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How to recognise a healthy forest: Perspectives from private forest managers in Britain

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ABSTRACT

The managers of private forests have critical roles in responding to forest health challenges. Basic knowledge of how they interpret and understand the health of their trees is, however, very sparse. Via an online survey of private forest managers in Britain, we reveal the basic characteristics of this group's understandings of tree and forest health both in general and, more specifically, in relation to the health (and ill health) of oak species. The survey generated 441 valid responses – from forest owners, forestry agents and other professionals. The majority of our respondents believe the forest(s) they manage to be healthy or very healthy, although vulnerable to future threats. We identify key themes within managers' understandings of the factors that promote tree health, and describe the visual signs of good- and ill-health used by them as indicators. Oak trees and oak woodlands were similarly judged to be healthy currently, but again this positivity was set against a sense of vulnerability and potential future decline. The biggest threat to oaks was considered to be browsing and bark stripping by mammals – a very long standing concern – rather than more recently emergent threats. Through this research we provide a clear sense of how forest managers think about, and make judgements on, the health of their trees and forests. This understanding needs to inform the increasing efforts by the forestry sector in engaging private forest managers in forest protection.

1. Introduction

A substantial increase in effort and resources has been dedicated to preventing and mitigating forest health challenges in recent years. The impacts of specific pests and diseases – such as the emerald ash borer in North America (Herms and McCullough, 2014), ash dieback across Europe (Vasaitis and Enderle, 2017), and kauri dieback in Aotearoa New Zealand (Bradshaw et al., 2020) - have been particularly prominent amongst these challenges, although more general concerns such as climate change also constitute a major ongoing threat (Ramsfield et al., 2016; Hartmann et al., 2022). Given the large proportion of forests in private ownership across these regions, the managers of private forests have critical roles in responding to these challenges. This numerous and varied group often have highly-diverse motivations for owning and making use of woodland (Urquhart and Courtney, 2011; Ficko et al., 2019), but in the forest health context not only do they have the opportunity to act as 'monitors' keeping watch over their forests for signs of invasion or outbreak, but they must also be relied upon to take the management actions needed to prevent spread and mitigate impacts within their forests (Dandy et al., 2017). Thus, resilience of privately-owned forests is very much dependent on the activities of individual managers – which can include forestry agents and contracted workers, along with the owners themselves.

Whilst there is an increasing amount of research regarding the forest health actions (or 'behaviours') that this broad stakeholder group are expected to undertake (e.g. Hemery et al., 2015; Marzano et al., 2017; Ambrose-Oji et al., 2018) and evidence that they consider maintaining the health and resilience to be an important component of forest management (Feliciano et al., 2017), knowledge of how they interpret and understand the health of their trees and forests is very sparse. This paper seeks to begin to fill this gap. Intuitively we might expect a link between a forest manager's perception of the health (and vulnerabilities) of their forests and their management actions and decision-making. It is probable, for example, that those managers who believe their trees to be healthy may undertake surveillance actions, but little else in terms of relevant direct management. In contrast, where a manager perceives ill

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health amongst their trees – or even anticipates ill health to arise in the future – more direct intervention and actions such as sanitation felling or pesticide application might be expected. Consequently, along with the myriad of other factors which might influence this decision-making process, understanding the ways in which managers make judgements about forest health is critical to improve policy intervention and practice guidance in the sector, as is an awareness of the criteria and indicators used as a basis for these judgements.

Private forest managers may have deep experiential knowledge of their forests; the majority have, however, undergone little or no formal training in forestry practice or tree health. Often, they instead draw knowledge and guidance from a vast array of institutional, educational, experiential, and informal sources (Eriksson and Fries, 2020). This implies considerable variation in the competencies and capacities amongst this group for understanding the sometimes complex dimensions of tree health. As a result, problems may arise if managers have knowledge gaps with regard to tree health. Over-estimating or simply being unaware of the health and resilience of their forests; or miscalculating risks, threats and vulnerabilities may lead to management inactivity or inertia. Conversely, perceiving threats or ill health incorrectly could lead to ineffective or unnecessary, often destructive, intervention and tree loss. Judgements about tree health are perhaps more likely to be based primarily on informal and intuitive signs, rather than 'scientific' observation and testing. However, little is known about how private forest managers make these judgements, nor the signs or everyday indicators that they use to reach these conclusions. Addressing this research gap is a critical prerequisite for understanding not only the manner in which forest health is being pursued currently, but also for informing future effective policy and practice interventions.

This paper therefore seeks to provide insights into the basic characteristics of private forest managers' understandings of tree and forest health. It engages with forest managers in Britain via survey research designed to reveal perceptions and beliefs regarding tree health, including in relation to differentiating 'healthy' and 'unhealthy' trees. It also assesses broad perceptions of contemporary forest health and influencing factors. It then considers what managers believe to be the key future threats to their forests. It additionally briefly considers where this knowledge is being drawn from.

We add depth to these general insights through a set of questions focused specifically on perceptions of the health (and ill health) of oak species in Britain. We chose oak for this purpose as it has long been a highly-valued and iconic species in Britain (Rackham, 1974) and it faces a novel threat in the form of acute oak decline (AOD) (Denman et al., 2014). Recent research on AOD has linked it to complex ecological interactions between host, environment, microbiota, and insects (Doonan et al., 2020). Ecologically-informed relational models of disease, such as AOD, offer a distinct challenge to established ways of understanding tree health. Therefore, a focus on oak species offers the opportunity to study managers' understandings of tree health grounded in a context of high conservation and management concern and at the cutting-edge of forest health science.

2. Methods and data analysis

2.1. Methodological approach

The primary data presented in this paper was collected for the Future Oak project (Ref: BB/T01069X/1) via the British Woodlands Survey (BWS). The BWS is a well-established online survey series delivered by Sylva Foundation in the UK. The co-authors worked collaboratively to design the survey instrument, which incorporated a set of standard BWS demographic questions along with project-specific questions encompassing overall perceptions of the health of forests, understandings of the factors that promote tree health, and signs of health and ill health. A number of questions focused directly on managers' thoughts about oak health specifically and asked which species they expected to form the 'resilient' forests of the future in the UK. Questions relating directly to the management of oak species were asked only of respondents who indicated that oak was encompassed within their management responsibility.

