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Pests in the City: Managing Public Health Risks and Social Values in Response to Oak Processionary Moth (*Thaumetopoea processionea*) in the United Kingdom

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Abstract: Oak processionary moth (*Thaumetopoea processionea*) or OPM was accidentally introduced into London on imported oak trees and now poses a threat to the future of oak in the urban landscape. Early attempts at eradication of the moth failed and significant resources have since been spent by government on monitoring and controlling OPM (through the use of insecticides or bio-pesticides) as it spreads into new areas. OPM is regulated in the UK to minimize risk of new introductions and reduce spread. Surveying for OPM and issuing of statutory notices for control is based on a geographical system of core, control and protected zones. While OPM will defoliate the trees leaving them vulnerable to other pests and diseases and stress factors, the caterpillars can also harm people and animals via tiny urticating hairs with the potential for dermatological or respiratory impacts. However, the biggest threat to the iconic British oak may be that the perceived risks associated with OPM, and costs of management may lead land managers to fell their oak trees, and not plant oak in the future. There is a need to better understand awareness, risk perceptions and decision-making around OPM management. We use a conceptual framework to explore decision-making and the trade-offs between the social, economic and ecological values associated with oak trees, and assessment of risk related to both the moth and control options. Twenty nine interviews were conducted in two London boroughs and across Greater London and in some surrounding counties covering a range of land types (e.g., parks, school grounds, amenity areas and private gardens) with infested or non-infested oak. We found a lack of evidence of human health impacts from OPM although land managers were concerned about public duty of care and potential reputational damage if they do not manage OPM. To address the challenges of dealing with OPM, land managers were taking a risk-based approach and managing OPM where it posed the highest potential risk to people. Respondents expressed strong emotional attachments to oak but it also has high biodiversity value which can lead to difficult decisions about management options. A risk-based approach moves beyond a ‘one-size-fits-all’ control method and focuses available resources where they are most needed and socially acceptable. An approach that allows for multiple values and perspectives on risk may provide a more sustainable long-term option for OPM management to ensure the future of oak in the city.

Keywords: OPM; trade-offs; values; risks; urban; tree health

1. Introduction

The parks and wooded greenspaces of the United Kingdom (UK) are highly valued for the ecosystem services they provide [1–3]. There is evidence that in heavily built up urban areas these values may be more pronounced because the supply of such services falls below demand [4–6]. The

importance of urban parks and greenspaces providing urban populations with economic, social and health and wellbeing benefits cannot therefore be underestimated. However, invasive tree pests and diseases are increasingly impacting natural resources and the benefits and services they provide. Research on the social dimensions of tree health has provided a range of insights into the risk perceptions, decision-making and behaviors of owners and managers of woodlands and forests [7–9]. Research suggests that biosecurity actions depend on: the range of values and beliefs structuring attitudes and willingness to act or to accept pest control and management measures [10,11]; assessments of risk, how these are socially mediated and resulting trade-offs [12,13]; whether advice about control and management and the need for action is considered to be “legitimate” or come from a legitimate source [10]; a belief in the control or management option actually being effective [14]; and, being able to assign responsibility for management [15]. The potential biosecurity responses and management options open to land managers depends on the type of pests or diseases being dealt with as well as the perceived level of socio-economic and ecological risk associated with them. Although some work has been done on these issues in traditional forestry contexts, there are still gaps in our understanding of how land managers in urban areas understand and react to these risks, particularly where the public and other stakeholders are able to scrutinize and affect their decision making.

The oak processionary moth (*Thaumetopoea processionea*) or OPM, is a defoliating pest of oak that can threaten the health of trees through increased stress. OPM raises particular concerns for managers because of the potential risks the caterpillars pose to public and animal health [16,17]. Published research on the moth’s population ecology and management techniques is increasing (see for example [18]). However, there is a need to better understand awareness, experience, risk perceptions and decision-making around OPM management amongst different land managers. As an iconic British tree, oak (particularly English oak *Quercus robur* and Sessile oak *Quercus petraea*) is the most common broadleaf species in Britain and a highly valued component of the British landscape. Oak contributes significantly to the survival of native flora and fauna as well as the provision of other important ecosystem services such as carbon storage, recreational and amenity values [19]. The widespread distribution of oak trees includes urban areas. For example, there are nearly one million oak trees in London although they are not evenly distributed across the city. Amongst native British trees, the oak holds specific and important cultural, symbolic and emotional value and is linked with national myths, historical stories, as well as the country’s political and economic history (see for example [20]). There is widespread concern in the UK over threats to oak from a number of pests and diseases. Acute oak decline (AOD) and OPM are among the most important. Initiatives supported by policy makers, such as Action Oak [21] aim to encourage more owners, managers and wider publics to engage with, and care for, oak trees and woodlands [19].

1.1. Distribution and Policy Response to OPM in Britain

OPM is native to central/southern Europe but has been extending its range across central and northern Europe, specifically northern France, Germany, Netherlands and the UK: This may be in response to climatic changes [17,22]. The history of the introduction of OPM into the UK is similar to other pests and diseases such as ash dieback (caused by *Hymenoscyphus fraxineus*) and Asian longhorn beetle (*Anoplophora glabripennis*) where the organisms were brought in through international plant trading networks. OPM was accidentally introduced via imported oak, to areas of the southeast of Britain in 2006, with two London boroughs initially affected [15,17]. Recommendations for managing OPM effectively, involve insecticide spraying (most commonly using *Bacillus thuringiensis* or BT) of oak trees and/or nest removal. Early attempts to eradicate the pest which were unsuccessful [15]. The distribution has increased as the moth has continued to spread further outwards into new peri-urban and rural areas, but up until spring 2019, OPM was still largely confined to Greater London and in some surrounding counties (see Figure 1.).

