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When the Bough Breaks: How Do Local Authorities in the UK Assess Risk and Prepare a Response to Ash Dieback?

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Abstract: Ash dieback *Hymenoscyphus fraxineus* (T. Kowalski), is an alien fungal disease probably introduced to Europe from Asia that currently presents a significant threat to native ash (*Fraxinus* L. spp.). In the United Kingdom a large proportion of ash trees are found outside of woodlands. This means that a wide diversity of land owners and managers are stakeholders in the response to ash dieback. Local authorities (local government units) hold responsibility for managing ash trees along the highways and other public sites, with a focus on maintaining public health and safety. Developing local action plans (LAPs) for ash dieback is promoted by the government as way for local authorities to plan an effective strategic response at a landscape scale. However, risk assessment frameworks and the knowledge about ash dieback that is needed for quality decision-making at this level is still lacking. The scientific uncertainty around ash dieback progression, mortality rates, and the hazards presented by the trees at different stages of infection present knowledge problems. The research aims to (i) develop and evaluate an approach to addressing ash dieback suited to local authorities across the United Kingdom, and (ii) address the research gaps surrounding the local authority approaches to risk assessment and overcoming "knowledge problems." Our hypothesis is that action research can be used to develop an effective risk assessment framework and knowledge tools that can improve decision-making. Our research questions in support of these objectives are: (i) How do local authorities perceive, assess, and plan for risks? (ii) What information and knowledge do local authorities need to assess and manage the specific risks of ash dieback? Lastly, (iii) what processes drive the local authorities toward preparing and implementing LAPs? Data collection occurred between 2015–2019 and included: deliberative co-production and validation workshops, two survey questionnaires, and evaluative semi-structured interviews (SSIs). Local authorities were shown to assess risk and proportionality of response to ash dieback through processes of deliberative social learning mixing opinion, scientific and practice-based knowledge to reach a consensus over the methods and knowledge that would be used in decision-making. Placing ash dieback on corporate risk registers that cut across the multiple departments dealing with the problem facilitated political approval, action planning, and budget allocation. Generating locally specific knowledge and finding the resources and personnel to drive forward strategic planning and implementation were key to landscape scale responses and ratifying LAPs. Collaborative action research working on ways of assessing, learning, and responding to tree pests and diseases offer an important approach to problem-solving and developing responses at the landscape scale.

Keywords: ash dieback; risk assessment; knowledge problems; social learning; tree health; biosecurity; trees outside forests

1. Introduction

1.1. Ash Dieback as a Threat to Trees in the UK

Climate change and globalization are increasing the threats to tree health, including the accelerating global emergence and spread of novel and invasive tree pests and diseases. In Europe the number of these emerging pests and diseases is increasing [1–6]. What is commonly known as ash dieback is one such threat affecting the European ash (*Fraxinus excelsior* L.) and narrow-leaved ash (*Fraxinus angustifolia* Vahl.) [7]. The fungal pathogen responsible for ash dieback *Hymenoscyphus fraxineus* (T. Kowalski), is believed to have been introduced from Asia. It was first noticed in Poland in the 1990s, and has moved across much of the European continent from east to west, causing significant crown dieback and tree mortality [8,9]. Studies suggest that natural resistance or tolerance to the disease in *F. excelsior* is low [10,11], so mortality is likely to be high, with significant knock-on ecological impacts because of the tree's keystone species status [8,12,13]. However, there is a high degree of uncertainty about these issues. The likely rates of mortality vary quite significantly, with a pan-European study of woodland and plantation trees estimating between 50%–75% [14], and other individual country studies reporting higher and lower estimates [15,16]. The impact of the disease in urban areas where trees tend to be under greater biophysical stress is poorly understood [17]. The condition of surviving trees, the potential impact of secondary infections, e.g., *Armillaria mellea* (Vahl) P. Kumm., and the increased risk of "tree failure" [9,14,18,19] is still under investigation.

The disease is believed to have reached the United Kingdom (UK) around 2004/05 probably via two different pathways [20], i.e., natural movement via the wind, as well as a commercial pathway through the pan-European supply chain. However, *H. fraxineus* was first identified in Britain in 2012 in southern England on nursery stock that had been imported from the Netherlands [21]. At this point the Forestry Commission and other government agencies undertook national surveys and established an extensive surveillance programme to map the extent and spread of the disease [20,22]. By April 2019, *H. fraxineus* had been recorded in 54.5% of the United Kingdom's 10-km monitoring grid squares, including 70% of those in England [23]. However, there is significant regional variation in the recorded rates of dieback and levels of mortality. This may be due to differences in site conditions, as well as differences in the genetic heritage of ash trees in different parts of the country [15]. Therefore, the situation that has developed in the south and east of England where the disease was first encountered, and where the damage caused by ash dieback is now quite significant, may not provide a reliable model for the rest of the United Kingdom [15].

