Comparing and valuing the impacts of Oak processionary moth in the Netherlands to England

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List of abbreviations/acronyms

EU	European Union
FC	Forestry Commission
GGD	Gemeentelijke Gezondheids Dienst (Municipal Health Services)
GP	General Practitioner
NVWA	Nederlandse Voedsel en Waren Autoriteit (Dutch Food Authority)
OPM	Oak processionary moth
PHE	Public Health England
RIA	Regulatory Impact Assessment
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (National institute for public health and the environment)

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Executive summary

The Oak processionary moth (OPM), *Thaumetopoea processionea L.*, is a pest originating from southern and central continental Europe. It has expanded northwards since the 1980s and is now well-established in France, Germany, Belgium and the Netherlands, and high populations are being recorded in Germany. In 2006 the first OPM infestations were discovered in the west London boroughs of Ealing and Richmond. Smaller outbreaks have been detected and eradicated further afield (e.g. Leeds and Sheffield). The pest poses a threat to oak trees and their ecosystems and to human and animal health, and is subject to statutory control to prevent spread, with the current management regime focusing on a combination of control and eradication within the known area of distribution, predominantly in and around London.

In the face of potentially mounting control costs the Forestry Commission is seeking evidence on the feasibility and cost-effectiveness of control alternatives including information that clarifies the cost of alternatives relative to the likely wider impacts incurred or avoided (i.e. benefits). This report sought evidence on different approaches and practice in the Netherlands where the inevitability of spread is accepted. The study was largely desk-based, reviewing existing published and unpublished literature and drawing on expert opinion from bodies engaged in OPM control in both countries.

In the Netherlands OPM is considered to be a public health problem rather than a plant health issue, and the focus of management is not on eradicating the pest but on minimising the health impacts (a risk-based approach). The aim of this study is to compare and value the impacts of OPM in the Netherlands to the potential impacts in England if OPM were to become more widespread. This would serve to inform on potential costs in England and any key lessons that can be taken from the Netherlands. This includes clarifying how management works in the Netherlands and what a risk-based approach entails and what it implies in English conditions.

OPM health impacts are allergic reactions to the urticating hairs of the caterpillars, which lead to skin irritation and, in more severe cases, to breathing difficulties in humans and animals. Studies on health impacts in the Netherlands report that 0.01% to 0.5% of the Dutch population may have suffered from health impacts relating to OPM, rising to 4.3% in areas with higher oak densities. Public health authorities inform the public about the risks of OPM through information leaflets and websites. Occasionally, when there is a particularly high risk to human health, walking and cycling routes are diverted until OPM is removed.

The Dutch Food Authority (NVWA) facilitates the exchange of knowledge and experience, and has developed guidelines for OPM management, advising a risk-based approach. There is no other central coordination of OPM management and the application of NVWA guidelines varies across Dutch municipalities and local authorities, to which management responsibility is devolved. Amsterdam offers the closest approximation of how the approach might operate in an urbanised context, which in some aspects might approximate to conditions in the highly populated urban and suburban areas of England. The risk-based approach applied in Amsterdam centres around a risk assessment of OPM where the focus is on reducing the impacts to human health. Using a digital system all activities related to the notification, monitoring and treatment of OPM are recorded.

According to Dutch legislation, the negative impact (of OPM management) on other species and the environment should be prevented or minimised. There is a tendency for replacing chemical pesticides in preventative spraying with the biological insecticide *Bacillus thuringiensis* (Bt) and nematodes, (roundworms that can be deployed as natural pest control). Both have a potentially lower environmental impact with Bt (bacteria or bio-pesticide) preferred as easier to apply, with at least equal effectiveness and environmental impacts.

There are significant differences between the Netherlands (and Amsterdam in particular) and England that need to be considered before drawing conclusions on how well a risk-based approach might work in England, and the costs to both private and public stakeholders therein England. Obvious differences are higher human population and oak densities in urban and suburban areas of London (relative to Amsterdam), greater potential exposures in relative populations, identification of risk hotspots in the mosaic of private and public woodlands (London), and the clear assignment of responsibilities and hence incentives to collaborate in control.

Notwithstanding these constraints and challenges, the extent to which applicability in England could be within a reasonable cost envelope will be determined by the extent of risk reduction being sought[1] In turn this decision would need to be informed by further input on the public willingness to accept the specific environmental risks and the modified behaviours their presence entails. At present there is no convincing evidence to help understand public preferences for pest control nor how the wider public might prefer this and other pests to be managed.

While management in England has been partly informed by an internal regulatory impact assessment (RIA) (Forestry Commission, 2013b), this did not at the time consider anything like a risk-based scenario that might fit English conditions. Moreover neither country offers a sound evidence base comparing both costs and benefits. While costs of control are relatively observable, the evidence on benefits remains largely undocumented and anecdotal in both countries. As noted, this is the case even with the most politically sensitive health impact.

England has a suitable habitat and climate for OPM and further spread seems inevitable. A management approach focusing on minimising the impacts could be an alternative to the current approach, which in our view appears to be buying time for the development of a containment-eradication combination that is not yet based on any impact assessment or clear articulation of long-term scenarios for the eventuality and likelihood of widespread infestation.

A revised RIA to inform an alternative approach to management needs to be mindful of both the likely health impacts and public attitudes to pest prevalence. On the one hand Public Health England (2015) has suggested that OPM impacts are currently not demonstrably large but that symptom awareness needs to be increased among clinicians

[1] In other words, the extent to which management seeks to implement a precautionary approach.

and pharmacists. On the other hand very little is known about public preferences for pest prevalence and the willingness to pay to minimise exposure or symptoms. At the very least, better public information about the likely inevitability of spread and health consequences should form part of any move to a risk-based approach. Specifically, such information can provide the basis for the relevant behavioural change that is a form of joint responsibility and cost-sharing effort between government and tree owners/managers. As a research agenda we would also suggest the following elements:

- Developing tools to monitor OPM spread in a scientifically robust way
- Modelling OPM prevalence under risk-based management scenarios
- A feasibility study on the digitisation of tree locations and treatment histories
- Health exposure impact modelling in potential hotspot locations, where the latter are sites of high oak density and high visitor numbers
- Valuation of impacts and/or public preferences on presence/tolerance and management options including tree owner and government cost sharing scenarios
- Developing OPM awareness possibly as a good example of citizen science monitoring initiatives.

A summary of the key differences between England and the NL can be found in Annex 3. Annex 4 presents a tentative framework for considering the partial costs and benefits of OPM were it to become widespread throughout London.

1 Background and project aims

The Forestry Commission is seeking guidance on the control of Oak processionary moth and the relative effectiveness and efficiency[2] of potentially altering its current management approach, which is characterised as containment and eradication in and around the main zone of pest prevalence. This contrasts to an alternative risk-based approach used in Amsterdam, which often involves complete removal of detected infestations. Drawing on quantitative and qualitative evidence this largely desk-based study sought to address key questions to guide any potential review of management by key stakeholders in England. Specifically the aims as set out in the original project specification were to:

- Review OPM literature & data in both countries (i.e. England and the Netherlands);
- Consider impacts specifically in London and Amsterdam either as a whole or taking specific geographical areas within the cities;
- Examine all potential impacts e.g. on ecosystem services, human & animal health and costs of controls to various parties;
- Compare the different management approaches between the countries, the different distribution and composition of oak trees and how these differences may affect the impacts;
- Identify lessons for strategies to mitigate the impacts of OPM in England including a consideration of potential impacts in England if OPM were to become more widespread.

In pursuit of these objectives we have undertaken a review of relevant literatures in the UK and the Netherlands, while seeking the view of key informants engaged in OPM control. A list of these contacts is included as Annex A1. We concentrate mainly on Amsterdam, but draw on contrasting approaches elsewhere in the Netherlands where relevant.

The remainder of this report is broadly structured as follows.

Section two provides some background on the nature and impacts of OPM, the ecosystem services that are affected and the current regulatory and technical control methods used in the UK.

Section three concentrates on management approaches and evidence on effectiveness and cost from the Netherlands. The evidence focuses on Amsterdam in particular and the use of the risk-based approach.

Section four draws some conclusions on the relevance of Dutch conditions to management decisions in England. The aim is to indicate the extent to which we can say whether such an approach leads to a more favourable balance of reduced control costs relative to benefits compared to continuing current practice. In this context benefits consist of the avoided impacts to ecosystems and human health.

[2] Where efficiency in this context relates to the balance of costs and benefits to society of changing a control approach.

2 Background to OPM in England

The Oak processionary moth (OPM), *Thaumetopoea processionea L.*, is a pest that originates from southern and central continental Europe. It has expanded northwards since the 1980s and is now well-established in France, Germany, Belgium and The Netherlands and high populations are being recorded in Germany. In 2006 the first OPM infestations were discovered in the west London boroughs of Ealing and Richmond. It is likely that the larvae eggs were imported into Britain on imported oak trees from infested areas in mainland Europe (Parks & Townsend, 2011). Since its first detection, the pest has continued to spread to other areas in London and several other small outbreaks, the result of separate introductions from Europe, have occurred in places outside London (e.g. Pangbourne-on-Thames (Berkshire), Leeds, and Sheffield (Forestry Commission, 2013a). The outbreaks in Leeds and Sheffield were confined to the imported trees and did not establish in the wider area. The number of OPM nests recorded has increased rapidly. In 2011 the infested area in London covered 96 km^2 (9600 ha); in 2013 it was 223 km^2 (22,300 ha) (Forestry Commission, 2013a; Parks & Towsend, 2011, Parks, 2012). It is now known that the pest is spread over at least 10 London boroughs making London the core outbreak area.

[redacted] 2.1 Plant & health impacts

OPM larvae are considered a pest as they can be a threat to oak trees and to human and animal health. The caterpillar has a preference for native European oak species asespecially *Quercus robur, Quercus petraea, Quercus frainett o.* and *Quercus cerris* (Fransen, 2013). The American oak, Quercus rubra, is less attractive, but can also be colonised in cases of severe outbreaks and where there is a lack of native oak species. Annex 2 shows that native oak species are widespread across England, with particularly high densities in parts of London (e.g. Richmond Park, Croydon and Bromley).

OPM larvae mainly feed on oak leaves and rarely can cause complete defoliation of trees. Repeated infestations over several years increase the vulnerability of trees to attacks by other organisms, such as insects, buprestid beetles and fungi, and weaken their ability to withstand environmental stresses (Townsend, 2009). Eventually this can result in the death of a tree, and the loss of the associated ecosystem services it provides. Besides being a defoliator of trees, the caterpillars also pose significant risks to human and animal health (Jans, 2011). The caterpillars have thousands of minute urticating hairs that can cause allergic reactions in humans and animals leading to skin rashes, inflammation of the eye and respiratory problems. The symptoms become more severe after repeated exposure (Zijlstra et al., 2015). This health hazard from old nests can be present for as long as six years. The presence of nests and their removal therefore represent a significant occupational health consideration. The environmental and health impacts will be higher in more densely populated urban areas where the risk of exposure is higher. Because of the possible loss of ecosystem services (e.g. potential recreation values), and the potentially significant health impacts to humans and animals, the efficient control of OPM is both an environmental and a public health concern.

[redacted] 2.2 Ecosystem service impacts

As in other areas of environmental management, the benefits and costs of tree health have been framed in terms of ecosystem service provision, with the use of an Ecosystems Framework potentially helping to guide interventions (e.g. Defra 2013, NEA 2011). In essence the framework formalises the different benefits (and sometimes disbenefits) of ecosystems, highlighting how benefits or services arise directly, indirectly and in passive (or non-use) ways from underlying ecosystem functions. Figure 1 illustrates these in relation to ash, but can equally apply to oak. In this framework trees and woodland have direct market values in relation to their economic contribution to the economy (e.g. timber) and indirect values (e.g. trees also sequester carbon, which is a service that reduces climate change). Healthy trees also provision wellbeing due to their mere existence, and the fact that we or others might exercise an option to recreate (i.e. use) them at some future date[3]. Information on these values or the extent of their impairment is potentially an important component of OPM management and any regulatory impact assessment (RIA) should attempt to quantify them.

Valuation evidence related to oak woodlands has identified different elements of this value – for example Defra (2014) using a benefits transfer approach, and drawing on a more detailed ash valuation exercise for Great Britain (Defra, 2013), inferred the social and environmental value of oak at around £135 million per year. This is added to the commercial value of oak, which is estimated at just under £40 million per year; hence a total of around £175 million per year. Note however that the value of urban trees might be associated with significantly higher values than those in peri-urban and rural spaces. In an urban context, preferences will be more heavily related to the non-market values: local climate regulation, air quality, noise abatement, water flow regulation, biodiversity, aesthetics, recreation and health and well-being.