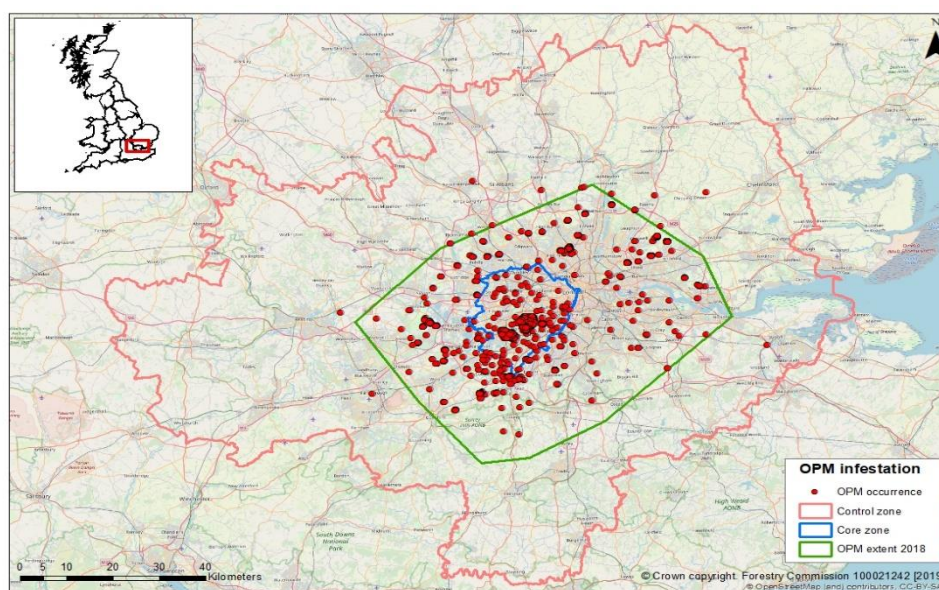


Figure 1. Map of OPM distribution and zoning areas in Greater London and in some surrounding counties. The red dots indicate OPM presence, the blue outline the core zone, red outline the control zone and the green outline the previous year's extent of OPM presence.

The OPM caterpillars are particularly distinctive as they march head-to-tail in long lines across the trunks of oaks to reach the foliage. The human and animal health risks arise from the caterpillars' thousands of tiny urticating hairs. These readily detach and can either travel some distance through wind blow or linger in the caterpillar nests and around the base of the trees. Coming into contact with the hairs or inhaling them has the potential to cause dermatological, respiratory and ocular problems [23,24]. The range of indirect impacts managers need to consider are numerous. For example, managers of publicly accessible areas with oak trees and OPM are at risk of financial losses if they close sites to avoid harm to the public, or where there is a reduction in visitors as people avoid potentially hazardous or unsightly parks and gardens [17].

United Kingdom (UK) policy approaches to OPM are focused on limiting the spread and intensity of the pest, and reducing the potential impacts on human, animal and tree health [23]. The Greater London area (and some surrounding counties) has been divided into three policy response zones (see Figure 1). The Core Zone delineates an area where OPM is well established. The focus here is on risk-based management of the pest. No government-funded control works takes place here, though support and advice is offered to land managers to undertake management themselves [23]. A Control Zone surrounds the Core Zone. The focus of government intervention in the Control Zone is on control of the pest to slow the spread, reduce the impacts of OPM, and to defend the Protected Zone. Here, Statutory Plant Health Notices (SPHNs) which are legally enforceable instruments requesting access to control OPM, are issued. Government sponsored surveys of oaks identify the presence of the pest, which is followed by treatment with an insecticide or bio-pesticide with financial support currently from the UK government for land managers. The Protected Zone effectively covers the rest of the country across areas that are currently recorded as free of OPM infestation. A zero-tolerance approach is taken in this area with monitoring programmes to survey for any new incidence of OPM and if any are found action is taken to eradicate the pest [23]. Government support for OPM control and management is coordinated and delivered by the Oak Processionary Moth Control Programme (OPMCP), which is delivered by the Forestry Commission.

1.2. Land Manager Responses to OPM

At present, it is suspected that the incidence and level of infestation of OPM in the UK has been managed to such a degree that public health impacts have been minimized [15,25]. However, this could

change if either the spread and population levels of OPM increase, or if government policy changes and the level of support (e.g., for the control OPM in the Control Zone) given to land managers declines. Researchers examined early governance and management challenges after the initial discovery of OPM in London [15]. Concerns at that time included delays in assigning statutory responsibility for agencies to take on the issue of OPM in oak trees in urban centers. Part of this delay was due to lack of clarity over whether the pest was a tree health or a public health issue. The complex mosaic of ownership that is typical in urban areas is an additional complicating factor in developing effective landscape-scale management.

The research presented in this paper highlights what motivates the choice and degree of response undertaken by urban land managers for OPM. We explore how their risk perceptions interact with individual values around the benefits associated with oak in the urban landscape. Specifically, we investigate the views of individuals from local authorities, recreation and conservation heritage organizations, businesses, private organizations, transport agencies and residents in relation to: (a) The risk posed by OPM to staff and/or visitors; (b) the values attributed to oak; (c) how these risks and values are traded off in decision making; and (d) how these trade-offs have influenced the current and intended management responses to OPM. We consider these findings and present an assessment of the social and governance implications of future responses to OPM.

1.3. Conceptualising Trade-Offs between Risk Perceptions and Values

Existing research shows that the decision-making context for land managers dealing with OPM is very complex, and there are a whole range of competing issues, individual and societal level values influencing actions. We can conceptualize these factors and the interactions between them, as shown in Figure 2. The factors likely to be influencing decision making include: features of the site being managed including the number of visitors or the vulnerability of them to potential health impacts; land managers' knowledge and understanding of OPM and what can be done to manage it; as well as the context in which they are situated, e.g., whether in the Core or Control zone, or the scale of the operation whether a private resident's garden (site-based decision making) or multiple sites managed by a local authority (strategic level decision making).

