015). To date there is little evidence on the effectiveness of current phytosanitary measures across Europe as only limited data on pests is collected at borders.

One very significant limitation on pest and disease awareness amongst tree professionals is the scale and complexity of the enormous volumes of live plant material or wood products involved in global trade pathways – and the associated institutional structures. The resources required to prevent or mitigate introductions, or control pests, are rarely sufficient. For example, several authors claim that inspection at ports of entry is inadequate (Brasier 2008; Liebhold et al 2012; Clark 2013; Roy et al 2014). No matter how knowledgeable and aware tree professionals may become, these issues of scale and resource will likely persist. Moreover, although the time taken up by biosecurity issues is undoubtedly increasing, tree professionals can rarely focus entirely on tackling pests and pathogens. Tree health is one of many tasks that tree professionals have when managing forest assets (Quine et al 2014). Consequently, there is growing interest in 'citizen science' to assist in surveillance and early detection efforts – which may have the added value of raising awareness and enhancing public acceptability of outbreak management methods (Gupta 2010; Sacco 2004; Brockerhoff et al 2010).

Additional complexity relates to institutional structures and the different roles and responsibilities of tree professionals. In Europe there are separate structures for the governance of forests, agricultural plants and horticulture. For example, in Switzerland the regulations for planting material for forest regeneration differ from those governing the import of all other plants.[i] In the UK, responsibilities for plant health is devolved to the country level (England, Wales, Scotland and Northern Ireland), which allows distinctive priorities to be followed under the umbrella of the National Plant Protection Organisation (NPPO). Other countries no doubt face similar situations, which can influence knowledge and awareness amongst different tree professionals.

Information provision alone is unlikely to change behaviour (e.g. Dwyer et al 2007; Parks and Theobald 2011), but participants did highlight the need for information provision and education about the negative impacts of certain behaviours. Calls for greater education and awareness-raising to prevent non-native invasions in the plant world are common in the literature (e.g. Webber 2010; Dehnen-Schmutz et al 2010). Roy et al (2014) highlighted a wide range of sectors that needed to raise their levels of awareness of tree health issues, including policy, industry, forestry, conservation and the plant-buying public. However, Marzano et al (2015) called for more detailed research to be conducted into how different stakeholder groups actively seek and receive information and which sources are likely to be the most trusted and effective. The results presented here add to the current knowledge base about which information sources are preferred and trusted.

In this study we found that the internet was the most popular form of communicating information on pests and diseases, although most respondents used multiple sources and especially appreciated education and training as an approach. The most prevalent requests for information and learning from professionals surveyed here was for visual learning on biology, prevention, detection and management methods and there was a concern that this should come from trusted scientific sources. This corresponds with, for example, Roy et al's (2014) call for the scientific community to be leading educational efforts. However, requests for this type of information as opposed to information on communication strategies may be an artefact of the intrinsic preferences of tree professionals.

It is critical to note that there is undoubtedly already a very significant amount of information on tree pests and diseases available on the internet from scientific or government institutions and professional bodies (see for example in the UK www.forestry.gov.uk/fr/INFD-5STC8A; Serbia www.sfb.bg.ac.rs and www.hortikultura.org.rs.; Switzerland http://www.wsl.ch/dienstleistungen/waldschutz/_index_EN and http://www.jardinsuisse.ch/; Greece www.fri.gr). It is legitimate, therefore, to ask whether people are accessing what is already available in the format they have requested? If not, this may be a result of a lack of time to search for and read such information or a lack of perceived risk, as suggested by Breukers et al (2009). Despite internet-based forms of information being explicitly perceived as desirable by tree professionals, other more proactive forms of information dissemination, such as mobile alerts, face-to-face engagement by tree health 'champions' or engagement with professional social networks, may actually be considerably more effective in terms of achieving changes to behaviour. Further detailed qualitative research is needed to assess the efficacy on different engagement measures in increasing knowledge and changing behaviours, with different stakeholder groups at different stages of an outbreak.