1.2. Local Authorities as Risk Managers

The potential scale of ash dieback represents a serious issue for land managers across Britain, not just foresters and woodland owners. Ash woodland makes up on average 5.4% of the woodland cover across the United Kingdom, and up to 11% in England. Ash are the second most common tree outside of woodlands (after oak *Quercus* L. spp), and account for 17% of the important veteran trees [24]. Between 27–60 million planted and wilding ash trees are thought to exist in hedgerows, roadsides, brownfield, and other urban sites [25]. The location of non-woodland ash trees along the infrastructure corridors is significant: Highways England estimated that there are at least 4 million ash trees next to their strategic road network; and Network Rail estimated that there are 400,000 large ash trees adjacent to the national railway infrastructure [25].

It is the distribution of ash trees and their numbers in and outside of woodlands which presents a novel and problematic situation. A far wider group than traditional forest managers are implicated in the response to the disease. Among these are the 408 local authorities, the units of local governance in the United Kingdom. Local authorities range in size from 2.9–25,650 km^2 and are organized in various forms, including Unitary, County, Borough, and District Councils. Local authorities have a responsibility to maintain transport and other important infrastructure, areas of high conservation value and amenity sites with significant public access. Consequently, they have legal obligations to

manage the risks and hazards associated with ash dieback. For local authorities of significant spatial extent and high numbers of ash trees, this presents significant challenges. A preliminary assessment of the cost of managing ash dieback in the United Kingdom sets it at around £15 billion and attributes the largest operational portion to roadside and urban safety felling, much of which falls within local authority responsibility [26]. This emphasizes how far local authorities are likely to bear the risks, hazards, and costs of managing ash dieback, and how their response decisions are likely to have significant economic, ecological, and aesthetic impacts.

Experience with tree health threats in the United Kingdom suggests that government policy and stakeholder action pass through various stages. Early stages attempt to control, remove, or slow the spread of the threat, and, if unsuccessful, a management phase follows [27,28]. Policy response to ash dieback has now moved to management and adaptation [24]. The United Kingdom Government's Tree Health Resilience Strategy (THRS) [29] sets out goals for resilient treescapes, and suggests land managers adopt a risk-based approach to action to lessen the hazards and impacts of ash dieback [30]. Although not mandatory, the THRS [29] also suggests local authorities should be developing local action plans (LAPs) to structure their spatially strategic risk assessments and response.

Local authorities are known to be reactive and formulate defensive, strongly risk averse strategies to deal with issues of public safety, particularly where these relate to trees [31,32]. They generally have a well-developed system of tree risk identification, assessment, and response [33]. This is used to formulate tree risk management plans (TRMPs) and site-based monitoring and treatment plans, underpinned by a framework of legal instruments [34,35]. Local authorities employ these systems differently depending on: The level of available resources they have for tree and woodland management; the value they place on trees in the landscape; and whether authority areas are mainly urban or rural.

However, these TRMP and site-based risk management systems were not designed to meet the landscape scale challenges of ash dieback. Ash dieback requires a landscape scale approach because of the numbers of trees and the geographical extent of ash tree distribution. For example, Devon County Council has the responsibility for more than 12,000 km of highways with an estimated 447,639 ash trees within falling distance of roads [36]. The existing risk management systems do not necessarily help in situations where local authorities need to deal with a complex and interconnected system of public and private land ownership and risk management responsibility between neighbors. Nor do they present systems which balance the long-term ecological, socio-economic, and cultural impacts of short-term management actions over wide spatial areas. In addition, uncertainty about the best way to respond to ash dieback in these circumstances is driven by a fast-evolving epidemiology and developing scientific knowledge base about the features of the disease and appropriate hazard management.

1.3. Approaches to Understanding Risk in Decision-Making

How local authorities perceive and react to the risks presented by tree diseases at such a significant scale as ash dieback is poorly researched. There is some work which applies the amplification of risk framework (SARF) [37–42]. This shows that media attention, social networks, and politicized judgements about the level of public concern about ash dieback have raised the profile of the disease and amplified the perception about the need for action to be taken. Risk managers are responding not only to the hazard itself, but to public expectations and the social acceptability of the proposed interventions [38,43]. This situation complicates the communication between policy-makers, scientists, and local authority risk managers trying to deal with the problem, particularly where the expert risk perceptions are "heterogeneous and dynamic" [38] (p. 177).

In summary, local authorities find themselves with a strong need for reliable knowledge to formulate their response to ash dieback. However, some of the information they require is absent, and the scientific understanding of ash dieback is constantly developing. There is therefore a high degree of uncertainty among local authorities about what scientific evidence to apply. Insights from other risk management decision studies would suggest that these "knowledge problems" can be characterized as having particular features [44]. These include: (i) Knowledge is intricate, i.e., there are multiple lines of

information and evidence available or required, and more than can easily be processed; (ii) knowledge is equivocal, i.e., there are competing hypotheses and models of the problem; and (iii) knowledge is ambiguous, i.e., there is a lack of an appropriate risk model to aid interpretation of information. These knowledge problems are exasperated by the generally low value placed on trees [45], and a situation where the benefits, e.g., ecosystem services or enhanced property values, are accrued by local authority departments with little or no responsibility for trees. The challenge then is for the development of a risk assessment framework that can improve the quality of decision-making around these knowledge problems and associated limitations. This is not straightforward. Developing and using risk assessment techniques may represent intrinsic risks to local authority managers. The levels of deliberation and transparency needed may introduce politically and socially charged risks and conflicts. Indeed "a risk-averse attitude toward certain innovations may appear wise, particularly when managers adopt decisions in a procedurally rational way, e.g., assessing trade-offs among long and short-term risks." [44] (p.39).