After an initial pilot with selected former BWS respondents, Future Oak project advisory board members, and departmental colleagues, a final question list was agreed which included closed, 'Likert' style, multiple choice, and short text questions in Limesurvey (https://www.limesurvey.org/), an open source online survey tool. The survey was published in the summer of 2021 and was open to respondents for eight weeks. The survey was advertised by Sylva Foundation via their extensive land-based network, by the Future Oak social media platforms, by institutional and NGO partners, and general promotion in forestry sector media.

2.2. Data analysis

The majority of the analyses reported here used basic descriptive statistical methods. We did not undertake a segmentation analysis using, for example, principal component analysis or similar techniques. A number of studies have previously performed such analysis with relatively stable outcomes in terms of categorising managers in relation to their objectives (e.g. Eves et al., 2015a, 2015b; Ficko et al., 2019; Urquhart and Courtney, 2011). In the analysis reported here we present some aspects of our data disaggregated in line with some of the primary types identified via these prior typologies. Specifically, we compare the responses of respondents who reported a higher than sample mean average commitment to capital growth and investment, the protection of water quality, and recreation for management objectives. These reflect three common management types described by these published typologies described variously under the labels 'investors', 'conservationists' and 'recreationists' (Ficko et al., 2019).

Answers to questions exploring forest managers' understandings of the promotion and 'signs' of health and ill-health were given in short free-text form. For each question, respondents were invited to provide up to three short textual statements. These responses were initially analysed using simple word count content analysis software which enabled the identification of prominent / common keywords, terms and phrases. These were subsequently used to structure a deductive thematic analysis of the responses, the results of which are presented here.

3. Results – Forest manager understandings of healthy trees and forests

3.1. Respondent managers and their objectives

We received 441 valid responses to the survey (completed the survey sufficiently to allow meaningful analysis). The online instrument was accessed a further 165 times, but 156 of these offered no responses to the questions, and a further 9 did not provide sufficient data for analysis and are therefore not included. 326 of our 441 respondents reported that they personally owned (and managed) forests in the UK. Forestry agents ($n = 55$) and other professional forest management stakeholders (e.g. tenet land managers; forest scientists; forest business owners) made up the remaining respondents ($n = 60$). The vast majority of survey questions were optional. In addition, the survey instrument routed different categories of forest managers to varying questions sets. For example, certain questions connected specifically to oak management were put only to those respondents who indicated they had oak species within their management responsibilities ($n = 333$). These factors resulted in varied total n across the questions as not all 441 respondents answered every question.

Membership of forestry and farming sector organisations was strong with around three-quarters (73.5%, $n = 324$) of respondents being a member of at least one national level organisation. On average, respondents were members of just a single organisation (mean = 1.3;

median = 1), although a large number ($n = 173$, 39%) were members of more than one. The most popular memberships were the Royal Forestry Society (25% of all respondents), Woodland Trust (24%), and Small Woods (24%). Over half (58.7%) have some experience of recent forest health challenges, reporting that the trees they manage have been affected by pests or diseases within five years. Only a very small number of them, however, have been subject to formalised pest and disease regulation in the form of a Statutory Plant Health Notice ($n = 26$) or participated in dedicated voluntary biosecurity schemes ($n = 28$). The vast majority of our respondents ($n = 333$, 75.5%) reported they had oak species within their management responsibility. 169 respondents (38.3%) stated they had a current woodland management plan, although only 91 of these (20.6% of the total sample) reported that these were 'compliant' with the UK Forestry Standard (the UK government's forest management standard).

Our respondents reported drawing information on tree health from a range of sources. When asked which source was the "most significant to your decision making on tree health", respondents were evenly divided between the four options presented. Around one quarter of our respondents identified membership organisations (27%), professional woodland advisors or consultants (24%), and (informal) peer network (22%) as this 'most significant' source. The remaining quarter (26%) noted 'Other' sources. These included a relatively small number ($n = 28$, 6%) citing governmental sources (e.g. Forest Research; Defra; NRW) and 'the internet' ($n = 18$, 4%).

With regard to forest management motivations the survey asked respondents to select their priority objectives from a list of 15 options, but also asked them to rank these by importance.

As such, not every option was selected and ranked by every participant, although most selected a relatively high number of options (median 12; mean 9.7). As illustrated by Fig. 1, the protection of nature, personal pleasure, and landscape protection were the most commonly selected *and* most important management objectives amongst our respondents. The protection of nature was attributed a mean score of 8.72 (out of 10) for its importance, with personal pleasure also achieving a score above 8 (8.22). Hunting and shooting (mean = 3.16) along with capital growth or investment (3.54) were the least common and least important motivations for forest ownership.

Eighty-three respondents attributed an above mean average (3.54) to capital growth or investment as a forest management aim, 111 respondents attributed an above mean average (5.35) to protection of water as a forest management aim, and 114 respondents attributed an above mean average (6.03) to recreation as a forest management aim.

3.2. Perceptions of general forest health and current prospects

Nearly two-thirds of the respondents (64.8%) expressed their belief that, overall, the forest(s) they manage are healthy or very healthy, while around one-third (32.9%) were neutral about this (giving a score of 3 out of 5, mean = 3.74). Very few managers (just 2.3%) felt that their trees and forests are currently 'unhealthy' (Table 1). However, against this general positivity, nearly two-fifths (39.2%) of respondents agreed or strongly agreed with the statement that "The health of my woodland has declined over the last decade". A third (32.8%) disagreed with this statement. We asked respondents about two broad potential threats to forest health: climate change, and pests and diseases. A very substantial proportion of respondents (78%) felt that 'anthropogenic climate change is a threat to British forests' - with nearly one-third of respondents (32.9%) 'strongly' agreeing with this statement. In parallel with this, an even larger proportion of respondents (72.9%) agreed with the statement 'Pest and pathogens are part of the natural ecosystem'. The majority (67.8%) felt, however, that their trees were 'vulnerable' to these pests and diseases.

