Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 May 2020 doi:10.20944/preprints202005.0168.v1

Catalogue of pests and pathogens of trees on the island of Ireland

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Abstract

Trees provide key ecosystem services, but the health and sustainability of these plants is under increasing biotic and abiotic threat, including from the growing incidences of non-native invasive plant pests (including pathogens). The island of Ireland (Ireland and Northern Ireland) is generally accepted to have a high plant health status, in part due to its island status and because of the national and international regulations aimed at protecting plant health. To establish a baseline of the current pest threats to tree health for the island of Ireland, the literature and unpublished sources were reviewed to produce a dataset of pests of trees on the island of Ireland. The dataset contains 396 records of pests of trees on the island of Ireland, the majority of pests being arthropods and fungi, and indicating potentially more than 44 non-native pest introductions. The reliability of many (378) of the records was judged to be high, therefore the dataset provides a robust assessment of the state of pests of trees recorded on the island of Ireland. We analyse this dataset and review the history of plant pest invasions, including (i) discussion on notable native and non-native pests of trees, (ii) pest interceptions at borders and (iii) pests and climate change. The dataset establishes an important baseline for the knowledge of plant pests on the island of Ireland, and will be a valuable resource for future plant health research and policy making.

Introduction

The incidences of non-native pests (including pathogens) of plants are increasing globally, and these pests threaten important ecosystem services (Boyd et al. 2013; Crous et al. 2016), with this increase mainly thought to be due to increased globalisation (Desprez-Loustau et al. 2010; Liebhold et al. 2012; Santini et al. 2013), and climate change (Desprez-Loustau et al. 2007; Bebber 2015; Ramsfield et al. 2016). Reviews in the USA (Aukema et al. 2010), New Zealand (Sikes et al. 2018) and the UK (Freer-Smith and Webber 2015) have shown an increase in the records of highly damaging non-native pests of woody plants since the late 20th century. One such pest causing significant economic and environmental damage is the emerald ash borer (*Agrilus planipennis* Fairmaire) in North America, spreading since its introduction in the 1990s (Herms and McCullagh 2014). This pest is considered a very serious threat to ash (*Fraxinus excelsior*) in Europe (EPPO 2013), where another non-native pest (*Hymenoscyphus fraxineus* Baral et al) is causing widespread decline and mortality in the form of ash dieback disease (Kowalski 2006; Gross et al. 2014). Ash dieback is estimated to be costing many billions of euros in economic damage, with estimated from the UK alone reaching £15 billion (Hill et al. 2019). Eradication of these pests is difficult (Liebhold and Kean 2019), and bioeconomic modelling indicates that resources are best allocated to activities preventing these invasive species introductions rather than those trying to eradicated or control invasive species (Leung et al. 2002).

Forests provide vital ecosystem services (FAO 2018), but these are under threat from non-native pests (Boyd et al. 2013). Ireland is one of the least forested countries in the EU (FRA 2015), with forests covering 770,020ha or around 11% of the land area (Anon 2018). Northern Ireland has over 112,000 ha of forestry (DAERA 2018), equating to roughly 8% of the land area. Historic forest clearance across the island of Ireland (i.e. Ireland and Northern Ireland) led to almost complete deforestation, with estimates of just 1% remaining forest cover in the late 18th century (Cross 1998). The forest area in Ireland has increased in recent years, being composed primarily of the exotic species *Picea sitchensis* (Bong.) Carr. (51% of forest area), *Pinus controta* Douglas (10%), *Picea abies* (L.) H. Karst. (4%), and *Larix kaempferi* (Lamb.) Carr. (3&)(Anon 2018). In Northern Ireland, almost 62% of the forest area is composed of conifer or conifer mixtures (DAERA 2018). Outside of forests, there are also a large number of trees scattered across the island of Ireland, with estimates from Northern Ireland indicating there are more than 5 million trees in hedgerows (Spaans et al 2018). The low cover of forest across the island of Ireland probably had a significant impact on the numbers of know forest associated species, such as forest associated fungi (O'Hanlon and Harrington 2011) and insects (Morris 1993; Reilly 2008), compared to that in similar regions such as England or Scotland. The historically low level of forest cover (as low as 1% in the early 1900s; Rackham 1997 as cited in Cross 2006) probably also contributed to the development of a depauperate community of forest associated pests, with the forests of the island of Ireland generally known to have less diseases due to pests than similarly sized European regions (Grégoire and Evans 2004; McCracken 2013).

As well as the newness of the forest estate, the island status also confers a strong natural advantage in terms of forest health (DAFM, 2014); and at a European level Ireland's forests are recognised as being relatively healthy. However, in the 1970s due to the then structure and composition of Ireland's spruce plantations, de Brit and McAree (1977) flagged their potential susceptibility to introduced pests, and in recent years there has been a growing concern over the threat that non-native pests pose to tree and forest health on the island of Ireland (McCracken 2013; O'Hanlon 2015)(Figure 1a,b,c,d,e,f). Many of the recently introduced pests arrived with trade consignments, such as *Phytophthora ramorum* Werres et al. and the eucalyptus psyllid *Ctenarytaina eucalypti* Maskell on plants for planting (Purvis et al. 2002; O'Hanlon et al. 2016a). Plants for planting, and wood packaging material such as pallets and crates are known pathways for introducing non-native pests worldwide (Kenis et al. 2007; Brasier 2008; Humble 2010; Liebhold et al. 2012; Eyre et al. 2018), and thus are regulated under plant health legislation.

Plant disease, phytosanitary measures and the international year of plant health

The United Nations General Assembly declared 2020 as the International Year of Plant Health (IYPH; http://www.fao.org/plant-health-2020/home/en/). Governments and organisations across the world have seized on the opportunity to raise global awareness on how protecting plant health can help end hunger, reduce poverty, protect the environment, and boost economic development. Plant diseases are caused by biotic and abiotic factors, and in recent years the threat from plant diseases to global food security and environmental sustainability had come to prominence (Boyd et al. 2013; MacLeod et al. 2016). Protection of plant health worldwide is enshrined in the agreements of the International Plant Protection Convention (IPPC; www.ippc.int). This convention aims to protect the world's plant resources from the spread and introduction of pests, while also promoting safe trade. Within the EU the measures to calculate and reduce the risk to plant health are contained in the EU Plant Health Regulation (EU 2016/2031), which replaces the previous Plant Health Directive (2000/29/EC).

There are three types of regulated pests in the EU Plant Health Regulation: (i) priority pests, (ii) quarantine pests, and (iii) regulated non-quarantine pests (RNQP). There are 20 priority pests, and EU Member States (MS) must carry out annual surveys and monitoring to ensure that these highly threatening pests are not present in their jurisdiction. For each of the priority pests, MS have to put in place contingency plans and information/outreach activities in order to prevent these pests establishing in their jurisdiction. Quarantine pests are those whose presence would have an unacceptable economic, social or environmental impact within the EU. These pests are made up of union quarantine pests (n=173) and protected zone (PZ) pests (n=31). Member States are required to conduct one survey every five years for each union quarantine pest, if that pest has the potential to establish in their jurisdiction. Ireland and Northern Ireland enjoy PZ status for many harmful forest pests. A PZ is essentially an area in the EU where a pest of quarantine significance, established in other parts of the EU, is not present despite favourable conditions for it to establish. Annual surveys for PZ pests must be conducted to prove freedom from the pest, in order to maintain a PZ status. RNQP are those pests that are spread on plants for planting or planting material, and can cause unacceptable yield or quality losses on those plants.

The EU plant health regulation is administered and implemented by the National Plant Protection Organisations (NPPO), which in Ireland is the Department of Agriculture, Food and the Marine (DAFM). In the UK, plant health is a devolved matter, with the Department of Agriculture, Environment and Rural Affairs (DAERA) being responsible for plant health matters in Northern Ireland. DAERA work closely with the Department of the Environment, Food and Rural Affairs, who act as the NPPO for the UK. The island of Ireland is treated as a single epidemiological unit when it comes to matters of plant or animal health. Due to the harmonised approach to plant health on the island (DAFM 2019a), and the EU Plant Health Regulation, there are limited physical checks on plants or plant products moving between Ireland and Northern Ireland, or vice-versa. However, with the new EU Plant Health Regulation, conifer wood that is not bark-free needs to be accompanied by a plant passport which provides assurance that the commodity has been inspected by the NPPO of the exporting country and complies with the rules of the Plant Health Regulation. The UK plans to leave the EU in 2020; however, at present the specific plant health rules that the UK will implement are as of yet unclear and will be agreed during the transitional period (Spence 2020).

Developing a dataset of pest detections on the island of Ireland

The aim of this article is to provide a list of occurrences of pests of trees on the island of Ireland. Despite having a strong history of plant pathology expertise (Muskett 1976; Kavanagh and Brennan 1993), the island of Ireland has in recent years seen a reduction in the number of practicing forest pathologists, mycologists and entomologists (Copeland and Dowley 2010; Skilling and Batzer 1995; Battisti and Faccoli 2004; Dahlberg et al. 2009; O'Hanlon 2016; O'Hanlon et al. 2016b). Data from the Tree CD project found that just 2% of forest researchers' time in Ireland was devoted to forest protection compared to 13, 17 and 11% in Austria, Switzerland and the UK, respectively (Bystriakova and Schuck 1999). This is in line with similar recent declines in tree and forest health specialists in Britain (Jones and Baker 2007; Anon 2013c) and more widely in Europe (EPPO 2004). The information and results from years of work in the disciplines of forest pathology and entomology on the island of Ireland is scattered across many sources, both published and unpublished. Collating this type of historic data is important because it offers the opportunity to assess if trends are evident in new pest invasions, or if climate change may be having an effect on the distribution of pests (Jeger and Pautasso 2008).

This research provides a dataset containing a range of important details of pests detected on the island of Ireland is presented here (Supplementary table 1). Pests in this article and dataset are taken to include arthropods, fungi, oomycetes, and bacteria. Although viruses and nematodes are also important pests of woody plants, the published knowledge on the diseases of woody plants on the island of Ireland caused by these groups is particularly scant (NBDC 2010). For example, in a published dataset of nematode abundances from around the world, no data was available for nematodes of forest sites from the island of Ireland (van Hoogen et al. 2020). A number of literature sources were examined for reports of diseases of trees. Some reports of disease on other woody plants, though not generally considered trees, were also included. Many pests that cause disease on woody shrubs can also cause disease on trees, and therefore pose a risk to tree health. In this case a disease is any damage or ill health, which may or may not have been caused by a pest. This literature examined included published literature (e.g. *Irish Naturalists Journal*), grey literature (e.g.

the Annual Reports of the respective Departments of Agriculture in Ireland, and Northern Ireland; Table 1), and the private records of the authors and colleagues. A search of the literature was conducted in Google scholar using the search terms "pathogen OR pest AND forest OR tree AND Ireland". The results were reviewed, and relevant literature examined. The *Trees of Great Britain and Ireland* (Elwes and Henry 1906) were also searched for the terms "pest", "parasite", "pathogen", "insect", "fungus", and "disease".

Along with developing the dataset for the island of Ireland, other sources were also consulted to compare the detections of pests with those in Britain (i.e. England, Scotland and Wales) and Europe. These sources provided information on pest detections, risk rating, and native status for pathogens (Kloet and Hincks 1945; Moore 1959; Jones and Baker 2007; Freer-Smith and Weber 2015; FRDBI 2020; CABI 2020a; DAERA 2020) and arthropod pests (Browne 1968; BRC 2018; CABI 2020a) in Britain, and for pathogens (Santini et al. 2013) and arthropod pests (Day and Leather 1997) in Europe. Pests not found in either Britain or the island of Ireland, but with a risk rating of over 80 on the Northern Ireland health risk register (DAERA 2020) were also included. Information on a pests' behaviour and ecology in its native range is useful in designing control strategies for that pest in areas where it has potential to invade (Webber et al. 2012). However, assigning native or non-native status to pests, especially microbial pests is not straightforward (Regan et al. 2010; Jung et al. 2016), therefore this information should be taken as evidence of putative native status. Synonyms were resolved for fungi by means of the Index Fungorum (www.indexfungorum.org), and for arthropods using a number of websites (e.g. NBN atlas 2020). The taxonomic position of the pest was also listed from EPPO (2020a), along with the binomial authority for the species. In cases where the year of first detection was not specified, the date of the publication was taken as the date of the detection. There were many relevant pest records reported in Browne (1968), which unfortunately does not assign a year of detection. Therefore, the dataset reflects that many pests records were reported in 1968, though this does not mean these pests were first recorded in 1968. The pest detections in regular surveys and monitoring carried out in Ireland (by, or on behalf of the DAFM and its precursor Departments) and Northern Ireland (by, or on behalf of the DAERA and its precursor Departments) were split by year of publication, in order to provide a measure of a pests' frequency of occurrence. Where available, the host on which the pest was detected was also noted.

The records of pest detections on the island of Ireland were scored on their reliability, based on the guidelines given in ISPM 8 (FAO 2017). For reports published by the NPPO, or in peer reviewed scientific journals within the last 20 years, a rank of 1 (the most reliable source) was given. The European and Mediterranean Plant Protection Organisation (EPPO) Reporting Service (EPPO 2020b) was the primary source for NPPO reports of pests, although the official websites of the NPPO in Ireland also provided several pest reports. For reports that were either an official historical record (>20 years old), or published in a non-peer reviewed scientific journal or a technical journal, a rank of 2 was given. Rank 3 was attributed to reports in specialist amateur publications, or in unpublished scientific or technical documents. Rank 4 (the least reliable source) was given to reports in non-technical media (e.g. periodical, newspaper), or to personal communications or unpublished records. Ranking the reliability of records is important to allow readers attach a degree of uncertainty to any analysis that uses these records. The economic consequences of a pest presence in a country can be significant, therefore great care should be taken in interpreting these reports. Contact directly with the NPPO via their respective websites in Ireland (https://www.agriculture.gov.ie/farmingsectors/planthealthtrade/) and Northern Ireland (https://www.daera-ni.gov.uk/topics/plant-and-tree-health) is the most reliable way of finding information about the official status of a pest in that jurisdiction.

Sources of notable pests of trees on the island of Ireland

There is speculative evidence from pollen core and tree ring radiocarbon dating of a pest contributing to the decline of elm trees in Ireland and the UK around 5000 years ago (Parker et al. 2002; Mitchell 2006). Following this, and up to the early 1900's there were few records found of tree pests, and these were scattered in periodicals such as *Gardeners Chronicle* and its successor titles. Some of these reports were included in reviews of pests of plants and trees in Ireland and the UK (Johnson and Halbert 1902; Massee 1913; Adams and Pethybridge 1910; Brooks 1928; McKay 1952; Muskett 1976; Moore 1959; Peace 1962; Browne 1968; Muskett and Malone 1978, 1980a, 1980b, 1983, 1984, 1985; Phillips and Burdekin 1982; Mangan 2008), while other records appeared sporadically in the more nationally important journals *Irish Naturalists Journal* (previously known as *Irish Naturalist*) and *Irish Forestry*. The first published reports from the government departments responsible for forest health (the name of which changed several times; OCarroll and Joyce 2004) started in Ireland in 1933, and in Northern Ireland in 1952 (Table 1). These continued almost annually and are considered here up until 2015, although the level of detail on the pests reported varies widely across the years. The research reports from the horticulture, horticulture and forestry, plant sciences and crop husbandry, and soils divisions of An Foras Taluntais (now known as Teagasc) between 1962 and 2002 were also examined for information on pests of woody plants.

Monitoring for forest pests during the period 1938 and 1956 was commissioned by the Department of Agriculture Ireland and carried out by scientists from University College Dublin (Anon 1938; 1943). Between 1986 and 2006 a European forest health monitoring scheme known as the International Co-operative Programme (ICP) was established as part of an EU wide programme to monitor forest condition in response to concerns over increasing atmospheric pollution. These plots were established across Ireland, with results reported sporadically (Keane et al 1989; McCarthy 1993; Ward and Keane 1993; Anon 2006a, 2007a, 2008a). Recording focussed on disease symptoms rather than causal organisms, limiting the use of the data for the purposes of this pest list. There were no ICP plots were established in Northern Ireland (Brown et al. 2019). The National Forest Inventory of Ireland recorded the presence of forest damage in the assessment plots during its three previous cycles (Anon 2007, 2013, 2018). In the most recent inventory, 24% of the forests had obvious damage due to biotic causes, including over 6000ha of damage due to pests. The methodology for

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recording damage from pests was based on the presence of symptoms of the pests *Heterobasidion. annosum*, *Armillaria* spp., *Rhizina undulata* Fr., *H. fraxineus*, *P. ramorum*, *Phytophthora alni* Brasier & S.A. Kirk, *Dothistroma* sp., *Hylobius abietis* (L.), *Elatobium abietinum* (Walker), *Rhyacionia buoliana* (Denis & Schiffermüller).