1.4. Action Research as a Theoretical and Practical Approach to Tree Health Problems

Internationally there is a move toward employing methods based on multi-stakeholder collaborative and social learning processes in forestry and other environmental domains dealing with large scale, risky, and intractable issues exhibiting such "knowledge problems" [46–48]. Participatory action research (PAR) is one such approach. PAR can be characterized as "an orientation to (scientific) inquiry that seeks to create participative communities of inquiry in which qualities of engagement, curiosity, and question are brought to bear on significant practical issues" [49] (p.1). PAR has been suggested as a route to overcoming knowledge problems by actively involving both researchers (with scientific knowledge) and stakeholders (with practice-based and contextual knowledge) in "relational, collaborative learning processes with experiments that provoke future learning" and the co-production of problem-focused, impact-oriented knowledge [50,51]. Within PAR, co-production is "not just about advancing scientific understanding or theory, but launches from the assumption that scientific knowledge combined with others' knowledge is itself a powerful agent of change" [52] (p.107). Knowledge produced through PAR has been shown to increase the uptake and application by stakeholders, as well as promoting internal and cross-institutional learning transforming the management of environmental risk [47,53].

1.5. Research Objectives

Our objectives are to (i) develop and evaluate an approach to addressing ash dieback suited to local authorities across the United Kingdom, and (ii) address the research gaps surrounding local authority approaches to risk and overcoming "knowledge problems." Our hypothesis was that PAR could be used to develop an effective risk assessment framework and knowledge tools that improved the decision-making. Our research questions in support of these objectives are: (i) How do local authorities perceive, assess, and plan for risks? (ii) What information and knowledge do local authorities need to assess and manage the specific risks of ash dieback? (iii) What processes drive the local authorities toward preparing and implementing LAPs? Testing our hypothesis, we also aimed to comment on the effectiveness of collaborative approaches to knowledge production for tackling complex environmental management problems such as large-scale tree disease outbreaks.

2. Materials and Methods

2.1. Study Population

The research process was led by The Tree Council (an NGO), and Fera Science Limited (formerly the Food and Environment Research Agency). The PAR started in 2014, and resulted in a co-produced toolkit to help local authorities in the United Kingdom produce LAPs, launched at the end of February 2019 [36]. PAR was undertaken during the early stages of ash dieback, i.e., within 5–10 years of the initial policy

response. The process involved local authorities, NGOs, and scientists and other professionals. Local authorities involved in the action research process were self-selecting, depending on their willingness and ability to take part in an extended period of collaborative engagement. This is usual with PAR processes. Most authorities were from the south and east of England. These local authorities were keen to start developing LAPs because of the progression of ash dieback and the extent of the ash tree resource in their landscapes. Local authority personnel involved included strategic decision-makers and budget holders, senior team managers, as well as those working at an on-the-ground operational level, e.g., Tree Officers.

2.2. Data Collection and Analysis

The action research process followed a series of steps, namely:

1. Scoping phase—involving initial contact with local authorities and a period of fact finding.
2. Co-production phase—focused on deliberation, knowledge exchange, and collaborative design of risk assessment and risk management tools.
3. Validation and evaluation phase—involving an assessment of the co-design process and the validity, utility, and transferability of the knowledge products and toolkit to other local authorities.

Evidence and data collection methods and the numbers of local authority staff involved varied depending on the step in the PAR process as shown in Table 1.

The scoping phase involved a series of meetings with local authorities and a questionnaire survey (see Supplementary File 1). The meetings were initiated by the Tree Council. The purpose was to recruit local authorities into the PAR process and establish a basic understanding of their governance structures and their fundamental knowledge problems. Local authorities therefore elected to take part in the process.

The scoping survey was designed to provide baseline data about local authority knowledge needs and issues. It was deployed in 2015 using the Tree Council database of local authority contacts. The 2015 survey included 21 predominantly closed questions, investigating perceived institutional awareness and preparedness for ash dieback, decision-making responsibilities for ash dieback at strategic and operational level, and the key barriers to action. The questions were developed by the research team and in consultation with the Department for Environment, Food and Rural Affairs (Defra), i.e., the government department with primary responsibility for tree health and the THRS.

The co-production phase included formal meetings and workshops. These were deliberative and focused on sharing risk perspectives, the latest scientific knowledge about ash dieback, and identifying knowledge gaps and risk assessment approaches that local authorities felt had potential for overcoming barriers to developing LAPs. The PAR process was iterative and responsive to local authority demand. The degree of engagement therefore varied. Between one and five co-production encounters were organized depending on the local authorities concerned. The Tree Council was always present, and the number of other scientists and researchers involved varied depending on the knowledge problems being discussed.