Table 1 also illustrates that there is only minor variation of these perceptions within the sample, with sub-groups of managers providing broadly very similar responses. Amongst the minor differences it is notable that managers with recreation as an above-average priority are seemingly less certain that their woods have declined in health over

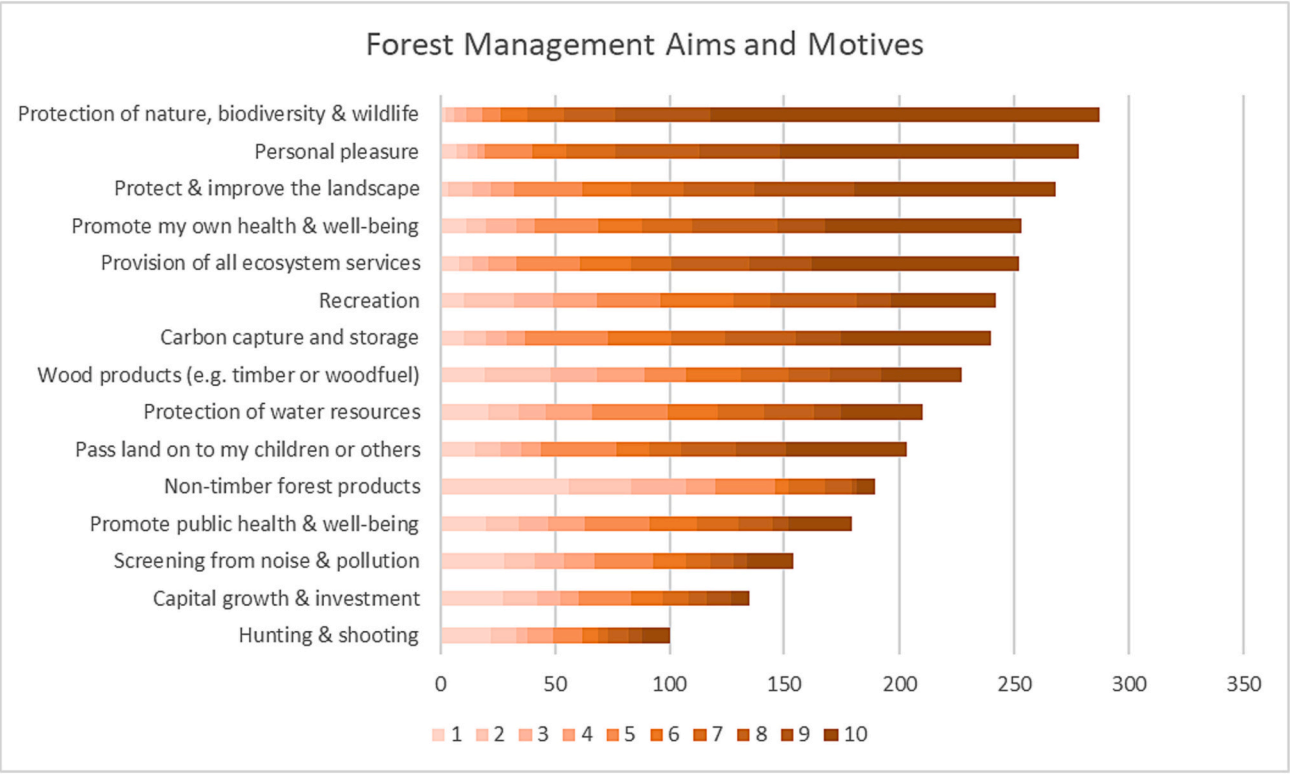

Fig. 1. Respondent management aims and motivations [*x* axis shows number of respondents that selected each aim or motive, while shade indicates the importance attributed to each (score out of 10)].

Table. 1
Forest manager broad perceptions of forest health (varied *n* due to some respondents choosing not to answer every question).

		Whole sample %	Capital Growth %	Water %	Recreation %
		(*n* = 347)	(*n* = 83)	(*n* = 111)	(*n* = 114)
Overall, how healthy do you feel your woodland to be	Very unhealthy	**0.3**	0.0	0.0	0.0
	Unhealthy	**2.0**	2.4	1.8	1.8
	Neutral	**32.9**	34.9	31.8	28.3
	Healthy	**53.0**	53.0	56.4	58.4
	Very Healthy	**11.8**	9.6	10.0	11.5
		(*n* = 296)	(*n* = 76)	(*n* = 98)	(*n* = 92)
The health of my woodland has declined over the last decade	Strongly Agree	**7.4**	9.2	8.2	4.3
	Agree	**31.8**	31.6	27.6	22.8
	Neutral	**28.0**	25.0	26.5	37.0
	Disagree	**26.0**	27.6	31.6	29.3
	Strongly Disagree	**6.8**	6.6	6.1	6.5
		(*n* = 328)	(*n* = 78)	(*n* = 103)	(n = 98)
Anthropogenic climate change is a threat to British woodland	Strongly Agree	**32.9**	25.6	36.9	30.6
	Agree	**45.1**	44.9	40.8	51.0
	Neutral	**16.5**	20.5	17.5	15.3
	Disagree	**3.4**	6.4	1.9	2.0
	Strongly Disagree	**2.1**	2.6	2.9	1.0
		(*n* = 332)	(*n* = 79)	(*n* = 104)	(*n* = 100)
Pest and pathogens are part of the natural ecosystem of a woodland	Strongly Agree	**7.8**	6.3	5.8	6.0
	Agree	**65.1**	63.3	69.2	72.0
	Neutral	**22.0**	26.6	20.2	17.0
	Disagree	**4.5**	3.8	4.8	4.0
	Strongly Disagree	**0.6**	0.0	0.0	1.0
		(*n* = 314)	(*n* = 80)	(*n* = 106)	(n = 100)
My woodland is vulnerable to pests and diseases	Strongly Agree	**13.4**	18.8	13.2	12.0
	Agree	**54.5**	53.8	59.4	61.0
	Neutral	**24.5**	21.3	20.8	23.0
	Disagree	**6.4**	6.3	4.7	4.0
	Strongly Disagree	**1.3**	0.0	1.9	0.0

time. Further, only 70.5% of managers for whom capital growth is a significant objective see climate change as a threat: slightly lower than the whole cohort average (78.0%). A larger proportion of managers prioritising recreation (81.6%) agree that this is a threat to their woods. Broadly, however, our respondents' different aims and motives generated very little variation within their overall perspectives on forest health.

Along with these reflections on the health of forests overall, respondents were asked to assess the future prospects for 10 common British tree species chosen in consultation with expert stakeholders in the UK forestry sector - giving a score between 5 (improving health) and − 5 (worsening health), with 0 signifying 'no change'. It is somewhat concerning that only two species – holly and yew – gained an overall positive mean average score, and it should be noted that yew's positive score was extremely small (+0.02, see Table 2). The health prospects of

Table 2
Forest managers' opinions on the future prospects for 10 common tree species in the UK, by overall mean score. Negative numbers represent an overall perceived worsening of health, whilst positive numbers represent perceived improving health. The prospects for most of these species is considered to be declining.