5. Conclusion

In this study we surveyed nearly 400 tree professionals from across Europe to assess their levels of knowledge and awareness of key dimensions of tree health. We revealed what can at best be described as modest levels of awareness amongst some of the stakeholders who are at the forefront of efforts to protect Europe's trees, woods and forests from the threats posed by harmful introduced pests and diseases. We therefore conclude that continued and increased efforts are required to improve awareness amongst these professional groups. However, this cannot consist simply of the generation and provision of yet more scientific information relating to each pest or disease as it emerges – despite the fact that this is commonly requested. Whilst that type of information is clearly needed, there is already a considerable amount of it available – and there has long been so, with seemingly limited impact on awareness amongst tree professionals. Our study suggests that promoting opportunities for more experienced tree professionals to share their knowledge of tree pests and diseases, better explaining pest and disease pathways, harnessing digital communications, highlighting the effectiveness of biosecurity practices within the complex context of trade, and promoting novel opportunities to connect consumers to biosecure sources are some of the ways in which knowledge and awareness can be improved amongst tree professionals.

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Figure 1:Respondent Age by country

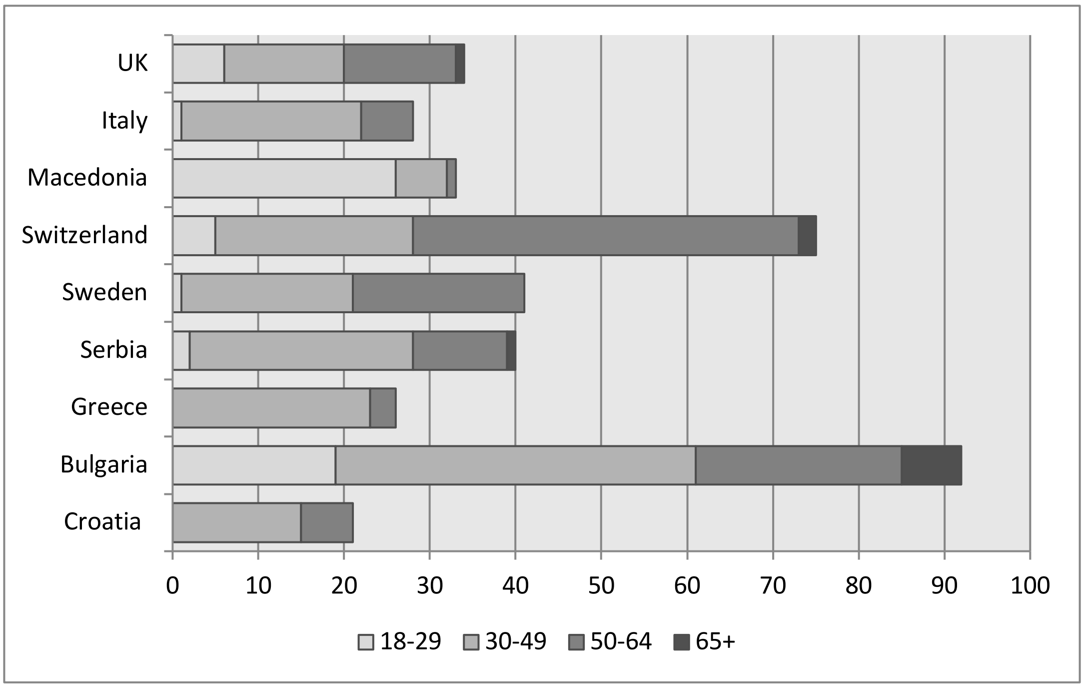
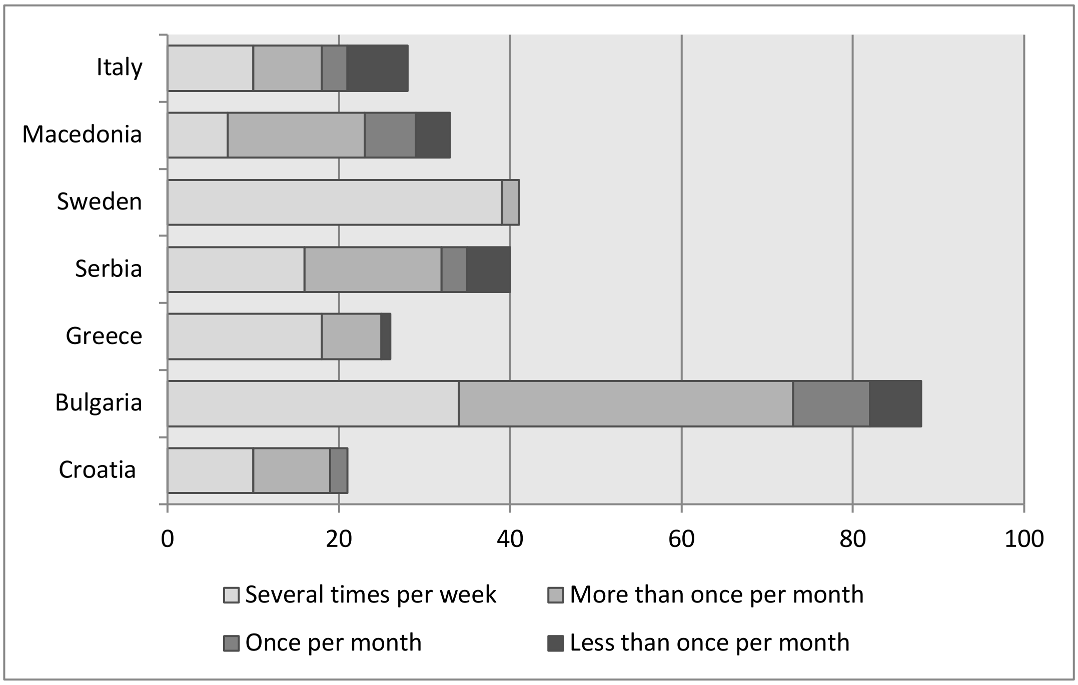