The validation phase involved meetings as well as workshops, some of which were linked to the launch of the toolkit. These encounters involved discussion about local authority needs and the suitability of the risk assessment tools developed. Semi-structured interviews (SSIs) were undertaken with purposively selected local authority personnel. The SSIs included evaluative questions assessing the action research process, the utility of the risk assessment framework, and the key drivers in the decision to produce and approve a LAP (see Supplementary File 2). The SSIs were either conducted in person or over the phone and lasted between 45 and 90 minutes. In addition, a second survey was developed as part of the validation process to investigate knowledge and information needs and how far the toolkit had serviced those requirements (see Supplementary File 3). Distributed during the validation workshops in 2018/2019 the survey did not include the same sample as in 2015. The validation survey used 11 closed and multiple-choice questions, some using a five-point LIKERT type response scale.

Table 1. Sources of evidence and numbers of participants in the participatory action research (PAR) process with local authorities between 2014–2019 (n = the numbers of local authority staff involved).

Local Authority Area	Region	Incidence of Ash Dieback at Time of Research	Year(s)	1. Scoping Phase	2. Co-Production Phase	3. Validation and Evaluation Phase		
				Survey Responses	Workshop Participants	Workshop Participants	Semi-Structured Interviews (SSI)	Survey Responses
Tree Council database	UK-wide	Low-Moderate	2015	97	–	–	–	–
Somerset	South West	Moderate-High	2019	–	37	–	–	7
Devon	South West	Low	2014–2018	–	43	–	5	–
West Sussex	South East	Low-High	2014–2018	–	12	–	1	–
Kent	South East	Low-High	2014–2018	–	17	–	1	–
LTOA [1]	London	Low	2016–2018	–	11	–	3	–
Norfolk	East of England	Moderate-High	2014–2018	–	2	–	–	–
Suffolk	East of England	Moderate-High	2014–2018	–	1	–	–	–
Leicestershire	East Midlands	Moderate-High	2016–2018	–	14	–	6	–
MTOA [2]	East Midlands	Low	2019	–	–	35	–	31
Herefordshire	West Midlands	Low	2014–2018	–	52	–	2	–
Lincolnshire	North East	Low	2017	–	21	–	2	–
NWTHG [3]	North West	Low-Moderate	2019	–	–	50	–	40
South Wales	South Wales	Moderate	2019	–	–	90	–	83
		TOTAL		97	258	175	20	161

[1] LTOA–London Tree Officers Association, a membership organization for Tree Officers from all of London's local authorities. [2] MTOA–Municipal Tree Officers Association, a membership organization for Tree Officers from all municipal local authorities. [3] North West Tree Health Group, forum for all land managers dealing with trees and forests, including but not exclusive to local authorities.

Data collection during the co-production and validation workshops relied on facilitator workshop notes and synthesized internal project reports, as well as digital recordings of discussions which were transcribed verbatim. The SSIs were all digitally recorded and transcribed verbatim. Nvivo 12 qualitative analysis software was used to analyze the transcripts from the co-production and validation workshops and the SSIs. This was done using a deductive thematic method [54] based on manual and digital coding. Content analysis was used to interrogate the qualitative data and identify emerging themes and sub-themes [55]. Themes and sub-themes provide a common point of reference and have a high degree of generality around the ideas, issues, and concepts of greatest importance and saliency among research participants [56,57].

Analysis of the questionnaire data was using Excel and SPSS (version 19) to produce descriptive statistical summaries of the main trends. Read across between the two surveys carried out at different points in the PAR process was maintained through a core set of seven questions.

3. Results

3.1. Risk Perception, Assessment, and Planning

A major theme to emerge from the qualitative data collected through the scoping, co-production, and validation phases, was the importance of personal experience of ash dieback in the local area. Observable and felt impacts of ash dieback were the factors driving the risk perceptions of local authority staff, and their initiation of risk-based assessments and actions. Therefore, the development of operational and strategic level responses was reactive based on the obvious visual indicators. There was no evidence of proactive preparedness or testing for the asymptomatic presence of the disease. Awareness of ash dieback and local authority willingness to respond, consequently lagged behind the progression of the disease. The following comments were typical:

"ever since 2012, it's been difficult to get people to take it seriously, because they couldn't see it. Now it's everywhere, so it's sort of, seeing is believing" (SSI. Local authority senior operational team manager, south east England, 2018)

"at that time, going back those years, people were very skeptical . . . [there was a feeling that] . . . there was no such thing as ash dieback, it was a European problem and not a UK problem . . . then it started to turn up on their doorsteps and then the penny dropped" (Validation workshop. Local authority Tree Officer, south west England, 2018).

A second theme to come through the data was the fragmented nature of decision-making linked with trees. Local authorities described significant variation in their internal organization, but all local authorities reported that those responsible for making decisions about ash trees sit across several different departments, e.g., highways, parks, environment, and waste management. This is because ash trees exist in so many locations across the local authority risk management landscape. Issues of particular financial and political significance are decided by the elected cabinet members. The cabinet make corporate level strategic decisions about the direction of policy and the allocation of local authority resources. They are linked to departmental staff through senior management teams and cabinet committees. This means there is a certain degree of institutional separation between risk managers operating at different governance levels, and within different departmental realms (see Figure 1). Consequently, there may be more than one risk assessment and decision-making locus for ash dieback within a single local authority.