Figure 1a - *Phytophthora lateralis* dieback in Lawson cypress (*Chamaecyparis lawsoniana*) in Co. Antrim, Northern Ireland. The trees with the sparse crowns and foliage in the centre of the figure are affected by *P. lateralis* (R. O'Hanlon)

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Figure 1b - Ash dieback disease on ash (*Fraxinus excelsior*) in Co. Fermanagh, Northern Ireland. The diamond shaped lesion emanating from the small side shoot in the centre of the figure is characteristic of ash dieback disease caused by *Hymenoscyphus fraxineus* (R. O'Hanlon)	

Figure 1c - Aerial view of roadside Sitka spruce (*Picea sitchensis*) damage caused by green spruce aphid (*Elatobium abietinum*) in Co. Antrim, Northern Ireland. The grey coniferous trees in the centre of the figure are diseased due to *E. abietinum* (DAERA)	
Figure 1d – *Heterobasidion annosum* on a Sitka spruce (*Picea sitchensis*) root (R. O'Hanlon)	

Figure 1e - Ash sawfly (*Tomostethus nigritus*) caterpillar feeding on an ash (*Fraxinus excelsior*) tree (A.K. Murchie)	
Figure 1f – *Ips typographus* galleries on Norway spruce (*Picea abies*) in Kent, England (A.K. Murchie)	

Figure 1, a, b, c, d, e, f. Symptoms of pests and pathogens of woody plants and trees recorded on the island of Ireland

There have been several initiatives nationally and internationally to increase plant health expertise and knowledge sharing previously. The Society of Irish Plant Pathologists (SIPP) was founded in 1968, and organised seminars on plant health almost every year since its inception. Reports of forest pathology activities can be found in several of SIPPs newsletters, including details of the involvement of SIPP members in the informal Forest Pathology group, which included experts from Ireland and the UK, which met regularly from 1960 to 1996 (SIPP 1970, 1975, 1982, 1987), even hosting a joint meeting with members of the British Mycological Society in 1969 (SIPP 1970). In an attempt to build a forest health resource for future research and diagnostics, a herbarium for forest disease and mycorrhizal fungi was set up in 1981 (Forest and Wildlife Service 1982). This herbarium was maintained and expanded in 1985 and 1987 (Anon 1986b, 1988). Other large forest pathology initiatives

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included the development of an All-island Plant Health and Research Strategy in 2005 (Anon 2006a), and the All Ireland Chalara Control Strategy in 2013 (Anon 2013a).

Table 1 Details of the annual plant health survey information published by the responsible government department in Ireland and Northern Ireland and included in this review. The data from these reports is included in the dataset (Supplementary table 1).

Region	Years	Reference
Ireland	1933-1975	Report of the Minister for Lands on Forestry
	1971-1985	Forest and Wildlife Service reports
	1986-1988	Forest Service reports
	1991-2011	DAFF annual report
	2012-2015	DAFM annual report
Northern Ireland	1952-1967	Record of agricultural research
	1963-1969	Annual progress report on research and technical work
	1963	Ministry of Agriculture NI
	1970-1987	Annual report NI
	1995-2017	AFBI records

The dataset of pest of trees on the island of Ireland

A total of 396 pests were recorded on trees on the island of Ireland. Also included in the dataset are 49 cases from the island of Ireland where the pest could not be identified, and are indicated in the dataset by "?" preceding the name. A further 57 pests are also included in the dataset, which have not been detected on the island of Ireland, but are judged to be of high risk to the health trees on the island of Ireland if they have been recorded in Britain, or have a risk rating of 80 or above on the Northern Ireland Plant Pest Risk Register. There is evidence that 45 of the pests recorded on the island of Ireland are potentially native, with a further 129 of the pests being native to at least some parts of Europe. The literature suggests that 12 pests are non-native to the island of Ireland, while 31 are non-native to Europe. A further 12 species have a cryptic biology and so their native status is not easy to conclude. No information could be found on the native status of the remaining 216 pests. A total of 294 of the pests recorded on the island of Ireland have a host associated with them. The hosts most frequently recorded (i.e. more than 20 pests associated with them) were *Larix*, *Populus*, *Quercus*, *Alnus*, *Betula*, *Picea*, *Pinus* and *Salix*. Of the 396 pests detected in Ireland, 378 have a reliability rating of 1 or 2, indicating a high degree of certainty in their detection.

A total of 33 of the pests listed in the dataset are regulated under the EU plant health regulation, of which 23 have been recorded on the island of Ireland, with 5 of these as interceptions at ports and 12 being RNQP. None of the priority pests have ever been recorded on the island of Ireland. Of the 123 pathogens listed as threatening to forests in Europe (Santini et al. 2013), 41 have been recorded in Ireland. A total of 63 of the 99 pests listed by Day and Leather (1997) as major forest pests in Europe have been recorded on the island of Ireland.

The 396 recorded pests included 11 bacteria, 20 oomycetes, 150 fungi and 215 arthropods. It is likely that all of these groups have been under-recorded, given the lack of experts in certain groups of pests including insects and bacteria (NBDC 2010; Regan et al. 2010), fungi (Dahlberg et al. 2009; O'Hanlon and Harrington 2011; O'Hanlon 2016) and oomycetes (O'Hanlon et al. 2016b). Between 1970 and 2004, Jones and Baker (2007) examined records from several sectors (including horticulture, agriculture and forestry) and recorded 234 pathogens in Britain, while only 42 were recorded during the same period on the island of Ireland. It is also likely that the number of microbial (bacteria, fungal and oomycete) pests are under-recorded because of inherent difficulties in detecting and identifying these pests (Brasier 2008; Morales et al. 2019), and their ability to infect plants asymptomatically (e.g. Migliorini et al. 2015). Recent studies by O'Hanlon et al. (2016a) and McEvoy et al. (2016) used molecular analysis to identify 13 new records of plant pathogenic microorganisms for Ireland. Similarly, analysis of *P. sitchensis* needle endophytes in four sites in Scotland identified 13 taxa of fungi (Stewart et al. 2018), of which none have been recorded from conifers on the island of Ireland. This lack of understanding of the fungal and bacterial communities of plants in Ireland is worrying as these are some of the most threatening pests to tree and plant health globally (Wingfield et al. 2001; Crous et al. 2016).

The Irish forest estate was relatively free from serious diseases cause by pests during the 20th century, as evidenced by the low number of publications dealing with plant health in the primary technical journal for Irish foresters, *Irish forestry* (Quirke 1946; Clear 1951; McKay and Clear 1953, 1957; de Brit 1967; McAree 1975, 1987; de Brit and McAree 1977; Keane 1986). Indeed, several other sources highlight the relatively low impact of disease in Irish forests during the 20th century (Anon 1920; Quirke 1946; McCarthy 1993). In recent years, pest reports have continued to increase at a relatively steady rate (Fig. 2). This is in line with records of new non-native pathogens (Jones and Baker 2007) and arthropod pests (Smith et al. 2007) in Britain. The large spike (71 new arthropod pests) in records in the year 1968 (Fig 2) in the dataset is due to the publication of a large number of reports in Browne (1968). As the Browne (1968) did not give the source of the records, the date of publication of the book (i.e. 1968) is used as the first report. During the five decades starting in the 1970s, the number of new pest reports was 26, 27, 16, 37, and 28 up to 2017.

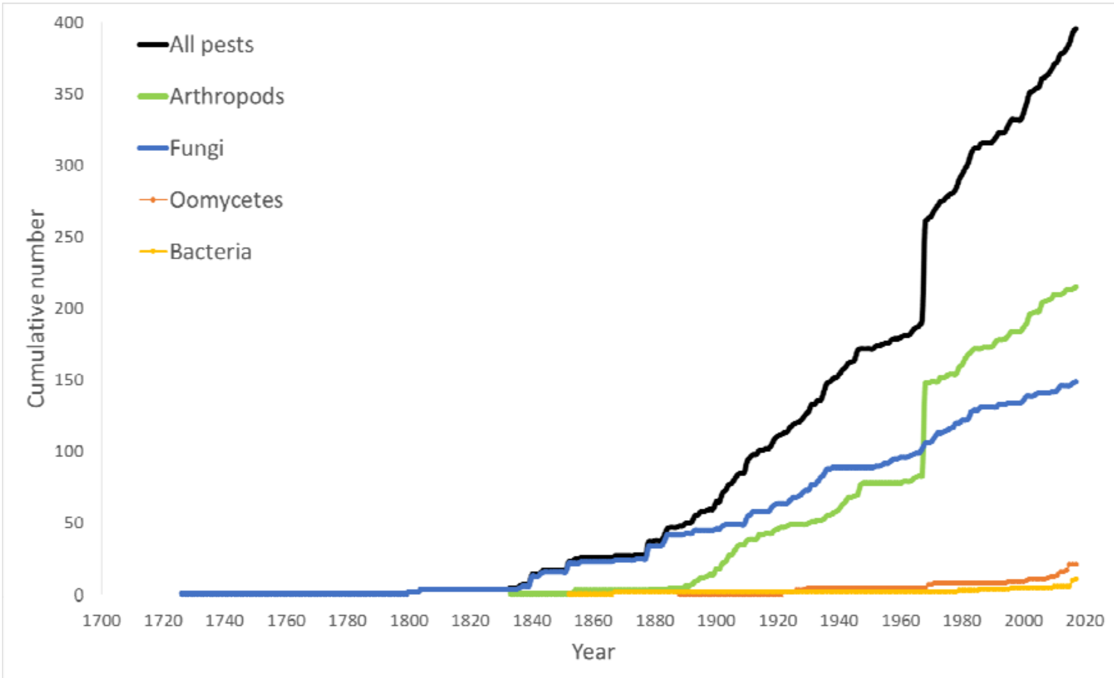

Figure 2 Species accumulation curve for the pests (including pathogens) reported from trees on the island of Ireland.

Important diseases caused by native pests

Native plants develop mechanisms to reduce the amount of disease from native pests through co-evolution. However, in certain circumstances native pests gain an advantage over native plants, allowing them to cause more disease than normal. Several examples of this are reviewed in Riggins and Londo (2009), including an increased amount of damage caused by the oak pinhole borer, *Platypus cylindrus* (Fabricius) in Britain following several years of favourable breeding conditions for the pest. Diseases caused by native pests on non-native hosts are probably more threatening, as there is probably a lack of co-evolution in the host (Wingfield et al. 2010). Liebhold (2012) identified non-native forest plantations as high risk and prone to catastrophic damage from both native and non-native pests. More than 60% of the forest estate in Ireland is composed of two non-native tree species (*P. sitchensis* and *P. contorta*), therefore pests pose a major threat to the Irish forest industry. Species diversification and the use of alternative silvicultural systems (e.g. uneven aged silviculture) have been identified as ways to buffer against large scale pest epidemics in forests (Ennos 2015; Jactel et al. 2017; Roberts et al. 2020).

The dataset contains reports of 77 native pests associated with native genera of trees and woody plants, and 51 native pests associated with non-native genera of trees and woody plants. Reports of large scale disease caused by native pests on native trees are generally rare.

Quirke (1946) noted the fungi *Armillaria mellea* (Vahl) P. Kumm. to be damaging to various native broadleaf trees, and *Neonectria ditissima* (Tul. & C. Tul.) Samuels & Rossman causing disease on native *Betula* and *Fraxinus*. Large native bracket forming fungi such as *Ganoderma*, *Inonotus* and *Porodaedalea* (previously *Phellinus*) are probably a factor in the death of many mature native trees, however they are generally known as secondary or destabilising pathogens and are not suited to causing large epidemics in native trees (Hansen and Goheen 2000). Disease caused by native pests on non-native trees are more frequently reported. Damage caused by the gall adelgid (*Adelges cooleyi* [Gillette]) in 1930s and 1940s led to Douglas fir (*Pseudotsuga menzeisii* [Mirbel] Franco) falling out of favour with many Irish foresters (Clear 1951). The pest *R. buoliana* has been an issue for Irish forestry for many years. Regular surveys were carried out, using pheromones traps in Northern Ireland in the early 1980's (Anon 1982a, 1983a).

Group dying of conifers (especially *P. sitchensis*) caused by *Rhizina undulata* (Schaeff.) Sacc. was first noted (under the synonym *Rhizina inflata*) in Ireland in 1952 (McKay and Clear 1953, 1955), after similar reports in Britain in 1936 (Murray 1953). The pathogen that causes the disease was noted to fruit prolifically on fire sites, and restrictions on burning fires in forest sites has led to the disease being controlled (Joyce and OCarroll 2002). Quirke (1946) listed several pests of importance to Irish forestry, including pests of broadleaves (*N. ditissima*, and *Prays fraxinella* Bjerkander) and conifers (*R. buoliana*, *E. abietinum*, *A. mellea*, and *H. annosum*). The fungus *H. annosum* causes annosus root disease in many trees, and is listed as the most significant pathogen for forestry in Ireland (Joyce and OCarroll 2002). Records of this fungus go back as far as 1836, while records of *A. mellea* go to back 1843 (Muskett and Malone 1980), indicating that both are probably native. Reviews by de Brit (1968), McAree (1975) and de Brit and McAree (1977) discussed several of these pathogens and their significance on the island of Ireland. These pests have also affected forestry practices on the island of Ireland, with the forest service in Northern Ireland stopping the use of chemical thinning in coniferous forests over concerns that this encouraged *H. annosum* (Anon 1992).

Ever since the establishment of plantation forestry in Europe, the large pine weevil (*Hylobius abietis* L.) has been a major pest (Munro, 1927). In newly clear-felled stands adult female weevils are attracted by the volatiles and oviposit just under the bark of the stumps. Weevil larvae subsequently develop in the protected environment under the bark for one to three years depending on temperature (Leather et al., 1999; Inward et al., 2012). Following emergence, adults feed on the bark of young trees and replanted sites can suffer up to 100% mortality of newly planted trees if no control measures are taken. Pine weevil was estimated to cost the UK economy £2 million *per annum* (Weslien 1998; Leather et al. 1999). Current control measures include the synthetic chemicals alpha cypermethrin or cypermethrin, which are administered in nursery pre-treatment either via electrodyne application or dipping of young trees prior to planting and/or through on-site post-planting spray. However, with concerns over potential environmental impacts, cypermethrin is being phased out across Europe (E.C., 2012). Under Forest Stewardship Council (FSC) guidelines, alpha cypermethrin and cypermethrin are considered "highly hazardous chemicals" applied only under derogation, so there is an obligation on FSC certified companies to find alternatives to chemical control. Furthermore, current pesticides have a repellent effect on the pine weevil and, while this protects young plants, it does little to impact on the local populations of the pest (Torr et al., 2005; Leather et al. 1999).

In Ireland there has been much work on the use of biological control agents to help mitigate the pine weevil problem. There have been many studies assessing the efficacy of entomopathogenic nematodes (EPN) in the control of pine weevil (Brixey et al., 2006; Dillon et al., 2006; Dillon et al., 2007; Dillon et al., 2008; Torr et al., 2007). Williams et al. (2013a) in a meta-analaysis of EPN efficacy found, for two EPN species, *Steinernema carpocapsae* (Weiser) and *Heterorhabditis downesi* Stock, Griffin & Burnell, that efficacy was greater on sites with a peaty substrate than sites with a mineral substrate. The species of the tree stump did not affect efficacy and there was no density-dependence. A more recent study by Kapranas et al. (2017) found site specific differences were more important than substrate type per se. More recently there has been a focus on entomopathogenic fungi (EPF) with *Beauveria bassiana* (Bals.-Criv.) Vuill., *Metarhzium anisopliae* (Metchnikoff) Sorokin and *Beauveria caledonica* Bissett & Widden being used in combination with EPNs (Williams et al, 2013b and McNamara et al., 2018).

Important diseases caused by non-native pests

The first reported outbreak in the dataset of a non-native pest of trees in Ireland was that of Dutch elm disease. This disease is caused by fungi from the genus *Ophiostoma* (namely *Ophiostoma ulmi* (Buisman) Melin & Nannf., and *Ophiostoma novo-ulmi* Brasier) which are vectored by the bark beetle of the genus *Scolytus*. The first outbreak in Ireland was caused by the less pathogenic *O. ulmi* in 1958 (Mangan and Walsh 1980), after a similar outbreak in Britain in 1927 (Moore 1959). Following further reports of widespread elm decline in Britain in the late 1960's, the more aggressive pathogen *Ophiostoma novo-ulmi* Brasier was detected in Britain in 1965 (Potter et al. 2011) and in Ireland in 1977 (Walsh and Mangan 1977). The pathogen was recorded as causing large amounts of mortality to *Ulmus* in Northern Ireland throughout the 1970s. The vectors of *O. ulmi* and *O. novo-ulmi* on the island of Ireland are the non-native elm bark beetles (*Scolytus multistriatus* Marsham and *Scolytus scolytus* [Fabricius]), which were first reported in Ireland in 1980 and 1943, respectively (O'Callaghan 1982; Quirke, 1943).

The link between pest findings in Britain and Ireland has been indicated previously (O'Hanlon 2015; O'Hanlon et al. 2016b). The pests *Blumeriella jaapii, Pulvinaria regalis, O. novo-ulmi, Seiridium cardinal, Kabatina juniper, Chondroplea populea, Cinara kochiana, Gymnosporangium asiaticum, Cinara cupressi, Cylindrocladium buxicola, Pseudomonas syringae* pv. *aesculi, Cameraria ohridella, P. ramorum, Phytophthora kernoviae, Phytophthora lateralis*, and *Hymenoscyphus fraxineus* are all non-native pests that established in Britain after 1960 and have since become established on the island of Ireland.

The average delay in these pests being recorded on the island of Ireland after their detection in Britain is 10 years. Pests that have established in Britain pose a higher risk to plant health on the island of Ireland due to the similar conditions (suitable environment, similar hosts), close geographic proximity, and the high amounts of movement of consignments and travellers between the two regions. In 2018 an estimated 30,000 tonnes of conifer roundwood from Scotland was moved into Northern Ireland for processing (Smith 2019).

The fungus that causes larch canker (*Lachnellula willkommii* [Hartig] Dennis) has been noted as native to parts of Europe (Yde Anderson 1979; Santini et al. 2013), and was first recorded in Ireland in 1840 (Muskett and Malone 1983), having been recorded in Britain since 1800 (Oppermann 1923 as cited in Yde Anderson 1979). *Lachnellula willkommii* is specific to *Larix* and *Pseudolarix* (Yde Anderson 1979; CABI 2020a; FRDBI 2020). During the 1970s and 80s investigations into *Pinus controta* shoot dieback identified a causal relationship with the fungal pathogens *Sydowia polyspora* (Bref. & Tavel) E. Müll. (syn. *Sclerophoma pithyophilla* V. Hohn.) and *Ramichloridium pini* de Hoog & Rhaman. Further testing and assessments during the 1980s confirmed *Ramichloridium pini* was the main cause of the shoot dieback of lodgepole pine (Anon 1986b). Whether *S. polyspora* and *R. pini* are native or not is unclear. Santini et al. (2013) noted that the cryptic lifestyle of *R. pini* made it difficult to say if it was native to Europe. *Sydowia polyspora* has been detected on healthy pine plants and seeds in the USA (Ridout and Newcombe 2018), possibly identifying the trade in seed as a pathway for this pathogen into Ireland, if the pathogen is non-native.