Species	Total Sample Mean	Total Count	Capital Growth	Water	Recreation
Ash (*Fraxinus excelsior*)	−3.64	307	−3.59	−3.74	−3.56
Oaks (*Quercus robur / petraea*)	−1.49	243	−1.41	−1.39	−1.35
Sitka spruce (*Picea sitchensis*)	−0.53	136	−0.26	−0.50	−0.19
Scots pine (*Pinus sylvestris*)	−0.46	158	−0.51	−0.50	−0.27
Common walnut (*Juglans regia*)	−0.23	120	−0.03	−0.11	−0.06
Small-leaved lime (*Tilia cordata*)	−0.19	147	−0.33	−0.27	−0.15
Douglas fir (*Pseudotsuga menziesii*)	−0.16	127	−0.06	−0.15	0.03
Silver birch (*Betula pendula*)	−0.04	180	0.17	−0.13	0.22
Yew (*Taxus baccata*)	0.02	133	−0.03	−0.03	0.03
Holly (*Ilex aquifolium*)	0.46	162	0.13	0.45	0.82

all other species were considered to be worsening. Two species – ash and oak – stand out from the group both in that considerably more respondents offered a health assessment, and they had a notably lower mean score than other species (see Fig. 2).

Once again, there appears to be only very slight variation here within the sample. Respondents with an above cohort average commitment to capital growth showed a very slightly less negative view of the prospects of Sitka spruce than the sample as a whole. However, respondents oriented towards recreation showed the same tendency. Those with capital growth and recreation objectives also reported a slightly positive outlook for silver birch in contrast to the overall sample's slightly negative assessment.

Despite these perceptions of generally worsening prospects, our respondents believe a number of these species will remain important in the future in the UK. When asked to identify which tree species they expected to be 'dominant' in Britain's future forests, oak ($n = 176$), birch ($n = 135$), and sycamore ($n = 131$) were by far the most common responses. Beech ($n = 81$) was the next most popular, with hazel, holly, and hornbeam each identified more than 50 times. Maple, lime, willow, cherry, alder, Scots pine, and hawthorn received between 40 and 50 mentions. In total, more than 50 species were named at least once in response to this question, including all of the species mentioned in Table 2 above (ash $n = 34$; Douglas fir $n = 34$; Stika spruce $n = 14$; yew $n = 9$; walnut $n = 5$).

3.3. Factors promoting general forest health

A number of themes were identified from the data relating to managers' understandings of the factors that 'promote the health' of trees (See Table 3). These related broadly to biophysical dimensions of the forest environment and the interactions of people with trees. These were open questions, enabling managers to freely input short text answers rather than drawing from a predetermined list.

The most prominent response was the importance of '**active management**' to tree health. This included the related use of various positively value-laden terms such as 'good', 'careful' and 'correct' that emphasise attentiveness and managerial intervention. Especially strong within this theme was a focus on silvicultural thinning as a route

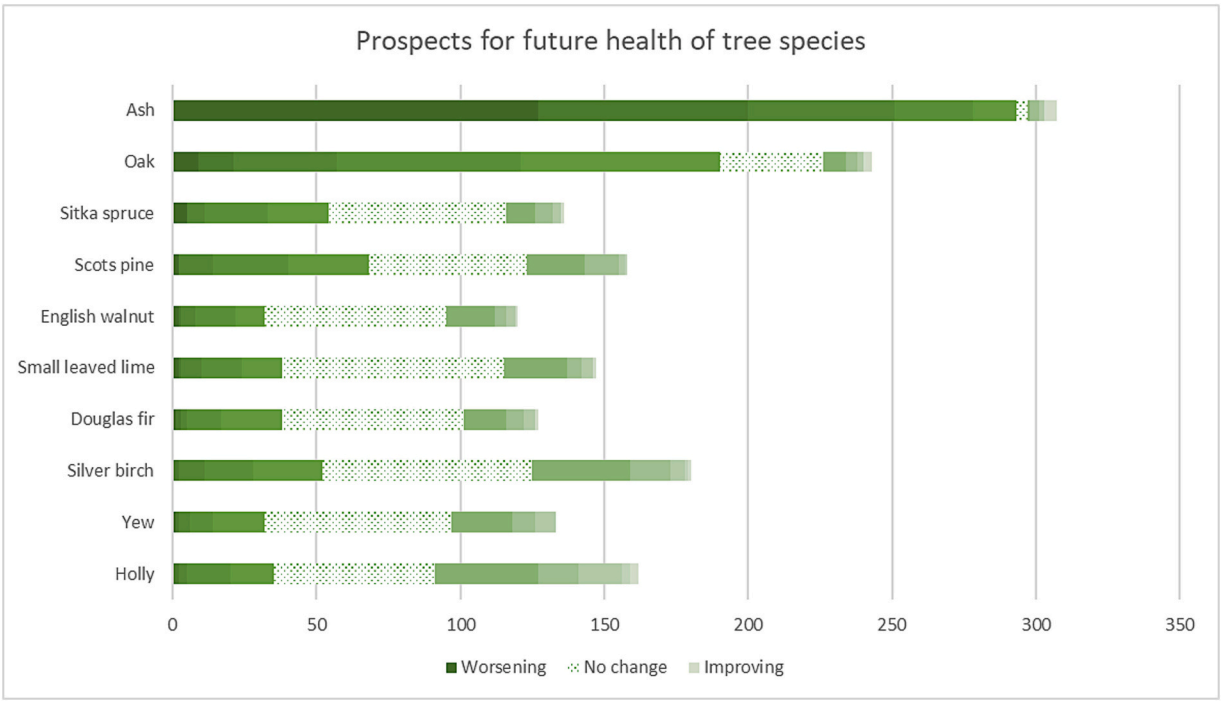

Fig. 2. Future prospects for 10 common tree species in the UK, by count. Not only do ash and oak have the lowest mean scores (Table 2, above), but also a far greater number of forest managers considered these species to be declining in health.

towards creating the conditions for good tree and forest health. Three other management-related themes were evident in the data, further characterising the perceived best ways to manage forests to promote tree health. The need for **protection from mammals** – specifically deer, squirrels, and rabbits – was very prominent, with associated terms including 'control', 'fencing', 'damage' and 'exclusion'. Similarly, although less common, there was a need expressed for control and removal of weeds and invasive species. Appropriate **planting** of new 'clean', 'reputable', 'local' stock was a second additional aspect of management identified as key to maintaining forest health. In particular, it was expressed that planting should have the goal of achieving resilience, through the use of 'native' and 'mixed' species. Third, there was some recognition of the importance of **'regular' inspection** and monitoring in contributing to good forest health.