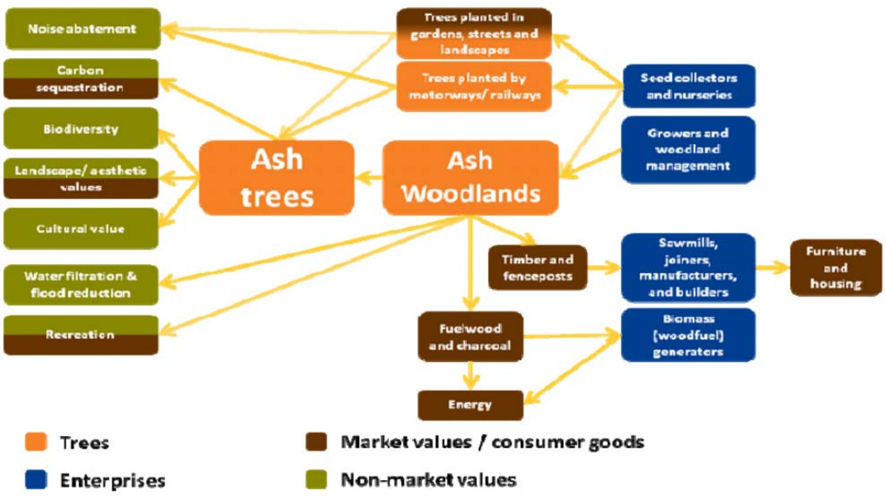

Figure 1. The Uses and Values of Ash Trees[4].

Pro-rating any of this value (loss) to marginal and localised OPM impacts is more challenging. To date, outbreaks have been small and isolated with no systematic data

[3] Conversely irrespective of use intentions people are psychologically diminished by the loss of trees or the presence of infestation.

[4] Defra (2013) Chalara in Ash Trees; a Framework for Assessing Ecosystem Impacts and Appraising Options' https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/200396/pb13906-chalara-socio-economic-framework.pdf

collection on either the market or non-market impacts. The most evident social costs[5] entail the extent of surveillance and control costs (see section 3.6). Beyond this, the evidence on recreational/amenity losses and human and animal health impacts are somewhat anecdotal, with limited recreational restrictions in the core area (e.g. Richmond Park). However, there have been no targeted revealed or stated preference studies to substantiate the value of these impacts. We might however argue that OPM also has a negative option value impact since some people may avoid areas of potential outbreaks or activities risking exposure regardless of whether an outbreak or exposure actually occurs.

The more serious health impact (to humans and animals) is also not easily quantified since contact symptoms are infrequent, not systematically recorded, or else are not easily distinguished from other allergic reactions that present (typically in pharmacies) as minor skin and respiratory ailments[6]. More serious anaphylactic reactions are possible, but notified cases appear to be rare and potentially due to insect spraying (Bosma and Jans 1998). Because of a more general lack of awareness and potential attribution (to OPM contact), and the relatively straightforward treatment, there appears to be no systematic UK record of attributable health impacts collected by clinicians, pharmacies, or veterinarians.

Partly addressing this gap a recent systematic review of the evidence by Public Health England (2015) outlined the evidence and risks as identified in the existing published and grey literature with specific reference to anaphylaxis. The report indicates that with current data it is impossible to reliably deduce a generalizable value for the prevalence of health effects associated with outbreaks of OPM. While acknowledging the exposure risks among specific groups (e.g. children playing) and in densely populated areas, the report restricted its advice to the need to develop more awareness and information for prescribing groups. In itself, this does not downplay the impact of less extreme health episodes (e.g. dermatitis) and by extension the value of reducing any health impacts. But it does support the need for a more systematic level of data collection to inform any monetary valuation exercise, and the need to inform the public of specific risk elements, which by extension need to be strategically managed when outbreaks occur.

Note in relation to health impact valuation, that the medium of illness may also be significant. In other words, an episode of unattributed allergic symptoms may be valued in one way by sufferers, but the value may change significantly with information on its cause, particularly when the latter is associated with some element of dread. This cannot be substantiated by any existing evidence, but we suggest that this factor might be significant in the case of OPM.

In summary therefore, without further valuation information addressing more extensive outbreak scenarios (and exposure assessments that in turn inform prevalence), a brief review of ecosystem-based impacts (benefits and costs) does not significantly lead to any broad conclusions on management options. However, it may also be instructive to consider evidence from the Netherlands (section 3.3), which may provide a clearer picture on these impacts in a risk-based management scenario.

[5] Social costs being the term used to denote financial costs incurred by government on behalf of wider society.
[6] For which over-the-counter antihistamine treatments (loratidone or Cetirizine) might be recommended at a cost of around £3.

[redacted] 2.3 Regulatory Control

Since first detection in 2006 OPM management has passed through three overlapping phases. Initially in the period 2006-2011 the aim was eradication and the use of statutory notices to enforce control measures on all properties. From 2011 the emphasis changed to eradication and containment. Based on OPM survey findings in 2010 it was concluded that the moth was established in the core area (i.e. London) and that eradication of OPM was no longer feasible (Parks & Townsend, 2011). As a result, government policy became one of containment in London and eradication in other infested areas. The “core zone” and “buffer zone” relate only to the main infestation area in west London, and in both zones the objective is containment (or at least slowing the rate of spread to 1 km/year or less). The difference between the “buffer zone” and “core zone” is that in the former the Forestry Commission surveys and manages OPM directly, whereas in the “core zone” OPM control is the responsibility of landowners. But the overall objective in both zones is the same. Elsewhere, where there are smaller isolated outbreaks outside the main area of infestation (Pangbourne, Croydon/Bromley), the objective is eradication.

During this period the UK Plant Health (Forestry) Order 2005 was amended to include OPM as a quarantine pest (SI2008/644). As a consequence, all imported oak trees from EU member states must be accompanied by an official statement that they have been nursery grown and that the place of production and its immediate vicinity have been free of OPM since the beginning of last growing season. In 2014, all areas in the UK that were unaffected by OPM received the status of ‘protected zone’ by EU legislation, meaning that all oak trees supplied to the protected zone must be free from OPM (Forestry Commission, 2015).

Since 2013 an enhanced control pilot has been operated, essentially ramping-up control and surveillance, and increasing awareness and supporting research on OPM and similar threats. In practical terms, the first stage of OPM control is to identify infestations through physical surveys and pheromone traps. Once identified, OPM has been controlled by spraying insecticides and through manual nest removal. Different levels of proactive (i.e. prophylactic) and reactive surveillance and control imply different levels of cost for the affected parties.

In 2013 the OPM control programme resulted in total expenditures of £1.9 million (Forestry Commission, 2013c). This cost is however a lower-bound estimate as it excludes cost incurred by smaller landowners and some larger ones like Network Rail. The overall cost was financed by different parties: Defra spent £1.1 million; Local Authorities £135,000; Forestry Commission £242,000; Royal Parks £226,000; and other major landowners £174,000. Despite the initial intention for cost sharing through the use of statutory requirements, the reality has been more skewed towards public control either by park authorities or local authorities.

Current management is partly informed by an internal (to Forestry Commission) Regulatory Impact Assessment (RIA) that typically sets out the intervention logic; i.e. the net benefits (benefits minus costs) to society relative to a baseline of no intervention. While the original RIA considered baseline and two options (i.e. Option 1: continued level of current intervention; Option 2: increased intervention), current policy is ultimately different to any of the options modelled, in that activity was significantly increased and spending is over £1 million per year because certain treatments of nests are paid for with public money while the

RIA assumed such costs would be borne by the private sector. It is the FC view that the cost might ultimately be reduced by economies of scale, meaning a lower unit cost and much more being done to try to slow the rate of spread.

Clearly under any blanket approach to monitoring and eradication, costs are likely to increase with the spread of the pest, and the intensity of the control option. But this cost discrepancy (in turn partly due to early lack of clarity about relative public and private rights, roles and responsibilities) is one of a number of unanticipated institutional and behavioural challenges confronted in the initial management of OPM identified by Tomlinson et al., (2015). The FC is seeking evidence on alternative cost-effective management approaches that might help to address these challenges. These might include moving from the current ?eradication/containment strategy to something characterised as 'living with' the pest; or more accurately acknowledging the likelihood that eradication/containment needs to be complemented by a so-called risk-based approach (see section 3.5 below), which in turn recognises the eventuality that the pest will become more widespread, and that the costs of any management need to be reconsidered relative to impacts or benefits[7]. Ultimately, this decision needs to be informed by information that clarifies the cost of such an approach relative to the likely wider impacts incurred or avoided (i.e. benefits).

While the information sought by this project might provide some basis for an improved assessment, we note that a revised RIA is not the main aim of this project. The report does however seek to clarify how management works in the Netherlands and what a risk-based approach entails and what it implies in English conditions.

3 OPM in the Netherlands

This section sets out the general background and key variables that characterise the regulatory approach to OPM in the Netherlands. Particular focus is on Amsterdam where a risk-based approach is in operation. Annex 2. Spatial distribution of oak trees in the Netherlands and England~~Annex 2 'Spatial distribution of oak trees in the Netherlands and England~~' provides some information on the distribution of oak species. As far as can be discerned OPM management is not determined by any formal regulatory impacts assessment or cost-benefit evidence. The following sections attempt to scope some relevant information and to review wider attitudes to tree disease control in the Netherlands.

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[redacted]3.1 Background

The first OPM infestations in the Netherlands were recorded in 1991, followed by spread northwards with severe outbreaks in 1996, 2004 and 2007 (CBS, PBL, Wageningen UR, 2012). OPM is now found throughout the country (**Error! Reference source not found.**~~Figure 2~~), mainly along streets in built up areas, as well as on oaks near wooded areas (Van Ass, 2008; Jans, 2011). OPM is less likely to be found in denser forest areas due to higher numbers of natural predators (e.g. two-spot ladybird, *Adalia bipunctata*, and bugs, *Rhabdomiris striatellus*) and colder temperatures (van Ass, 2008; Jans, 2011;

[7] Note that in the RIA practice a cost of control is typically weighted against a benefit, which is expressed in terms of the avoided damages or loss that would have occurred in a baseline of no intervention (hence cost) to control. By extension, the logical comparison for any scenarios is the relative change in cost relative to the change in benefit. In general the simplest baseline is doing nothing.

Hellingman & Mulder, 2012; Fransen, 2013). Research has shown that higher temperatures and lower rainfall contribute to the spread of OPM (van Oudenhoven et al., 2008).

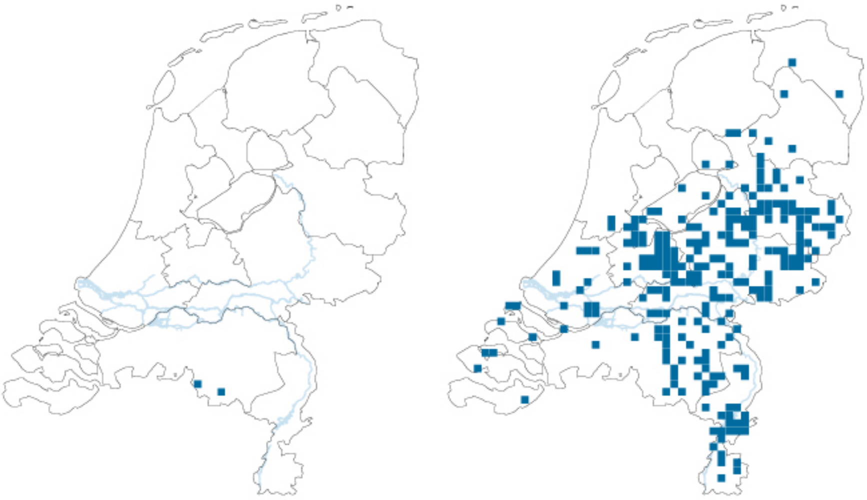

Figure 2 OPM infestations in 1991 (left) and 2011 (right) in the Netherlands[8].

[8] CBS, PBL, Wageningen UR (2013). Eikenprocessierups en klimaatverandering, 1991-2011 (indicator 1110, versie 06, 26 maart 2013). www.compendiumvoordeleefomgeving.nl. CBS, Den Haag; Planbureau voor de Leefomgeving, Den Haag/Bilthoven en Wageningen UR, Wageningen.