The next major outbreak of a non-native pest of trees and woody plants was that of the bacteria *Erwinia amylovora* (Burrill) Winslow et al. in 1986 (Hume and Conway 1993), which causes a disease of woody plants called fireblight. The pest had previously been detected in Northern Ireland on plants (*Stranvaesia* sp. and *Crataegus* sp.) imported from the Netherlands in 1985 (Anon 1985a). This outbreak led to a strict eradication programme being instigated, with a Fireblight prevention programme launched in 1986 (Anon 1990). In 1992, both Ireland and Northern Ireland were granted PZ status for *E. amylovora*, with Northern Ireland relinquishing this in 2016 in favour of restricted buffer zone status due to the increased spread of the pest in the wider environment (DAERA 2016). Most of Ireland, except Galway city, retains a PZ for *E. amylovora* to mid-2020. Efforts to eradicate the pest in the Galway city area between 2005 and 2013 were not successful. The pest is also regulated by the NPPO as an RNQP pest under the EU plant health regulation. Genotypic analysis of the *E. amylovora* isolates detected in Ireland showed no clear genetic structuring in relation to host or location (Brennan et al. 2002), possibly indicating that multiple genotypes had been introduced into Ireland. Indeed, *E. amylovora* infected plants have been intercepted at the Irish border on several occasions (EUROPHYT 2016).

McAree and MacKenzie (1993) listed eight forest pests (*Bupalus piniaria* [L.], *Cephalcia lariciphila* Wachtl, *Dendroctonus micans* (Kugelann), *Gilpinia hercyniae* (Htg.), *Ips cembrae* (Heer), *Ips sexdentatus* (Börner), *Pristiphora abietina* (Christ), and *G. abietina* (Lagerberg) Morelet) that were present in Britain, but absent from the island of Ireland. The pests *B. piniaria*, *P. abietina* and *G. abietina* have since been recorded on the island of

Ireland. *Gremmeniella abietina* is a threat to several coniferous trees, especially *Pinus* (Jeger et al. 2017a), and up until recently, both Ireland and Northern Ireland have PZ for *G. abietina*. This history of detections of *G. abietina* in Northern Ireland provides a useful insight into the process for official detections of plant health pests. Official detections of pests should follow international legislation, and should work according to international or regional guidance. For many regulated pests, official diagnostic standards exist, either published by international (i.e. International Standards for Phytosanitary Measures, ISPM; FAO 2020) or regional (EPPO) organisations. For *G. abietina*, the EPPO standard (EPPO 2009) relies on morphological detection of the pest, and although molecular identification methods did exist when the standard was agreed, these were not deemed suitable due to confusion over the taxonomy of the pest. In 2008 in Northern Ireland, samples from three sites indicated the present of the pest using a nested PCR method (Zeng et al. 2005), however no morphological structures of the fungus were observed. In 2009, DNA sequencing of extracts of fungal DNA from symptomatic *Pinus* samples indicated a match to the type culture of *G. abietina*. The records in 2008 and 2009 did not satisfy the EPPO standard and so were not officially recognised. Apothecia (i.e. fruiting structures) of the pathogen were first visually observed on *Pinus* in Northern Ireland in the 2012, and hence count as the first valid official record of the pest. Isolation of the fungus into pure culture, which is another acceptable identification method, was achieved in Northern Ireland in 2015. These findings of *G. abietina* in Northern Ireland have led to removal of the PZ in that jurisdiction, while the pest has not been confirmed in Ireland and the PZ status is maintained. Findings of the needle blight pathogen *Lecanosticta acicola* (now listed as an RNQP under the Plant Health Regulation 2016/2031) in Ireland (Mullett et al. 2018) in recent years warrant further surveys to delimit the distribution of this pest on the island of Ireland. The case of *G. abietina*, *L. acicola* and *P. kernoviae* represent detections of pathogens in one jurisdiction, but not in the other. Indeed, the case of the distribution of the lineages of *P. ramorum* on the island of Ireland is another example of a clear difference between Ireland and Northern Ireland. In Ireland, only the EU1 lineage has been detected, while in Northern Ireland both the EU1 and EU2 lineages have been detected, though the EU1 has never been detected in the wider environment (O'Hanlon et al. 2016b). Both Ireland and Northern Ireland have 14 PZ in place for pests of woody plants and trees in Ireland, with most common to both jurisdictions (Table 2). It is planned to apply for PZ for *Thaumetopoea pityocampa* (pine processionary moth) for Ireland in the near future, and surveys are currently being compiled to demonstrate its absence from the jurisdiction.

Table 2 Protected zone status of pests of woody plants and trees in Ireland and Northern Ireland as per Commission Implementing Regulation (EU) 2019/2072

Pest	Ireland PZ	Northern Ireland PZ

Erwinia amylovora	Yes	
Xanthomonas arboricola pv. pruni		Yes
Cryphonectria parasitica	Yes	Yes
Entoleuca mammata	Yes	Yes
Gremmeniella abietina	Yes	
Cephalcia lariciphila	Yes	Yes
Dendroctonus micans	Yes	Yes
Dryocosmus kuriphilus	Yes	Yes
Gilpinia hercyniae	Yes	Yes
Ips amitinus	Yes	Yes
Ips cembrae	Yes	Yes
Ips duplicatus	Yes	Yes
Ips sexdentatus	Yes	Yes
Ips typographus	Yes	Yes
Thaumetopoea pityocampa		Yes
Thaumetopoea processionea	Yes	Yes

Since the beginning of the 21st century, there have been a number of pest epidemics of trees and forestry. One particular group of plant pathogens, the genus *Phytophthora*, is a serious risk to plant health globally (Martin et al. 2012; Jung et al. 2018), and have been reasonably well studied in agricultural settings on the island of Ireland (O'Hanlon et al. 2016b). The outbreak of *P. ramorum* in 2002 initially started as a pest of the horticulture and ornamental plant industries (EPPO 2020b), which was followed by findings in wild invasive rhododendron in forests. The pathogen became a major threat to the forest estate in 2010 when found causing disease on Japanese larch (*Larix kaempferi*) (EPPO 2020b). Since the original detection on imported *Rhododendron* spp. and *Viburnum* spp. in Ireland in 2002 (EPPO 2020b), the pest has caused disease on 30 different hosts in both horticultural and forest environments (O'Hanlon et al. 2016a). The introduction of *P. ramorum* was followed by the detection of other non-native *Phytophthora* species, including *Phytophthora kernoviae* Brasier in 2008 (not detected in Northern Ireland) and *P. lateralis* Tucker & Milbrath in 2011 (O'Hanlon et al. 2016a). Detected on *Larix* and *Nothofagus* in Ireland, *Phytophthora*

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pseudosyringae has also been found in the last decade in the course of DAFM official surveys. This pathogen is also damaging to *Nothofagus* species in the UK (Scanu *et al*. 2012). The pathogen *Phytophthora cinnamomi* is one of the 10 most threatening oomycetes globally (Kamoun et al. 2014), but has only been causing minor issues to woody plants and trees on the island of Ireland, mainly in the plant nursery industry (Anon 1969a; Anon 1975a; Shafizadeh and Kavanagh 2005). *Phytophthora* disease of alder (caused by several different *Phytophthora* species) is causing many issues across Europe (Bjelke et al. 2016), and this was confirmed in Ireland in 2001 (Clancy and Hamilton 2001), while evidence of the disease was noted as far back as 1995 (McCracken 1996). In 2019, alder disease caused by *Phytophthora plurivora* was recorded along the river Lagan in Belfast, Northern Ireland (O'Hanlon et al. 2019). It is likely that there a many *Phytophthora* species present but yet to be recorded, as O'Hanlon et al. (2016b) suggested that based on the species richness in Britain, at least 11 more species of *Phytophthora* are potentially to be discovered on the island of Ireland.

More recently, the ash dieback fungal pathogen *Hymenoscyphus fraxineus* (T. Kowalski) Baral, Queloz & Hosoya has spread across Europe from Poland in the 1990's (Gross et al. 2014) finally being confirmed in Ireland and Northern Ireland in 2012 (EPPO 2020b; DAERA 2017). Notable attempts to eradicate the pest from the island of Ireland were made early in the invasion, with clear efforts at cooperation established via the All Ireland Chalara control strategy (Anon 2013a). The disease causes dieback of European ash (*Fraxinus excelsior*) and is now recorded in every county in Northern Ireland and Ireland (DAERA 2017; Ryan 2018). The economic value (over 13,000 ha of ash were grant aided by government in Ireland between 1992 and 2012; McCracken et al. 2017) and ecosystem services (there are more than 2.9 million ash trees in Northern Irish hedgerows; Spaans et al. 2019) provided by ash trees on the island of Ireland are now under serious threat from by *H. fraxineus*. As well as the large economic losses incurred because of ash dieback (Hill et al. 2019), the disease also threatens biodiversity associated with ash trees (e.g. over 1000 species thought to be associated with ash trees in the UK; Mitchell et al. 2014). Ash dieback disease causes high levels of mortality in European ash in forests (Gross et al. 2014), though recent evidence suggests that survival of solitary trees and those isolated from other ash trees may be better than previously expected (Grosdidier et al. 2020).

Another recent non-native pest (though only locally important) on trees has been the outbreak of horse chestnut leaf miner *Cameraria ohridella* Deschka & Dimić on horse chestnut (*Aesculus hippocastanum* L.) in Dublin in 2013 (Moths Ireland 2020). Symptoms of the pest have now been reported from several counties along the east of Ireland and Northern Ireland. The damage due to *C. ohridella*, combined with other present threats to horse chestnut, namely bacterial canker of horse chestnut (*Pseudomonas syringae aesculi*) and Guignardia leaf blotch (*Guignardia aesculi*), mean that the health of horse chestnut is under increasing threat. Horse chestnut is a commonly planted tree in urban environments, with 684 present within the Belfast city area, or which 171 are in poor health. The ash sawfly (*Tomostethus nigritus* [Fabricius]) was first detected in Northern Ireland in 2016 (Jess et al.

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2017), and led to defoliation of hundreds of trees in 2017 in south Belfast (Ian Rea unpublished data).

Pest interceptions at borders

The two most recognised pathways for introduction of exotic plant pests are (i) wood packaging material (Eyre et al. 2018; Meurisse et al. 2019 and (ii) plants for planting (Liebhold et al. 2012). Although phytosanitary treatments are in place for both of these pathways, there are a number of examples where pests have been transported on commodities despite controls. Haack (2006) reviewed 25 new beetle (Coleoptera) pest records in the USA and found that most were associated with wood packaging material. Similarly, Brockerhoff et al. (2006) examined interception data from the USA and New Zealand and found that 82% of the most frequently intercepted pests have become established as invasive plant pests worldwide. Inward (2019) highlighted potential shortcomings in debarking of roundwood as an effective treatment for regulation of plant pest ambrosia beetles, and concluded that appropriate heat treatment, fumigation or irradiation are more effective measures than debarking alone.

It is the remit of the NPPO of each country to survey for and apply controls for quarantine organisms. These pests are usually identified using a risk based approach, such as using the Northern Irish Plant Health Risk Register (DAERA 2020) in Northern Ireland. Commodities imported into the EU that are found to have harmful pests present are reported to the EU and the country of export via the Europhyt reporting system (EUROPHYT 2016). Europhyt is the database of consignments received by the EU MS that violate any of the EU's plant health requirements. Northern Ireland reports of pests are included in the overall UK reports. Based on the Europhyt data between the dates February 2006 and November 2016, inspections of imports into the UK and Ireland intercepted numerous pests including the following that are known tree pests: *Anoplophora chinensis* (Forster) (in 2006, 2007, 2008, 2010), *Anoplophora glabripennis* (Motschulsky) (2016), *H. fraxineus* (2012), *Ips typographus* (L.) (2009), *Oemona hirta* Fabricius (2010), *Opogona sacchari* (Bojer) (2010), *Monochamus alternatus* Hope (2013, 2015), *Phytophthora ramorum* (2006-2016), and *Thaumetopoea processionea* (L.) (2016)(EUROPHYT 2016). *Anoplophora chinensis* was also intercepted in Britain in 2005 (EPPO 2020b). There are potentially many more pests going undetected, as a recent analysis by Eyre et al. (2018) indicated that the surveillance systems in place in most EU countries are not sufficient to detect all of the potential pests on wood packaging material. Brockerhoff et al. (2003) also highlight the threat of wood and wood packaging material for transferring pests, listing 1468 records of interceptions of at least 98 plant pest beetles into New Zealand between 1952 and 2000. While it would be extremely difficult to inspect all wood packaging imported, in recent years an EU-wide monitoring programme has focussed on wood packaging associated with imports of high risk commodities such as stone from China (EU Commission decision 2013/92/EU). Under the new EU plant health regulation MS are required to implement a risk-based surveillance regime on wood packaging imports.

Ashe et al. (2002) published findings of beetles imported into Ireland on commodities from China, finding *M. alternatus* and *Cryptorhynchus rufescens* Roelofs. The former is very threatening due to its ability to vector the Pine wood nematode *Bursaphelenchus xylophilus* (Steiner & Buhrer) Nickle, currently causing a large epidemic in Portugal and Spain (Futai 2013). There is no evidence to indicate that *Monochamus* spp. are native to the island of Ireland, though Kloet and Hincks (1945) judged *Monochamus sutor* to be at least native to parts of Europe. Interestingly, one adult of *M. sutor* was detected in a furniture shop in Northern Ireland in 2017, presumably emerging as an adult having pupated for several years inside a wooden piece of imported furniture (A.K. Murchie unpublished data). Further detections of arthropods pests present on imported wood and wood packaging into Ireland included *Dendroctonus rufipennis* Kirby, *Dryocoetes affaber* (Mannerheim), *Ips acuminatus* (Gyllenhal) and *Ips typographus* as part of the 'Insects imported into Ireland' series of articles (O'Connor and Nash 1979, 1982, 1983). There is no evidence that any of the latter insect pests have become established in Ireland or Northern Ireland. O'Connor et al. (1991) identified insect pests (specifically Scolytids) that had been found in Britain but which were not yet known from Ireland. These included *Dendroctonus micans*, *Ips amitinus* (Eichhoff), *Ips cembrae* and *Ips sexdentatus*. These pests are the subject of longstanding annual PZ surveys and are not present on the island of Ireland. Furthermore, phytosanitary checks and monitoring are carried out on imports of unprocessed conifer wood (a high risk for transporting bark beetles) from Scotland. These imports are only allowed if the wood has come from an officially designated area that has been surveyed by the NPPO there and shown to be free from the pest *D. micans*. However, it is likely that, great spruce bark beetle, *D. micans*, is the most imminent insect pest threat to Northern Irish forestry since it is present in Dumfries and Galloway, approximately 70 km from Northern Ireland, and is expanding its range in Scotland (Jeger *et al*. 2017b; Forest Commission Scotland 2019). To counter this, a contingency plan is currently being drawn up by DAERA. In addition to plant health biosecurity measures, the contingency plan also considers the release of the predatory beetle *Rhizofagus grandis* Gyllenhal, which has been used successfully to control *D. micans* in Great Britain (Fielding and Evans 1997; Jeger *et al*. 2017b).

To prevent the establishment of high risk pests, early detection and eradication is vital. There have been two major eradication campaigns against insect pests in England in the last 10 years, the first was the Asian longhorn beetle (*Anoplophora glabripennis*) in 2012, and the second *Ips typographus* in 2018. The eradication operation for the *A. glabripennis* was recently concluded in England (Anon 2019a), successfully eradicating the outbreak in 2019 (EPPO 2020b). Detailed research at the site has indicated that the beetle (or beetles) probably arrived at the site around 2000, and from there colonised the surrounding trees. In total, the cost of monitoring and eradication actions for *A. glabripennis* was estimated at £2 million (Straw et al. 2016). This pest has often been intercepted in the UK associated with

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Acer plants for planting (EPPO 2020b) and wood packaging material from China (EPPO 2020b). This pest was first found in Europe in 2001, after which it has since been detected in 10 EU countries. Genetic testing of the European populations indicates that there were most likely several introductions of this pest into Europe, probably originally on wood and/or wood packaging material before moving within Europe by similar pathways (Javal et al. 2019). The related Citrus longhorn beetle *Anoplophora chinensis* has never been intercepted on the island of Ireland, but there have been several interceptions in England. This pest has also been discovered causing infestations in several countries in Europe, notably on 36 occasions in Italy (Hérard and Maspero 2019).