These factors will inform assessments of the risks posed by OPM and the appropriate risk management responses. Individuals and organizations will evaluate the trade-offs between the management options identified, and the impact these may have on the values associated with oak trees. Trade-offs occur when "getting more of one thing you value requires giving up something else that is also desirable" ([12], p. 462). Evidence from the literature suggests that trade-offs become increasingly difficult when they involve non-commodities or public goods, where there will be a diversity of values and views about the perceived risks [12,13]. Decision-making is complicated further when individuals or organizations are faced with uncertainty, conflicting evidence or competing goals [13]. The management of OPM raises all of these issues as there continues to be uncertainty about the degree of public health risk the caterpillars pose, population distribution and density varies year on year, and the values stakeholders attach to oak trees requires weighing up the need to manage with concerns about negative impacts of management tools which varies significantly across urban landscapes.

Predicting and evaluating subsequent trade-offs provides land managers with further consideration of whether resulting impacts of decisions taken are acceptable [26]. Choices over which management option to take could be hard for some people and potential impacts or consequences may mean that decisions are avoided entirely [13]. Weighing up the cultural and ecological values of oak trees in the urban cityscape against the risks posed by OPM could be considered a "morally challenging" decision which are often the most difficult to address ([13], p. 17). However, trade-offs are thought to be easier if certain options enhance strong moral convictions ([13], p. 20). Final decisions about what OPM management strategies to undertake will also be related to available budgets, and the scale of interventions required.

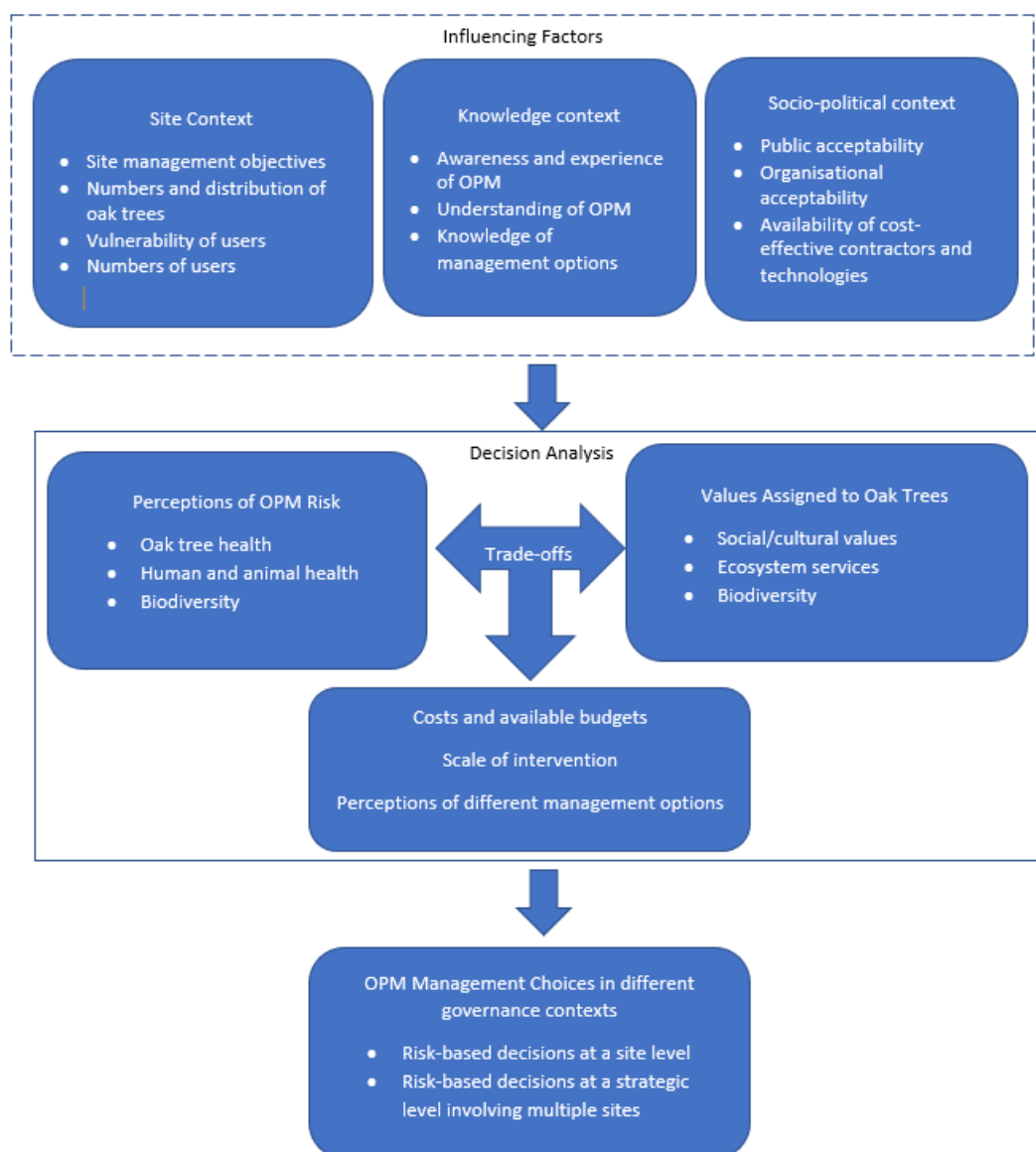


Figure 2. Conceptual Framework highlighting trade-offs between values associated with oak and perceptions of OPM risk. (a) Factors likely to influence decision-making are based around the site in question, knowledge and awareness of OPM and OPM impacts and wider socio-political contexts; (b) Influencing factors will inform assessments of risk and what is economically feasible as well as socially acceptable when considering the multiple values associated with oak trees; (c) Decisions will also be influenced by scale e.g., whether it is a single site or multiple sites of varying sizes.