OPM spread is obviously related to the presence of oak trees. Annex 2 includes two figures of oak densities in the Netherlands and Amsterdam. Highest oak densities are found in the south and east of the country. In Amsterdam oak species represent about 3.6% of all trees, approximately 14,350 oak trees in 2014 (Kuppen & Buijs, 2013; Kuppen & Buijs, 2015a). **Error! Reference source not found.**~~Figure 3~~ shows the locations of oak trees and OPM infestations in Amsterdam since records began in 2009. Most oaks are found in the Amsterdamse Bos, Amsterdam Zuidoost and Amsterdam Noord, and many oak trees are also found along lanes streets and in parks. The first infestations in Amsterdam were reported in 2009, after which OPM spread to different areas of the city. The number of infested trees decreased from 857 in 2011 to 199 in 2013, but increased again in 2014 to 751 (Kuppen & Buijs, 2015a). Nest numbers in London steadily increased until 2012 after which the number of nests declined by about 50% in 2013. From 2013 to 2014 the number of OPM nests more than doubled and 4043 trees were infested (Forestry Commission, 2014). The areas Zuidoost & AMC and Zuid (including Amstelpark and Amsterdamse Bos) had highest numbers of OPM infestations. Weather conditions in 2014, with a relatively warm winter and spring seem to have been favourable for OPM (Kuppen & Buijs, 2015a). Mid-size oaks of 10-15 metres high are preferred by OPM (Kuppen & Buijs, 2012).

Analysis of the monitoring results of previous years show that most infested trees are found along lanes, in fringe woodland and in tree canopies in forest areas where trees are exposed to sunlight (Kuppen, 2012; Kuppen & Buijs, 2013). OPM is less likely to be found in dense forest patches.

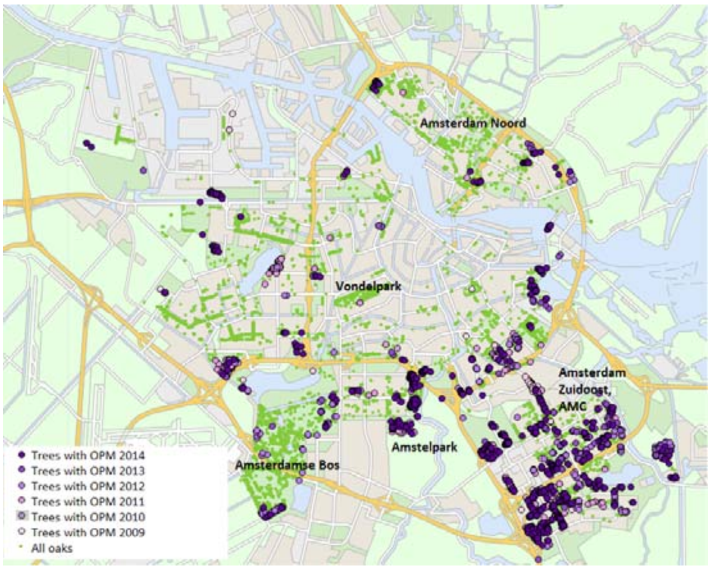

Figure 3. Oaks (green dots) and OPM infestations in Amsterdam 2009–2014.

[redacted]3.2 Regulatory approach

The Dutch Food Authority (NVWA) (part of the Ministry of Economic Affairs) is the central body facilitating the exchange of knowledge and experience about the management of OPM in the Netherlands. The NVWA works together with different governmental institutes and expert organisations forming an OPM expert group to advise on OPM management. The national institute for public health and the environment (RIVM) and regional public health services (GGD) investigate and update information on the health impacts of OPM. Alterra Wageningen University is a research organisation that conducts research on the spread of OPM and its natural predators. Natuurkalender (Nature calendar)[9] is a national citizen science project that aims to monitor, analyse, forecast and communicate the spread of OPM based on notifications by the public. The knowledge centre/platform on OPM, formed by different experts in the field, monitors the development of OPM, provides reports through different media and keeps an online platform where information can be exchanged (http://www.fsd.nl/eikenprocessierups).

Apart from the expert group on OPM there is no central coordination of OPM management in the Netherlands. The management is delegated to local government authorities, nature organisations or water boards. As long as they operate within the boundaries of the law, these tree managers can select the control methods that they perceive to be feasible. The NVWA only informs and advises public and private tree managers on control methods and impacts and has developed flexible OPM management guidelines to facilitate this. The last update was published in 2013 and outlines the risk-based approach, which is explained in section 3.5.

The guidelines focus on minimising the health impacts of OPM, but there is no clearly stated rationale explaining the public health status. However, we suspect that this status might partly be explained by a particularly large health impact related to an OPM outbreak in 1996 (Van Ass, 2008).

Since first recorded in Amsterdam in 2009, the coordination of OPM management is with the local public health service GGD Amsterdam. This body is the central point of contact for OPM issues; it coordinates monitoring and treatment of OPM and maintains contact with GPs and veterinarians. Its management is based on the NVWA guidelines.

The Sixth Dutch Forestry Inventory conducted in 2014 provides data on the extent and type of forests and ownership in the Netherlands. The national government owns 33.8% of forests, and local governmental bodies own 17.6% (Schelhaas et al., 2014). Other tree owners are nature protection organisations (19.3%) and private landowners and business (31.3%).

[redacted] 3.2.1 Jurisdiction and legislation

Several acts shape the management of OPM in relation to public health, the environment and working conditions (Visser & Goudzwaard, 2011). Under some of these acts, tree owners have a duty of care to prevent and combat nuisance from OPM because of the risk to public health (Fransen, 2013; Visser & Goudzwaard, 2011). Accordingly, tree owners have to actively treat OPM and inform the public about the possible health problems. If no adequate measures have been taken, tree owners can be held legally responsible for the impacts (Visser & Goudzwaard, 2011). There are some cases of court decisions related to the duty of care as specified in these acts. However, when a tree owner can show that he has carefully treated OPM, and has adequately informed the public, it is unlikely that a claim will be successful (Visser & Goudzwaard, 2011).

[9] Coordinated by the Environmental Systems Analysis Group of Wageningen University

Separately, the Flora and Fauna Act 1998 (FFA) relates to the environmental impact of treating OPM, roughly specifying that negative impacts to flora and fauna should be prevented. Visser and Goudzwaard (2011) however conclude that the FFA has no direct effect on the treatment of OPM as it is not specific enough. It has only an ‘appeal’ to careful action in nature and thereby to prevent damage to protected species. It is therefore up to tree managers themselves to take these protected species into account and to restrict treatment activities accordingly. In addition to the protected species, there exists a ‘red list’ of endangered moth species. Although not legally enforceable, tree managers are asked to take the red list species into account when applying control methods. As Amsterdam aims to stimulate the optimal use and enjoyment of green areas in the city, it does not spray areas where species from the red list are present.

The Dutch Working Conditions Legislation (Arbowet)[10] states that protective measures have to be taken by those monitoring, spraying and removing OPM. In general the employer is responsible for taking protective measures (e.g. clothing) and the employee has to respect these measures.

[redacted] 3.3 OPM impacts

As in the UK, environmental management in the Netherlands is influenced by the need to safeguard ecosystem services enjoyed by the public. Unlike the UK there has been no national ecosystem assessment that provides an overview of forest values. Nor has there previously been any attempt at non-market valuation of OPM impacts. Here we attempt to review relevant data that might inform a preliminary estimate of health costs.

An important factor to note is that the Netherlands population in 2015 is approximately 17 million people with over 40% living in urban areas (CBS, 2005; CBS, 2015). The average population density is 500 citizens per squared kilometre (The World Bank Group, 2015). Amsterdam has a population of 822,272 inhabitants and a population density of 4,908/km^2 O+S Amsterdam, 2014). This compares to England where in 2011, 81.5 per cent (45.7 million) of the usually resident population of England and Wales lived in urban areas and 18.5 per cent (10.3 million) lived in rural areas. Population densities in England and Wales are 413/km^2 and 149/km^2 respectively (Office for National Statistics, 2014). London has a population of 8.6 million and a population density of 5,491/km^2 (Greater London Authority, 2015). Different population densities, land ownership and levels of public exposures to OPM are likely to be an underlying determinant or alternative influence on how OPM is managed. However, these data mask the identification of specific risk hot-spots that need to be determined using a set of further criteria that include tree locations relative to populations and the design of parks and other forest amenities.

[redacted] 3.3.1 Health impacts

OPM is predominantly considered to be a public health issue and management is therefore focused on reducing the impacts to human and animal health. The management strategies differ between areas in the Netherlands depending on levels of finance available and the number of oak trees. As a result a range of approaches are adopted, including preventative spraying only, to a full risk-based approach, which is applied in Amsterdam (see section 5.5).

[10] For an English translation see https://osha.europa.eu/fop/netherlands/en/legislation/index_html

OPM health impacts are not registered in any systematic way in the data recording systems operated by doctors (GP) practice systems. Therefore, data on patient visits to GPs in relation to OPM health impacts are not available nationally. However, two studies have investigated the numbers of health cases. Based on data collected in 1996-1998 and on oak densities, it was estimated that annually 80,000 citizens (0.5%) in the Netherlands experience health problems from OPM (Schellart & Jans, 1996; Jans & Franssen, 2008). Around one third of these episodes results in a GP visit (Rots-de Vries, 2000). Note however that the years 1996-1998 saw large outbreaks of OPM and therefore this figure is thought to be an overestimate. Importantly health experts are seeing a decline in the number of health impacts as awareness increases and people recognise how to protect themselves against the urticating hairs and avoid certain areas to prevent impacts. These experts also say that the current management regime has resulted in a manageable situation, but that any budget restrictions may pose a threat to this.

Results from the health monitor Overijssel (2012)[11] estimated that 4.3% of the population suffered from OPM impacts in 2012. It should be noted that Overijssel is a province with a relatively high density of oaks – 7,925ha of oak dominated forest, which is 12.3% of all oak dominated forest in the Netherlands (Schelhaas et al., 2014), and so this estimate is therefore unrepresentative of the Netherlands as a whole. However, it does give an indication of the health impacts in potential hot-spot areas. Consistent with previous studies (e.g. Rots-de Vries, 2000) the health monitor found that one third of the people experiencing health problems visited the GP, which corresponds to 1.5% of the total population.

Public health services GGD Twente and GGD IJsselland conducted a study to determine the extent and severity of OPM health impacts in the Netherlands over the period 2012 – 2014, summarised in Table 1. The data were collected using a national network of GPs and cover 0.7% of the total Dutch population. It was estimated that the total number of GP visits with OPM-related health problems in the Netherlands was 1,800 in 2012, 1,700 in 2013 and 2,500 in 2014. Table 1 shows that the number of reported health cases has risen over the period, especially in the North of the country. But there are large regional differences that seem to correspond to the distribution of oaks (Table 2).

The differences in the number of GP visits are also discernibly higher in areas where OPM is a relatively new phenomenon. These numbers suggest that 0.01% (2000 people, the average of the three years) of the population visits their GP with OPM-related health problems. Taking into account that one third of the people experiencing health problems visit their GP, the total number of people suffering from OPM related health problems would be 6000 (0.03%). This number is much lower than previous studies (e.g. Jans & Franssen, 2008 and Rots-de Vries, 2000), and there are several reasons why this is probably an underestimation. In general the years 2012-2014 have seen low to medium pest pressure. Other factors are that GPs may lack experience recognizing OPM-related health problems and that the measuring stations were located in areas with low pest pressure (Zijlstra et al., 2015).

[11] National health survey conducted by GGD, RIVM and CBS which included a section on OPM in 2012

Table 1. Number of GP visits related to OPM health problems per region and year

	North (per 100,000 citizens)	East (per 100,000 citizens)	South (per 100,000 citizens)	West (per 100,000 citizens)	Nether-lands (per 100,000 citizens)	Total GP visits (estimated)	95% confidence interval
2012	12.9	31.7	3.9	2.6	10.8	1800	1000-3200
2013	0	25.4	11.3	5.1	10.1	1700	900-3100
2014	34.9	25.4	15.1	2.6	15.1	2500	1500-4200

Source: Zijlstra et al. (2015) Landelijke registratie gezondheidsklachten eikenprocessierups (EPR) bij huisartsenpraktijken. GGD Twente, GGD IJsselland, NIVEL. Onderdeel van de Academische Werkplaats Milieu en Gezondheid. -

Table 2. Regional differences in the Netherlands

	North	East	South	West	Netherlands
Area of oak dominated forest (ha)	13,869	24,657	16,181	9,577	64,283
Oak dominated forest as a percentage of total surface area	1.7%	2.5%	1.8%	1.4%	1.9%
Population density (per km2)	207	367	449	1095	406

Schelhaas, M.J., A.P.P.M. Clerkx, W.P. Daamen, J.F. Oldenburger, G. Velema, P. Schnitger,H. Schoonderwoerd & H. Kramer, (2014). Zesde Nederlandse Bosinventarisatie; Methoden en basisresultaten. – Mulder, M. RIVM (2014). Bevolkingsdichtheid per gemeente 2013. In: Volksgezondheid Toekomst Verkenning, Nationale Atlas Volksgezondheid. Bilthoven: RIVM, http://www.zorgatlas.nl

In Amsterdam no OPM-related health cases have been reported (GGD Amsterdam). The management approach, focused on minimising the risk to human health, may play a role in this. But it should also be noted that the oak densities in Amsterdam are low compared to other areas in the Netherlands.