The consequence of this is differential risk perception and politicized decision-making. Slow reactions, under-reactions, and over-reactions were all described as outcomes. For example, some operational managers described an "over-reaction" in terms of perceptions of the problem, i.e., that all ash trees will be affected evenly and that all trees may require intervention. In contrast, local authority staff clearly described a significant "under-reaction" in terms of engaging cabinet members and budget holders, who did not properly appreciate the potential scale of the hazard and risks to their authorities. The cross-departmental nature of ash dieback acted as a barrier to communication, and to

the action needed to generate a single coordinated local authority risk-based response appropriate to the landscape scale nature of ash dieback. The 2015 scoping phase survey illustrates this in the results that 86% of the local authority staff (n = 97) ranked tree safety the highest priority, and 94% ranked developing an organizational strategy for ash dieback the lowest.

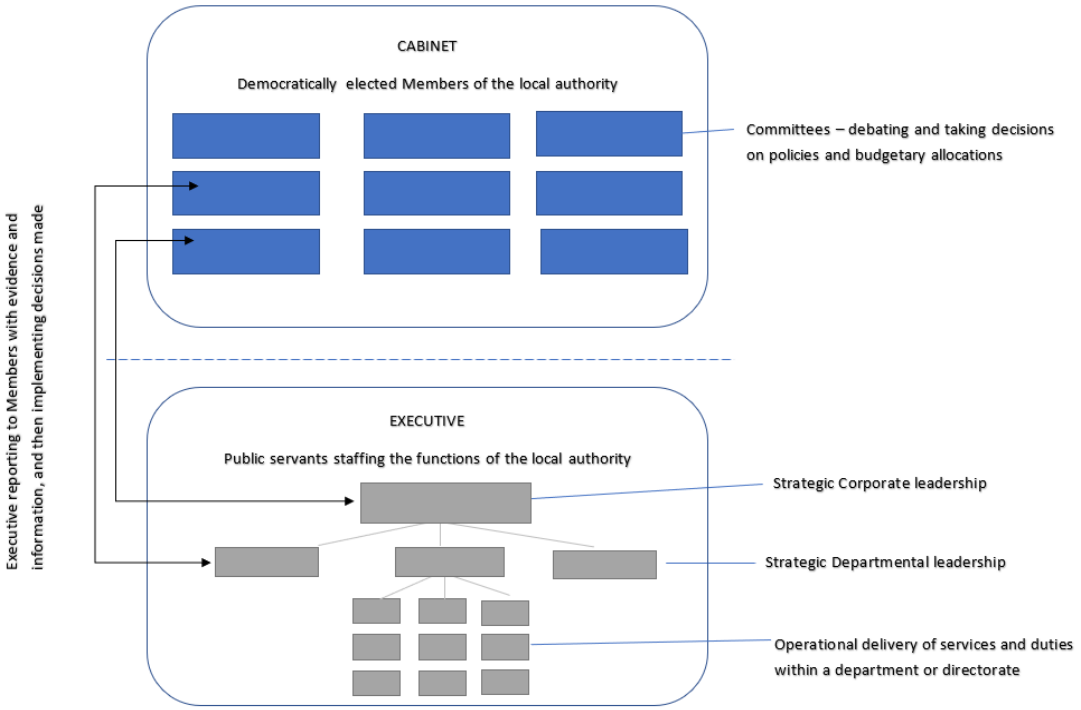

Figure 1. Stylized local authority organizational structure relevant to risk management decision-making.

Continuing to work through risk perceptions as part of the co-production phase of the PAR, what emerged from debates was a clear hierarchy of risk types. Local authority staff in the different meetings discussed and agreed upon the importance of hazards by placing them in rank order. Averaging ranks across the data the order of importance was: (i) Corporate risk, i.e., risks that may affect the ability of the authority to achieve corporate objectives; (ii) health and safety risks; (iii) economic and financial risks; (iv) reputational risks; and (v) risks in maintaining biodiversity including landscape connectivity. These risk types were linked with local authorities' statutory functions and service delivery duties, and to wider legal liabilities. Articulating the conceptualization and language of risk assessment within existing corporate systems and establishing the hierarchy of risk, enabled the co-production of an ash dieback risk triage and assessment system which incorporated these perspectives. The framework was designed to be used by local authorities to structure their deliberations about the degree of risk from ash dieback and appropriate levels of response [36].