2. Material and Methods

The research presented in this paper was based on the collection of qualitative data between November and December 2018. Data presented here was derived from interviews with two groups of stakeholders (Table 1): (1) Land managers and residents in two specific London Boroughs (2) land managers with experience of managing or planning to manage OPM across Greater London and some surrounding counties. All interviews used a semi-structured interview guide. Group one interviews were mostly ($n = 15$) carried out face-to-face whilst interviews for Group two were conducted exclusively over the phone. Questions across the two groups focused on interviewee role and responsibilities regarding tree health; values relating to oak; how different sites are used; knowledge about OPM; the known and perceived health impacts of OPM; attitudes to OPM risks and how these are managed; information and support required to manage OPM in the future.

Table 1. Land managers interviewed across two London Boroughs and more generally across Greater London and in some surrounding counties. They span different site and land manager types. Most had experience of OPM.

Site Type	Land Manager Type	London Borough 1 (in Core Zone)	London Borough 2 (in Control Zone)	Greater London and Some Surrounding Counties (GL)	Grand Total	OPM Present
Amenity area	Private organization/business	1			1	1
Cemetery or churchyard	Local Authority		1		1	1
Cemetery or churchyard	Private organization/business	1			1	1
Multiple site types	Local authority	1	2	3	6	5
Multiple site types	Transport		1	1	2	2
Park or public garden/visitor attraction	Charity or Trust	1		6	7	6
Private garden/residential garden	Private organization/business	2			2	0
Private garden/residential garden	Private residents		3		3	0
Private woodland	Private residents			1	1	0
School grounds	School (LA)		1		1	1
School grounds	School (private)	1			1	1
Sports grounds	School		1		1	0
Sports grounds	Private organization/business		1	1	2	2
Grand Total		7	10	12	29	20

The two London boroughs were chosen as “typical” in terms of oak abundance and distribution (See Table 1). They exhibited similar geographic characteristics with a mixture of land types that included infested and non-infested oak trees (e.g., parks or public gardens, sports grounds and amenity areas, school grounds, private gardens and cemeteries), and a range of stakeholders. However, one borough is representative of sites in the Core Zone where no financial support has been available for some time, while the other borough is located in the current Control Zone. The second set of interviews was conducted with land managers outside of the case study boroughs, across the wider London region that included the Core, Control, and Protected Zones.

Data from OPM surveys conducted by the OPMCP were used to construct the sampling frame for the interviews in the two London Boroughs. Each land-holding in the database was categorized in relation to the land manager type, site type, number of oak trees on site and the occurrence of OPM. These data were entered into a geographic information system and a selection drawn to provide a sample of land manager attributes and their geographic distribution within each of the two study boroughs. From the initial stakeholder list, 30 individuals were invited to participate in the study. Of those that responded we conducted 17 interviews with 22 land managers (two interviews included more than one person) involving six stakeholder categories and eight site types (Table 1). The additional London-wide interviews were selected from the OPMCP stakeholder database and involved 12 stakeholders covering five land manager types across five site types. Most of the sites that interviewees managed were open to the public and a greater number had experienced OPM than not (Table 1).

Informed consent was given by interviewees. All but one of the interviews was digitally recorded. The audio files were transcribed by a professional transcription service and subsequently checked for accuracy. Coding of the qualitative data was carried out by two of the authors using Nvivo. Codes are a useful way to develop categories and group responses when exploring descriptive data [27,28]. The data were initially examined to scope out initial framings and themes followed by an open coding approach [28] which facilitated the development of broad coding categories. These categories were subsequently refined and structured around the key themes identified relating to: risk perceptions; values around oak; knowledge of OPM; managing trees generally, managing OPM; social acceptability of OPM management measures; managing other pests and diseases; communication needs (around OPM); future support needed for OPM management. Quotes are anonymised but labelled to identify site type, manager type and whether OPM was present.

3. Results

3.1. *What Influences How Land Managers React to OPM? Site, Knowledge and Socio-Political Contexts*

There were differences in the levels of knowledge about OPM between land managers, depending on the size of their sites, numbers of oak trees at risk, experiences of OPM and whether they were managing for public access or not. Knowledge and understanding of the OPM management options was reported as an important influence on land manager assessment of risk and response. Managers of larger sites with public access were generally better informed about the existence and nature of OPM, which was partly due to information flows from the OPMCP through guidance and the issuing of SPHNs, but also through their professional networks. For these managers, it was their perceptions of the risks of OPM to human health that was the biggest concern. Their duty of care/liabilities in these circumstances was a key driver to their information seeking. However, they did not necessarily know the locations of all their oak trees, especially if oak were in high numbers over large areas. Private residents and smaller land managers generally had lower awareness of OPM as a potential pest on oak in their gardens. This was particularly evidenced by respondents from the London borough in the Control Zone where OPM may or may not be present. Here, respondents largely became aware of OPM following a contractor-led survey conducted for the project to identify location of oaks and

presence of OPM. Thus, amongst some stakeholder groups OPM is still a little-known problem and awareness currently relies on contact with knowledgeable others such as the OPMCP.