A population of the eight-toothed spruce bark beetle *Ips typographus*, a PZ quarantine pest, was discovered in Kent, England in November 2018. A demarcated area was set up and intensive monitoring and eradication actions are ongoing (Forestry Commission 2019). This being the first established population of *I. typographus* in the British Isles, it represents an increased threat from this damaging pest to spruce forests on the island of Ireland and has prompted increased risk-based surveys and monitoring to bolster existing surveys for the beetle. Considered as the most damaging insect pest of spruce, *I. typographus* has a widespread distribution throughout continental Europe and northern Asia. The summers of 2018 and 2019 were hot and dry, which stressed trees and led to *I. typographus* outbreaks across much of the spruce-growing parts of Europe (Jonsson 2020), with for example, the Czech Republic seeing an increase in salvaged timber from bark beetle outbreaks from 5.3 million m^3 in 2017 to 18 million in 2018 (Hlásny *et al*. 2019). Although not conclusive, it is thought that the incursion into Kent was from windborne migratory beetle flight and may have occurred several years earlier, with beetle populations only becoming detectable following a second generation during the hot summer of 2018 (Forest Research, pers. comm.). For the island of Ireland, importation of timber and bark remain the most likely pathway for introduction of *I. typographus*. In February 2004, 9,000 m^3 of wood bark from Estonia were detained at Belfast port following a routine examination for quarantine pests. Despite having the necessary documentation showing with evidence of fumigation by methyl bromide, living invertebrates (larval Diptera, Coleoptera, mites and rhabditid nematodes) were found, along with galleries typical of *I. typographus*. The consignment was reloaded onto the ship and fumigated at sea, at a cost exceeding €170,000. Subsequently, two live adult *I. typographus* were reared from incubated bark samples (S. Clawson, pers. comm.).

While wood and wood packaging material is known as the main vector for insect pests (Humble 2010), plants for planting is the commodity most often associated with the transfer of non-native plant pathogens (Jones and Baker 2007; Liebhold et al. 2012). Migliorini et al. (2015) tested plants from 2 large nurseries in Italy and found that 70% of the asymptomatic plants contained a plant pathogenic *Phytophthora* species. The records from the island of Ireland for harmful pathogens being intercepted during border inspections are less frequent than those of arthropod pests, probably because pathogens often have cryptic life stages which makes them difficult to detect. The pathogen *Gymnosporangium haraerum* was reported on Japanese bonsai juniper plants imported into Northern Ireland in 1974 (Anon 1974), while the pathogen *Discula destructiva* (Fr.) Munk ex H. Kern was reported on dogwood (*Cornus* sp.) in Northern Ireland in 1995 (McCracken 1996). Apart from the already noted cases of *E. amylovora*, *P. ramorum* and *H. fraxineus* on imported plants for planting to the island of Ireland, the low level of reports of pathogens on imported consignments is most likely due to pathogens often having cryptic lifecycles (see Migliorini et al. 2015), and the difficulty in surveying for plant pathogenic microorganisms in general (Morales et al. 2019). Furthermore, the use of pesticides on plants for planting can often mask symptoms of disease caused by pathogens, leading to the pathogen not being detected during border surveillance (Brasier 2008). New technologies, such as those based using high throughput sequencing offer the potential to identify the presence of even latent microbial pests in plants (Tedersoo et al. 2018), though the application of these techniques for phytosanitary and biosecurity purposes is not straightforward (e.g. McTaggart et al. 2016; Holdaway et al. 2017).

The global trade in tree seed has recently been identified as a plant health risk (Cleary et al. 2019; Franic et al. 2019). The latter two references sampled seed of three conifer and one broadleaf tree genera and detected potential pests from the genera *Megastigmus*, *Diaporthe*, *Fusarium*, *Giberella*, *Pestalotiopsis*, *Neonectria*, and *Diplodia*. The hymenopteran genus *Megastigmus* is a known plant health threat with potential to be spread by seed trade, with 11 of the 21 seed wasp species in the genus *Megastigmus* being introduced to Europe (Roques and Skrzypczyńska 2003). Seeds of trees are currently subject to the same rules as they were under the previous EU plant health legislation (2000/29/EC), but this will change at the end of 2020 when they will be regulated under the same rules as all other plant material. At present, seeds of the trees in the genus *Pinus* and *Pseudotsgua menziesii* can be imported into and moved within the EU only if they have official certification to show that they are free of the pitch canker pathogen of pine *Fusarium circinatum* Nirenberg & O'Donnell. Franic et al. (2019) concluded that seeds of trees represented a large threat to plant health in the EU.

Pests and climate change

The island of Ireland is expected to have fewer frost days, more rain in winter, increased chance of drought in summer and increased average annual temperatures by up to 2°C by the mid-21st century (Sweeney and Fealy, 2002). These changes are likely to affect the amounts of damage caused by pests in trees, through a combination of effects related to range shifts in pests and their natural enemies, adapted physiological or behavioural responses in pests and phenological changes in host (Zvereva and Kozlov 2006; Cornelissen 2011). Across Europe, Neumann et al. (2017) found that recent variations in climate have led to large scale tree mortality. Research has shown that recent outbreaks of bark beetles such as *Ips typographus* in continental Europe and defoliating insects could be linked to climate change (Heliovaara Peltonen 1999; Pureswaran et al. 2018). Similarly, outbreaks of the weevil *Hylastes ater*

Paykull (Leahy et al. 2007) and green spruce aphid *E. abietinum* (Westgarth-Smith et al. 2007) may increase under warming conditions. This could be due to milder winter temperatures which can result in reduced arthropod mortality and decreased diapause, thus directly affecting arthropod abundance (Ramsfield et al. 2016). Indirectly, more frequent weather extremes (e.g. drought) led to compromised tree host defences and increased frequency of arthropod damage. Secondary pests such as *E. abietinum* are likely to become primary pests causing mortality of trees when the tree is suffering from drought conditions as is predicted for future summer months in Ireland with climate change (Sweeney and Fealy, 2002).

The threat from pathogens of plants may also change under different climate scenarios. This includes bacterial (Wainhouse et al. 2016), oomycete (Jung et al. 2018) and fungal pathogens (La porta et al 2008; Pautasso et al. 2012). Jung et al. (2018) suggest that disease in oaks (*Quercus* spp.) in Europe due to *Phytophthora* will increase under future climate scenarios. Several pests may become more of a threat to the forest health in Ireland under future climate scenarios, including the temperature limited pathogens *Phytophthora kernoviae* and *Phytophthora cinnamomi*. The dataset should be useful in tracking the effects of climate change on damage caused by pests. For example, the fungus *Neonectria fuckeliana* (C. Booth) Castl. & Rossman is currently associated with widespread damage to Sitka spruce forests in Northern Ireland (O'Hanlon and Fleming 2018). Whether this is a new or re-emerging disease is not clear, as records of other similar *Nectria*/*Neonectria* taxa (the genus has been through several taxonomic changes) causing frequent damage on conifers in Wicklow in 1984 (Anon 1985b).

The tree species planted in forests on the island of Ireland in the coming years will need to be resilient against the pressures of future climate and pest outbreaks. Building resilience through greater species and structural diversity would seem to be a useful strategy (Ennos 2015). DAFM currently supports the grant aided forest planting of over thirty species of conifers and broadleaves (DAFM, 2016) yet from 2012 to 2018 Sitka spruce dominated the species mix being planted under DAFM grant aided afforestation schemes and its proportion actually increased significantly (DAFM, 2019b). This is likely linked with the removal of ash and Japanese larch from the menu of grant-aided species but increasing reliance on Sitka spruce should take into account the biotic threats to that species (Cameron 2015; Tuffen and Grogan 2019). Tree suitability modelling in Ireland has shown that some conifers from the pacific northwest of America have potential to replace larch in future planned Sitka spruce forest mixtures (Walsh et al. 2017).

Conclusions

The forests of Ireland have generally suffered less damage from pests than mainland European countries, but this trend is changing with increased damage occurring in recent years caused by invasive pests. Until quite recently pest management in Irish forestry focussed largely on control of *H. abietis* and *Heterobasdion annosum*. In the last decade however, the greatest risk to trees and forest on the island of Ireland comes from the introduction of non-native pests. Evidence globally indicates that eradication efforts against non-native tree pests globally are rarely successful unless the eradication is attempted soon after the pest has arrived (Pluess et al. 2012; Liebhold et al. 2016). The resilience of the forest to pest outbreaks is also important in protecting the forest estate. Good silviculture has always been about planting the right trees in the right places but today foresters are faced with increasingly complex planting decisions due to the considerable uncertainties surrounding climate change and threats from pests over the lifetime of a forest crop. This dataset of pests of trees on the island of Ireland sets an important baseline for pest frequency, and such datasets provide a valuable resource for future research and policy making in plant health (Shivas et al. 2006). As is the case with pest lists from other countries (Kenis 2005; Jones and Baker 2007; Smith et al. 2007; Martinez and Malausa, 2000 as cited in Smith et al. 2007), this list can be taken as a starting point for developing regular assessments of the threat to tree and forest health on the island of Ireland. These regular assessments need to be underpinned by scientific capacity in specialisms such as mycology, entomology, plant pathology and in broader areas including plant health diagnostics, taxonomy, and risk based surveillance. An educational pipeline for producing graduates with plant health training is needed in order to provide the plant health experts of the future (Anon 2019b). For effective protection of plant health on the island of Ireland, continued cross-border working in partnership between all stakeholders (government, industry, academia, NGOs and the public) is vital to safeguarding Ireland's trees.

Acknowledgements

ROH and AKM was funded by the Department of Agriculture, Environment, and Rural Affairs, Northern Ireland. The authors are grateful to the following for sharing details of unpublished records: AnneMarie Hamilton, Seamus O'Brien, Alistair Pfeifer, and Brian McGuinness.

References

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 May 2020 doi:10.20944/preprints202005.0168.v1

Adams, I.P., Fox, A., Boonham, N., Massart, S. and De Jonghe, K., 2018. The impact of high throughput sequencing on plant health diagnostics. European Journal of Plant Pathology, 152, 909-919.

Adams, J. and Pethybridge, G.H. (1910) A census catalouge of Irish fungi. Proceedings of the Royal Irish academy. 28, 120-166

Alcock, N. L. and Maxwell, I. 1925. Successional diseases on willow. Transactions of the Royal Scottish Arboricultural Society 39: 34–37.

Alexander, K.N., 2007. Goat Moth *Cossus cossus* L.(Lepidoptera: Cossidae) in Co Galway. The Irish Naturalists' Journal, 28, pp.420-420.

Anderson Stewart, C.R., Doilom, M. and Taylor, J.E., 2019. Analysis of fungal endophytes in Scottish Sitka spruce plantations shows extensive infections, novel host partners and gives insights into origins. *Forest Pathology*, *49*(1), p.e12471.

Anon (1884) *Transactions of Scottish Arboriculture*. 253. as cited in Elwes and Henry 1909; Trees of Great Britain and Ireland. Vol 4. Edinburgh, Self published.

Anon (1903) A Conifer disease. Journal of the Board of Agriculture Ireland.

Anon (1920) Survey of forest insect conditions in the British Isles. Forectry Commission. Online: https://www.forestresearch.gov.uk/documents/6464/FCBU002.pdf

Anon (1938) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1943) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1950) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1951) FAO Report on forestry mission to Ireland. The stationary office, Dublin.

Anon (1952) Record of Agricultural research. Belfast, Ministry of Agriculture.

Anon (1953) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1956) Record of Agricultural research. Belfast, Ministry of Agriculture.

Anon (1957a) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1957b) Record of Agricultural research. Belfast, Ministry of Agriculture.

Anon (1958a) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1958b) Record of Agricultural research. Belfast, Ministry of Agriculture.

Anon (1959a) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1959b) Record of Agricultural research. Belfast, Ministry of Agriculture.

Anon (1960a) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1960b) Record of Agricultural research. Belfast, Ministry of Agriculture.

Anon (1961a) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1961b) Record of Agricultural research. Belfast, Ministry of Agriculture.

Anon (1962a) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1962b) Record of Agricultural research. Belfast, Ministry of Agriculture.

Anon (1963) Annual report on research, development and technical work of the Department of Agriculture for Northern Ireland. Belfast, Department of Agriculture.

Anon (1963a) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1963b) Northern Ireland agriculture: General report of the Ministry of Agriculture. Belfast, Ministry of Agriculture.

Anon (1964a) Annual report on research, development and technical work of the Department of Agriculture for Northern Ireland. Belfast, Department of Agriculture.

Anon (1964b) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1965) Annual report on research, development and technical work of the Department of Agriculture for Northern Ireland. Belfast, Department of Agriculture.

Anon (1966a) Annual report on research, development and technical work of the Department of Agriculture for Northern Ireland. Belfast, Department of Agriculture.

Anon (1966b) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1967a) Annual report on research, development and technical work of the Department of Agriculture for Northern Ireland. Belfast, Department of Agriculture.

Anon (1967b) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1967c) Record of Agricultural research. Belfast, Ministry of Agriculture.

Anon (1968) Annual report on research, development and technical work of the Department of Agriculture for Northern Ireland. Belfast, Department of Agriculture.

Anon (1969a) Annual report on research, development and technical work of the Department of Agriculture for Northern Ireland. Belfast, Department of Agriculture.

Anon (1969b) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1970a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1970b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1970c) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1971a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1971b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1971c) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1971d) Report of the Minister for lands on the forest and wildlife service. Dublin: The Stationery Office.

Anon (1972a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1972b) Forest and Wildlife Service. Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1972c) Report of the Minister for lands on the forest and wildlife service. Dublin: The Stationery Office.

Anon (1973a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1973b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1974) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1975a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1975b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1975c) Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1975d) Report of the Minister for lands on the forest and wildlife service. Dublin: The Stationery Office.

Anon (1976a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1976b) Annual report, Forest Service DARD. Belfast, Forest Service.

Anon (1976c) Report of the Minister for Lands in Forestry. Dublin: The Stationery Office.

Anon (1976d) Report of the Minister for lands on the forest and wildlife service. Dublin: The Stationery Office.

Anon (1976e) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1977a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1977b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1978a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1978b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1979a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1979b) Annual report, Forest Service DARD. Belfast, Forest Service.

Anon (1979c) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

 doi:10.20944/preprints202005.0168.v1

Anon (1980a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1980b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1981a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1981b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1982a) Northern Ireland Forest Service Annual report. Belfast, Department of Agriculture Northern Ireland.

Anon (1982b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1982c) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1983a) Annual report, Forest Service DARD. Belfast, Forest Service.

Anon (1983b) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1983c) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1983d) Northern Ireland Forest Service Annual report. Belfast, Department of Agriculture Northern Ireland.

Anon (1984a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1984b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1985a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1985b) Forest and wildlife service research report. Dublin: Forest and Wildlife Service.

Anon (1986a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1986b) Forest Service Report. Dublin: Stationary office.

Anon (1987a) Annual report on research and development - Department of Agriculture for Northern Ireland.

Anon (1987b) Forest Service Report. Dublin: Stationary office.

Anon (1987c) Report of the Minister for Energy on the forest and wildlife service 1986. Dublin: Stationary Office. Anon (1990) Forest service report for 1988. Dublin: Stationary Office.

Anon (1988) Forest Service Report. Dublin: Stationary office.

Anon (1990) Annual report of the minister of Agriculture and Food. Dublin, Stationary office.

Anon (1992) Northern Ireland Forest Service annual report. Belfast, Department of Agriculture Northern Ireland.

Anon (1993) Annual report of the Minister for Agriculture and Food. Dublin: Stationary office.

Anon (1994) Annual report of the Minister for Agriculture and Food. Dublin: Stationary office.

Anon (1995) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (1996a) Annual report of the Minister for Agriculture and Food. Dublin: Stationary office.

Anon (1996b) Coillte Annual report. Dublin: Coillte.

Anon (1996c) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (1997a) Coillte annual report. Dublin, Coillte.

Anon (1997b) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (1998a) Annual report of the Minister for Agriculture and Food. Dublin: Stationary office.

Anon (1998b) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (1999a) Annual report of the Minister for Agriculture and Food. Dublin: Stationary office.

 doi:10.20944/preprints202005.0168.v1

Anon (1999b) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (2000) EU-forest health survey for Ireland. Department of Agriculture and Food, Ireland, Unpublished report.

Anon (2000a) Annual report of the Minister for Agriculture and Food. Dublin: Stationary office.

Anon (2000b) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (2001) EU-forest health survey for Ireland. Unpublished report, Department of Agriculture and Food, Ireland.

Anon (2001) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (2002) EU-forest health survey for Ireland. Unpublished report, Department of Agriculture and Food, Ireland.

Anon (2002) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (2003) EU-forest health survey for Ireland. Unpublished report, Department of Agriculture and Food, Ireland.

Anon (2003) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (2004a) Annual report of the Minister for Agriculture and Food. Dublin: Stationary office.

Anon (2004b) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (2005a) Annual report of the Minister for Agriculture and Food. Online: https://www.agriculture.gov.ie/publications/2005

Anon (2005b) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (2006a) Annual report of the Minister for Agriculture and Food. Online: https://www.agriculture.gov.ie/publications/2006

Anon (2006b) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (2007a) Annual report of the Minister for Agriculture and Food. Online: https://www.agriculture.gov.ie/publications/2007

Anon (2007b) Results of pest and pathogen surveys and monitoring. DARD science service unpublished records.

Anon (2008a) Annual report of the minister of agriculture, fisheries and food. Online: https://www.agriculture.gov.ie/publications/2008

Anon (2008b) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2009a) Annual report of the minister of agriculture, fisheries and food. Online: https://www.agriculture.gov.ie/publications/2008

Anon (2009b) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2010a) Annual report of the minister of agriculture, fisheries and food. Online: https://www.agriculture.gov.ie/publications/2008

Anon (2010b) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2011a) Annual report of the minister of agriculture, fisheries and food. Online: https://www.agriculture.gov.ie/publications/2008

Anon (2011b) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2012a) Annual report of the minister of agriculture, food and the marine. Online: https://www.agriculture.gov.ie/publications/2012

Anon (2012b) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2013a) All-Ireland Chalara Control Strategy. https://www.daera-ni.gov.uk/sites/default/files/publications/dard/ireland-control-strategy_0.ppt

Anon (2013b) Annual report of the minister of agriculture, food and the marine. Online: https://www.agriculture.gov.ie/publications/2013

Anon (2013c) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2013d) Tree Health and Plant Biosecurity Expert Taskforce. Online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/200393/pb13878-tree-health-taskforce-final-report.pdf

Anon (2014a) Annual report of the minister of agriculture, food and the marine. Online: https://www.agriculture.gov.ie/publications/2014

Anon (2014b) Protecting Plant Health A Plant Biosecurity Strategy for Great Britain. Online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/307355/pb14168-plant-health-strategy.pdf

Anon (2014c) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2015a) Annual report of the minister of agriculture, food and the marine. Online: https://www.agriculture.gov.ie/publications/2015

Anon (2015b) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2016) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2017) Results of pest and pathogen surveys and monitoring. AFBI unpublished records.