Having identified corporate risk as the most important category, local authority staff and the Tree Council tested methods to locate ash dieback within corporate risk registers (CRR). A risk triage framework was developed to do this which was built on existing local authority methods. Once on the CRR ash dieback was elevated from a site-based operational issue to a risk requiring strategic cross-departmental response at the center of political governance. It was the acknowledgement of risk at this level which also triggered the development of LAPs. For example, Leicestershire County Council's Environment and Transport Departmental Management Team sat to consider the risks and implications of ash dieback during 2017. Included in the deliberations were representatives from other departments including, finance, property services, insurance, the transformation unit, and human resources. An ordered discussion using the risk triage framework considered both likelihood of risk and impact of risk. Using the framework made explicit the implications of the disease and facilitated

the escalation of ash dieback as an issue for the corporate management team to consider adding to the council's corporate risk register.

In Leicestershire as well as other local authorities, internal deliberation to reach a consensus about the best course of action, relied not only on the opinions of staff, but also on using a mix of scientific and practice-based knowledge from a variety of sources including the PAR. Operational staff across departments needed to generate and agree on hypotheses about the likely outcomes to present a clear level of risk and course of action to decision-makers:

"we had to test our approach to the risk, where on the spectrum we were as an authority, whether we were to cut it all down or leave it all, debate it at Officer level to get to the appropriate answer with reasoning, and then we went to Members to kind of almost sound out were they comfortable with that approach." (SSI. Local authority, departmental manager, east of England 2018).

One element of corporate risk assessment that proved to be a critical knowledge challenge, was assessing the potential costs of managing ash dieback and what impact this would have on central budgets. In the 2015 scoping survey 94% of local authority respondents (n = 97) said they had not calculated the costs of dealing with ash dieback, and 70% said that they were unlikely to have the resources to cope with the disease. In the 2019 validation survey, 82% of local authority respondents (n = 161) said they would not have the resources required to deal with ash dieback, and 91% of them felt additional financial support from central government or elsewhere was critical to enable their effective response. Uncertainty about some of the key variables required to best assess the financial risk of ash dieback was described as a particularly significant barrier to establishing financial risk.

Currently local authorities in the United Kingdom have a considerably reduced budget from the central government, but additional responsibilities are being devolved from central to local authority level. With significant and competing demands on budgets, allocating substantial sums to the management of trees is a politically sensitive issue for cabinet members. Discussions during the co-design phase revealed the importance of approved and published local authority tree strategies. These are policy documents describing the strategic corporate vision for trees and tree-filled landscapes within a local authority area. Tree strategies provided a justification for landscape scale response and management of ash dieback as part of the local authority's core policies. They were an additional tool helping to place ash dieback onto CRRs and generate a strategic corporate response. Results from the 2015 scoping survey reinforce this view, since 91% of local authority respondents (n = 97) agreed that tree safety management at strategic and operational level was the most important set of policies to flow from tree strategies. However, responses from the same scoping survey showed that although around two-thirds of local authorities in the sample (n = 97) had a tree strategy, many of these were neither up to date nor active.

3.2. Knowledge Needs, Gaps, and the Generation of New Knowledge

During the scoping and co-production phases, local authorities agreed that their specific priorities were to generate knowledge that could help with better quality risk assessment and decision-making around the five types of risk in their hierarchy. This required generating information and knowledge that had not been the traditional focus of corporate tree safety assessments, nor traditional forest science. Estimating the spatial extent and severity of ash dieback required basic data about the location and number of ash trees, the health status and condition of those trees, and the rate of progression of ash dieback across a landscape. Data collection methods needed to be easy to apply and quick to generate information. Methods and results also needed to be open to critical deliberation by local authority staff in their assessment of risks and costs. A strong theme among participants was the importance of pragmatism in evidence generation and the acceptability of "good enough" information, rather than high levels of scientific certainty in the data and interpretation. As some people expressed it:

"we understand there is much research going on, that the information is changing all the time, we tend to use what we can at the time, but we don't rely on any of it as 'certain,' the evidence gets talked about and argued over" (SSI. Local authority, departmental manager, south east England 2018).

"we have had to make a lot of assumptions, but even though the evidence is not that credible in places, we have just had to press on with something rather than nothing" (Validation workshop. Local authority, operations manager, south Wales 2019).

These practical considerations did not rule out the generation of scientifically robust data. In one local authority for example, the specific institutional structure used to respond to ash dieback followed an emergency response "command and control" approach. This included a standing Scientific and Technical Advice Cell. This provided the opportunity for the co-production of scientific data with universities and research agencies, as they explained:

"I think the one thing that [mentions name of authority] has always tried to be, is rigorous about evidence and rigorous about science and understanding it, and we do not do anything unless it has been informed by some sort of rigor in the background" (SSI. Local authority, strategic corporate manager, south east England 2018).

Local authorities developed knowledge using methods appropriate to their institutional and specific physical circumstances. For example, Norfolk County Council developed and implemented a fully costed systematic tree survey methodology along the highways and non-highway (footpath and trail) routes over a three-year period. Norfolk and Suffolk councils developed their own ash canopy assessment tool (with four risk condition categories) which provided a county level overview of the extent of the disease and the degree of intervention likely to be required. Suffolk produced a Precautionary Method Statement that paid attention to the strategic and operational implications for biodiversity if removing ash trees from the landscape, giving attention to European Protected Species. Kent, West Sussex, Suffolk, and Norfolk also developed risk assessment matrices and decision-support models which enabled a risk-based proportionate response to intervention planning and implementation, prioritizing areas, sites, and individual trees for treatment rather than a blanket response and large-scale removal. Some authorities simply changed their policies around existing procedures, e.g., shortening the interval between highway tree monitoring from five or three years to two.