Alongside these management interventions, respondents highlighted **biophysical conditions and characteristics** as being significant for promoting healthy trees. A large number of responses noted the need for generally **positive environmental conditions**, such as healthy soil, clean water, fresh air, and good light. These, air and water in particular, were commonly linked back to thinning as a management practice. Finally, three ecologically-oriented characteristics and processes were deemed important for promoting tree and forest health. The need for diversity and variation at all scales was identified by numerous respondents: from genetic diversity, to mixed species, ages, stand types and overall structure. Interestingly, and in contrast to the planting theme noted above, the concept of 'resilience' was virtually absent from this theme of diversity. **Allowing natural regeneration** was another pathway to healthy forests for the respondents, and in an echo of this, limiting (human) disturbance to forests was a third relatively minor theme. This involved limiting 'public access' and keeping 'people out' so nature could be 'left alone'.

3.4. *Visual signs of health and ill-health in trees*

Respondents were asked to provide keywords or short phrases describing the visual signs of the health (and, separately, ill health) of trees. This generated considerable short text data which, as noted above, was analysed via word counts and subsequent thematic analysis, focused around the physical form of trees, their dynamic qualities, and their relational context (see Fig. 3).

The majority of responses focused on *physical characteristics* of the visible parts of trees: their bark, branches, leaves, and crown or canopy. **Colour** was one of the most significant dimensions of these descriptions across health and ill health, with 'vibrant' or 'bright' green colours (of leaves) being an especially common indication of good health. Although brown(ing) was only occasionally mentioned as a sign of ill health, a more general 'discolouration' was widely noted. **Density** – especially in relation to the crown and leaves – was also a major aspect of these descriptions. A 'full' or 'dense' canopy was considered a key indicator of good health, whilst 'sparse', 'bare' or thin(ning) canopy indicated the opposite. Comments on basic tree **form** also spanned good and ill health. Healthy trees were identified by being 'upright', 'straight', 'stable' or having 'good form', whilst unhealthy trees were 'distorted' and often displayed epicormic growth. Direct **markers** of ill health were widely identified. These ranged from quite general descriptions, such as the presence of 'damage', through to more specific references to bark 'lesions' and 'bleeds', along with the presence of 'fungus' and the widespread identification of 'dieback' (especially of branches and crown).

Our respondent forest managers frequently went beyond immediate physical indicators of health, to identify certain *dynamic qualities* of trees and woodlands that gave clues as to their condition over time. Chief amongst these was reference to **growth**. Unhealthy trees demonstrated 'poor', 'stunted' or 'slow' growth over time, whereas healthy trees display 'vigorous', 'good', 'strong' and 'new' growth. Signs of **natural productivity** – such as abundant fruit, flowers, and seed - were considered demonstrative of good health. A temporal or **change**-related dimension emerged from a number of descriptions of ill health with adjectives such as 'early', 'premature', and 'rapid' being commonly used in relation to biological changes such as leaf loss and senescence.

Two *contextual signs* of health and ill health were also reported by our respondents. Primary amongst these was the presence or absence of associated and **synergistic life** around the trees in question. Healthy trees in particular are signalled by adjacent or associated wildlife, biodiversity, or 'compatible' species (birdlife; moss; lichens). A

Table 3
Factors understood by forest managers to promote the health of trees. Illustrative qualitative data in response to short answer open-ended survey questions, organised thematically.

Management	
'Active management'	
'Careful management'	
'Proactive management (coppicing, thinning, more considered planting)'	**Biophysical conditions**
'Good management – in line with best practice'	'Light & air'
'Management to encourage more birds, insects and animals'	'Clean air quality'
'Proper long term management of both our woods and adjoining ones'	'Establishment of more healthy soil active biology'
'Programme of thinning to increase light and air round the trees'	'Healthy soil environment'
'Regular interventions, thinning, pruning'	'Soil quality and care'
	'Thinning to improve light levels through the canopy'
	'Managing light levels to support trees at all stages of growth cycle'
	'Water - not too little, not too much'
	'Clean water'
Mammal (& invasive plants) protection	**Diversity & variation**
'Control of grey squirrel and deer numbers'	'Structural and age diversity of trees within the woodland.'
'Protect regen oak from grey squirrel/ deer'	'Genetic diversity within species and between species.'
'Protection of young trees from deer'	'Species resilience in the form of species and structural diversity'
'Exclusion of deer'	'Having a mix of age classes and a variable woodland structure'
'Keeping rabbits and squirrels from bark stripping'	'planting a diverse mix of species and provenances'
'Protect regen oak from grey squirrel/ deer'	
'control of invasive non-native plants'	
Planting	
'Planting of new woodland and replacing fallen trees with diverse but local species'	**Regeneration**
'Increasing range of species diversity in new planting.'	'Encouraging broadleaf regeneration'
'Interplanting with resilient native species'	'Allow trees to regenerate naturally.'
'Using planting stock from reputable Grown-in-Britain nurseries'	'Regen and reseeding with local seed.'
	'Coppicing to refresh existing plants and allow light to reach the soil for natural regen.'
	'Thinning of conifers around regenerating broad leaved trees'
Inspection	
'Regular observation and inspections'	**Limiting (human) disturbance**
'Regular monitoring and inspection'	'Keeping people out.- Vectors of disease/ waste/ compaction/ trampling/invasive species'
'being alert to risks and careful observations as well as keeping updated on risks'	'Minimal human activity and disturbance within the woodland'
'Being checked for signs of distress/ attack regularly'	'Lack of public access and disturbance'

secondary, less widespread, indicator of tree and forest health was the **ambient conditions** of the wood – especially the amount of light and space. Unhealthy woods were 'overcrowded', with trees 'reaching for light', whilst healthy woods were those where trees had 'enough light and space to grow'.

The data elicited via this question set exhibited a great deal of value-laden language, often with somewhat intangible subjectivity. Claims to naturalness were not uncommon, such as reference to 'unnatural leaves' or 'growing naturally'. Allied to this was the use of adjectives such as (in)appropriate and (ab)normal. However, respondents also occasionally identified healthy trees as 'graceful', 'happy', 'life affirming' or as having a 'steadfast spirit'. Similarly, unhealthy trees were described as appearing 'sad', 'unhappy', 'tragic' or 'weak'.