Anon (2019a) Asian Longhorn Beetle eradicated in the UK. Online: https://www.gov.uk/government/news/asian-longhorn-beetle-eradicated-in-the-uk

Anon (2019b) Growing the future. Online: https://www.rsb.org.uk/images/UKPSF_Growing_the_future.pdf

Anon (2019c) Larger eight-toothed European spruce bark beetle (Ips typographus). Online: https://www.gov.uk/guidance/eight-toothed-european-spruce-bark-beetle-ips-typographus

Anon (2020a) Biological records centre. Online: www.brc.ac.uk

Anon (2020b) The Butterflies and Moths of Northern Ireland. Online: http://www.habitas.org.uk/moths/frameset.html ;

Anon 2007 National Forestry Inventory of Ireland. Online: https://www.agriculture.gov.ie/nfi/nfifirstcycle2006/nationalforestinventoryresultsdata2006/

Anon 2013 National Forestry Inventory of Ireland. Online: https://www.agriculture.gov.ie/nfi/nfisecondcycle2012/nationalforestinventoryresultsdata2012/

Anon 2018 National Forestry Inventory of Ireland. Online: https://www.agriculture.gov.ie/nfi/nfithirdcycle2017/nationalforestinventoryresultsdata2017/

Ashe, P., Cahalane, G. and O'Connor, J.P., (2002) Chinese beetles (Coleoptera) imported into Ireland. The Irish Naturalists' Journal, 27, 140-142.

Aukema, J.E., McCullough, D.G., Von Holle, B., Liebhold, A.M., Britton, K. and Frankel, S.J., 2010. Historical accumulation of nonindigenous forest pests in the continental United States. BioScience, 60, 886-897.

Battisti, A. and Faccoli, M. (2004) The Directory of European Experts. In Lieutier, F., Day, K.R., Battisti, A., Gregoire, J.C. and Evans, H.F. eds., 2004. Bark and wood boring insects in living trees in Europe: a synthesis (p. 569). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Baynes, E. S. A. (1964) A revised catalogue of Irish Lepidoptera. Classey, MiddlesexBeirne, B., 1938. New Irish Microlepidoptera. The Irish Naturalists' Journal, pp.12-15.;

Bebber, D.P., 2015. Range-expanding pests and pathogens in a warming world. Annual review of phytopathology, 53, 335-356.

Bevan, D. (1987) Forest insects. A guide to insects feeding on trees in Britain. Forestry Commission, Handbook No. 1. HMSO, London, UK.

Billany, D.J. and Brown, R.M., 1977. The geographical distribution of Gilpinia hercyniae Hymenoptera: Diprionidae in the United Kingdom. *Forestry* 50(2), pp.155-160.

Bjelke, U., Boberg, J., Oliva, J., Tattersdill, K. and McKie, B.G., 2016. Dieback of riparian alder caused by the *Phytophthora alni* complex: projected consequences for stream ecosystems. *Freshwater biology*, *61*(5), pp.565-579.

Blackith, R. and Blackith, R., 1986. *Pygostolus sticticus* Fab.(Hymenoptera: Braconidae) parasitic on *Otiorhynchus singularis* (L.)(Coleoptera: Curculionidae) in an Irish pine forest. *The Irish Naturalists' Journal*, 22, 69-71.

Bond, K.G.M. and O'Connor, J.P. (2012) Additions, deletions and corrections to an Annotated Checklist of the Irish Butterflies and Moths (Lepidoptera) with a concise checklist of Irish species and *Elachista biatomella* (Stainton, 1848) new to Ireland. *Bulletin of the Irish Biogeographical Society* 36

Bond, K.G.M., Nash R. and O'Connor J.P. (2006) *An annotated checklist of the Irish butterflies and moths (Lepidoptera)*. Dublin. Irish Biogeographical Society.

Boyd, I.L., Freer-Smith, P.H., Gilligan, C.A. and Godfray, H.C.J., 2013. The consequence of tree pests and diseases for ecosystem services. *Science*, *342*, p.1235773.

Brasier, C.M., 2008. The biosecurity threat to the UK and global environment from international trade in plants. *Plant Pathology*, 57, 792-808.

 doi:10.20944/preprints202005.0168.v1

Brasier, C.M., Beales, P.A., Denman, S. And Rose, J (2005). *Phytophthora kernoviae* sp. Nov., an invasive pathogen causing bleeding stem lesions on forest trees and foliar necrosis of ornamentals in the UK. *Mycological Research*, 109, 853-859.

Brennan J, Cummins D, Kearney S, Cahalane G, Nolan S & Choiseul J (2010) Phytophthora ramorum and Phytophthora kernoviae in Ireland: The current situation. Phytopathology 100, S17.

Brennan, J.M., Doohan, F.M., Egan, D., Scanlan, H. and Hayes, D., 2002. Characterization and differentiation of Irish *Erwinia amylovora* isolates. *Journal of Phytopathology*, *150*(8□9), pp.414-422.

Brixey, J.M., Moore, R. and Milner, A.D. 2006. Effect of entomopathogenic nematode (*Steinernema carpocapsae* Weiser) application technique on the efficacy and distribution of infection of the large pine weevil (*Hylobius abietis* L.) in stumps of Sitka spruce (*Picea sitchensis* Carr.) created at different times. *Forest Ecology and Management* 226, 161-172.

Brixey, J.M., Moore, R. and Milner, A.D., 2006. Effect of entomopathogenic nematode (*Steinernema carpocapsae* Weiser) application technique on the efficacy and distribution of infection of the large pine weevil (*Hylobius abietis* L.) in stumps of Sitka spruce (*Picea sitchensis* Carr.) created at different times. *Forest Ecology and Management*, 226, 161-172.

Brockerhoff, E., Knízek, M., Bain, J. (2003) Checklist of indigenous and adventive bark and ambrosia beetles (Curculionidae: Scolytinae and Platypodinae) of New Zealand and interceptions of exotic species (1952-2000). *New Zealand Entomologist* 26, 29-44

Brockerhoff, E.G., Bain, J., Kimberley, M. and Knížek, M., 2006. Interception frequency of exotic bark and ambrosia beetles (Coleoptera: Scolytinae) and relationship with establishment in New Zealand and worldwide. *Canadian Journal of Forest Research*, 36, 289-298.

Brockerhoff, E.G., Knížek, M. and Bain, J., 2003. Checklist of indigenous and adventive bark and ambrosia beetles (Curculionidae: Scolytinae and Platypodinae) of New Zealand and interceptions of exotic species (1952-2000). *New Zealand Entomologist*, 26, 29-44.

Brooks, FT (1928) Plant Diseases. Oxford University Press, Oxford.

Brown, N., Broadmeadow, S., Brown, P., Crow, P., Ditchburn, B., O'Hanlon, R., Jeger, M., Mitchell, R., Perez-Sierra, A. (2019) Monitoring Oak Health. In Quine, C., Atkinson, N., Denman, S., Desprez-Loustau, M., Jackson, R., Kirby, K. (eds) Action Oak Knowledge Review. Online: http://www.actionoak.org/downloads/1-knowledge-review-12-06-2019/file

Browne, F. G. (1968) Pests and diseases of forest plantation trees: an annotated list of the principal species occurring in the British Commonwealth. Oxford, Clarendon Press.

Bullock, E., 1914. Coleoptera from the south west of Ireland. The Irish Naturalist, 23(5), pp.105-112.

 doi:10.20944/preprints202005.0168.v1

Bullock, E., 1930. Some new records of Coleoptera from Ireland. Entomologist's mon. Mag, 66: 140-141.

Burdon, E. R. (1908) The spruce-gall and larch-blight diseases caused by Chermes and suggestions for their prevention. *Journal of Economic Biology* 2. 1-13, 63-67..

Bystriakova, N. and Schuck, A., 1999. *Forest research capacities in 18 European countries*. Office for Official Publications of the European Community.

CABI (2020a) Distribution Maps of Plant Diseases. Online: https://www.cabi.org/dmpdCMI

CABI (2020b) PLantwise. Online: https://www.cabi.org/projects/plantwise/

Cairns, H. and Muskett, A.E., 1933. *Phytophthora megasperma* causing pink rot of the potato. Nature, 131, 277-277.

Cameron, A.D., 2015. Building resilience into Sitka spruce (*Picea sitchensis* (Bong.) Carr.) forests in Scotland in response to the threat of climate change. Forests, 6, 398-415.
Carpenter, G.H. (1902) Injurious insects observed in Ireland during the year 1901. Economic Proceedings of the Royal Dublin Society, 1, 132-160.

Carpenter, G.H. (1902) The animals of Ireland. In Coyne, W.P. (ed.) Ireland; industrial and agricultural. Dublin, Browne and Nolan.

Carpenter, G.H. (1903) Injurious insects and other animals observed in Ireland during the year 1902. Economic Proceedings of the Royal Dublin Society 1, 195-222.

Carpenter, G.H. (1904) Injurious insects and other animals observed in Ireland during the year 1903. Economic Proceedings of the Royal Dublin Society 1, 249-266.

Carpenter, G.H. (1905) Injurious insects and other animals observed in Ireland during the year 1904. Economic Proceedings of the Royal Dublin Society 1, 281-305.

Carpenter, G.H. (1906) Injurious insects and other animals observed in Ireland during the year 1905. Economic Proceedings of the Royal Dublin Society 1, 321-344.

Carpenter, G.H. (1907) Injurious insects and other animals observed in Ireland during the year 1906. Economic Proceedings of the Royal Dublin Society 1, 421-452.

Carpenter, G.H. (1908) Injurious insects and other animals observed in Ireland during the year 1907. Economic Proceedings of the Royal Dublin Society 1, 559-588.

Carpenter, G.H. (1909) Injurious insects and other animals observed in Ireland during the year 1908. Economic Proceedings of the Royal Dublin Society 1, 589-611.

Carter, C. and Winter, T., 1998. *Christmas tree pests*. Dublin, Stationery Office.

Carter, C.I., Wood-Baker, C.S. and Polaszek, A. 1987 Species, host plants and distribution of aphids occurring in Ireland. Irish Naturalists' Journal 22, 266–84.

 doi:10.20944/preprints202005.0168.v1

Carter, D.J. (1984) Pest Lepidoptera of Europe, with special reference to the British Isles. Series Entomologica, Volume 31.

Clancy, K.J. (1986) Plant disease. Research report UCD.

Clancy, K.J. and Hamilton, A. (2001) *Phytophthora* of Alder. *SIPP Newsletter* 28: 25-26.

Clawson, S. and Anderson, R., 2006. The banded pine weevils *Pissodes pini* (Linnaeus, 1758) and *P. castaneus* (DeGeer, 1775) (Coleoptera: Curculionidae) established in Ireland. *Entomologists Gazette*, 57, 269.

Clear, T., 1951. Douglas Fire in Co. Wicklow. *Irish Forestry*. 8-18.

Cleary, M., Oskay, F., Doğmuş, H.T., Lehtijärvi, A., Woodward, S. and Vettraino, A.M., 2019. Cryptic Risks to Forest Biosecurity Associated with the Global Movement of Commercial Seed. F*orests*, *10*, 459.

Copeland, R. and Dowley, L (2010) SIPP Newsletter No. 31.

Cornelissen, T., 2011. Climate change and its effects on terrestrial insects and herbivory patterns. Neotropical Entomology, 40(2), pp.155-163.Cotton, A.D., 1917. The occurrence of oak mildew on beech in Britain. Transactions of the British Mycological Society, 6, 198-200.

Cornelissen, T., 2011. Climate change and its effects on terrestrial insects and herbivory patterns. *Neotropical Entomology*, 40, 155-163.

Cross, J.R., 1998. An outline and map of the potential natural vegetation of Ireland. *Applied Vegetation Science*, 1, 241-252.

Cross, J.R., 2006, The potential natural vegetation of Ireland. Biology and Environment: Proceedings of the Royal Irish Academy 106, 65-116.

Crous, P.W., Groenewald, J.Z., Slippers, B., Wingfield, M.J. 2016. Global food and fibre security threatened by current inefficiencies in fungal identification. Philospohical Transactions of the Royal Society B 371: 20160024. http://dx.doi.org/10.1098/rstb.2016.0024

DAERA (2016) A proposal to remove Protected Zone Status in Northern Ireland for Fireblight (*Erwinia amylovora*) and implement buffer zone arrangements https://www.daera-ni.gov.uk/consultations/proposal-remove-protected-zone-status-northern-ireland-fireblight-erwinia-amylovora-and-implement accessed 27/10/18

DAERA (2017) Ash dieback/Chalara dieback of ash. Online: https://www.daera-ni.gov.uk/articles/chalara-dieback-ash

DAERA (2020) Northern Irish Plant Health Risk Register. Online: https://www.daera-ni.gov.uk/topics/plant-and-tree-health/northern-ireland-plant-health-risk-register

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 May 2020 doi:10.20944/preprints202005.0168.v1

DAERA 2018 Woodland register. https://www.daera-ni.gov.uk/sites/default/files/publications/daera/Woodland%20register%20categorised%20by%20Forestry%20Planning%20Area.xlsx

DAFM 2014, Forests, products and people Ireland's forest policy – a renewed vision. Department of Agriculture, Food and the Marine, Agriculture House, Kildare Street, Dublin 2.

DAFM, 2016 Circular 5/2016 Accepted tree species and provenances. Online: https://www.agriculture.gov.ie/media/migration/forestry/grantandpremiumschemes/schemecirculars/2016/Cir52016040416.pdf

DAFM, 2019a Plant Health and Biosecurity Strategy 2020-2025. Online: https://www.agriculture.gov.ie/media/migration/farmingsectors/planthealthandtrade/dontriskit/planthealthbio-securitystrategy/DAFMPlantHealthandBiosecurityStrategy070220.pdf

DAFM, 2019b Forest Statistics Ireland 2019. Department of Agriculture, Food & the Marine, Johnstown Castle Estate Co. Wexford.

Dahlberg, A., Genney, D.R. and Heilmann-Clausen, J., 2010. Developing a comprehensive strategy for fungal conservation in Europe: current status and future needs. *Fungal Ecology*, *3*(2), pp.50-64.

Day, K.R. and Leather, S.R., 1997. Threats to forestry by insect pests in Europe. *Forests and insects. Chapman and Hall, UK*, pp.177-205.

Day, K.R. and Watt, A.D., 1989. Population studies of the beech leaf mining weevil (*Rhynchaenus fagi*) in Ireland and Scotland. Ecological Entomology, 14(1), pp.23-30.;

de Brit, G. (1967) Forest protection. In Anon (ed) Forest Research Review 1957-1964 Dublin: Stationary Office

de Brit, G. (1972) Forest protection. In Anon (ed) Forest Research Review 1964-1970. Dublin: Stationary Office

de Brit, G., and MCAree, D. (1977) Pests and diseases of Sitka spruce. Irish Forestry. 34 22-30.

De Courcy Williams, M. (1986). Odinia bolentina (Zetterstedt) (Diptera: Odiniidae) New to Ireland. The Irish Naturalists' Journal, 22(3), 117-118.

DEFRA (2020) Pest and disease factsheet. Online: https://planthealthportal.defra.gov.uk/pests-and-diseases/pest-and-disease-factsheets/ .

Denman, S., Brady, C., Kirk, S., Cleenwerck, I., Venter, S., Coutinho, T. and De Vos, P., 2012. Brenneria goodwinii sp. nov., associated with acute oak decline in the UK. International Journal of Systematic and Evolutionary Microbiology, 62: 2451.

Denman, S., Plummer, S., Kirk, S., Peace, A., McDonald, J. (2016) Isolation studies reveal a shift in the cultivable microbiome of oak affected with Acute Oak Decline. Systematic and Applied Microbiology 39: 484–490

Desprez-Loustau, M.L., Courtecuisse, R., Robin, C., Husson, C., Moreau, P.A., Blancard, D., Selosse, M.A., Lung-Escarmant, B., Piou, D. and Sache, I., 2010. Species diversity and drivers of spread of alien fungi (sensu lato) in Europe with a particular focus on France. *Biological Invasions*, *12*(1), p.157.

Desprez-Loustau, M.L., Robin, C., Reynaud, G., Déqué, M., Badeau, V., Piou, D., Husson, C. and Marcais, B., 2007. Simulating the effects of a climate-change scenario on the geographical range and activity of forest-pathogenic fungi. *Canadian Journal of Plant Pathology*, 29(2), pp.101-120.

Dillon, A.B., Downes, M.J., Ward, D. and Griffin, C.T. 2007. Optimizing application of entomopathogenic nematodes to manage large pine weevil, *Hylobius abietis* L. (Coleoptera: Curculionidae) populations developing in pine stumps, *Pinus sylvestris*. *Biological Control* 40: 253-263.

Dillon, A.B., Rolston, A.N., Meade, C.V., Downes, M.J. and Griffin, C.T. 2008. Establishment, Persistence, and Introgression of Entomopathogenic Nematodes in a Forest Ecosystem. *Ecological Applications* 18: 735-747.

Dillon, A.B., Ward, D., Downes, M.J. and Griffin, C.T. 2006. Suppression of the large pine weevil *Hylobius abietis* (L.) (Coleoptera: Curculionidae) in pine stumps by entomopathogenic nematodes with different foraging strategies. *Biological Control* 38: 217-226.