What emerged from workshop and SSI data collected during the co-production and validation phases, was a theme relating to the legitimacy of knowledge and information. Local authorities legitimized the information and methods generated by their own community, i.e., developed and shared by other local authorities. They responded positively to the way in which risk was framed because it included the specific local authority responsibilities for ash dieback hazards. They were comfortable implementing methodological models that built on procedures common to local authority circumstances and ways of working.

Access to information and knowledge which enables local authorities to conduct strategic risk assessments to guide action or to develop LAPs is still an issue. The 2015 scoping survey showed that 53% of respondents (n = 97) felt they "had enough information to enable them to manage the arrival of ash dieback," whereas the 2019 validation survey showed that 72% of the local authority representatives (n = 161), "very strongly" or "strongly" agreed that they "did not have the information they needed to be able to plan for ash dieback effectively at a corporate level." The 2015 questionnaire also showed that 72% of the local authority respondents (n = 97) had not surveyed their ash trees, and 67% said they had not yet made any plans to survey their ash resource. The 2019 validation survey showed a situation where 11% of local authority staff (n = 161) said they had undertaken a survey, 4% said they had estimated their ash tree resource using other available data, and 40% were working with "rough approximations." The remaining 45% still had no data about the spatial extent and numbers of ash trees nor did they have plans to survey. Participants reported a shift toward surveying and data gathering because of the realization of the scale of ash dieback around the country, and evidence of tree mortality at landscape scale. They also mentioned the awareness raising and networking among local authorities that had been prompted as a result of the PAR project. Local authority officers stated that although their awareness and access to information had increased, they perceived a continuing lack of awareness among political cabinet members about the extent and degree of risk presented by ash dieback. Part of the PAR methodology was to test whether presenting cabinet members with

information from external organizations and trusted institutions about ash dieback could change perceptions. Engaging with the cabinet proved an essential step in leveraging political acceptance of the scale and urgency of responding to ash dieback.

3.3. Processes Driving the Development of Local Action Plans (LAP)

The objective of the action research reported here, was to develop a national framework and toolkit to support local authorities produce LAPs for ash dieback. Only a small number of local authorities in the United Kingdom have currently moved forward with the development and implementation of LAPs (see Table 2). The plans are advisory and do not have specific legal standing. They are intended to support risk managers within the local authorities co-ordinate a proactive and clearly articulated response to ash dieback, and identify budget requirements for management and restoration activities. The co-production and validation phases of the PAR investigated and evaluated the factors leading to successful realization of these response strategies. Besides adequate knowledge and information for risk assessment, there were four key influences that emerged as important. The first theme was about institutional awareness and acceptance of the scale of the issue within the executive.

Table 2. Local authorities with local action plans (LAP) for managing ash dieback as of June 2019.

Local Authority Area	Region	Year Engaged in LAP Action Research Process	Year LAP Developed	Year Approved with Budget
Somerset	South West	2019	2019	
Devon [58]	South West	2015	2016	2016
West Sussex	South East	2013	2018	expected 2019
Kent [59]	South East	2012	2013	2013
Test Valley–Hampshire	South East	2019	2019	expected 2019
Norfolk	East of England	2014	2018	expected 2019
Suffolk	East of England	2015	2018	expected 2019
Leicestershire [60]	East Midlands	2017	2018	2018
East Lindsey–Lincolnshire [61]	East Midlands	2017	2018	2018
Herefordshire	West Midlands	2014	In development	

The second thematic influence was effective coordinated working between the departments and organizations. Local authorities described different ways this could be arranged. For example, Kent County Council coordinated a multi-agency "command and control" structure familiar as part of civil resilience and emergency response as the basis for the Ash Dieback Civil Contingency Emergency Plan. Devon County Council established the Devon Ash Dieback Resilience Forum as the multi-partner collaboration for developing knowledge and implementing the County's LAP. Local authority staff reported that collaborative working can help overcome some of the knowledge challenges and facilitate a coordinated response within a local authority, and between an authority and its neighbors. This can increase efficiency and reduce costs.

The third significant influence identified in the qualitative data was the question of dedicated resources. Locating ash dieback within corporate risk systems is not enough to progress the development of LAPs. Evidence from SSIs showed that local authorities that had progressed LAPs found it necessary to have a "LAP champion," somebody who could act as a dedicated risk manager able to work with the issue across corporate departments. Implementing the LAP also requires resourcing. Staff time and other resources were needed to drive and oversee the management of the LAP at strategic corporate level as well as implementing risk-based interventions at operational level. Those authorities engaged in developing LAPs had not initially considered the staffing or budget implications of progressing and implementing LAPs.

Finally, the fourth thematic factor was about linking governance functions and building effective communication and knowledge flows between the cabinet and the executive. What local authority staff reported as critical here was being able to demonstrate that ash dieback could interfere with the

delivery of statutory duties, including a significant increase in expenditure posing risks to other service delivery budgets.