Land managers on larger sites with public access but who had less knowledge or experience of OPM registered their uncertainty about the impacts of OPM, the best approaches for management and availability of contractors:

“Our opinion is that there’s been a lot of information about OPM but not much about how anyone is supposed to deal with it. There is a lot of false information, a lot of the literature still says that it’s a public health hazard whereas the public health authorities don’t consider it so.” (Cemetery_Local Authority_LB2_OPM present)

“I just think it would really be helpful if there was more information about—because what it [website] said is, it’s your responsibility as a landlord to get rid of it. The emphasis was more on, I felt, you must get rid of it but not how.” (Cemetery_Private organisation/business_LB1_OPM present)

“So we don’t really know what to do ... We thought maybe you could give us some ideas as to what to do. We know that some pesticides will kill them but I can’t get up 15 metres, and you can’t really spray from the ground.” (Sports ground_Private organisation/business_LB2_OPM present)

Even those land managers who were knowledgeable about OPM were unsure about some aspects of OPM ecology and the full range of possible management options. There was some uncertainty about whether present low reporting of public health impacts was attributable to current control efforts. Others felt that the real risk of OPM was to land manager reputation and public or organisational acceptability of their response. Reputational risk, and the perception of managers of larger land holdings was that they needed to be seen to be actively doing something about OPM and this was a key feature of decision making. Protecting visitors and wider publics was considered particularly important for land managers dealing with sites that are directly accessible or could indirectly have an impact on the public and particularly vulnerable users. These views were highlighted by two respondents from organizations with large multi-site land holdings:

“This spend that is taking place on it, is it proportionate to the risk posed, and I would say it isn’t. It’s disproportionate and it’s been done for a different reason and that reason is probably reputational risk rather than health and safety risk always for trees.” (Multiple sites_Local Authority_LB2_OPM present)

“From our own staff point of view, working in the vicinity of trees that may have had nests in them and then causing all the hairs to start floating again, and also the implication that if we don’t do anything, and everybody else is doing something ... is not good for reputation. So, it is relevant to our workforce safety and public safety ... ” (Multiple sites_Transport_LB2_OPM present)

Amongst land managers of smaller properties including private residents, was a sense of moral responsibility to manage OPM to reduce the risk of spread onto neighbouring land and trees.

“... I don’t think we would be jumping up and down and saying someone else has got to pay for this, this is not our fault. I think we’re responsible enough that we know that things come in to our garden beyond our control and it would be irresponsible of us not to deal with them...” (Private garden_Private resident_LB1_No OPM present)

“So we’re in a difficult position because (A) we don’t want the things there, (B) they could spread to other people’s trees, so it’s a bit antisocial ... What’s the word I’m trying to think of? Not considerate to one’s neighbours, not to have this removed.” (Private garden_Private resident_LB2_OPM present)

Respondents reported on a range of methods for OPM management that they were aware of, including spraying with an insecticide or bio-pesticide, nest removal and zoning of high-risk areas to warn visitors of the presence of the pest, and felling of oak trees. Many of the conversations around management measures focused on the spraying of insecticides and bio-insecticides but there was a general lack of knowledge about the impacts of the specific chemicals or biological materials used, particularly amongst land managers of smaller sites. There was also a widespread perception that spraying would not be considered acceptable by the public and so respondents talked of using this option at times of day when fewer people were around to avoid any potential public concern over spraying impacts.

“We have pesticides and I try and do that . . . really only on a Saturday morning or something when no one is around. I mean, no one would have a go at me, but I just feel weird” (Park or public garden_Charity or Trust_LB1_OPM present)

3.2. Values and Perceived Risks

3.2.1. The Values Assigned to Oak Trees

Interview results confirmed that oak is a highly valued tree for many reasons such as age and historical importance, size, aesthetics, landscape (e.g., boundaries and hedgerows) and biodiversity value. A strong theme in the data was how oak symbolizes Britain and British cultural heritage:

“I mean, I think you know, trees in general are magnificent things . . . oak trees are kind of, they’re almost like the royalty of trees.” (School grounds_school (LA)_LB2_No OPM present)

“It’s old England, it’s a beautiful shape . . . It’s just history. Oak trees grow massive don’t they . . . They’re kept at all costs.” (Amenity area_Private organization/business_LB1_OPM present)

The values attached to oak may be emphasized in urban areas where oak trees are relatively scarce as street trees or garden trees. Distribution of oak across London is patchy and many parts, including our study areas, have relatively few oak due to their size and space requirements. Interviewees stressed that oak were generally not suited as street trees in dense urban environments but could be planted in park areas and other open spaces. One participant highlighted that oak provided important ecosystem services such as improved air quality:

I think they’re really important in London just in terms of providing the lungs for the city. So yes, oak is important. (Cemetery_Private organization/business_LB1_OPM present)

However, the difficulties that oak face in built up areas underlines the importance of the longevity of existing trees for many people and examples were given where oak was a key species of choice where it was possible to plant them:

“We tend to have a lot of donation trees and a lot of commemorative trees and quite a few of the oaks are those. They’re chosen as those because obviously they last a very long time or are supposed to.” (Amenity area_Private organization/business_LB1_OPM present)

3.2.2. Perceptions of Risks Posed by OPM

Even though there is information about how OPM might affect individuals, evidence of the public health impacts, i.e., impacts at community or societal level, is scarce and remains largely anecdotal. This did not reduce risk perceptions. Respondents were concerned about the potential impacts on residents living in close proximity to infested oak trees (on public land); people visiting or using public areas and gardens; children at school, outdoor nurseries or using sports grounds; elderly people accessing church grounds and gardens; and site staff such as the gardeners or volunteers who work

amongst the oak trees. Private residents too raised concerns about the potential impacts on their own and their family's health when out in their garden.

It was the perceived risks to vulnerable groups in particular that emerged as a strong theme with little discussion of impacts on animal or oak tree health. Some examples of human health concerns included the potential for breathing difficulties amongst children as highlighted by a sports groundskeeper that had OPM on two oak trees near the playing fields:

“... if kids get the hairs from the caterpillar on them, they get rashes and some of them do have asthma anyway, I know that. So, if they have breathing problems, it could make it worse.” (Sports ground_ Private organisation/business_LB2_OPM present)

The perceived danger to children that were considered vulnerable was an incentive to manage the potential risk. Another example focused on children playing near an infested oak tree at a private members club which was subsequently reported to the club managers and the business instituted safeguards to divert people away from the area.