3.5. Oak health and threats

Following questions regarding the general health of forests, our survey asked respondents to consider the health of oak species in Britain[1] (Fig. 4). Around three-fifths (59.5%) of respondents believed that Britain's oaks are 'under serious threat', with only around 5% disagreeing with this. There was also a degree of scepticism regarding their long-term future, with only one-fifth (20.1%) confident that oaks will continue to 'stand the test of time' in Britain.

We directed a number of questions exclusively to those forest manager respondents who had ownership of, or other responsibility for, oaks. A clear majority (70.1%) of these believed that the oak trees and oak woodlands they manage were *currently* healthy but this positivity was set against a sense of vulnerability and potential future decline. A similarly large majority (66.3%) of respondents considered their oaks to be 'vulnerable to pests and diseases' and very few (13.5%) felt the health of their oak trees had improved over the past decade. This echoes data reported above (section 3.2) where forest managers judged the future prospects of oak to be poor, second worst only to ash trees. Despite the threat of acute oak decline, managers largely (75.9%) remain committed to continued planting of oak (Fig. 4).

These managers perceived the biggest threat to their oaks to be browsing and bark stripping by mammals (in the UK this implies deer and squirrels) (Fig. 5), nearly three-fifths of respondents (58.8%) considering this to be a threat. Three other threats were also clearly of substantial concern: acute oak decline (41.2%), drought (40.9%), and the potentially slow rate of oaks' adaptation to environmental change (39.4%). Other prominent pests and diseases (e.g. *Xylella fastidiosa*, 9.5%; and Oak processionary caterpillar/moth, 25.5%) were, however, seen as less of a threat.

4. Discussion

The results reported in this paper provide a clear sense of how forest managers in the UK think about, and make judgements on, the health of their trees and forests. At a general level, our respondents – who are broadly similar to past British Woodlands Survey cohorts in relation to their management motivations – are not especially concerned about the *current* health of their trees, woods, and forests, but are worried about the future. Oak, specifically, was no different in this regard with a generally positive view of current oak health, but with the perception of serious threats and considerable concern for the future. In our sample, and aligning with existing analysis (e.g. Sousa-Silva et al., 2018; Deuffic et al., 2020), forest managers are cognizant of the interactions between climate change and forest health. They are alert to the threats posed by climate change (and associated problems such as drought and the lack of adaptive capacity of species such as oak), and are aware of their forests' interlinked vulnerability to pests and diseases. However, it is notable that the familiar and longstanding threat posed by mammals (deer and squirrels in the UK) is seen as substantively greater than any other. Our data seems to suggest, therefore, that managers understand the nature of current threats, but do not consider them insurmountable or an existential threat to their woods.

Looking forward, however, they expect challenges to the health of their trees and, as demonstrated by their judgements about the prospects of a number of species, they lack confidence in a range of species. It is noteworthy that currently common native species – oak and birch – are expected to remain important trees in their future forests. However, the potential for sycamore – a non-native but widely naturalised species in the UK – to become a considerably more dominant tree is also notable. It is likely that this is linked to the decline of ash as a result of ash dieback (*Hymenoscyphus fraxineus*), as sycamore is widely expected to fill the gaps within British forests left by this disease (Broome et al., 2019). It is also clear from our results that there is a substantial degree of uncertainty and/or ambiguity amongst managers' perceptions, with neutral and 'don't know' answers featuring prominently in the data.

[1] Two species of oak are native to Britain: *Quercus robur* and *Quercus petraea*.