4. Discussion

In terms of risk perceptions, our evidence suggests that moving from a state of awareness about a serious threat to trees, to a state of proactive behavior at a local authority level, relies on individual staff experiences of those threats in the local context. Insights from other behavioral science and climate change studies support this finding. They show that knowledge and information about a hazard is less likely to promote a response than actually experiencing that risk [62–65], and even where a "focus event" such as landscape scale visible dieback of trees raises the salience of an issue, habitual behaviors, social norms, and established ways of thinking may mitigate against developing a proactive response [62,63,66,67].

The results show that the development of risk assessment methods and LAPs was not only about the acceptance and generation of appropriate knowledge. It was also about how the issues and knowledge problems were framed. Framing refers to the ways in which problems are defined, causes diagnosed, judgments made, and remedies suggested [68] (p.279). How tree disease outbreaks are framed at local governance level seems to be an important requirement for action. As soon as local authorities found a way to define ash dieback risk using familiar corporate risk concepts and systems, they were able to develop their responses. However, framing ash dieback in this way seemed to perpetuate the language of risk around trees, and a perception of trees as liabilities rather than assets. Even though the level of public goods delivered by trees is high, particularly in urban and peri-urban contexts [45,69], persuading the cabinet members that a tree issue required budget allocation at all, was dependent on proving the scale of potential corporate liability.

Evidence from the evaluative SSIs showed that the action research process helped to facilitate deliberation within the local authorities as well as between different local authorities and external partners. This highlighted the importance of communication and deliberation between different internal departments within local authorities. The value of legitimate information and legitimate messengers was important. Local authorities were seen to be persuaded by and use evidence from people or organizations (including other local authorities), recognized not only for having scientific and practice-based knowledge of ash dieback, but also understanding local authority contexts. These interactions were social learning processes, where the most appropriate ways to collect and apply missing information and knowledge were negotiated and agreed upon.

It has been suggested that "the key to social learning is effectively engaging the necessary participation of system members in contributing to the collective knowledge of the system, and in generating policy choices" [70] (p. 613). This finding is a contrary view to the debates about risk, experimentation, and testing of suitable risk management approaches presenting unacceptable reputational risks to local authority managers [44]. Our research indicates that social learning was an ongoing process which evolved as the knowledge and risk context around ash dieback also changed. Sustained interactions within and between local authority departments, as well as with external stakeholders, enabled reassessment of the quality of information shared. It also enabled adaptation of risk assessment processes as new information was generated and new experiences shared. Our results point to social learning as a critical process in dealing with the uncertainty and the significant, complex risk profile of a tree disease threat such as ash dieback. Researchers and practitioners have for some time advocated social learning as the most appropriate way to address the complexity and uncertainty of natural resource management across a range of different environmental contexts, particularly as learning, knowledge-making, and policy-making have become increasingly related and intertwined [66,71–73].

5. Conclusions

Climate change and the continuing processes of globalization mean that the risks associated with the movement and arrival of novel and alien tree pests and diseases may increase in all regions of the

world. Effective control and prevention of tree pests and disease is not likely to be achievable over the long term other than for a minority of organisms, particularly in relation to the current regulatory framework for the horticultural trade which favors trade over biosecurity [4,74]. We draw three key conclusions from our research in response to these problems.

The first is that a range of stakeholders need to be included in the response. Tree pests and diseases threaten trees across rural and urban landscapes, not just within woodlands and forests. Scientists and policy-makers need to actively acknowledge the operating contexts and knowledge needs of this broader set of stakeholders, particularly those who manage trees in environments outside of traditional forestry.

Second, collaborative action research that works on ways of assessing, learning, and responding to tree pests and diseases offer an important approach to problem-solving and developing responses. Collaboration not only engages a wide range of stakeholders, the social learning it encourages builds the possibility for speedy and adaptive governance and action by moving away from traditional models which wait for science to disseminate answers later applied in practice. Action research and co-production may contribute as processes of transformation [52] that build on the "socio-political parameters" surrounding tree pests and diseases, improving "the chances of successful action/policy" [75] (p.1954). Further research investigating the potential for methods of social learning to accelerate responses to tree health issues seems essential.

Finally, we conclude that social learning is necessary, but it is not the only thing required for landscape scale, multi-habitat management of tree health issues. Other aspects are also important including organizational capacity, processes, and structures. Processes and structures that focus on the risk aspect of pest and disease management may move stakeholders to action. However, emphasizing a view of trees as liabilities rather than natural capital assets could have consequences, for example, acting as a barrier to restoration of trees in the landscape. There is further work to be done on how the full value of trees within and outside woodlands can be demonstrated and accepted.

Supplementary Materials: The following are available online at http://www.mdpi.com/1999-4907/10/10/886/s1, S1: 2014/15 Local Authority baseline scoping survey—Ash Dieback (Chalara); S2: Interview guide for local authority (LA) stakeholders in ash dieback Action Planning 2018–2019; S3: Participant Questionnaire.

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