Experiences and evidence of health impacts has mostly emerged from contractors involved in OPM removal with reports that continued and repeated exposure to OPM can lead to growing intolerance and increasing severity of the symptoms. As one interviewee highlights, the health and safety implications of continued contact with OPM can get progressively worse:

“I got approached by one of our contractors who sprayed OPM and his guys, because the allergy builds up doesn't it, the toxins, it's an accumulative effect but the allergy in some of his guys, they were really badly affected and they can't go near a tree with OPM anymore.” (Multiple Sites_Local Authority_LB2_OPM present)

Tales of suffering can intensify nervousness amongst land managers about the potential risks of OPM to visitors and staff.

3.3. Trade-Offs in OPM Management: How Perceived Risks and Values Influence Decision Making

3.3.1. Reluctance to Fell Oaks as a Management Response Influenced by Social Values

Land manager decision-making and assessment of the trade-offs between different management options and outcomes was determined by weighing up the perceived risks posed by OPM to oak trees and human health against the strong cultural values attached to oak with site context, knowledge and experience levels and perspectives on acceptability acting as key influencing factors. Our respondents, from large land managers with multiple oaks to private residents with possibly only one tree in their garden were adamant they wanted to protect the oak trees because of the stated values they hold and because oak are considered to be “*beloved by the general public*” (Multiple Sites_Local Authority_GL_OPM present).

The limited numbers of oak trees in some neighbourhoods also meant that land managers were often keen to conserve these trees, even where OPM could pose a potential risk to vulnerable groups. For example, a school caretaker emphasized that while they did not have many oak trees,

“... the ones that we do have, it's worth trying to maintain them and keep them healthy so they survive” (School grounds_ School (private)_ LB1_OPM present)

It was recognized that relationships with urban trees are complicated, and that there may be social pressures to remove ‘nuisance’ trees near properties. An oak infested with OPM could be considered such a nuisance tree. Our data provided evidence of the difficulties in navigating this relationship, as one local authority pointed out:

“Everyone is a tree expert. We've got 220,000 residents and they're all experts ... It's such an emotive issue. Everyone hates them, everyone loves them. They love them if they're outside someone else's house.” (Local authority_ multiple sites_LB2_OPM present)

However, for many interviewees getting rid of oak trees as a response to OPM was seen as a last resort:

“Oh no, you wouldn’t get any of that. No tree felling... If it got really bad and it affected the tree and they started actually killing the tree with it, then I think all possible measures, whether that be spraying or reduction or anything like that, would be actioned first. Felling would be the absolute last port of call.” (Amenity area_Private organisation/business_LB1_OPM present)

“Management is easier, surely. It’s better to have a vast, beautiful oak tree there than just nothing.” (Sports ground_Private Organisation/business_LB1_OPM present)

“Yeah, I don’t want the tree to be taken down, or anything nasty like that. It’s a lovely tree.” (Private garden_Private resident_LB2_OPM present)

3.3.2. Assessment of the Effectiveness of Management Options Influenced by Social and Ecological Values

Concerns around management options were largely focused around the use of insecticides and its impacts on human health and biodiversity. For example, there were questions around non-target impacts on the biodiversity that oak trees support, including other moths and butterflies, as highlighted below:

“Okay. So, I have no issue with us either using chemical or biological treatment methods, as long as they are used and targeted to the organism that we are trying to get rid of, although recognising that the spraying will always get other things. But as long as they’re not blanket bombing the whole of the south east ... if that deals with the risk and is proportionate then that’s fine” (Multiple sites_Transport_LB2_OPM present)

“You’d have to show me some evidence both that it’s effective and that it’s not going to have side effects on other species” (Private resident_Private garden_LB2_OPM not present)

Insecticides such as BT can in fact have a detrimental impact on other lepidoptera although it is considered to be less damaging than other available spray treatments [23]. However, concerns over effectiveness of spraying were magnified when coupled with human health impacts. Spraying of OPM and its perceived impact on people were considered in two ways; the first perspective was that spraying for OPM will protect human health whilst the alternative view was that it would be harmful to health:

“You’ve got to balance it haven’t you, between the welfare of the kids in spraying or not spraying and have some child who has got asthma have a proper asthma attack. I think we’d always err on the side of do it, just to be safe.” (Sports ground_Private organisation/business_LB2_OPM present)

“Well, that’s the thing you’ve got to be wary about. They spray out there and a child’s asthmatic or anything like that ... if it was going to be sprayed it will be done either at the weekends or during the holiday period so there’s no risk to the children.” (School grounds_School (Private)_LB1_OPM present)

A non-chemical management option is nest removal, which is most effective when carried out after the caterpillars have pupated but the pupae are still in the nests [23]. Nest removal—usually through trained contractors—was a common method for managing OPM across the broad range of land managers we spoke to as it was considered to be a relatively quick and cost-effective measure with little detrimental impact on other species. Some land managers with multiple infested oak trees found nest removal to be cheaper than spraying as one interviewee highlighted:

“If you spray, you’re spraying every tree, whether you think it’s got it or not, whereas removal, we are only removing what we know we’ve got. So that’s probably why we’re spending less money . . . ” (Park or public garden Charity or trust_LB1_OPM present)

However, nest removal without spraying of insecticides or bio-pesticides is considered less effective and re-infestation of the tree is more likely to occur.