[redacted]3.3.2 Valuing health impacts

As noted above, estimates of health incidence differ between existing studies. To value the health impacts on a national basis we take the estimates from Jans & Franssen (2008) as an upper bound and those of Zijlstra et al. (2015) as a lower bound. Jans & Franssen (2008) reported 80,000 health cases. Taking into account that one-third of people experiencing health problems visit the GP, this corresponds to 26,666 GP visits. Zijlstra et al. (2015) reports on average 2,000 GP visits over the years 2012, 2013 and 2014, which corresponds to an average of 6,000 health cases. The costs of OPM health impacts included in the valuation of health impacts are GP visits, sickness leave and hospital admissions.

GP visits

In the Netherlands the cost to an individual of a GP visit averages €12.50 (for visit duration of 15 minutes). Using 26,666 GP visits as an upper bound and 2,000 as a lower bound, the total cost of GP visits varies from €24,999 to €333,333 per annum. A GP visit implies a loss of labour time. It is assumed that it takes a person one hour to visit the GP for a short consultation. Taking an average wage of €30 and assuming that 50% of the whole population is employed results in a lower bound of €30,000 and an upper bound of €400,000.

Work absence

Jans & Franssen (2008) estimated that 1% of the population experiencing OPM health problems had general complaints such as fever, sleeplessness and listlessness. 2.1% experienced eye problems and 1.4% respiratory problems. Based on health literature related to allergic complaints it is assumed that the average period of work absence is two weeks as a result of general complaints. Again, it is assumed that 50% of the people experiencing health problems are employed and the average hourly wage is €30. This results in an upper bound for general complaints of €960,000 (1% * 80,000 * 10 working days * 8hrs * €30 * 50%) and a lower bound of €72,000.

Costs of hospital admissions

Jans & Franssen (2008) estimated that about 0.7% or 450 people a year with OPM related health problems visit a hospital voluntarily. The average cost to an individual for a short hospital consultation is €52. This results in an upper bound of €29,210 and a lower bound of €2,184. Patients who are referred to a hospital by their GP are not included in these estimates, due to a lack of available data.

About 4.4% (20 people a year) of those visiting a hospital with OPM related health problems showed severe symptoms (Jans & Franssen, 2008). In some cases long-lasting injuries are not ruled out (e.g. Bosma & Jans, 1998; Erich & Meulenbelt, 1993). Due to very weak evidence on the health costs related to these cases, these are not included in the calculations. Table 3summarises these health cost estimates.

Table 3. Overview of the annual costs to individuals of OPM health impacts

Health impact	Lower bound	Upper bound
GP visits (incl. loss of labour time)	€54,999	€733,333
Work absence	€72,000	€960,000
Hospital admissions	€2,184	€29,210
Total per annum	€129,183	€1,352,543

[redacted]3.3.3 Recreation and disamenity impacts

Different stakeholders (e.g. landscape organisations and GGDs) indicate that bicycle and walking paths can be closed for a short period of time when OPM infestations are found along these paths, posing a risk to human health. In summary, the impact seems to be low. Also, recreational areas such as parks can be closed for the same reasons until the nests have been removed, which usually happens within 24 hours. According to Noordelijke

Werkgroep Eikenprocessierups (2010), the threat of OPM is seen as a reason for tourists to avoid certain regions. It has not been determined whether this is actually the case and to what extent. There is currently no quantification of the impact cost of recreational losses.

[redacted] 3.4 Attitudes and behaviours

OPM has naturally spread northwards from south/eastern central Europe over the last century. Therefore it was no surprise when it was first reported in the Netherlands, which has a suitable habitat and climate. The inevitability of spread across continental borders explains some of the regulatory and public acceptance of its presence and the likely attitude to control relative to eradication.

The number of oaks felled annually may be indicative of attitudes and the cultural value of trees. Schelhaas et al. (2014) estimated that 131,000m^3 of oak is felled annually, corresponding to 1.9m^3/ha/year. There is no information available about the number of trees that this volume corresponds to. Felling fractions that indicate the chance that a tree will be felled in the following year depend on the size of the tree and the type of tree owner. Taking into account these two factors felling fractions vary from 0.22% to 1.95% (Schelhaas et al., 2014). This study was not focused specifically on OPM and trees can be felled for various reasons. Different stakeholders such as forest organisations and landscape organisations indicate that no oaks are felled due to OPM in the Netherlands. Equally OPM has not resulted in any oak felling in Amsterdam, because oaks are valued for the high potential for biodiversity (Personal communication with Jan Buijs and Henry Kuppen). In contrast, there is evidence in London of oaks being felled due to OPM. However, this information is insufficient to draw any conclusions regarding a difference in the cultural value of oak.

[redacted] 3.5 OPM control: the risk-based approach

NVWA control guidelines outline a risk-based approach in which a risk assessment, based on monitoring activities, feeds into the control measures taken. In this approach monitoring, spraying, nest removal and pheromone trapping are combined in order to minimize the impacts to human health and the environment. Therefore the focus of this risk-based approach is not on eradicating the pest but rather it is on minimising the impacts. The approach is consistent with taking no action in low risk areas with the potential for these untreated areas giving rise to further infestation in later years[12].

OPM management is delegated to the local authorities in the Netherlands, mostly municipalities. The NVWA guidelines outline the various control options, but it is up to the authorities to decide which methods to apply in the specific situations. Factors including available budget, number of trees and risk to human health play a role in this. Most tree owners in the Netherlands restrict their activities to informing the public about health effects, often working together with the local health authorities (Zijlstra et al., 2015). Some authorities spray large areas, which is the cheapest option of control, to lower the costs on curative measures. Curative measures (i.e. nest removal) are in many cases only taken in areas where there is a high risk to human health, e.g. along bicycle and walking tracks or highly visited wooded areas.

[12] Remnant nests can disperse urticating hairs and moths for up to six years.

[redacted] 3.5.1 OPM management in Amsterdam

Amsterdam appears to be the municipality adhering most closely to the NVWA guidelines. This involves a combination of preventative spraying, tree inspections, reactive nest removal, pheromone trapping, a central registration system of infestations, GIS database, and communication to the public (Kuppen & Buijs, 2015b: Bleeker & Kaljee, 2013). **Error! Reference source not found.**~~Figure 4~~ depicts the management approach in the city. The colours represent the different partners involved, roughly representing the different activities in OPM management. Amsterdam has seven tree managers (blue), one in each of the seven city districts, appointed by the municipality (the tree owner). Tree managers are responsible for OPM management and hire different contracting specialists for the monitoring and treatment activities. The OPM coordinator, GGD Amsterdam (orange) is involved with the overall coordination of the seven districts together. Monitoring and treatment activities are each conducted by separate contracting partners to clearly distinguish their roles.

Amsterdam uses a comprehensive digital GPS system, Digidis, to report information about OPM infestations. The tree managers, monitoring specialists, treatment specialists and the OPM coordinator from GGD Amsterdam have access to this system. The personal digital assistant (PDA) is used during inspections and treatments in the field. In this system every oak tree is represented by a dot based on GPS coordinates that shows locations of all oak trees. It also includes information on current and previous OPM infestations, type of nests, level of urgency assigned by the monitoring specialist (low, medium, and high), previous control methods applied per tree and results of (previous) pheromone trapping. Every activity (e.g. type of tree, infestation, priority level, treatment etc.) is digitally recorded in Digidis. Once an activity is recorded, the information is readily available for others.

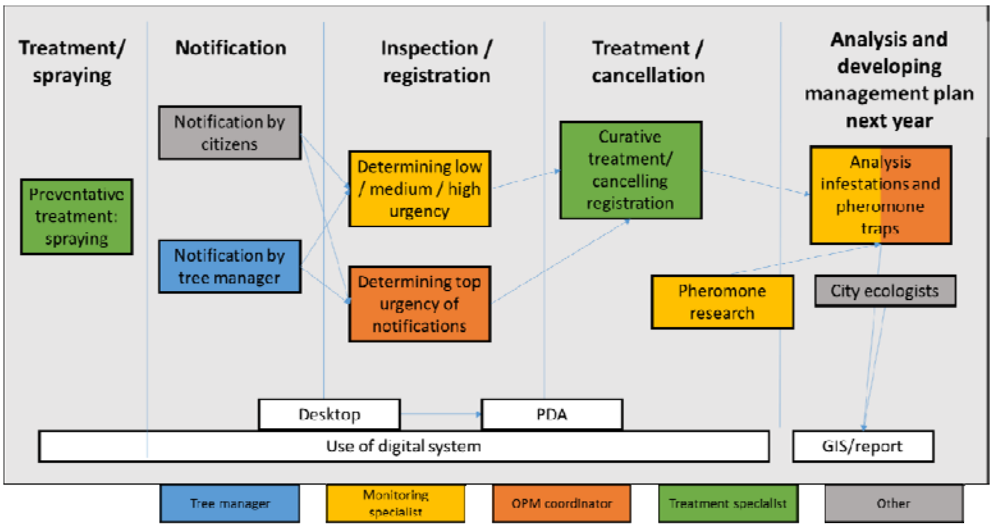

Figure 4. Overview of management approach in Amsterdam[13]

[13] Adapted from Kuppen, H. & Buijs, J.A. (2013). De eikenprocessierups in Amsterdam Rapportage 2013. GGD Amsterdam, Cluster Leefomgeving, Afdeling Dierplaagbeheersing.

The OPM management process in Amsterdam distinguishes five stages. Spraying and inspection areas for OPM have been assigned the previous year based on that year's monitoring results. The first management stage involves preventative spraying of selected areas. From the moment the caterpillars start to develop, citizens and tree managers can notify OPM to the OPM coordinator. He or she can send a monitoring specialist to this location or assign an urgency level based on the information received. During the inspection and registration stage, the monitoring specialist inspects the inspection areas. He reports signs of OPM and urgency levels in the digital system using a PDA (tablet). The treatment specialist then applies the control methods and cancels the registration made by the monitoring specialist. The monitoring and treatment results are analysed and described in a report. This feeds into the selection of spraying and inspection areas the following year.

Error! Reference source not found.~~Figure 5~~ provides an overview of the monitoring and treatment activities in Amsterdam over the period of 2009-2013. Since 2011 spraying has increased significantly and 2013 saw the lowest number of infested trees since the start of the treatment programme[14]. Despite the low number of trees infested, the number of trees inspected has almost doubled; the reason being that the pest has spread throughout the city and therefore the at-risk areas have increased.

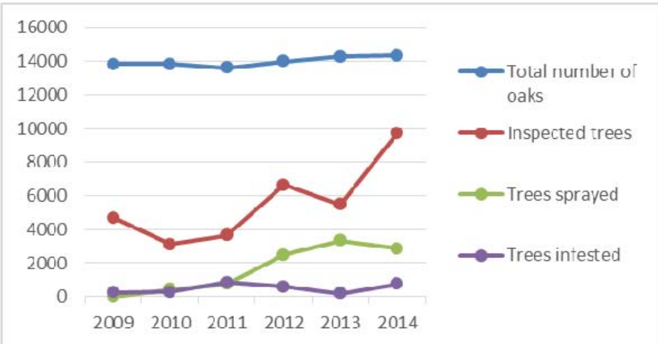

Figure 5. Overview of monitoring and treatment activity in Amsterdam[15].

[redacted]3.5.2 Inspection areas in Amsterdam

Information about infestations in the previous year and pheromone trapping are used to determine OPM risk areas for the current year. Inspection areas are assigned based on infestations on oak trees, pheromone traps and abundance of oak. Caterpillars prefer young and mid-age trees in an open landscape and areas with monocultures of native oak species are most at risk. Locations along roads, fields and sandy ground are also attractive as they release warmth during spring. **Error! Reference source not found.**~~Figure 6~~ shows the inspection areas for 2015. Oaks are inspected from the fourth larval stage (L4) (late May/early June) when they are well visible in trees (Kuppen & Buijs, 2015a). In addition, old infestations are inspected to evaluate the effectiveness of control methods used the previous year. Areas in Amsterdam that are suspected to be at risk of OPM infestations are randomly

[14] As was the case in London.

[15] Kuppen, H. & Buijs, J.A. (2013). De eikenprocessierups in Amsterdam Rapportage 2013. GGD Amsterdam, Cluster Leefomgeving, Afdeling Dierplaagbeheersing.

checked based on last year's inspection results. Locations with a high number of moths in the pheromone traps in the previous year are checked more carefully.