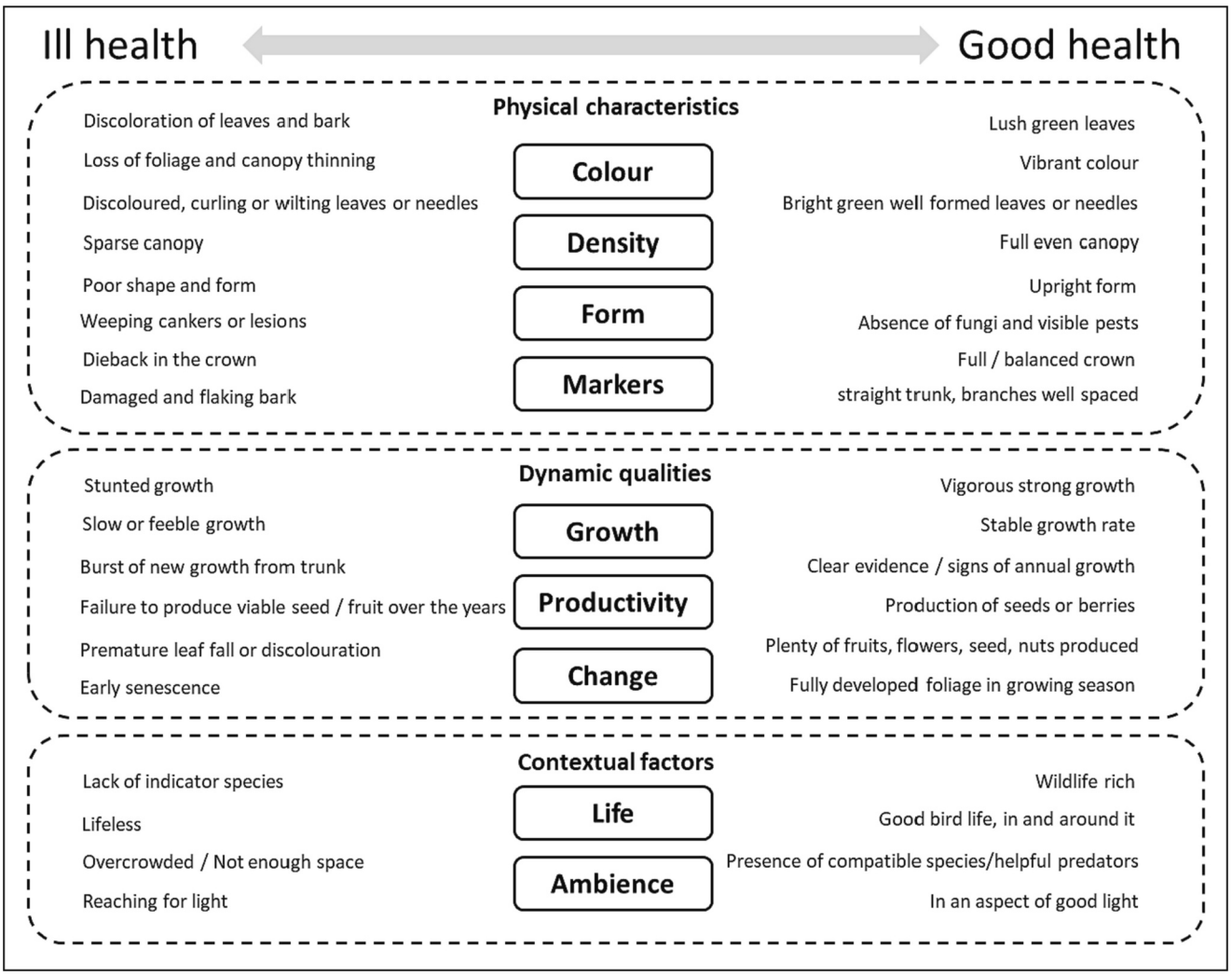

Fig. 3. The visual signs used by forest managers to judge good health and ill health of their trees and forests. Illustrative qualitative data in response to short answer open-ended survey questions, organised thematically.

To some extent, our findings echo Lawrence and Marzano's (2014) conclusion that managers focus primarily on immediate threats to their forests - in their analysis, the prioritisation of dealing with existing pests and diseases over longer-term adaptation to climate change. Markowski-Lindsay et al. (2020) also establish clear links between the emergence of pests and diseases and forest manager's harvesting decisions. Lawrence and Marzano also highlighted the uncertainty felt by managers about the future, including scepticism of climate change predictions, and the impact of this on willingness to undertake adaptive management. These uncertainties were also a key finding by Lidskog and Sjödin (2014) in their analysis of post-storm forest management decisions in Sweden. From our data, therefore, given the combination of current contentment (i.e. the general absence of immediate threats) and uncertainty over the future amongst our cohort of forest managers, we might expect somewhat limited 'energy' or enthusiasm for contemporary active management to promote forest health, similar to the lack of enthusiasm for adaptive management revealed by Lawrence and Marzano's analysis. In this regard, forest managers in the UK appear to be relatively circumspect, yet watchful.

Although natural regeneration features as a theme within our analysis, our respondents widely echo the prevailing opinion in Britain that human intervention and management are vital to contemporary forest health. The UK government's current *England Tree Strategy*, for example, states "We *must* manage existing trees and woodlands to increase their resilience to climate change and pests and disease" (UK Government 2021: 24, emphasis added). This managerial paradigm permeates throughout the data with, for example, reference to active management, planting, control of 'pests', and silvicultural activities intended to 'improve' natural conditions. It is also clearly illustrated by the majority's rejection of the suggestion that "Oak trees will be healthy without any intervention by me". Further work is required to ascertain how (if at all) this perception varies across different manager types, however, given it's prominence in our data, a commitment to a managerial approach in some form or another seems likely to be shared across types. This paradigm fits neatly not only with the long-standing government narrative focused on 'under-management' (see Dandy, 2016), but also matches historical analyses of British and European woods as distinctly anthropogenic (e.g. Rackham, 2015; Kirby and Watkins, 2015) and reflects past calls from conservation organisations for more active management (e.g. Wildlife and Countryside Link, 2009). What this paradigm deters, however, is fuller consideration of the potential role and status of natural processes and agents within forest health and its management.

Emerging contemporary approaches to environmental management are increasingly focusing on low-impact and limited-intervention approaches, including natural regeneration and 'rewilding'. These trends are emerging amongst forest owners and managers beyond the UK (e.g. see Gobster et al., 2022 in the north American context). The challenges associated with land managers engaging with such approaches have

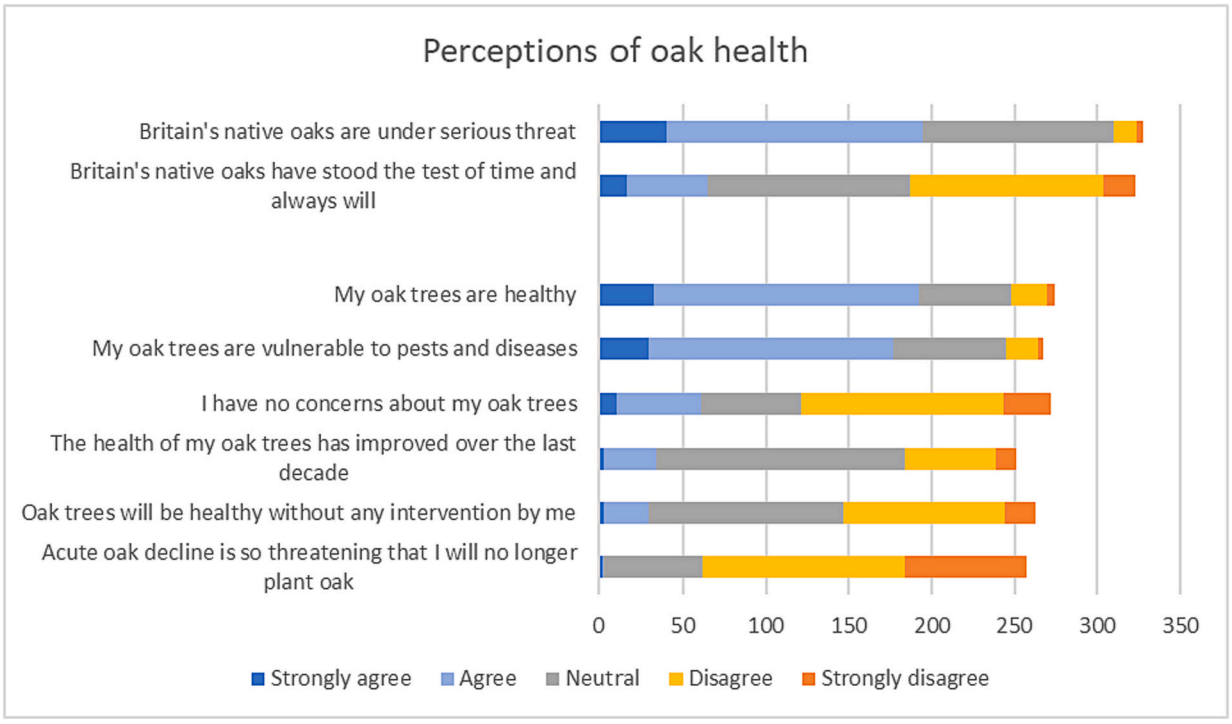

Fig. 4. Perceptions of oak health amongst oak managers. A strong perception of current overall oak health is balanced against a concern for their vulnerability.