Other non-chemical measures include temporary zoning and signage. These could be used where infested trees are being actively managed or where no management is taking place but there is a need to warn the public of OPM in areas accessible to visitors. Zoning and signage was seen as a mechanism of complying with their duty of care although there was some scepticism around whether people read or heed the warnings:

“As soon as we see evidence of OPM, we will basically tape off the tree . . . there’s no way we can tape off the canopy because it would just be the entire garden, but around the base . . . and we put up a temporary message of please don’t go near the tree . . . it’s mainly to cover our own backs. Obviously people will always do what people want to do and if they want to run up to the tree and touch them, they’ll do that. A little bit of tape isn’t going to stop them doing that. But that’s what we do.” (Amenity area_Private organisation/business_LB1_OPM present)

3.3.3. Costs of Management—An Important Influence on Decision Making

While the study established concerns around the use of spraying to reduce the impact of OPM, a key challenge to any management of OPM is cost. Tackling OPM can be costly due to the need for trained contractors, specialist equipment and personal protective gear. The costs of hiring contractors can be a burden for many land owners and managers, particularly urban residents [16]. Economies of scale mean that individual households could face a much larger bill for spraying and/or nest removal of individual trees than organizations and businesses with many more oak. Nevertheless, even the larger land managers highlighted significant budget constraints particularly where they have multiple responsibilities in the community:

“One of the problems is going to be financial. We’ve got increasing cutbacks, we need to make increasing cost savings, so another financial burden would be problematic. That I’m afraid is the nature of the way things are at the moment.” (Cemetery_Local Authority_LB2_OPM present)

The financial implications of OPM management have prompted concerns over the efficacy of management approaches to date, which could be considered in two contrasting ways. Firstly, the absence of large-scale negative impacts was considered by some as evidence that current control mechanisms were having an effect. Second, as OPM appears to return to sites that have been sprayed and is also spreading into new areas, this is evidence for some that government policy for management of OPM is not sustainable:

“What you’re looking for I guess as to how sustainable the programme is, and I think that’s quite an interesting debate because it does seem to be getting away and it’s progressing, obviously every year it’s moving out a bit further” (Park or Public Garden_Charity or Trust_GL_OPM present)

“You can contain it up to a point; they’ve sort of managed that in [XXXX] but that was through using broad spectrum non-biological controls which had a massive impact on all their invertebrate population and I think they’ve moved away from that now and even that didn’t eradicate the problem because it still managed to hold on within that site itself” (Park or Public Garden_Charity or Trust_No OPM present)

There were also reports that OPM management was not being undertaken at all due to the on-going financial implications. Fears were expressed by larger land managers who do manage OPM that current efforts are financially unsustainable in the long term.

“The problem is if you decide to spray it’s expensive, it’s damaging and it doesn’t actually eradicate the problem, and are you going to just do it ad infinitum?” (Cemetery_Local Authority_LB2_OPM present)

For smaller land managers, the long-term financial implications of OPM presence, particularly if they are located in zones where management is legally required, may act as a deterrent to reporting the pest. The activities and incentives of smaller land managers for example, private residents, to manage OPM were largely unknown:

“One of my main concerns would be private trees, because we need to convince private tenants to come forward and feel that they’ve got support . . . Private owners, if they know they’re going to be hit with a big, ongoing cost, it might prevent them from saying anything. So, that’s something I would be concerned about and I think . . . private owners need more support than we do.” (Multiple sites_Local Authority_LB2_OPM present)

Not everyone agreed that management of OPM was necessary. While it was acknowledged that contractors who are repeatedly exposed to OPM through control activities can suffer health effects, the lack of evidence of wide-scale ill health from OPM has raised some scepticism about the sustainability of diverting significant resources to long-term management of OPM to the detriment of other tree safety or pest and disease issues. Land managers highlighted that resources are needed to manage the threat from ageing, unstable or vulnerable trees and fallen branches, particularly in publicly accessible areas.

Decisions are being made amongst some land managers to explore non-chemical options for managing OPM with interviewees suggesting that you can learn to live with OPM if you take appropriate actions:

“It’s only a small percentage of people that are particularly sensitive. Well, fine, if you are particularly sensitive then you do not walk near oak trees during the time of year when the caterpillars are active. It’s common sense” (Private Garden_Private resident_No OPM present)

“The consequences of living with OPM, and I looked into it . . . if you’re a little bit careful, are not that bad” (Multiple sites_Local Authority_No OPM present)

Moreover, as organizational budgets are increasingly squeezed several interviewees suggested that as OPM is primarily a risk for human rather than tree health it should fall under the responsibility of the health sector:

“If it’s a human health risk then surely that’s something that the health arm of the government should be taking into control, because as far as I know OPM doesn’t kill trees . . . we don’t go out and spray everywhere free of charge for wasps, do we, and more people probably get stung and end up in hospital from wasp stings than OPM . . . ” (Multiple sites_Local authority_LB2_OPM present)

4. Discussion

Policy responses to OPM have focused on safeguarding the protected zone and reducing impacts on human, animal and oak health through survey and control (e.g., spraying of infested trees), but underlying this premise are concerns over the future of oak as a key tree species in the city landscape. We used a conceptual framework (Figure 2) to explore how land managers make decisions about OPM management options, and how they weigh up their choices against the impacts they have on the

values associated with oak and the biodiversity they support. We have demonstrated that the risk of reputational damage from not managing OPM is potentially greater in urban areas where there are larger numbers of people that can encounter infested oak and more potential for complaints over health impacts. Given the iconic status of oak, leaving infested trees to be defoliated by OPM—an event that can render oak trees vulnerable to other stresses—may also be considered unacceptable by different publics and stakeholders. However, managing for OPM can also have implications where current insecticides or bio-pesticides are not solely targeted to OPM and there is no guarantee that other biodiversity will not be affected. Complete removal of nests may also inhibit the development of native parasitoids that prey on OPM. Research on predation effectiveness of parasitoids is ongoing. Thus, not spraying OPM or carrying out any management may be an active choice where biodiversity values are important and there is a belief amongst some respondents that potential risks to human health can be managed.