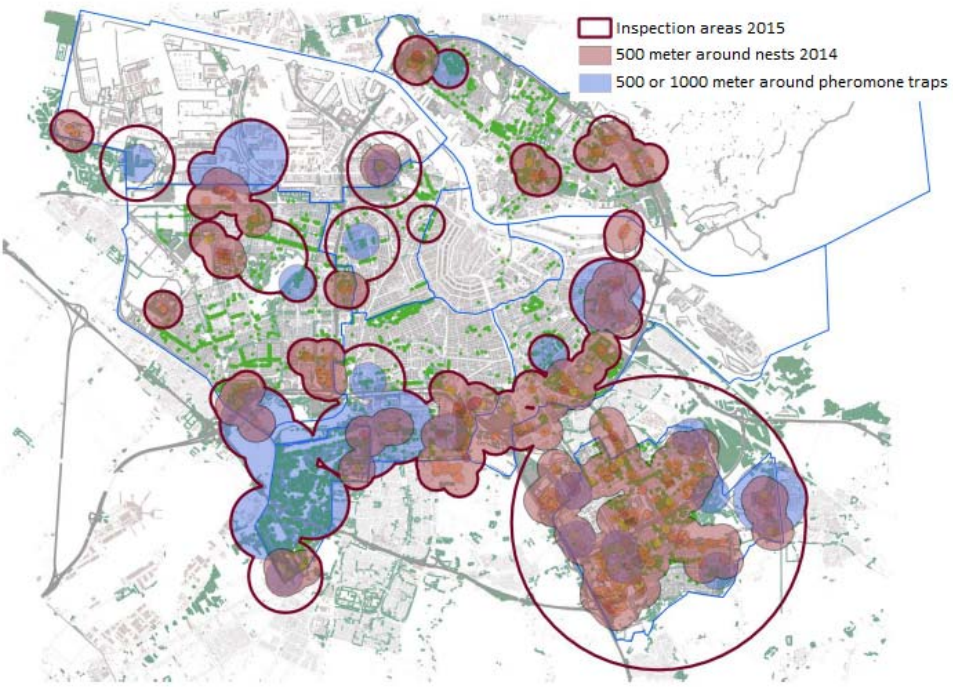

Figure 6. Inspection areas for 2015 in Amsterdam[16].

[redacted] 3.5.3 Monitoring

Monitoring egg and larval development provides essential information for the effective use of control methods. Egg development can be monitored on trees where eggs have been tagged or in a model station where the larvae are monitored in a test-environment (used in Amsterdam). In combination with temperature data, information about the egg and larval development is used for optimal timing of inspection, spraying and nest removal.

When an infested tree is found, a risk analysis is undertaken by the tree inspector based on the position of the larvae in the tree, larval stage, size of the nest and location, thereby taking into account the chance of human and animal exposure. Areas that are highly visited are of high risk due to increased risk of health impacts. Examples of high risk environments are cycling and walking routes, shopping centres, health centres, schools,

[16] Kuppen, H. & Buijs, J.A. 2015a De eikenprocessierups in Amsterdam Beheer in 2014. GGD Amsterdam, Cluster Leefomgeving, Afdeling Dierplaagbeheersing.

camping sites and outdoor events. Fields close to infested oaks are also of high risk to animals. Forestry areas are of low risk due to lower visitation rates.

A priority level of high, standard or low is assigned, depending on the timeframe that the control methods need to be applied within 24 hours, 72 hours and 10 working days respectively. The higher the probability or consequences of impacts, the more urgent is the need for nest removal. Trees on which no infestations are found are marked as control locations. Trees with highest priority are usually located in parks, where risk of contact with humans and animals is highest, larvae are in stages L4-L6 or starting to pupate, and nests are lower than 2.5m above the ground. Trees with lowest priority are found along roads with low pedestrian or cyclist frequency (Kuppen, 2012). The exact characteristics of nests needing to be reported at different levels of urgency are described in the manual for OPM management (Kuppen & Buijs, 2015b). For notifications by the public or tree managers outside inspection areas, the OPM coordinator adds this to the digital system and assigns a priority level to it.

Pheromone trapping is a tool for gathering information about the extent of the future population and the effectiveness of control measures taken. Traps are used to estimate the number of moths and future egg densities. This method is applied from the moment the moths leave the nests in the beginning of July to the end of September. The pheromone traps serve as an indication for the pest pressure in already colonised areas, but they are also a signal for detecting OPM in new areas. In 2014, 96 pheromone traps were distributed over the city in 32 clusters (Kuppen & Buijs, 2015a). In contrast, in London about 200 traps were deployed in 2014, 700 in 2015 and 900 for the whole programme, which includes Pangbourne and a survey corridor from Pangbourne to West London.

[redacted] 3.5.4 Treatment measures

3.5.4.1 Spraying

OPM spraying is most effective when the caterpillar is in the first to third larval stages. From the fourth larval stage the larvae develop their toxic urticating hairs and spraying does not reduce nuisance as effectively as in earlier stages. For maximum effectiveness timing of spraying is therefore crucial and should ideally be applied when the oaks have developed at least 40% of leaves and before the fourth larval stage (Kenniscentrum eikenprocessierups, 2015a)[17].

Chemical spraying with insecticides was traditionally used, but has decreased in recent years. Chemical pesticides (Diflubenzuron or Dimilin) are less selective to OPM caterpillars than biological methods, and may be counter-productive in the long-run as they may also affect natural predators (Franssen, 2013). Chemical spraying is now barely used in the Netherlands and is replaced by Bacillus thuringiensis (Bt) (Xen Tari WG in Amsterdam), which has a lower environmental impact. Caterpillars are killed through eating the sprayed leaves. The higher the trees, the less effective spraying is considered to be.

Nematodes (Tp nema in Amsterdam) are a recently developed alternative to Bt. Nematodes are thought to have less detrimental effects on their environment and are therefore preferred in areas of high visitation and in the vicinity of surface water (Kuppen &

[17] In the UK ADAS research suggests treatment as early as possible using Bt whereas Diflubenzuron acts on contact rather than though ingestion.

Buijs, 2013). However, the use of nematodes is still in the pilot phase and more research is needed to examine and compare the environmental impacts of each method.

In Amsterdam both bacterial and nematode spraying are used and spraying areas are assigned based on economic and ecological factors (Kuppen & Buijs, 2013). Nematodes are mainly used in areas near surface water and people, for example on the grounds of the Amsterdam Medical Centre and at the sports park De Aanloop. To reduce the ecological impact, spraying (both nematodes and Bt) is restricted and areas with protected species and species from the 'red list' are excluded from spraying.

3.5.4.2 Nest removal

Inspections show where nests have developed and urgency levels assigned by the tree inspector determine the time frame in which nests have to be removed. Nests can be removed using industrial vacuum equipment or burnt off. Vacuum equipment can be used from aerial working platforms or by hand by tree climbers. Aerial working platforms are safer, quicker and more practical if nests are high up in the trees. When nests are more difficult to reach with large equipment, tree climbers are needed to remove nests by hand. Protective clothing is important essential to prevent health impacts. Thermal heating is labour-intensive and has the disadvantage that the toxic hairs are blown away and thus spread. Mechanic removal of nests is therefore preferred over thermal heating.

3.5.4.3 Public information and awareness

Posters, flyers, websites, media and notification boards inform visitors of certain areas of possible OPM presence. The general public can use the website (http://www.natuurkalender.nl) to report signs of natural phenomena that can have an impact on human health, e.g. ticks, hay fever and OPM. News about the development of OPM is also published on another website: www.natuurbericht.nl. This website also publishes news about other natural phenomena. Most of the OPM news on natuurbericht.nl is written by the members of the knowledge centre, with news items occasionally being followed by local and national media attention.

The RIVM has developed a toolkit for OPM with materials and information that can directly be used by stakeholders to inform the public[18]. It includes folders, posters and presentations that can be used directly by stakeholders. The guidelines developed by the NVWA also provide advice to inform land owners of adjacent land, private tree owners of infested trees and employees involved in treatment methods. In Amsterdam information posters are located where there is a particular high risk for the public.

3.5.4.4 Area closures

In the event of high infestation areas can be closed temporarily. It can occasionally be necessary to close down an area during treatment. When areas are closed, bicycle and walking routes can be diverted. In 2014 the immediate grounds around some infested individual trees in Amstelpark were closed. There have been no cases of closure of bicycle or walking lanes to date. In the event of infestation these places would be given high priority and closed until the nests have been removed. When marked with high urgency this would be within two working days.

[18] Materials including English examples can be found here http://toolkits.loketgezondleven.nl/milieu_en_leefomgeving/?page_id=160

[redacted] 3.6 Costs of control

The costs of OPM control in the Netherlands are borne by the tree owners. These are:

- Municipalities which are responsible for vegetation in their area;
- Provincial authorities which are responsible for the vegetation in the surrounding of provincial roads; and
- Nature protection organisations and forest owners that responsible for the management of those areas.

[redacted] 3.6.1 Municipalities and other governmental organisations

The total management costs incurred by Dutch municipalities have been estimated in 2012 to average between €4.8 million and €7.8 million (Fransen, 2013) or approximately between €5 million and €8 million in 2015. The costs include monitoring, preventative and curative measures. The costs incurred by other governmental authorities have been estimated at €1.5 million – 1.6 million a year. The total amount for the government is therefore estimated to average €6.6 million a year with a maximum of €9.6 million/ year (Fransen, 2013).

The costs of OPM management differ significantly across 393 municipalities, differentiated by size[19] and human and tree populations. In 2007 52% of municipalities spent between €1,000 and €10,000, 25% between €10,000 and €25,000, and some cases of expenditures over €200,000 were reported (Fransen, 2013). The differences in costs are a result of the differences in pest pressure and experience with OPM (Fransen, 2013). Due to increasing pest pressure throughout the country most municipalities will now face costs between €10,000 and €50,000 (Fransen, 2013).

[redacted] 3.6.2 Nature and forest owners

Owners of forestry and nature areas face hardly any costs due to OPM. Costs have only been borne incidentally in the eastern part of the country, when cycling tracks were closed as a result of an infested tree close to the tracks. When infestations are found in dense forests where there is low risk of human health impacts, no measures are taken. Correspondingly nature and forest owners incur relatively low costs ranging from €0 to €1,000 per year.

[redacted] 3.6.3 Costs in Amsterdam

Table 4~~Table 4~~ shows the costs for OPM management in Amsterdam for 2014 and 2015. These comprise budgets for monitoring, treatment and coordination activities which are conducted by separate external contractors. The monitoring budget involves costs for inspecting trees, installing and inspecting pheromone traps, license costs for Digidis and compiling the annual report. Inspecting an oak after notification by the public or tree owner is more expensive than inspection of an oak in an assigned inspection area. The treatment budget comprises the preventative and curative measures. Spraying and next removal costs depend on the priority and difficulty (access) factors previously mentioned. The data show that total number of infested trees rose from 811 in 2014 to 1,253 in 2015. Correspondingly, total management costs increased from €186,542.40 in 2014 to €225,175.10 in 2015. Costs per infested tree were lower in 2015 than in 2014. GGD Amsterdam funds €30,000 of their

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[19] Varying in size from 7.84 km^2 to 841.56 km^2

coordination costs. The other costs are paid for via the tree management budget of the municipality.

Table 4. Overview of OPM management costs in Amsterdam in 2014 and 2015

Activity	2014	2015
Number of infestations	811	1,253
Preventative measures	€21,000	€26,000
Curative measures	€50,186	€75,152.50
Inspection	€22,400	€28,156.80
Pheromone traps	€17,456.40	€20,365.80
Coordination GGD	€60,000	€60,000
Report	€11,000	€11,000
DIGIDIS license	€4,500	€4,500
Total	€186,542.40	€225,175.10
Financed by		
GGD	€30,000	€30,000
Tree management	€156,867.40	€195,675.10
Costs per infested tree	€230.06	€179.71
Costs per tree (13000 in AMS)	€14.35	€17.32

4 Implications for management in England

In seeking lessons for OPM control in England the previous section has highlighted a number of features that distinguish the approach adopted in Amsterdam from that in the Netherlands more generally. This section summarises the key observations and highlights some remaining information needs to facilitate any comparison with England or lessons for management.

OPM is predominantly a public health issue in the Netherlands and NVWA provides the only level of central coordination, although its role is limited to providing guidance, while authority for management and control is devolved to municipalities. The control guidelines are for a risk-based approach in which a risk assessment, based on monitoring activities feeds into the control measures taken. In this approach monitoring, spraying, nest removal and pheromone trapping are combined in order to minimize the impacts to human health.