Figure 2: Respondent Forest Visit Frequency by country



	←← LOW	*Knowledge and awareness*		HIGH →→	
	'I have never heard of it'	*'I have heard of it, but know nothing about it'*	*'I have some knowledge about it'*	*'I know a lot about it'*	
Asian longhorn beetle (valid responses *n*=333)	20.4%	24.9%	30.3%	24.3%	
Chestnut blight (*n*=312)	15.7%	15.7%	28.2%	40.4%	
Great spruce bark beetle (*n*=275)	28.0%	23.6%	30.2%	18.1%	
Emerald ash borer (*n*=339)	36.3%	28.6%	19.1%	15.9%	
Ash dieback (*n*=350)	21.1%	18.9%	33.4%	26.6%	
Median Degree of Awareness (*n*=377)	20.4%	31.0%	26.5%	22.0%	

Table 1: Levels of pest and disease awareness amongst tree professionals

	ALB	CB	GSBB	EAB	AD
Croatia	71	**100**	**-**	-	**71**
Bulgaria	55	**68**	**71**	56	39
Greece	35	**43**	72	24	14
Serbia	81	**96**	**-**	74	88
Sweden	29	-	**-**	24	**88**
Switzerland	**87**	**56**	**23**	22	**83**
Macedonia	33	**88**	64	36	27
Italy	**-**	**100**	**50**	29	**43**
United Kingdom	**12**	**26**	**18**	6	**74**

Table 2: Proportion of respondents reporting 'some' or 'a lot of' knowledge of each pest (%). Bold type indicates pest is present.

	ALB		EAB		CB		AD	
	n	%	*n*	%	*n*	%	*n*	%
Valid Answer Given	237	**66.2**	181	**50.6**	203	**56.7**	219	**61.2**
No Answer Given	121	**33.8**	177	**49.4**	155	**43.3**	139	**38.8**
Pathway								
On imported plants	101	**42.6**	95	**52.5**	155	**76.4**	118	**53.9**
On imported wood	197	**83.1**	105	**58.0**	66	**32.5**	59	**26.9**
Natural Dispersal	33	**13.9**	47	**26.0**	87	**42.9**	111	**50.7**
On firewood	34	**14.3**	32	**17.7**	34	**16.7**	27	**12.3**
via water	2	**0.8**	8	**4.4**	20	**9.9**	13	**5.9**
On animals	6	**2.5**	4	**2.2**	30	**14.8**	15	**6.8**
Via humans	25	**10.5**	12	**6.6**	48	**23.6**	22	**10.0**

Table 3: Knowledge of introductory pathways

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[i] (Forest Ordinance WaV 321.01, governed by the Department for Environment as opposed to the Plant Health Regulation PSV 916.20, which is governed by the Department for Agriculture).