Current perceptions of OPM posing a danger to human health in the UK are not linked to evidence. Despite the high policy priority given to OPM in the UK, the health impacts of OPM in other countries such as Germany [29] and the Netherlands have been much better recorded [16]. A key challenge in assessing health impacts is the lack of reporting. All respondents agreed that reporting on the health impacts of OPM did not generally happen either by professional organizations and contracting businesses or by land managers. Reasons given included the lack of appropriate recording systems within organizations that specify OPM as the cause of sickness absence; OPM impacts not regarded as a legitimate health and safety issue reinforced by a working culture that does not encourage “*fussing about a rash*”; and the lack of a central web-based recording system that could collate London-wide records to provide a general picture of health impacts. One respondent recounted that a member of the public who was jogging through their park had reported health effects in relation to OPM but that such reporting was rare leading to uncertainty over whether OPM really is an issue. Limited reporting of OPM health impacts could be due to lack of awareness of OPM and symptoms on contact but lack of experience will influence whether there is a need or demand to engage with management activities [30].

Another big challenge given the lack of health evidence, is the cost of OPM management options where there is no current government support for surveying for OPM and spraying. For managers of larger areas of land, when there is a public duty of care and potential ‘hotspots’ where visitors and OPM may meet, funds for management may be found but respondents indicated that this was not sustainable in the long-term. Where there is little or no public access the financial costs are harder for land managers to justify. The costs appear to be prohibitive for some smaller land owners or managers such as private residents who signaled a need for guidance on what the economic implications of management should be, who could carry out the management and whether financial or other support is available. Collective action could potentially reduce costs and collaboration is an important component of OPM management particularly as lack of action from one land manager can increase the challenge of managing OPM levels for neighbors who want to act. However, the sheer variety of site types and and/or difficulties in identifying ownership in cities like London can hinder communication. Efforts to engage with neighbors on OPM varied between land managers but while many acknowledged that they had good relations with most of their neighbors, it was difficult to find time to communicate about OPM management actions.

A Risk-Based Approach to OPM Management

Given the logistical challenges and financial costs involved in surveying for OPM and dealing with infestations, managers of large areas of land located in the core zone (which expands almost every year) are already adopting risk-based approaches based on the likelihood of OPM coming into contact with people and animals. They are learning to live with the pest, particularly in the core zone, and a number of interviewees indicated that management such as spraying and nest removal is largely undertaken when infested trees are located in areas of high footfall, and where the potential health risk

is greater, e.g., because nests are lower down the tree. This approach has allowed managers to focus on OPM where they feel it is needed, save resources for other tree management issues and provide a level of flexibility when faced with infested oak in areas of high biodiversity such as Special Protection Areas (SPA) and Sites of Special Scientific Interest (SSSIs). Notwithstanding the current desire to ensure that the UK retains its Protected Zone status as OPM-free outside of Greater London and some surrounding counties (see Figure 1), a risk-based approach to OPM could be more sustainable in the future for both the government and land managers. However, a closer examination of the existing policy that relies on issuing of statutory instruments (SPHNS) based on simple geographical zoning would be needed. A 'one-size-fits-all' approach could be replaced or augmented by land manager decision-making around what action should be taken, where and when. A risk-based approach recognizes there are difficult trade-offs to be made where there are different governance contexts and levels of risk to human, animal/biodiversity and oak health of OPM at a single site or at a strategic level involving multiple and varied sites. Preparedness for OPM would be a key component of a risk-based approach which requires an investment in building up OPM-based knowledge of urban (and potentially peri-urban as OPM continues to spread) land managers and providing support in the form of decision-based tools to facilitate strategic and operational planning.

5. Conclusions

Management responses to tree pests and diseases are often justified for the greater public good including saving our trees and associated biodiversity and/or protecting human health. However, evidence suggests that policies and practices lacking societal acceptance and approval will ultimately fail where public support is necessary and this certainly applies to the successful implementation of pest control programmes [31,32]. Published evidence across a range of pests suggest that the public is generally accepting of the need to control for invasive pests [33,34]. The few studies that have explored attitudes towards pest management have revealed that a 'do nothing' approach is generally considered unacceptable [33,35]. However, our research suggests that in urban areas there are complex trade-offs between values and risk which may lead to management decisions that are not aligned with current government policy on OPM control.

Difficult trade-offs can lead to emotion-based decision-making where simplified strategies are chosen based on what is perceived to be the most important attribute and more weight is given to losses or disadvantages than gains [13]. A potential concern in heavily built up cities is that urban trees may become viewed as liabilities rather than assets, leading to the removal of trees to avoid the costs of managing them. Uncertainty around the value of trees in the urban landscape will be compounded by conflicting or lack of knowledge on management options. However, oak is perhaps a special case as it holds a high cultural value for many people and could be considered as a 'protected value' that can resist trade-offs with other values [13]. Our evidence suggests that people have strong emotional attachments to oak and there were no respondents in our sample who considered felling of oak trees to remove the problem of OPM. Oak is also highly regarded for its biodiversity value and this has implications for which management options are considered acceptable in different site contexts. Multiple value dimensions [12] can make assessing trade-offs (e.g., human health versus biodiversity) even more difficult particularly where knowledge or evidence is lacking. Thus, a decision not to control OPM in the city could be a rational choice for some even if it is considered unacceptable to others. Understanding the trade-offs between value systems and risk perceptions provides a deeper insight into the difficult management choices that individuals and organizations have to make. We suggest further research is needed to identify OPM-related health impacts in addition to wider studies across Greater London and surrounding counties to gather evidence on oak values, OPM experiences and risk perceptions. It would also be useful to map levels of OPM awareness and pathways through which individuals and organizations are receiving information. This would facilitate further testing of the framework and improve our understanding of the trade-offs between risks and values that inform decision-making processes and behaviors. A risk-based approach to managing pests in the city that is

tailored to different site conditions, visitor access and governance contexts and reflects the diversity of stakeholder requirements and views may provide a more sustainable long-term solution for pest management in the future.

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