Doncaster, J.P. (1961). Francis Walker's aphids, 11-13. British Museum (Natural History), London. Donovan 1936, as cited in Baynes 1964;

Dowson, W. J. 1957. Plant Diseases due to Bacteria. Cambridge: Cambridge University Press.

Drenkhan, R., Tomešová‐Haataja, V., Fraser, S., Bradshaw, R.E., Vahalík, P., Mullett, M.S., Martín‐García, J., Bulman, L.S., Wingfield, M.J., Kirisits, T. and Cech, T.L., 2016. Global geographic distribution and host range of Dothistroma species: a comprehensive review. Forest Pathology, 46: 408-442.

E.C. 2012. Proposal for a revised directive of the European Parliament and of the Council on Priority Substances in the field of water quality. MEMO 12/59.

EFSA Panel on Plant Health (PLH), 2013. Scientific Opinion on the risk to plant health posed by *Dothistroma septosporum* (Dorog.) M. Morelet (*Mycosphaerella pini* E. Rostrup, syn. *Scirrhia pini*) and *Dothistroma pini* Hulbary to the EU territory with the identification and evaluation of risk reduction options. *EFSA Journal*, 11(1), p.3026.;

 doi:10.20944/preprints202005.0168.v1

Elliot, C. (1951) *Manual of bacterial plant pathogens*. New York, Stechert-Hafner Inc.

Elwes, H.J. and Henry, A. (1906) *Trees of Great Britain and Ireland*, Volume 1. Edinburgh, Private printing.

Elwes, H.J. and Henry, A. (1909) *Trees of Great Britain and Ireland* Vol 4. Edinburgh, Private printing.

Ennos, R.A., 2015. Resilience of forests to pathogens: an evolutionary ecology perspective. Forestry 88, 41-52.

EPPO (2004) Plant Health Endangered - State of Emergency. https://www.eppo.int/RESOURCES/position_papers/council_madeira_declaration 27/10/18

EPPO (2009) PM 7/92(1) *Gremmeniella abietina*. *EPPO Bulletin* 39, 310-317.

EPPO (2013) Pest Risk Analysis for *Agrilus planipennis*. Online: https://gd.eppo.int/download/doc/292_pra_full_AGRLPL.pdf

EPPO (2020a) Global Database. Online: https://gd.eppo.int/

EPPO (2020b) EPPO Reporting service. Online: https://gd.eppo.int/reporting/

EU (2017) https://ec.europa.eu/food/sites/food/files/plant/docs/phb_ho_annual_report_2015-6_en.pdf

EU (2018) https://ec.europa.eu/food/plant/plant_health_biosecurity/legislation/emergency_measures/xylella-fastidiosa_en

EUROPHYT (2016) Interception data. EU Unpublished data.

Eyre, D., Anderson, H., Baker, R., Cannon, R. (2013) Insect Pests of Trees Arriving and Spreading in Europe. *Outlooks on Pest Management*, 24: 176-180.

Eyre, D., Macarthur, R., Haack, R.A., Lu, Y. and Krehan, H., 2018. Variation in inspection efficacy by member states of wood packaging material entering the European Union. *Journal of economic entomology*, *111*(2), pp.707-715.

Fanning, P.D. and Baars, J.R., 2014. Biology of the Eucalyptus leaf beetle *Paropsisterna selmani* (Chrysomelidae: Paropsini): a new pest of Eucalyptus species (Myrtaceae) in Ireland. Agricultural and Forest Entomology, 16(1), pp.45-53.

FAO (2017) International Standard for Phytosanitary Management 8. https://www.ippc.int/static/media/files/publication/en/2017/06/ISPM_08_1998_En_2017-05-23_PostCPM12_InkAm.pdf

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 May 2020 doi:10.20944/preprints202005.0168.v1

FAO (2018). The State of the World's Forests 2018 - Forest pathways to sustainable development. Rome. Licence: CC BY-NC-SA 3.0 IGO.
FRA (2015) Global Forest resources assessment 2015. Online: www.fao.org

FAO (2020) Adopted standards- ISPMs. Online: https://www.ippc.int/en/core-activities/standards-setting/ispms/

Fennessy, J. (2012) Common alder (*Alnus glutinosa*) as a forest tree in Ireland. Online: http://www.coford.ie/media/coford/content/publications/projectreports/cofordconnects/Alder-reprod.pdf

Fielding, N.J. and Evans, H.F., 1997. Biological control of *Dendroctonus micans* (Scolytidae) in Great Britain. *Biocontrol News and Information*, *18*, pp.51N-60N.

Fischer, E. (1902) Silver fir witch's broom. Journal of the Royal Horticultural Society 27, 272.

Fitzpatrick, H.M. (1965) The Forests of Ireland. The Society of Irish Foresters. The Record Press Ltd., Bray, Co. Wicklow.

Foley, S. and McCormack, S., 2013. *Leptoglossus occidentalis* Heidemann (Hemiptera, Coreidae) new to Ireland. The Irish Naturalists' Journal, 33(1), pp.66-67.

Forbes, A.C., (1910) The economic importance of Scolytidae in Irish forestry. The Irish Naturalist, 19: 89-91.

Forest Service NI 1990 as cited in Thompson, R. and Nelson, B., 2006. The butterflies and moths of Northern Ireland. Blackstaff Press.,

Forestry Commission (1953) Annual Report. Online: file:///C:/Users/2339608/Downloads/FCAR_1952%20(1).pdf

Forestry Commission (2019) *Larger eight-toothed European spruce bark beetle (Ips typographus)* Available at https://www.gov.uk/guidance/eight-toothed-european-spruce-bark-beetle-ips-typographus (accessed on).
Franić, I., Prospero, S., Hartmann, M., Allan, E., Auger□Rozenberg, M.A., Grünwald, N.J., Kenis, M., Roques, A., Schneider, S., Sniezko, R. and Williams, W., 2019. Are traded forest tree seeds a potential source of nonnative pests?. *Ecological Applications*, *29*(7), p.e01971.

FRDBI (2020) The Fungal Records Database of Britain and Ireland. Online: http://www.frdbi.info/

Freer-Smith, P.H. and Webber, J.F., 2017. Tree pests and diseases: the threat to biodiversity and the delivery of ecosystem services. Biodiversity and Conservation, 26(13), pp.3167-3181.

Futai, K. (2013) Pine Wood Nematode, Bursaphelenchus xylophilus. Annual Review of Phytopathology, 51: 61-83.

Gillanders, A.T., 1908. Forest entomology. London, W. Blackwood and Sons.;

Good, J.A. and Hume, H., 1991. Silvanus bidentatus (F.)(Coleoptera: Silvanidae) imported into Ireland in bark of timber pallets. The Irish Naturalists' Journal, 23(11), pp.463-464.

Good, J.A. and McAree, D., 1991. *Chlorophorus fainanensis* Pic (Coleoptera: Cerambycidae), a Wood-Boring Beetle Imported in the Wood of a Pepper Pot. The Irish Naturalists' Journal, 23(10), pp.423-423.

Graham, M.W.R. 1948. Harpiphorus lepidus Klug (Hym., Tenthredinidae) in Ireland. Entomologist' monthly Magazine 84: 264

Green, S., Brasier, C.M., Schlenzig, A., McCracken, A., MacAskill, G.A., Wilson, M. and Webber, J.F. (2013) The destructive invasive pathogen Phytophthora lateralis found on Chamaecyparis lawsoniana across the UK. Forest Pathology, 43(1), pp.19-28.;

Grégoire, J. and Evans, H., 2004. Damage and control of BAWBILT organisms, an overview. 19–37. *Bark and Wood Boring Insects in Living Trees in Europe, a Synthesis. Kluwer Academic Publishers. Dordercht, The Netherlands*.

Grosdidier, M., Scordia, T., Ioos, R. and Marcais, B., 2020. Landscape epidemiology of ash dieback. Journal of Ecology. https://doi.org/10.1111/1365-2745.13383.

Gross, A., Holdenrieder, O., Pautasso, M., Queloz, V. and Sieber, T.N., 2014. Hymenoscyphus pseudoalbidus, the causal agent of E uropean ash dieback. *Molecular Plant Pathology*, *15*(1), pp.5-21.

Grove, W. B. 1937. British Stem- and Leaf-Fungi (Coelomycetes), vol. 2, Cambridge University Press, Cambridge.

Haack, R.A., 2006. Exotic bark-and wood-boring Coleoptera in the United States: recent establishments and interceptions. *Canadian Journal of Forest Research*, *36*(2), pp.269-288.

Hahn, G.G., 1957. A new species of Phacidiella causing the so-called Phomopsis disease of conifers. Mycologia, 49(2), pp.226-239.

Halbert, J.N., 1898. Beetles Collected at Mote Park, Mount Talbot, and Clonbrock. The Irish Naturalist, 7(4), pp.90-95.

Halbert, J.N., 1922. Magdalis carbonaria and other insects at Powerscourt. The Irish Naturalist, 31(1), pp.8-10.

Haliday, A. H. 1833 Catalogue of Diptera occurring about Holywood in Downshire. *Entomolgists' Monthly Magazine* 1: 147-180 as cited in D'Arcy-Burt, S. and Chandler, P.J. 1987 Irish Bibionidae and Scatopsidae (Diptera: Nematocera). *The Irish Naturalists' Journal*, 22 (6): 224-231.

Hansen, E.M. and Goheen, E.M. (2000) Phellinus Weirii and Other Native Root Pathogens as Determinants of Forest Structure and Process in Western North America. Annual Review of Phytopathology 38: 515-539

Heliovaara, K. and Peltonen, M. 1999 Bark beetles in a changing environment. Ecological Bulletins 47, 48-53.

Henricot, B., Sierra, A.P. and Prior, C., 2000. A new blight disease on Buxus in the UK caused by the fungus Cylindrocladium. Plant Pathology, 49(6).

Hérard, F. and Maspero, M., 2019. History of discoveries and management of the citrus longhorned beetle, Anoplophora chinensis, in Europe. Journal of pest science, 92(1), pp.117-130.

Herms, D.A. and McCullough, D.G., 2014. Emerald ash borer invasion of North America: history, biology, ecology, impacts, and management. *Annual review of entomology*, *59*, pp.13-30.

Hill, L., Jones, G., Atkinson, N., Hector, A., Hemery, G. and Brown, N., 2019. The£ 15 billion cost of ash dieback in Britain. *Current Biology*, *29*(9), pp.R315-R316.

Hlásny T., Krokene P., Liebhold A., Montagné-Huck C., Müller J., Qin H., Raffa K., Schelhaas M., Seidl R., Svoboda M. (2019) *Living with bark beetles: impacts, outlook and management options*. European Forest Institute.

Holdaway, R.J., Wood, J.R., Dickie, I.A., Orwin, K.H., Bellingham, P.J., Richardson, S.J., Lyver, P.O.B., Timoti, P. and Buckley, T.R., 2017. Using DNA metabarcoding to assess New Zealand's terrestrial biodiversity. *New Zealand Journal of Ecology*, *41*(2), pp.251-262.

Horgan, T., Keane, M., McCarthy, R., Lally, M., Thompson, D. and O'Carroll, J., 2004. A guide to forest tree species selection and silviculture in Ireland. Dublin: Coford.

Humble, L., 2010. Pest risk analysis and invasion pathways-insects and wood packing revisited: What have we learned. New Zealand Journal of Forestry Science, 40(Suppl).

Hume, H. and Conway, T. (1993) Recent introductions of alien pests and disease into Ireland. In Kavanagh, J. and Brennan, P. (eds) Plant health and 1992. Dublin, Royal Irish Academy.

Inward, D.J., 2019. Three new species of ambrosia beetles established in Great Britain illustrate unresolved risks from imported wood. *Journal of Pest Science*, pp.1-10.

Inward, D.J., Wainhouse, D. and Peace, A. 2012. The effect of temperature on the development and life cycle regulation of the pine weevil *Hylobius abietis* and the potential impacts of climate change. *Agricultural and Forest Entomology* 14: 348-357.

Jactel, H., Bauhus, J., Boberg, J., Bonal, D., Castagneyrol, B., Gardiner, B., Gonzalez-Olabarria, J., Koricheva, J., Meurisse, N., Brockerhof, E. (2017) Tree Diversity Drives Forest

Stand Resistance to Natural Disturbances. Curr Forestry Reports, DOI 10.1007/s40725-017-0064-1

Jactel, H., Brockerhoff, E. (2007) Tree diversity reduces herbivory by forest insects. Ecology Letters 10: 835-848.

Janson, O. E. (1924). Coleoptera at Lough Neagh (Co. Antrim) and Newcastle (Co. Down). The Irish Naturalist, 33(7), 69–72. Retrieved from www.jstor.org/stable/25525363

Javal, M., Roques, A., Haran, J., Hérard, F., Keena, M. and Roux, G., 2019. Complex invasion history of the Asian long-horned beetle: fifteen years after first detection in Europe. *Journal of Pest Science*, *92*(1), pp.173-187.

Jeger, M., Bragard, C., Caffier, D., Candresse, T., Chatzivassiliou, E., Dehnen□Schmutz, K., Gilioli, G., Gregoire, J.C., Miret, J.A.J., MacLeod, A. and Navarro, M.N., (2017a). Pest categorisation of *Gremmeniella abietina*. *EFSA Journal*, 15(11).

Jeger, M., Bragard, C., Caffier, D., Candresse, T., Chatzivassiliou, E., Dehnen□Schmutz, K., Gilioli, G., Miret, J.A.J., MacLeod, A., Navarro, M.N. and Niere, B., (2017b). Pest categorisation of *Ips typographus*. *EFSA Journal*, 15(7).

Jeger, M.J. and Pautasso, M., 2008. Plant disease and global change–the importance of long□term data sets. *New Phytologist*, *177*(1), pp.8-11.

Jess, S., Kildea, S., Moody, A., Rennick, G., Murchie, A.K. and Cooke, L.R., 2014. European Union policy on pesticides: implications for agriculture in Ireland. *Pest Management Science*, 70: 1646-1654.

Jess, S., Murchie, A., Allen, D. and Crory, A., 2017. First observation of *Tomostethus nigritus* (Fabricius) (Hymenoptera: Tenthredinidae) on urban ash trees in Ireland. *Irish Naturalists' Journal*, 35, 134-136.

Johnson, W. F. (1922). Insects at Carlingford, Co. Louth. The Irish Naturalist, 31(2), 13–17. Retrieved from www.jstor.org/stable/25525118

Johnson, W. F., & Halbert, J. N. (1902). A List of the Beetles of Ireland. Proceedings of the Royal Irish Academy 6: 535–827.

Johnson, W.F., 1893. Coleoptera at Ardara, Co. Donegal. The Irish Naturalist, 2(2), pp.53-55.

Johnson, W.F., 1895. Report on Insects Collected at Coolmore, Co. Donegal, for the Royal Irish Academy Flora and Fauna Committee, July, 1894. The Irish Naturalist, 4(4), pp.95-99.

Jones, D.R. and Baker, R.H.A., 2007. Introductions of non□native plant pathogens into Great Britain, 1970–2004. Plant Pathology, 56(5), pp.891-910.

Jonsson P. (2020) *The bark-beetle invades Europe*. Available at https://www.forestry.com/editorial/bark-beetle-invades-europe/ (accessed on 28 April 2020).

Joyce, P.M. and O'Carroll, N., 2002. *Sitka spruce in Ireland*. National Council for Forest Research and Development (COFORD).

Jung, T., Orlikowski, L., Henricot, B., Abad□Campos, P., Aday, A.G., Aguín Casal, O., Bakonyi, J., Cacciola, S.O., Cech, T., Chavarriaga, D., Corcobado, T., Cravador, A., Decourcelle, T., Denton, G., Diamandis, S., Doğmuş□Lehtijärvi, H.T., Franceschini, A., Ginetti, B., Green, S., Glavendekić, M., Hantula, J., Hartmann, G., Herrero, M., Ivic, D., Horta Jung, M., Lilja, A., Keca, N., Kramarets, V., Lyubenova, A., Machado, H., Magnano di San Lio, G., Mansilla Vázquez, P.J., Marçais, B., Matsiakh, I., Milenkovic, I., Moricca, S., Nagy, Z.Á., Nechwatal, J., Olsson, C., Oszako, T., Pane, A., Paplomatas, E.J., Pintos Varela, C., Prospero, S., Rial Martínez, C., Rigling, D., Robin, C., Rytkönen, A., Sánchez, M.E., Sanz Ros, A.V., Scanu, B., Schlenzig, A., Schumacher, J., Slavov, S., Solla, A., Sousa, E., Stenlid, J., Talgø, V., Tomic, Z., Tsopelas, P., Vannini, A., Vettraino, A.M., Wenneker, M., Woodward, S. and Peréz□Sierra, A. (2016), Widespread Phytophthora infestations in European nurseries put forest, semi□natural and horticultural ecosystems at high risk of Phytophthora diseases. *Forest Pathology* 46: 134-163.

Jung, T., Pérez-Sierra, A., Durán, A., Jung, M.H., Balci, Y. and Scanu, B., 2018. Canker and decline diseases caused by soil-and airborne Phytophthora species in forests and woodlands. *Persoonia: Molecular Phylogeny and Evolution of Fungi*, *40*, p.182.

Kamoun, S., Furzer, O., Jones, J.D., Judelson, H.S., Ali, G.S., Dalio, R.J., Roy, S.G., Schena, L., Zambounis, A., Panabières, F. and Cahill, D., 2015. The Top 10 oomycete pathogens in molecular plant pathology. *Molecular plant pathology*, *16*(4), pp.413-434.

Kapranas A., Malone B., Quinn S., Mc Namara L., Williams C.D., O'Tuama P., Peters A. and Griffin C.T. (2017) Efficacy of entomopathogenic nematodes for control of large pine weevil, *Hylobius abietis*: effects of soil type and pest density and spatial distribution. *Journal of Pest Science* 90: 495-505.