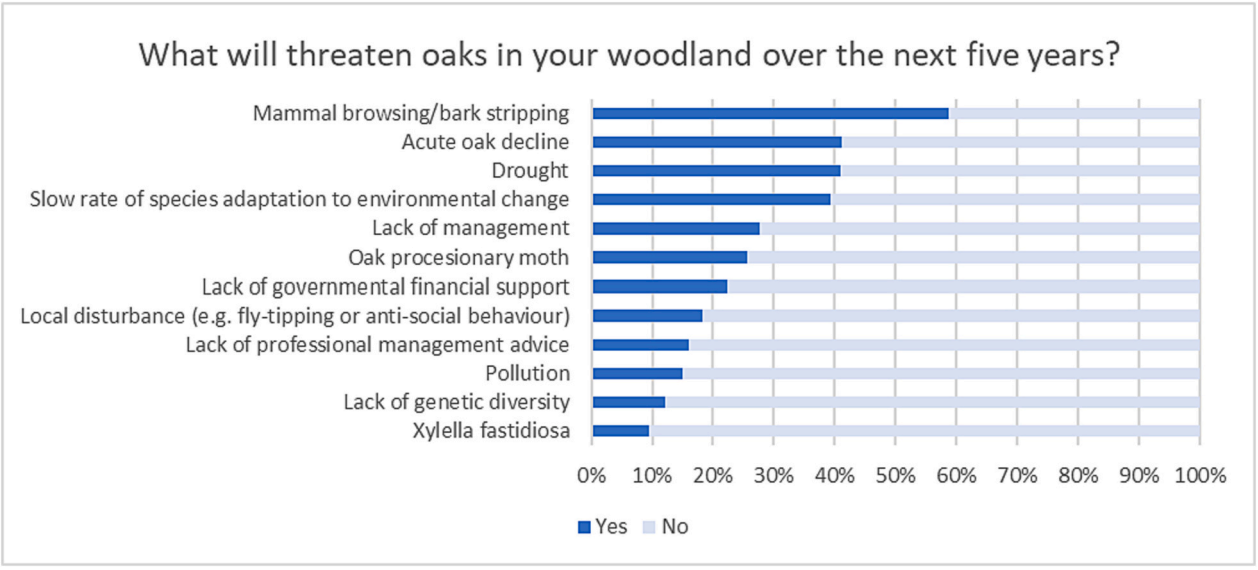

Fig. 5. Perceived threats to oak woodlands amongst forest managers. The common traditional concern regarding damage by wild deer and squirrels is notably more prominent than other concerns.

been highlighted previously (see Dandy and Wynne-Jones, 2019), and include aspects that our data show forest managers currently associate with forest ill-health – such as toleration of mammal 'damage'. This serves to highlight the problems intrinsic to defining a 'healthy' forest or tree in relation to biological diversity and 'naturalness'. Where are the thresholds between the 'healthy' interspecies relationships within functioning organisms and ecosystems, and the 'unhealthy' interspecies relationships that constitute an 'outbreak' of disease or pests and result in tree ill-health and death? Are there inherently different perspectives and social norms associated with a native pest versus a non-native pest? Social context is critical to relative judgements of value between 'upright', 'vibrant' healthy trees free from impairment by 'natural' phenomena, and trees which hold 'natural' biological and ecological relationships with their environment and other species.

Within our data it is interventions *within* the forest boundary that dominate responses, with only very limited reference made to wider societal and/or economic changes. It must be acknowledged that our chosen data collection method – a survey using predominantly closed questions – is not an effective way to capture data relating to broader thinking or issue definition relating to the subject matter. However, the restriction of managerial actions to the forest itself is still notable, especially including amongst responses to open questions, and further work using qualitative methods is required to unpick and further explore these aspects of managers' thinking.

In line with this seemingly relatively conventional thinking, our data shows that managers also make judgements about the health of their trees based on generally predictable and intuitive visual criteria, themselves based on their experience of their forest. The primary visual characteristics used by managers to make these judgements (e.g. colour; form; specific markers; growth) align well with characteristics that it might be expected non-experts and/or 'the public' would use. More technical language is only occasionally employed by private managers. This aligns strongly with the analysis presented by Lidskog and Sjödin (2014). They highlight the importance of experiential and embodied knowledge – obtained by forest owners over the long term – to making management decisions. They state "experience-based knowledge has proven effective over multiple generations, and the forest owners consider it *more* reliable than the forest consultants' abstract theoretical knowledge concerning future risks" (2014, p. 281, emphasis added). This has two broad implications. First, it re-confirms the long-established notion that any guidance relating to surveillance for tree health should utilise non-technical language and utilise in-field demonstration wherever possible. However, the common use of informal and often subjective language based on limited formal scientific knowledge also highlights the problems faced by science-driven policy-makers and practitioners (especially in official governmental roles) when communicating about tree and forest health. Our results also re-confirm (see, for example, Lawrence et al., 2020; Hamunen et al., 2014) the importance of non-governmental (e.g. membership organisations; peer networks) and informal sources of information for underpinning forest managers' understandings of tree health, particularly as a bridge between formal scientific and 'lay' actors in this arena.

5. Conclusion

The managers of private forests have critical roles to play in maintaining the health of our forests globally. However, we have very little concrete knowledge regarding how this diverse stakeholder group actually perceive and understand the health of the trees they manage. In our study we used data from a survey of private forest managers across the UK to begin to fill in this gap. We have shown that judgements about the health of trees are based on a range of physical characteristics, dynamic qualities and contextual factors. In general, forest managers in the UK are not overly concerned about the current state of their forests. However, there are concerns about their future. Intervention and active management remain critical components of maintaining forest health for these forest managers, perpetuating a strongly embedded dimension of forest management culture in Europe.

CRediT authorship contribution statement

Seumas Bates: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Gillian Petrokofsky:** Conceptualization, Methodology, Software, Data curation, Formal analysis, Writing – review & editing. **Gabriel Hemery:** Conceptualization, Funding acquisition, Methodology, Data curation, Formal analysis, Writing – review & editing. **Norman Dandy:** Conceptualization, Funding acquisition, Methodology, Formal analysis, Project administration, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Norman Dandy reports financial support was provided by UK Research and Innovation.

Data availability

The data that has been used is confidential.

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