Guidelines do not mandate management approaches, which are not systematic in the Netherlands, and there is considerable autonomy across different municipalities working under different cost constraints and driven by the severity of outbreaks and increasing public awareness that arguably reduces the need for public intervention and shares responsibility. This approach does not appear to be based on any form of regulatory impact assessment, but derives from the implicit acceptance that eradication is unfeasible and likely more costly relative to the alternative of living with OPM, including any social costs (health, recreation and amenity etc.).

Dutch data suggest higher costs of control corresponding to management intensity in newly infected zones, followed by a levelling off of effort as this becomes balanced by increased public awareness. While different tree managers have responsibility and liabilities for control, there does not appear to have been any significant incidents of social or legal conflict associated with control activities.

Differing oak and population densities across the Netherlands are invariably leading to different results in terms of management costs and the minimisation of impact. With current information it is impossible to draw clear implications from relatively successful municipal management strategies. Equally, while it is possible to derive notional impact cost estimates, there is no way of knowing whether the severity will be increasing each year, or whether these are likely to become more stable as OPM becomes a more common public hazard.

Amsterdam appears to be the municipality applying the most rigorous version of risk-based management. Information on outbreaks is coordinated electronically and there is a clearly defined process for sharing information, monitoring and control activities. There is a remarkably low level of impact to either health or amenity recorded in the city, and in some aspects this would seem to suggest that the risk-based approach has been a success using this criterion alone.

As the city is densely populated, it offers a limited opportunity for comparison with London. Total population in Amsterdam is obviously lower as is the amount of total green space. This reduces exposure risk and permits a more forensic approach to tree health. It is unclear whether such a system could operate in say, London and how it might be coordinated among the different local authorities. Evidence from elsewhere in the Netherlands implies residual impacts arising from less rigorous variants of the approach. For example, figures suggesting that 0.01–0.5% of the population being affected, rising to 4.3% in denser oak areas (some areas consisting of 80% oak trees), and one-third of these visiting a GP. Such figures could be applied in England but would require more careful definition of exposure under risk-based management scenarios.

In short, several differences need to be considered before drawing conclusions on how well a risk-based approach might work and the costs to both private and public stakeholders. These are both human population and oak densities in urban and suburban areas, greater potential exposures in relative populations, identification of risk hotspots in the mosaic of private and public woodlands, the differing assignment of responsibilities and hence incentives to collaborate in control. These elements also need to be considered in the context of the existing regulatory regime; e.g. the UK protected zone and the obligation to eradicate new outbreaks as long as the zone is in place. Moreover there are implicit limitations inherent in UK Environmental Protection legislation with Defra legal opinion suggesting limited local authority power to enforce action against OPM on private land.

Notwithstanding these elements, the extent to which applicability in England could be within a reasonable cost envelope will be determined by the extent to which new control regimes are effective, and to which a precautionary approach is adopted to risk reduction. This decision would need to be informed by further input on the public willingness to accept the specific environmental risks and the modified behaviours their presence entails.

At present there is no convincing evidence to help understand public preferences for pest control nor how the wider public might prefer this and other pests to be managed. In fact, in contrast to the Netherlands, it is possible that the tendency to prolong eradication rhetoric has an unintended consequence of confirming a public predisposition to expect the absence of the pest, and an unwillingness to tolerate any presence or exposure. But again, there is no convincing evidence for this. But clearly regulatory decisions need to be mindful of wider behavioural implications and consequences. It may be simpler and less costly to nudge public attitudes in this case. But the role of behavioural change would appear to be a relevant research priority[20].

Ultimately, a combination of (currently) low impact and low public awareness and particular institutional constraints (i.e. land/tree ownership) may suggest a low public appetite for regulatory change. A risk-based approach is possible, although even this approach would not obviate some of the institutional, behavioural and incentive barriers mentioned above.

While the Forestry Commission has undertakenan RIA, this did not at the time consider anything like a risk-based scenario that might fit English conditions. Moreover, neither country offers a sound evidence base for comparing both costs and benefits. While costs of control are relatively observable, the evidence on benefits remains largely undocumented and anecdotal in both countries. As noted, this is the case even with the most politically sensitive health impact. However, the eventuality of increasing outbreaks

[20] Moseley, D. and Valatin (2013) review the relevance of behavioural economics to forestry but do not alight on any similar example.

and more frequent health episodes is a reality and there is therefore a need for some modelling of impact scenarios.

Aside from the pragmatic approach to control (rather than to eradicate), there is less evidence on any clear socio-cultural differences that underpin relative approaches. For example, there is no evidence of higher rates of tree-felling due to OPM or other pests in Netherlands, nor any clear evidence of lesser cultural attachment to trees. If anything, we can speculate that differing attitudes to OPM control are more likely to be driven by more nuanced property right differences that see trees as a more collective good (in the Netherlands) relative to privatised goods. These characteristics plus the fact that the public simply comes to expect government to take management responsibility for infestation may provide behavioural differences that might influence the cost-effectiveness of control measures. But this needs to be validated by further research that might also consider the interplay with other policy instruments such as the use of the planning system and tree preservation orders.

Annex A3 summarises key differences between England and the Netherlands. Total population at risk is larger in England than in the Netherlands, implying a larger number of possible health cases. Further, the total area of native oak-dominated forest in England is larger than in the Netherlands (158,665ha in England versus 64,283ha in the Netherlands). Other differences are in the management of OPM, which is devolved in the Netherlands and treated as a public health issue, while currently relatively centralised in England and managed as a plant health issue. This has potential implications in terms of both funding of management including public awareness of OPM impacts.

Mindful of the initial aim to consider potential impacts in England (if OPM became widespread) and data limitations, Annex 4 also scopes some rudimentary calculations drawing on evidence collected in this report. However, we note that more detailed information on the distribution of oaks and proximity of people and visitation numbers to these areas is needed to assess any human health risk. This information can be used in a possible future assessment of the feasibility of a risk-based approach for OPM management in England.

[redacted]4.1 Lessons for mitigating OPM impacts

England has a suitable habitat and climate for OPM to develop and spread further and eradication of the pest is accepted as unfeasible. A management approach focusing on minimising the impacts could be an alternative to the current approach, which appears to be buying time for the development of containment / eradication combination that may not actually correspond to any previous impact assessment scenario.

PHE (2015) has suggested that OPM awareness needs to be increased among clinicians and pharmacists and public information about the likely inevitability of spread and health consequences should form part of any move to a risk-based approach. Such information might also provide the basis for the relevant behavioural change among all stakeholders including the general public. Such behavioural change is one where the public take some responsibility for their potential interactions with OPM and is indirect way to manage control costs (i.e. a form of cost-sharing).

As a research agenda on OPM management we would also suggest the following elements:

- Developing tools to monitor OPM spread in a scientifically robust way
- Modelling OPM population behaviour under risk-based management scenarios;
- A feasibility study on the digitisation of tree locations and treatment histories (see Cowley *et al* 2015) for related recommendations. Possibly based on existing experience of at least one London borough[21]
- Health exposure impact modelling in potential hotspot locations, where the latter are sites of high of high oak density and visitation;
- Valuation of impact and/or public preferences on presence/tolerance and management options including cost sharing scenarios;
- Developing OPM awareness possibly as a good example of citizen science monitoring initiatives.). Implementing a version of the Dutch *Natuurkalender* project may be a cost-effective control approach.

[21] http://mappinglondon.co.uk/2015/street-trees-of-southwark/

5 References

Bleeker, D., & Kaljee, H. (2013). 2012 Annual Report Control of Tree Pests and Diseases in Amsterdam. City of Amsterdam, Physical Planning Department and Public Health Service,) https://www.amsterdam.nl/gemeente/organisatie/ruimte-economie/ruimte-duurzaamheid/ruimte-duurzaamheid/making-amsterdam/publications/control-tree-pests/

Bosma, A.H. & Jans, H.W.A. (1998). Ernstige anafylactische reactie in samenhang met de bestrijding van eikenprocessierups in noord Brabant, Nederlands tijdschrift geneeskunde 1998 142 (27).

Brus, D.J., G.M. Hengeveld, D.J.J. Walvoort, P.W. Goedhart, A.H. Heidema, G.J. Nabuurs, K. Gunia, 2011. Statistical mapping of tree species over Europe. European Journal of Forest Research 131 (1): 145–157.

CBS (2005). Meer inwoners in stedelijke omgeving. Webmagazine maandag 21 februari 2005. http://www.cbs.nl/nr/exeres/303BC759-92CE-4F0A-94E3-C56331697620.htm

CBS (2015). Bevolkingsteller

CBS, PBL, Wageningen UR (2013). Eikenprocessierups en klimaatverandering, 1991-2011 (indicator 1110, versie 06, 26 maart 2013). www.compendiumvoordeleefomgeving.nl. CBS, Den Haag; Planbureau voor de Leefomgeving, Den Haag/Bilthoven en Wageningen UR, Wageningen.

Cowley, D. J., Johnson, O., & Pocock, M. J. (2015). Using electric network theory to model the spread of Oak processionary moth, *Thaumetopoea processionea*, in urban woodland patches. Landscape Ecology, 30(5), 905-918.

Defra (2013). Chalara in Ash Trees; a Framework for Assessing Ecosystem Impacts and Appraising Options' https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/200396/pb13906-chalara-socio-economic-framework.pdf

Defra (2014). Tree Health Management Plan, https://www.gov.uk/.../pb14167-tree-health-management-plan.pdf

Erich, H.E., Meulentbelt, J. (1993). Behaarde rupsen, een oprukkende oorzaak van pseudo-allergische reactie in Nederland, Nederlands tijdschrift geneeskunde 1993.

FC, Forestry Statistics (2015) Woodland areas and planting http://www.forestry.gov.uk/website/forstats2015.nsf/LUContentsTop?openview&RestrictToCategory=1

Forestry Commission (2001) National Inventory of Woodland and Trees – England

Forestry Commission (2013a). Oak processionary moth – Control Plan for 2013/14

Forestry Commission (2013b). Control Options for London Outbreak for Oak processionary moth (OPM), Impact Assessment

Forestry Commission (2013c).Oak processionary moth: 2013 Control Programme Review Report

Forestry Commission (2014) Oak processionary moth: 2014 Control Programme Review Report. Last retrieved on 16-9-2015 from http://www.forestry.gov.uk/forestry/INFD-9Q5HNT

Forestry Commission (2015). Oak processionary moth (*Thaumetopoea processionea*) – Regulations, Restrictions and Powers. Last retrieved on 20-04-2015 from http://www.forestry.gov.uk/oakprocessionarymoth.

Fransen, J.J. (2013). Leidraad Beheersing Eikenprocessierups Update 2013. Expertgroep Eikenprocessierups. NVWA – Alterra, 51pp.

Greater London Authority (2015). Land Area and Population Density, Ward and Borough http://data.london.gov.uk/dataset/land-area-and-population-density-ward-and-borough

Jans, H. & Franssen, E. (2008). De brandharen van de eikenprocessierups, een reëel probleem voor de huisarts. Huisarts & Wetenschap 51 (8)

Jans, H.W.A. (2011). Samenvattingen Transmissiedag. Eikenprocessierups, een nog altijd aanwezig gezondheidsprobleem in Nederland. Infectieziekten Bulletin; Jaargang 22 (2): 49-51.

Hellingman, S. & Mulder, M. (2012) Opnieuw natuurlijk vijanden eikenprocessierups ontdekt. Last retrieved on 16-9-2015 from http://www.natuurbericht.nl/?id=8246

Kenniscentrum eikenprocessierups (2015). Beheer eikenprocessierups. Last retrieved on 19-6-2015 from http://www.fsd.nl/eikenprocessierups/78757/5/0/90

Kuppen, H.H.J.M. (2012). Rapportage 2012 Eikenprocessierupsen in de gemeente Amsterdam. Kuppen Boomverzorging. Gemeente Amsterdam commissioned report

Kuppen, H. & Buijs, J.A. (2013). De eikenprocessierups in Amsterdam Rapportage 2013. GGD Amsterdam, Cluster Leefomgeving, Afdeling Dierplaagbeheersing.

Kuppen, H. & Buijs, J.A. (2015a). De eikenprocessierups in Amsterdam Beheer in 2014. GGD Amsterdam, Cluster Leefomgeving, Afdeling Dierplaagbeheersing.

Kuppen, H. & Buijs, J.A. (2015b). Handleiding eikenprocessierupsen beheer 2015, gemeente Amsterdam

Moseley, D. and Valatin, G. (2013) Insights from behavioural economics for ecosystem services valuation and sustainability Forestry Commission Research Report. Forestry Commission, Edinburgh. i–vi + 1–24 pp.

Noordelijke Werkgroep Eikenprocessierups (2010). Beleidskader beheersing eikenprocessierups Noord-Nederland

Office for National Statistics, (2014). Compendium for UK statistics: population and migration. http://www.ons.gov.uk/ons/guide-method/compendiums/compendium-of-uk-statistics/population-and-migration/index.html

Oudenhoven A.P.E. van, A.J.H. van Vliet en L.G. Moraal (2008). Climate Change exacerbates the oak processionary caterpillar problem in the Netherlands. Gewasbescherming (39)6, pp 236, 237.