Kavanagh, J. (1993) A strategy for improving plant health. In Kavanagh, J. and Brennan, P. *Plant health and 1992*. Dublin, Royal Irish Academy.

Kavanagh, J. and Brennan, P. *Plant health and 1992*. Dublin, Royal Irish Academy.

Kavanagh, J.A., O'Malley, M. and Simmonds, A., 1969. Some observations on the rotting of apple fruits by *Phytophthora syringae* Kleb. Irish Journal of Agricultural Research, pp.439-441.;

Kavanagh, T. and Rath, N., 1982. Influence of fungicide applications for Botrytis control in strawberries on the incidence of leather rot (*Phytophthora cactorum*) and on the control of lesions on petioles and flower stalks. Irish Journal of Agricultural Research, pp.95-99.;

Keane, M. 1986. Lawson cypress in danger? *Irish Forestry* 43: 144.

Keane, M., McCarthy, R. and Hogan, J., 1989. Forest health surveys in Ireland: 1987 and 1988 results. *Irish Forestry*. 46: 59-62

Kenis, M. (2005) Insects – Insecta . An Inventory of Alien Species and their Threat to Biodiversity and Economy in Switzerland , Report to the Swiss Agency for Environment, Forests and Landscape SAEFL (ed. by R. Wittenberg), pp . 131 – 146 . CABI Bioscience Switzerland Centre , Switzerland.

Kenis, M., Rabitsch, W., Auger-Rozenberg, M.A. and Roques, A., 2007. How can alien species inventories and interception data help us prevent insect invasions?. *Bulletin of entomological research*, *97*(5), pp.489-502.

Kloet, G.S. and Hincks, W.D., 1945. A check list of British insects. London, Royal Entomological Society.

Kowalski, T., 2006. Chalara fraxinea sp. nov. associated with dieback of ash (Fraxinus excelsior) in Poland. *Forest Pathology*, *36*(4), pp.264-270.

La Porta, N., Capretti, P., Thomsen, I.M., Kasanen, R., Hietala, A.M. and Von Weissenberg, K., 2008. Forest pathogens with higher damage potential due to climate change in Europe. Canadian Journal of Plant Pathology, 30(2), pp.177-195.

Laing, F., 1922. Rhinocola eucalypti, Mask., in England. Entomologist's Monthly Magazine, 58(697).

Leahy, M.J., Oliver, T.H. and Leather, S.R., 2007. Feeding behaviour of the black pine beetle, Hylastes ater (Coleoptera: Scolytidae). *Agricultural and Forest Entomology*, *9*(2), pp.115-124.

Leahy, M.J.A., Oliver, T.H. and Leather, S.R. 2007 Feeding behaviour of the black pine beetle, *Hylastes ater* (Coleoptera: Scolytidae) *Agricultural and Forest Entomology* **9**, 115-24.

Leather, S.R., Day, K.R. and Salisbury, A.N.J. 1999. The biology and ecology of the large pine weevil, *Hylobius abietis* (Coleoptera: Curculionidae): a problem of dispersal? *Bulletin of Entomological Research* 89: 3-16.

Lee, U. (1988) Forest Pathology group meeting. SIPP Newsletter.

Lett, H. W. (1883) First Fungus Foray in Ireland 18.11.83, by B.F.N.C. Grevillea 12.;

Leung, B., Lodge, D.M., Finnoff, D., Shogren, J.F., Lewis, M.A. and Lamberti, G., 2002. An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *269*(1508), pp.2407-2413.

Leung, B., Lodge, D.M., Finnoff, D., Shogren, J.F., Lewis, M.A. and Lamberti, G., 2002. An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. Proceedings of the Royal Society of London. Series B: Biological Sciences, 269(1508), pp.2407-2413.

Liebhold, A.M. and Kean, J.M., 2019. Eradication and containment of non-native forest insects: successes and failures. *Journal of Pest Science*, *92*(1), pp.83-91.

Liebhold, A.M., 2012. Forest pest management in a changing world. *International Journal of Pest Management*, *58*(3), pp.289-295.

Liebhold, A.M., Berec, L., Brockerhoff, E.G., Epanchin-Niell, R.S., Hastings, A., Herms, D.A., Kean, J.M., McCullough, D.G., Suckling, D.M., Tobin, P.C. and Yamanaka, T., 2016. Eradication of invading insect populations: from concepts to applications. *Annual Review of Entomology*, *61*, pp.335-352.

Liebhold, A.M., Brockerhoff, E.G., Garrett, L.J., Parke, J.L. and Britton, K.O., 2012. Live plant imports: the major pathway for forest insect and pathogen invasions of the US. *Frontiers in Ecology and the Environment*, *10*(3), pp.135-143.

Liston, A.D. and Sheppard, D.A., Version: 18.11. 2008 checklist of british and irish hymenoptera symphyta. Online: http://www.record-lrc.co.uk/Downloads/UK_sawfly_checklist_18_Nov_2008[14032009].pdf ;

Liston, A.D., 1988. Noteworthy Symphyta (Hymenoptera) from Afforested Areas in Northern Ireland. The Irish Naturalists' Journal, 22(10), pp.445-447.

Liston, M.A.D., Knight, M.G.T., Sheppard, M.D.A., Broad, G.R. and Livermore, M.L., 2014. Checklist of British and Irish Hymenoptera-Sawflies,'Symphyta'. Biodiversity Data Journal, (2).

Lovett, G.M., Weiss, M., Liebhold, A.M., Holmes, T.P., Leung, B., Lambert, K.F., Orwig, D.A., Campbell, F.T., Rosenthal, J., McCullough, D.G. and Wildova, R., 2016. Nonnative forest insects and pathogens in the United States: Impacts and policy options. Ecological Applications, 26(5), pp.1437-1455.

MacDougal, R. 1900 The biology and forest importance of *Scolytus multistriatus*. Proceedings of the Royal Society of Edinburgh 23, 359-364.

MacDougal, R. 1906a. The large larch sawfly. Journal of the Board of Agriculture 13, 385-394

MacDougall, R.S., 1906b. Megastigmus spermotrophus Wachtl, as an enemy of Douglas Fir (Pseudotsuga douglasii). Trans. R. Scott. Arboricult Soc.

MacLeod, A., Jones, G.D., Anderson, H.M. and Mumford, R.A., 2016. Plant health and food security, linking science, economics, policy and industry. Food security, 8(1), pp.17-25.

Mangan, A. 2008 A bibliography of mycology and plant pathology in Ireland, 1976 to 2000. Glasra 4, 119_88.

Mangan, A. and Walsh, P.F., 1980. Some Observations on the Spread of Dutch Elm Disease in Ireland, 1978-79. Irish Journal of Agricultural Research, pp.133-140.;

Martin, F.N., Abad, Z.G., Balci, Y. and Ivors, K., 2012. Identification and detection of Phytophthora: reviewing our progress, identifying our needs. *Plant disease*, *96*(8), pp.1080-1103.

Massee, G., 1913. Diseases of cultivated plants and trees. Duckworth.

McArdle, D. and Lafferty, H.A., 1922. Didymosphaeria populina and Phytophthora syringae. Irish Naturalist, 31, p.137.;

McAree, D. (1972) P. contorta shoot dieback. SIPP Newsletter.

Mcaree, D. 1987 Some forestry aspects, of the EEC Plant health directive. SIPP Newsletter No 17.

McAree, D. T. and MacKenzie, R.F. (1993) Guarding against potential threats to Irish forests" in Kavanagh, J.A. and Brennan, P (eds) *Plant Health and 1992*. Royal Irish Academy, Dublin.

McAree, D.T., 1975. Fornes annosus-A forest pathogen. *Irish Forestry*. 118-128

McCarthy, R., 1993. Monitoring forest condition in Ireland (1988-1991). *Irish Forestry*. 50 21-34

McCracken, A. (1996) Two new diseases of dogwood and Alder. *SIPP Newsletter* 26: 4-5.

McCracken, A., 2013. Current and emerging threats to Ireland's trees from diseases and pests. Irish Forestry, pp.18-35.

McCracken, A.R., Douglas, G.C., Ryan, C., Destefanis, M. and Cooke, L.R., 2017. Ash dieback on the island of Ireland. Swedish University of Agricultural Sciences. Online: https://www.slu.se/globalassets/ew/org/inst/mykopat/forskning/stenlid/dieback-of-european-ash.pdf

McEvoy, A., O'Regan, F., Fleming, C.C., Moreland, B.P., Pollock, J.A., McGuinness, B.W. and Hodkinson, T.R., 2016. Bleeding canker of horse chestnut (Aesculus hippocastanum) in Ireland: incidence, severity and characterization using DNA sequences and real-time PCR. Plant Pathology, 65(9), pp.1419-1429.

McKay, R. 1952 Pioneer workers in the field of plant pathology in Ireland. Journal of the Depratment of Agriculture Ireland. 48

McKay, R. and Clear, T. 1953 Association of *Rhizina inflata* with group dying of Sitka spruce. Irish Forestry 10: 58-59.;

McKay, R. and Clear, T. 1955 A further note on group dying of Sitka spruce and Rhizina inflata. Irish Forestry 12: 58-63

McKay, R. and Clear, T. 1957 Violet root rot on Douglas fir and Pinus contorta. Irish Forestry 14: 90-97.

McNamara L., Kapranas A., Williams C.D., O'Tuama P., Kavanagh K. and Griffin C.T. (2018) Efficacy of entomopathogenic fungi against large pine weevil, *Hylobius abietis*, and their additive effects when combined with entomopathogenic nematodes. *Journal of Pest Science* 91(4): 1407-1419.

McTaggart, A.R., van der Nest, M.A., Steenkamp, E.T., Roux, J., Slippers, B., Shuey, L.S., Wingfield, M.J. and Drenth, A., 2016. Fungal genomics challenges the dogma of name-based biosecurity. *PLoS pathogens*, *12*(5).

Mergaert, J., Hauben, L., Cnockaert, M.C. and Swings, J., 1999. Reclassification of non-pigmented Erwinia herbicola strains from trees as Erwinia billingiae sp. nov. International Journal of Systematic and Evolutionary Microbiology, 49(2), pp.377-383.

Meurisse, N., Rassati, D., Hurley, B.P., Brockerhoff, E.G. and Haack, R.A., 2019. Common pathways by which non-native forest insects move internationally and domestically. *Journal of Pest Science*, *92*(1), pp.13-27.

Migliorini, D., Ghelardini, L., Tondini, E., Luchi, N. and Santini, A., 2015. The potential of symptomless potted plants for carrying invasive soilborne plant pathogens. *Diversity and Distributions*, *21*(10), pp.1218-1229.

Mitchel, D., Wright, M., Shannon, G. and Anderson, R., 2002. New or interesting records of Irish fungi. The Irish Naturalists' Journal, 27(1), pp.38-43.

Mitchell, F.J., 2006, November. Where did Ireland's trees come from?. In *Biology and environment: proceedings of the Royal Irish Academy* (pp. 251-259). Royal Irish Academy.

Mitchell, R.J., Beaton, J.K., Bellamy, P.E., Broome, A., Chetcuti, J., Eaton, S., Ellis, C.J., Gimona, A., Harmer, R., Hester, A.J. and Hewison, R.L., 2014. Ash dieback in the UK: a review of the ecological and conservation implications and potential management options. *Biological Conservation*, *175*, pp.95-109.

Moffat, C.B., 1897. Bupalus piniaria, L., in Ireland. The Irish Naturalist, 6(10), pp.283-283.

Moller, G.J., 1975. A list of Irish sawflies (Hymenoptera: Symphyta) in the Ulster Museum: Including a new Irish record and a note on a teratological specimen of Hemichroa Steph. The Irish Naturalists' Journal, pp.133-136.

Moore, W.C. 1959 British Parasitic Fungi. Cambrideg University Press; Cambirdge.

Morales-Rodríguez C., Anslan S., Auger-Rozenberg M.-A., Augustin S., Baranchikov Y., Bellahirech A., Burokienė D., Čepukoit D., Çota E., Davydenko K., Doğmuş Lehtijärvi H.T., Drenkhan R., Drenkhan T., Eschen R., Franić I., Glavendekić M., de Groot M., Kacprzyk M., Kenis M., Kirichenko N., Matsiakh I., Musolin D.L., Nowakowska J.A., O'Hanlon R., Prospero S., Roques A., Santini A., Talgø V., Tedersoo L., Uimari A., Vannini A., Witzell J., Woodward S., Zambounis A., Cleary M. 2019. Forewarned is forearmed: harmonized approaches for early detection of potentially invasive pests and pathogens in sentinel plantings. NeoBiota, 47: 95-123

Morris 2002 True Weevils (Part I): Family Curculionidae, subfamilies Raymondionyminae to Smicronychinae

Morris, M. G. (1966). Records of weevils (Coleoptera Curculionoidea) from counties Galway, Offaly and Roscommon. Ir. Nat. J., 15: 208-9.

Morris, M.G., 1968. Recent records of weevils (Coleoptera, Curculionoidea) from Ireland. The Irish Naturalists' Journal, pp.42-47.

Morris, M.G., 1993, A critical review of the weevils (Coleoptera, Curculionoidea) of Ireland and their distribution. Biology and Environment: (pp. 69-84).

Moths Ireland (2020) MothsIreland, mapping Ireland's moths. Online: www.mothsireland.com

Mowat, D.J. & Clawson, S. (1996) The need for pest control in Northern Ireland Bramley apple orchards. Crop Protection in Northern Britain, 2, 225–230.

Mullett, M.S., Adamson, K., Bragança, H., Bulgakov, T.S., Georgieva, M., Henriques, J., Jürisoo, L., Laas, M. and Drenkhan, R., 2018. New country and regional records of the pine needle blight pathogens Lecanosticta acicola, Dothistroma septosporum and Dothistroma pini. Forest pathology, 48(5), p.e12440.

Munro, J.W. 1917 The genus Hylastes and its importance in forestry. Proceedings of the Royal Philsophical Society of Edinburgh. 10, 3.

Munro, J.W. 1920. Survey of forest insect conditions in the British Isles. Bull. For. Comm., 2, p.35.

Munro, J.W. 1926 British bark beetles. Forestry Commission bulletin No. 8. London, HMSO.

Munro, J.W. 1927. The present position of forest entomology in Great Britain. *Forestry* 1: 44-46.

Murray, J.S., 1954. Two diseases of spruce under investigation in Great Britain. *Forestry: An International Journal of Forest Research*, *27*(1), pp.54-62.

Muskett, A.E. and Malone, J.P., 1978, January. Catalogue of Irish Fungi: I. Gasteromycetes. In *Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science* (pp. 1-11).

Muskett, A.E. and Malone, J.P., 1980, January. Catalogue of Irish Fungi: III. Teliomycetes. In Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science (pp. 343-366).

Muskett, A.E. and Malone, J.P., 1983, January. Catalogue of Irish Fungi: IV. Ascomycotina. Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science (pp. 151-213).

Muskett, A.E. and Malone, J.P., 1984, January. Catalogue of Irish Fungi: V. Mastigomycotina and Zygomycotina. In Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science (pp. 83-102).

Muskett, A.E. and Malone, J.P., 1985, January. Catalogue of Irish Fungi: VI. Deuteromycotina. Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science (pp. 133-200).

Muskett, A.E., 1976, January. Mycology and plant pathology in Ireland. *Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science* (pp. 393-472). Royal Irish Academy.

Muskett, A.E., Carrothers, E.N. and Cairns, H., 1931, January. Contributions to the fungus flora of Ulster. Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science 40, 37-55.

Muskett, A.E., Malone, J.P. and Nixon, C.J.W., 1980, January. Catalogue of Irish Fungi: II. Hymenomycetes. *Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science* (pp. 197-276). Royal Irish Academy.

NBDC (2010) Ireland's biodiversity in 2010. Online: https://www.biodiversityireland.ie/wordpress/wp-content/uploads/Irelands-Biodiversity-2010.pdf

NBN Atlas (2020) NBN Atlas. Online: https://nbnatlas.org/

Nechwatal, J., Bakonyi, J., Cacciola, S.O., Cooke, D.E.L., Jung, T., Nagy, Z.A., Vannini, A., Vettraino, A.M. and Brasier, C.M., 2013. The morphology, behaviour and molecular phylogeny of Phytophthora taxon Salixsoil and its redesignation as Phytophthora lacustris sp. nov. Plant Pathology, 62(2), pp.355-369.

Neumann, M., Mues, V., Moreno, A., Hasenauer, H. and Seidl, R., 2017. Climate variability drives recent tree mortality in Europe. *Global change biology*, *23*(11), pp.4788-4797.

Newstead, R. 1900. Felted beech coccus. Journal of the Royal Horticulture Society, 23: 249

Nicholson, G.W., 1914. Coleoptera from Cavan and Meath. The Irish Naturalist, 23(3), pp.68-72.

Norfolk Moths (2020) Norfolk moths. Online: www.norfolkmoths.co.uk

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 May 2020 doi:10.20944/preprints202005.0168.v1

O’Callaghan, D.P. (1982) Occurrence of the Small Elm Bark Beetle, Scolytus multistriatus, in Ireland. Irish Naturalist Journal. 20 384-385.

O'Connor, J.P., O'Connor, M.A. and Wistow, S., 1993. Some records of Irish Cynipidae (Hymenoptera) including ten species new to Ireland. The Irish Naturalists' Journal, 24(8), pp.321-325.

O'Connor, J.P. and Nash, R., 2000. Notes on the Irish Megastigmus (Hymenoptera: Torymidae) including two species new to Ireland. British Journal of Entomology and Natural History, 13(4).

O'Connor, J.P., Nash, R. and Bouček, Z., 2000. A catalogue of the Irish Chalcidoidea (Hymenoptera). Irish Biogeographical Society.

O’Connor, J.P. and Fox, H., 2000. The Horse Chestnut Scale Pulvinaria regalis Canard (Hemiptera: Coccidae) new to Ireland. Entomologist's Gazette, 51(2), pp.145-146.

O’Connor, J.P. and Nash, R. (1979) Record of Six Insect Species (Coleoptera: Orthopetra) Recently Imported into Ireland. The Irish Naturalists' Journal,19: 433-434. ;

O’Connor, J.P. and Nash, R. (1981) Notes on Five Species of Insect (Hemiptera: Coleoptera) Imported into Ireland. The Irish Naturalists' Journal, 20: 299-300

O’Connor, J.P. and Nash, R. (1982) Further Records of Insects (Dictyoptera, Lepidoptera, Coleoptera, Diptera) Imported into Ireland. The Irish Naturalists' Journal, 20: 393-395

O’Connor, J.P. and Nash, R. (1983) Insects Imported into Ireland. 5. Records of Orthoptera, Hemiptera, Hymenoptera and Coleoptera. The Irish Naturalists' Journal, 21: 114-117

O’Connor, J.P., 2003. Notes on Megastigmus dorsalis (Fabricius) and M. suspectus Borries (Hymenoptera: Torymidae) in Ireland. The Irish Naturalists' Journal, 27(7), pp.279-280.

O’Connor, J.P., Gertsson, C.A. and Malumphy, C., 2013. A review of the Irish scale insects (Hemiptera: Coccoidea). Irish Naturalists' Journal, pp.32-44.

O’Connor, J.P., Winter, T.G. and Good, G.A., 1991. A review of the Irish Scolytidae (Insecta: Coleoptera). The Irish Naturalists' Journal, 23(10), pp.403-409.

O’Connor, P., 1936. A contribution to knowledge of the Irish fungi. Scientific Proceedings of the Dublin Society 21: 381

O’Farrell, A.F., 1947. Lepidoptera in Northern Ireland, 1943-5. The Irish Naturalists' Journal, pp.76-77.

O’Hanlon, R. (2015) Two further threats to Ireland’s tree’s from non-native invasive Phytophthoras. Irish Forestry 72: 87-100.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 May 2020 doi:10.20944/preprints202005.0168.v1

O'Hanlon, R. (2016) Re. Options to protect forest and plant health in Ireland. Irish Forestry 73: 324-326.

O'Hanlon, R. and Fleming, C (2018) Neonectria fuckeliana as a pathogen of Sitka spruce in Northern Ireland. 27 https://nibio.brage.unit.no/nibio-xmlui/bitstream/handle/11250/2487247/NIBIO_BOK_2018_4_4.pdf?sequence=1&isAllowed=y

O'Hanlon, R. and Harrington, T.J., (2011) Diversity and distribution of mushroom-forming fungi (Agaricomycetes) in Ireland. In Biology and environment: proceedings of the Royal Irish Academy (pp. 117-133).

O'Hanlon, R. Wilson, J., Cox, D. (2019) Investigations into the declining health of alder (*Alnus glutinosa*) along the river Lagan in Belfast, including the first report of *Phytophthora lacustris* causing disease of Alnus in Northern Ireland. BioRXiv https://www.biorxiv.org/content/10.1101/2019.12.13.875229v1.full

O'Hanlon, R., Choiseul, J., Corrigan, M., Catarame, T. and Destefanis, M., 2016a. Diversity and detections of Phytophthora species from trade and non‐trade environments in Ireland. EPPO Bulletin, 46(3), pp.594-602.

O'Hanlon, R., McCracken, A.R. and Cooke, L.R., 2016b, January. Diversity and ecology of Phytophthora species on the island of Ireland. In Biology and Environment: Proceedings of the Royal Irish Academy (Vol. 116, No. 1, pp. 27-51). Royal Irish Academy.

OCarroll, N., & Joyce, P. M. (2004). A Forestry centenary. *Irish Forestry*. 61: 6-19.

Parker, A.G., Goudie, A.S., Anderson, D.E., Robinson, M.A. and Bonsall, C., 2002. A review of the mid-Holocene elm decline in the British Isles. *Progress in Physical Geography*, *26*(1), pp.1-45.

Paulson, R. 1900. An inquiry into the causes of death of birch trees in epping forest and elsewhere. Essex Naturalist 11, 273-284.

Pautasso, M., Döring, T.F., Garbelotto, M., Pellis, L. and Jeger, M.J., 2012. Impacts of climate change on plant diseases—opinions and trends. *European Journal of Plant Pathology*, *133*(1), pp.295-313.

Peace, T.R., 1962. Pathology of trees and shrubs with special reference to Britain. Pathology of Trees and Shrubs with Special Reference to Britain. Oxford, Clarendon press.

Pethybridge, G.H., 1918. Chrysomyxa abietis in Ireland. The Irish naturalist, 27(8/9), pp.130-130.

Phillips, D.H., Burdekin DA (1982) Diseases of Forest and Ornamental Trees. Mac Millan. London.

Pluess, T., Cannon, R., Jarošík, V., Pergl, J., Pyšek, P. and Bacher, S., 2012. When are eradication campaigns successful? A test of common assumptions. *Biological Invasions*, *14*(7), pp.1365-1378.

Potter, C., Harwood, T., Knight, J. and Tomlinson, I., 2011. Learning from history, predicting the future: the UK Dutch elm disease outbreak in relation to contemporary tree disease threats. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1573), pp.1966-1974.

Pureswaran, D.S., Roques, A. and Battisti, A., 2018. Forest insects and climate change. *Current forestry reports*, *4*(2), pp.35-50.

Purvis, G. Chauzat, M-P. Segonds-Pichon, A. and Dunne, R.; (2002) 'Life history and phenology of the eucalyptus psyllid, Ctenarytaina eucalypti (Homoptera: Psylloidea) in Ireland'. Annals of Applied Biology, 141 :283-292.

Quirke, D. A. 1943 Eccoptogaster scolytus F. (CoL, Ipidae) in Ireland. Entomologists Monthly Magazine. 79: 198

Quirke, D.A. 1947 Insect Pests of Irish Woodlands. Unpublished PhD Thesis, University College Dublin.

Quirke, D.A., 1946. Forest pathology. Irish Forestry 3: 10-25.

Ramsfield, T.D., Bentz, B.J., Faccoli, M., Jactel, H. and Brockerhoff, E.G., 2016. Forest health in a changing world: effects of globalization and climate change on forest insect and pathogen impacts. Forestry, 89(3), pp.245-252.

Regan, E., Nelson, B., McCormack, S., Nash, R., O'Connor, J.P. (2010) Countdown to 2010: Can we assess Ireland's insect species diversity and loss? Biology and Environment: Proceedings of the Royal Irish Academy, 110B: 109–117

Reilly, E. (2008) An ever-closing gap? Modern ecological and palaeoecological contributions towards understanding the Irish post-glacial insect fauna. The Irish Naturalists' Journal, 29: 63-71

Reynolds, S.C. and Reynolds, J.D., 2008. Knopper Gall Andricus quercuscalicis (Burgsdorf) records on oaks in Co. Limerick, with observations on the Artichoke Gall Andricus fecundator (Hartig). The Irish Naturalists' Journal, pp.13-17.

Ridout, M. and Newcombe, G., 2018. Sydowia polyspora is both a foliar endophyte and a preemergent seed pathogen in Pinus ponderosa. Plant disease, 102, pp.640-644.

Riggins, J.J. & Londo, A.J. (2009) Wolves in sheep's clothing: Outbreaks of previously obscure native forest insects. Forest Wisdom, (13), 6-7.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 10 May 2020 doi:10.20944/preprints202005.0168.v1

Roberts M, Gilligan CA, Kleczkowski A, Hanley N, Whalley AE and Healey JR (2020) The Effect of Forest Management Options on Forest Resilience to Pathogens. Front. For. Glob. Change 3:7. doi: 10.3389/ffgc.2020.00007.

Roques A, Skrzypczyńska M (2003) Seed-infesting chalcids of the genus Megastigmus Dalman (Hymenoptera: Torymidae) native and introduced to Europe: taxonomy, host specificity and distribution. Journal of Natural History 37: 127–238. doi: 10.1080/713834669

Ryan, C. (2018) *Hymenoscyphus fraxineus* in Ireland April 2018. Online: [https://www.agriculture.gov.ie/media/migration/forestry/publicconsultation/submissionsreceived2018/DAFMChalaraCR130418.ppt accessed 03/11/18](https://www.agriculture.gov.ie/media/migration/forestry/publicconsultation/submissionsreceived2018/DAFMChalaraCR130418.ppt).

Santini, A., Ghelardini, L., De Pace, C., Desprez□Loustau, M.L., Capretti, P., Chandelier, A., Cech, T., Chira, D., Diamandis, S., Gaitniekis, T. and Hantula, J., 2013. Biogeographical patterns and determinants of invasion by forest pathogens in Europe. New Phytologist, 197(1), pp.238-250.

Anon 1879 Scientific committee. Journal of the Royal Horticultural Society. 5, 119

Scannell, M. 1972, Ovulina azaelaea. SIPP Newsletter No. 3.

Scanu, B., Jones, B. and Webber, J.F., 2012. A new disease of Nothofagus in Britain caused by Phytophthora pseudosyringae. New Disease Reports, 25(27), pp.2044-0588.

Shafizadeh, S. and Kavanagh, J.A. 2005 Pathogenicity of *Phytophthora* species and *Pythium undulatum* isolated from *Abies procera* Christmas trees in Ireland. *Forest Pathology* **35**: 444-450.

Shivas, R.G., Beasley, D.R., Pascoe, I.G., Cunnington, J.H., Pitkethley, R.N. and Priest, M.J., 2006. Specimen-based databases of Australian plant pathogens: past, present and future. Australasian Plant Pathology, 35(2), pp.195-198.

Sikes, B.A., Bufford, J.L., Hulme, P.E., Cooper, J.A., Johnston, P.R. and Duncan, R.P., 2018. Import volumes and biosecurity interventions shape the arrival rate of fungal pathogens. *PLoS biology*, *16*(5).

SIPP (1970) SIPP Newsletter 1.

SIPP (1975) SIPP Newsletter 6.

SIPP (1982) SIPP Newsletter 12.

SIPP (1987) SIPP Newsletter 17

Skilling, D., and Batzer, H. (1995) World directory of forest pathologists and entomologists. International Union of Forest Research Organizations.

Smith A. (2019) Overview, Tree Health Technical Support Inspection. Forest Operations Plant Health Seminar, 23/05/19, Greenmount College

Smith, R.M., Baker, R.H., Malumphy, C.P., Hockland, S., Hammon, R.P., Ostojá-Starzewski, J.C. and Collins, D.W., 2007. Recent non-native invertebrate plant pest establishments in Great Britain: origins, pathways, and trends. *Agricultural and Forest Entomology*, *9*(4), pp.307-326.

Spaans, F., Caruso, T. and Montgomery, I., 2018, January. The abundance and condition of hedgerow tree standards in Northern Ireland. In *Biology and Environment: Proceedings of the Royal Irish Academy* (Vol. 118, No. 3, pp. 1-17).

Speight, M.C., 1985. The extinction of indigenous Pinus sylvestris in Ireland: relevant faunal data. The Irish Naturalists' Journal, 21(10), pp.449-453.

Speight, M.C.D. and Moller, G.J., 1979. Amauronematus mundus, Hemichroa australis and Nematus brevivalvis: sawflies new to Ireland, with notes on some other Irish sawflies (Hymenoptera: Symphyta). The Irish Naturalists' Journal, pp.443-445.

Spence, N., 2020. Implementation of the GB Plant Health and Biosecurity Strategy 2014–2019 with foresight on a new strategy for 2020. Outlook on Agriculture, p.0030727020906831.

Speyer, E.R. 1914. A contribution to the life-history of the larch chermes (Cnaphaldes strobilobius, kalt.) 1. Annals of Applied Biology, 6, p.171-182.

Stendall, J.A.S. (1922) Felted beech coccus in Ireland. Irish Naturalist 31.

Straw, N.A., Fielding, N.J., Tilbury, C., Williams, D.T. and Cull, T., 2016. History and development of an isolated outbreak of Asian longhorn beetle Anoplophora glabripennis (Coleoptera: Cerambycidae) in southern England. *Agricultural and Forest Entomology*, *18*(3), pp.280-293.

Sweeney, J. and Fealy, R., 2002, December. A preliminary investigation of future climate scenarios for Ireland. In *Biology and Environment: Proceedings of the Royal Irish Academy* (pp. 121-128).

Tedersoo, L., Drenkhan, R., Anslan, S., Morales-Rodriguez, C. and Cleary, M., 2019. High-throughput identification and diagnostics of pathogens and pests: overview and practical recommendations. *Molecular ecology resources*, *19*(1), pp.47-76.

Theobald, F. 1904. The larch Coleophora or leaf miner (Coleophora laricella Hubner). Gardeners Chronicle 36, 181-182.

Torr, P., Heritage, S. and Wilson, M.J. 2007. *Steinernema kraussei*, an indigenous nematode found in coniferous forests: efficacy and field persistence against *Hylobius abietis*. *Agricultural and Forest Entomology* 9: 181-188.

Torr, P.S., Wilson, M.J. and Heritage, S. 2005. Forestry Applications, In, *Nematodes as biocontrol agents*. Grewal, P.S., Ehlers, R.-U. and Shapiro-Ilan, D.I. (eds) CABI Publishing, Oxfordshire.

Tuffen, M.G. and Grogan, H.M., 2019. Current, emerging and potential pest threats to Sitka spruce plantations and the role of pest risk analysis in preventing new pest introductions to Ireland. *Forestry*, *92*(1), pp.26-41.

Turok, J., Eriksson, G. and Russel, K. (2002) Noble Hardwoods Network: Report of the Fourth Meeting, 4-6 September 1999, Gmunden, Austria and the Fifth Meeting, 17-19 May 2001, Blessington, Ireland. Bioversity International.

van den Hoogen, J., Geisen, S., Wall, D., Wardle, D., Traunspurger, W., de Goede, R., Adams, B., Ahmad, W., Ferris, H., Bardgett, R. and Bonkowski, M., 2020. A global database of soil nematode abundance and functional group composition. Scientific Data 7, 1-8.

Wainhouse, David & Inward, Daegan & Denman, Sandra & Green, Sarah & Webber, Joan. (2016). Agriculture and Forestry Climate Change Impacts Summary Report, Living With Environmental Change.. 10.13140/RG.2.2.17378.73929.

Walsh, P.M., Nash, D.W., Rippey, I., Rolston, E. and Tyner, A., 2013. Report on migrant and notable Lepidoptera in Ireland, 2009. Irish Naturalists' Journal, pp.89-98.

Walsh, P.F. and Mangan, A., 1977. Dutch elm disease survey, 1977. Journal, Department of Agriculture, Ireland, 74, pp.40-43.

Walsh, R., Cameron, A., Wilson, S.M. and Farrelly, N., 2017. The potential of alternative conifers to replace larch species in Ireland, in response to the threat of Phytophthora ramorum. *IrIsh Forestry*. 74 149-167.

Ward, D. and Keane, M. 1993 "Harmful organisms in forestry production" in Kavanagh, J.A. and Brennan, P. (eds.) Plant Health, Royal Irish Academy, Dublin.

Webber, J.F., Vettraino, A.M., Chang, T.T., Bellgard, S.E., Brasier, C.M. and Vannini, A., 2012. Isolation of Phytophthora lateralis from Chamaecyparis foliage in Taiwan. Forest Pathology, 42(2), pp.136-143.

Weslien, J. 1998. How much does the pine weevil damage cost? (Vad kostar snytbaggeskadorna?) *Kunglige Skogs-och Lantbruksakademins Tidskrift* 137: 19-22.

Westgarth-Smith, R., Leroy, S., Collins, P. and Harrington, R. (2007) Temporal variations in English populations of a forest insect pest, the green spruce aphid (Elatobium abietinum), associated with the North Atlantic Oscillation and global warming. Quaternary International, 173–174, 153-160

Williams C.D., Dillon A.B., Girling R. and Griffin C.T. 2013a. Organic soils promote the efficacy of entomopathogenic nematdoes, with different foraging strategies, in the control of a major forest pest: a meta-analysis of studies to date. *Biological Control* 65: 357-364.

Williams C.D., Dillon A.B., Hennessy R., Mc Namara L., Harvey C.D. and Griffin C.T. 2013b. Control of a major pest of forestry, *Hylobius abietis*, with entomopathogenic nematodes and fungi using eradicant and prophylactic strategies. *Forest Ecology and Management* 305: 212-222.

Wingfield, M.J., Slippers, B. and Wingfield, B.D., 2010. Novel associations between pathogens, insects and tree species threaten world forests. New Zealand Journal of Forestry Science 40 suppl. (2010) S95-S103

Wingfield, M.J., Slippers, B., Roux, J., Wingfield, B.D. 2001 Worldwide Movement of Exotic Forest Fungi, Especially in the Tropics and the Southern Hemisphere. Biosecince 51: 134-140.

Wormald, H., 1931. Bacterial Diseases of Stone Fruit Trees in Britain. III The Symptoms of Bacterial Canker in Plum Trees. Journal of Pomology and Horticultural Science, 9(4), pp.239-256.

Yde-Andersen, A. (1979) Host spectrum, host morphology and geographic distribution of larch canker, *Lachnellula willkommii*. A literature review. European Journal of Forest Pathology, 9: 211-219.

Zeng, Q.Y., Hansson, P. and Wang, X.R., 2005. Specific and sensitive detection of the conifer pathogen *Gremmeniella abietina* by nested PCR. *BMC microbiology*, *5*(1), p.65.

Zvereva, E.L. and Kozlov, M.V., 2006. Consequences of simultaneous elevation of carbon dioxide and temperature for plant–herbivore interactions: a metaanalysis. *Global change biology*, *12*(1), pp.27-41.