O+S Amsterdam (2014). Amsterdam in cijfers, Jaar boek 2014. een productie van O+S in opdracht van De gemeente Amsterdam http://www.ois.amsterdam.nl/media/Amsterdam%20in%20cijfers%202014/

Parks, R.A. (2012). Tree inspection and control of infestations of Oak processionary moth *Thaumetopoea processionea* (Linnaeus) (Lepidoptera: Thaumetopoeidae) (OPM) in London in 2011. Report to Plant Health Service, Forestry Commission

Parks, R.A., Townsend, M.C. (2011). Tree inspection and control of infestations of Oak Processionary Moth *Thaumetopoea processionea* (Linnaeus) (Lepidoptera: Thaumetopoeidae) (OPM) in the UK in 2010. Report to Plant Health Service, Forestry Commission

Public Health England (2015). Health effects of exposure to setae of oak processionary moth larvae: systemic review https://www.gov.uk/government/publications/oak-processionary-moth-opm-health-effects-of-exposure

Mulder, M. RIVM (2014). Bevolkingsdichtheid per gemeente 2013. In: Volksgezondheid Toekomst Verkenning, Nationale Atlas Volksgezondheid. Bilthoven: RIVM, <http://www.zorgatlas.nl> Zorgatlas\Beïnvloedende factoren\Demografie\Groei en spreidingRots-de Vries, M.C., Jans, H.W.A. (2000). Eikenprocessierupsen in Nederland en België. Verloop van een epidemie en evaluatie van een voorlichtingscampagne. TSG; 78(1): 28-34.

National Ecosystem Assessment (NEA) (2011). http://uknea.unep-wcmc.org/

Schellart M. and Jans H.W.A. (1996). Eikenprocessierups, gezondheidsklachten en vragen. Een inventarisatie van omvang, ernst en aard van gezondheidsklachten naar aanleiding van de overlast van de eikenprocessierups in de provincies Noord-Brabant en Limburg in de lente- en zomerperiode van 1996. Breda: Provinciaal Bureau Medische Milieukunde GGD's in Braband en Zeeland.

Schelhaas, M.J., A.P.P.M. Clerkx, W.P. Daamen, J.F. Oldenburger, G. Velema, P. Schnitger,H. Schoonderwoerd & H. Kramer, (2014). Zesde Nederlandse Bosinventarisatie; Methoden en basisresultaten. Wageningen : Alterra Wageningen UR, 2014 (Alterra-rapport 2545) - 96 p.

The World Bank Group (2015). Population density http://data.worldbank.org/indicator/EN.POP.DNST

Tomlinson, I., Potter, C., Bayliss, H. (2015). Managing tree pests and diseases in urban settings: The Case of Oak Processionary Moth in London, 2006-2012, Urban Forestry and Urban Greening, http://dx.doi.org/10.1016/j.ufug.2015.02.009

Townsend, M.C. (2009). Report on survey and control of Oak processionary moth Thaumetopoea processionea (Linnaeus) (Lepidoptera: Thaumetopoeidae) (OPM) in London in 2008 (report to Forestry Commission.

(http://www.forestresearch.gov.uk/pdf/fcopmsurv08reppub.pdf/$FILE/fcopmsurv08reppub.pdf)

Van Ass, M., Franssen, A.E.M., Jans, H.W.A., Van der Lelie, S., Schoeters, K., Van Vliet, A.J.H., Van Brederode, N.E. (2008). RIVM Rapport 609330007. GGD-richtlijn medische milieukunde: De eikenprocessierups en gezondheid.

Visser, B.M. & Goudzwaard, A.V.K. (2011). Juridisch kader in relatie tot eikenprocessierups – problematiek. Onderzoek gefinancierd door de NVWA, Divisie Landbouw en Natuur.

Zijlstra, A.G., Donker, G., Krol, W., de Wolf, J. (2015). Landelijke registratie gezondheidsklachten eikenprocessierups (EPR) bij huisartsenpraktijken. GGD Twente, GGD IJsselland, NIVEL. Onderdeel van de Academische Werkplaats Milieu en Gezondheid.

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Annex 2. Spatial distribution of oak trees in the Netherlands and England

Native oak species are the most common broad leaved species in Dutch forests accounting for 17.5% of the total forest area and about 40% of all broadleaved forest (Schelhaas et al., 2014). Native oak is the dominant tree species in 64,283 hectare of forests, with a total volume of 15,991,000m^3 (Schelhaas et al., 2014). Over 70% of the native oak dominated forests are found in the south and east of the country (Schelhaas et al., 2014). American oak is the dominant tree species in 8,696 hectare of forest and has a total volume of 3,229,000m^3. Growth exceeds felling for both native oak species (6.2 vs 1.9 m^3/ha/year) and American oak (7.2 vs 4.6 m^3/ha/year). Of the native oak dominated forest, 27,849 hectare has more than 80% native oak (Schelhaas et al., 2014). These monocultures of oak are particularly sensitive to OPM and facilitate the spread of the pest.

England has 158,665 hectare of oak dominated forest comprising 16.1% of total forest area and 24.5% of broadleaved forest area (Forestry Commission, 2001).

Error! Reference source not found.~~Figure 7~~ shows the oak densities in the Netherlands and England. The maps are based on data collected by Brus et al. (2011) and show that densities in the Netherlands differ greatly between regions. Some regions in the east of the country have high oak densities while other regions lack oak trees. Compared to the Netherlands, oak densities are more even in England with some high oak densities in the London area and North West of the country.

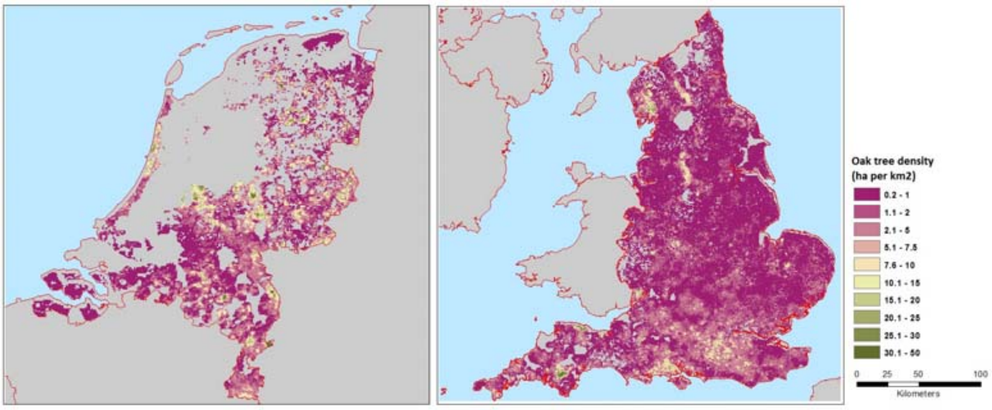

Figure 7. Oak densities in the Netherlands and England.

Figure 8~~Figure 8~~ shows oak densities in Amsterdam and London interpreted as the number of hectares containing an oak tree per squared kilometre. The London map is based on the data collected by Brus et al. (2011) while the Amsterdam map is based on the data available at the municipality level. We have noted a potential discrepancy in that data collected by Brus et al. (2011) appear to show no oak trees in Amsterdam. This contrasts with the data from the municipality showing over 14,000 oaks in the city.

Figure 8~~Figure 8~~ only includes oaks that are managed by the municipality of Amsterdam. It does not include any oaks on private land such as golf courses or on land managed by Rijkswaterstaat (authority responsible for road and waterway networks in the Netherlands). The highest oak densities are found in Amsterdamse Bos (bottom left), Amsterdam Zuidoost (bottom right) and Amsterdam Noord (upper middle). Figure 8~~Figure 8~~ shows that oaks are widespread across London with higher oak densities in for example Richmond Park, Croydon and Bromley. Both figures show that oak densities are lowest in the city centre.

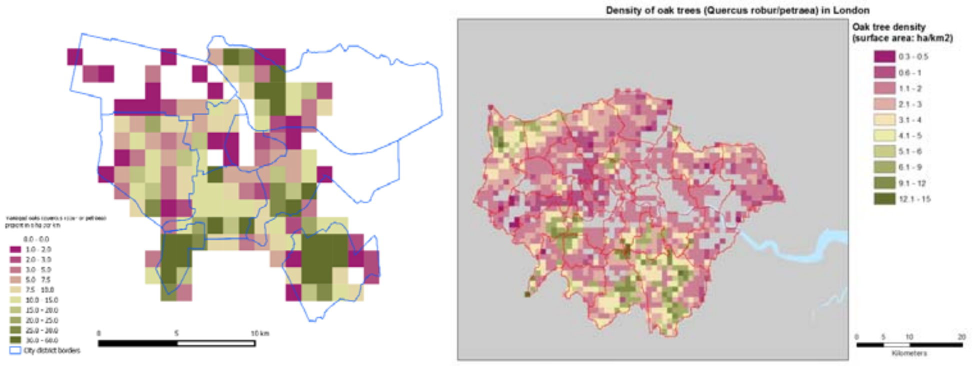

Figure 8. Oak densities in Amsterdam and London

Annex 3. Comparisons between England and the Netherlands

Variable	England	Netherlands
Distribution of oak trees	Oak species make up 16.1% of total forest area and 24.5% of broadleaf forest; England has 167,000hectares of oak dominated forest (FC, Forestry Statistics, 2015) There are 8.3m trees in Greater London (i-Tree project, 2015). Assuming 3% are oak trees, there are 249,000 oak trees in the City (City of London Economic Development, 2013). Assuming higher percentages (5-10%) of oak coverage in other boroughs, the number of oak trees in London is estimated to be 415,000 – 830,000.	Native oak species: 17.5% of total forest area; 40% of broad leaf forest; 64,283 hectares of oak dominated forests, with a total volume of 15,991,000m^3 (Schelhaas et al., 2014) In Amsterdam 14,350 registered oak trees in 2014, representing 3.6% of all registered trees in the city.
Ownership of forests dominated by native oak	Forest areas > 0.5 hectares: 9.6%% by Forestry Commission, 90.4% by other owners as local authorities, other public bodies (not FC), private landowners and business, communities and charitable organisations (FC, Forestry Statistics, 2015).	National government 33.8%; local governmental bodies 17.6%; nature protection organisations 19.3%; private landowners and businesses 31.3% (Schelhaas et all, 2014)
Spread of OPM	Relatively localised to date.	Countrywide, mainly along lanes streets in built up areas, as well as on oaks near wooded areas.
Human population	England: 54.3m inhabitants (2014); 81.5% living in urban areas; population density 413 per squared kilometre. London: 8.6m inhabitants; population density: 5,491/km2	Netherlands: 17m inhabitants (2015); 40% living in urban areas; population density 500 per squared kilometre. Amsterdam: 822,272 inhabitants; population density: 4,923/km2.
OPM related health cases	No systematic UK record of attributable health impacts. Public Health England has reviewed existing published	0.01% to 0.5% of the population in the Netherlands experiences health problems. In areas with higher abundance of oak this can

	evidence.	rise to 4.3%. No health cases in Amsterdam according to GGD Amsterdam.
Current management strategy informed by a RIA or CBA	Yes but only partially representative (an internal RIA conducted by the Forestry Commission in 2013)	No
Management strategy	Plant health first Containment/slowing the rate of OPM spread in the main outbreak area of infestation in west London and eradication elsewhere.	Public health first Approaches differ widely between responsible authorities in the Netherlands. Amsterdam: Risk-based control where control measures are based on a risk assessment.
Responsible authorities	There is currently a gap and a grey-area in terms of responsibility. DEFRA has overall responsibility for the OPM programme using the Forestry Commission and Animal Plant Health Agency to monitor OPM" Forestry Commission has been described as the 'competent authority' as regards protection of forest trees and timber (Great Britain is the Plant Health Act 1967). Defra has responsibility for nursery trees and imported plants.	NVWA: central body facilitating the exchange of knowledge and experience. RIVM and GGD: investigate and update information on the health impacts of OPM. Local authorities: management of OPM, deciding control strategies.
Jurisdiction/legislation	Amendments to the Plant Health (Forestry) Order 2005 (S12008/644) to include OPM as a quarantine pest, which allowed controls to be placed on imported oak trees. EU Plant Health Directive amended in 2004 to give state that those parts of the UK that are outside the affected area in west London	Several acts stating tree owners have a duty of care to prevent and combat OPM; The Flora and Fauna Act (FFA): negative impacts to flora and fauna should be prevented; The Dutch Working Conditions Legislation (Arbowet): protective measures have to be taken by those monitoring, spraying and

	have a ‘protected zone’ status. Plant Health Notices: the Forestry Commission may serve statutory Plant Health Notices on the owners of infested trees requiring removing the infestations.	removing OPM.
Who pays and how much for control measures	Total spent on OPM control programme 2013 £1,927,000 of which: Defra £1,150,000; Local authorities £135,000; Forestry Commission £242,000; Royal Parks £226,000; and other major landowners £174,000.	Total spent on OPM control programme estimated to be within €6,600,000 – €9,600,000 in 2011 of which: Local municipalities spent €5,000,000-€8,000,000; and provincial authorities €1,600,000. Nature protection organisations and forest owners: negligible Amsterdam: €212,175.10 for 2015 of which €23,500 by GGD Amsterdam; €16.32 per tree in Amsterdam; and €176.81 per infested tree.
Public and stakeholders awareness	Limited or unclear – leaflets, posters and letters have been distributed by FC/Defra each year, PHE (2015) recently recommended health awareness for clinicians and dispensers.	OPM management guidelines developed by the NVWA. Toolkit with informative posters, flyers and presentations developed by RIVM. Websites www.natuurbericht.nl and www.natuurkalender.nl informing the public about OPM development.
Public predisposition with respect to control approach	Unclear – lack of awareness and no survey of public preferences for control.	People generally know about OPM and stay away from it when they are advised to do so.
Socio cultural factors	Unclear - limited evidence	N/A
Overall control cost	£1.9 million per annum (2013) These costs are based on 4,756 infestations vs 811 in Amsterdam. Notably higher costs for spraying and surveying in London.	€6.6-€9.6million per annum (2011) Amsterdam: €173,542.40 in 2014 and €212,175.10 in 2015

Annex 4. Approximating OPM management costs in London

Recalling project objectives[22] this section presents an initial framework for analysing OPM and some rudimentary cost calculations based on elements of data covered in this report. These calculations use available information to: a) develop a scenario of management cost under a risk-based approach; b) to provide an estimate of the total health cost due to human infections; c) to provide a comparison of potential ranges of management costs versus potential ranges of health care costs. The calculations come with caveats due to the nature of assumptions made in lieu of data to be more specific about the form of a risk-based approach in London on e.g. spread, infestation rates and the desired target for minimisation of health impacts. It is important to recall that both London and England have a higher coverage of oak trees and a high population density than Amsterdam and the Netherlands, implying potentially higher risks of OPM.

The assumption is that OPM has spread throughout Greater London and that we are analysing different levels of OPM prevalence. Other social costs including recreational losses due to possible closure of parks, costs associated with pharmaceutical visits and wider public preferences for avoiding OPM have not been included in these calculations. There may also be reduced health impacts and reduced control costs that build up in future years from effective control now, which have not been possible to include in the current model.

We recommend that a more detailed economic analysis would require:

- A clearer specification of how a risk-based approach would operate in London, plus more specific scenarios to measure the value of these potential impacts.
- More detailed data on the infection and prevalence rates of OPM.
- Sensitivity analysis, such as potential economies of scale in relation to control costs and the inclusion of other benefits (avoided costs), would also allow further analysis on key variables.

Management cost

To calculate the annual cost of a risk-based management approach, basic data on the number of oak trees, observed or expected (modelled) infestation rates (i.e. prevalence of infested trees) as well as detailed costs of implementing a risk-based management approach are needed. As applied in Amsterdam the latter implies that all identified nests are treated. GGD Amsterdam has suggested that there may be scope for some 'nest tolerance' zones in London but in this analysis we assume the approach that is used in Amsterdam.

We recognise that data on the rate of infestation (i.e. prevalence of infested oak trees) and the cost of a risk-based management per infested tree are uncertain or currently unavailable, and we therefore use reasonable assumptions. Costs were calculated in two ways: 1) using fixed input values, meaning uncertainty was not included (deterministic); and 2) including

[22] *Inter alia* to "compare and value the impacts of OPM in the Netherlands to the potential impacts in England if OPM were to become more widespread…[to inform on potential costs in England and any key lessons that can be taken from the Netherlands"].

uncertainty for the input parameters used in the calculation (stochastic). In the stochastic calculation, a triangular probability distribution for the infestation rate and a uniform distribution for cost per infested tree were used with a Monte Carlo simulation[23]. The aim was to generate the expected distribution of the total costs and confidence intervals.

The infestation rates (i.e. prevalence) were modelled using a triangular distribution and were based on minimum, most likely, and maximum rates (1.4%, 4.2% and 6.1% respectively) that have been calculated based on the reported infestation in the Netherlands in 2009-2014 (see report Figure 5, page 23). The variation in control costs per infested tree in the Netherlands used in a uniform distribution were based on information reported in 2014 (€230) and 2015 (€179) (£168 and £131). These costs include preventative measures, curative measures, inspection pheromone traps, coordination, reporting and license cost for the digital recording system (for details see Table 4 in page 28). Table A4.1 presents the input parameters and values used in this calculation.

Table A4.1 Input parameters used to estimate annual cost a risk-based OPM management.

Management variable	Deterministic	Stochastic			*Note and references*
		Min	Most likely	Max	
Total number of trees in London	8,300,000				*i-Tree project 2015*
Percentage of oak trees	10%				*Authors' assumption*
Number of oak trees	830,000				*Calculated*
Infestation rate	3.7%	1.4%	4.2%	6.1%	*Triangular distribution based NL data, 2009-2014*
Number of infested oak trees	30,710	11,620	34,860	50,630	*Calculated*
Cost per infested tree (£/tree)	£149.60	£131.00		£168.00	*Uniform distribution based on NL data, 2014-2015*
Total simulated annual cost (£m)	£4.59m	£1.66m	£4.81m	£8.27m	

[23] Monte Carlo simulation is a computational method of sampling from a probability distribution for each variable to produce a number of possible outcomes.

Total annual cost of a risk-based approach in London is estimated at £4.6m per year using a deterministic method (Table A4.1). Adding uncertainty to the infestation rate and the management cost per tree, the average annual cost was estimated to be £4.8 with a standard deviation of £1.2m (Table A4.1 and Figure A4.1). The total cost incurred by the Forestry Commission and other organisations for the OPM control programme in England in 2013 was £1.9m (see Annex 3), which is approximately 60% lower than the estimated most-likely cost of our scenario. Note that our estimated figures are based on a probabilistic approach where a 3.7% infestation rate results in 30,710 infested oak trees, whereas the £1.9m OPM control cost reported by the Forestry Commission in England in 2013 was based on 4,756 observed infestations. Further, the management cost in our analysis was based on the reported costs in the Netherlands of £149 per infested tree. This may be higher than UK costs but there is currently no data available to provide a more specific costing for risk-based approach as would be implemented in the UK. It is therefore crucial to consider the input data and assumptions used when comparing these results with published cost figures. This analysis showed that 90% of projections indicate a total cost of less than £6.4m. Similarly, 50% of the projections indicate a total cost of less than £4.8m. Also 10% of the projections indicate a total cost of less than £3.1m (Table A4.3 and Figure A4.2).

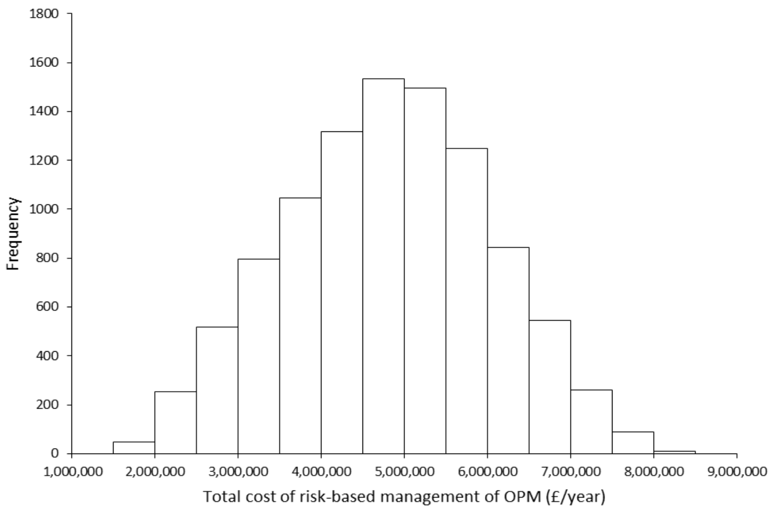

Figure A4.1 Histogram distribution of simulated annual cost (£) of OPM management in London.

The vertical axis in Figure A4.1 represents the frequency (i.e. number of observations) for a specific range of cost values. The horizontal axis represents ranges (intervals) of cost values. The height of the column shows the frequency for a specific range of costs.

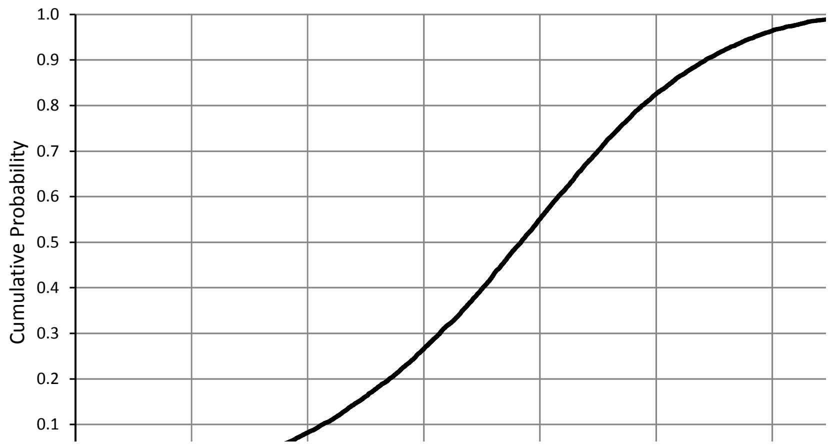

Figure A4.2 Cumulative distribution of simulated costs of OPM management in London

The vertical axis in Figure A4.2 represents the cumulative distribution and the horizontal axis represents the total costs per year. This graph shows the probability level associated with each cost level of OPM management either greater than or less than a specific cost value.

Table A4.3 Descriptive statistics of the results of 10,000 iterations (i.e. simulated observations) for the cost (£) of OPM management in London

Descriptive statistics				
Mean	4,810,334		Median	3,304,484
St. Dev.	1,233,965		Third Quartile	4,258,933
Mean St. Error	12,340		Maximum	8,292,742
Minimum	1,659,540		Skewness	0.6648
First Quartile	3,934,776			

Health impact

We assume that the total health cost consists of three items: i) infected people visiting a GP, ii) costs due to hospitalisation of severe cases, and iii) productivity cost due to absence from work. The total number of people suffering symptoms of OPM exposure was calculated by multiplying London's population (8.6m) by the assumed infection rate. In the deterministic scenario an infection rate of 0.01% was used, implying 860 infected people. Note that this rate was the lower bound of the rate reported in the Netherlands (higher bound was 4.3%). As the infection rate is an uncertain parameter, in the stochastic scenario we assumed a triangular distribution with the following values based on the rates reported in the Netherlands (minimum, most likely and maximum: 0.01%, 0.47% and 4.3%; see section 3.3.1of the current report). Table A4.2 presents the input parameters, related values and the assumptions used to estimate the health costs.

Cost of GP visits: We assume 33% of infected people visit their GP thus 287 GP visits, costing £46 per visit. It is envisaged that there will likely be costs associated with the other

66% who may visit a pharmacist, but this has not been included in the analysis due to lack of data.

Cost of hospital admissions: It was assumed that 0.7% of infected people or 6 cases under the deterministic scenario, will be admitted to a hospital for a short consultation or hospitalisation costing £246 per visit.

Cost of work absence: Costs incurred due to absence from work were calculated based on the assumptions and formula mentioned in Section 3.3.2 (Work absence, page 20) of this report. The main assumption was that 1% (approximately 9 people under the deterministic scenario) of the infected population experiencing OPM health problems had complaints such as fever, sleeplessness and listlessness. It was also assumed that 50% of these people are employed at an average hourly wage of £15.11.

Table A4.2 Input parameters used to estimate annual health costs of human OPM infection in London.

Management variable	Deterministic	Stochastic			*Note and references*
		Min	Most likely	Max	
London's population	8,600,000				
OPM infection rate	0.01%	0.01%	0.47%	4.3%	*NL data, current report*
Infected people	860	860	40,420	369,800	*calculated*
Proportion of infected people visiting GP	33%				*assumption*
Proportion of infected people hospitalised	0.7%				*NL*
Proportion of infected people who will be absent from work	1%				*assumption*
Proportion of employed amongst infected people	50%				*assumption*
Duration (hours) of absence from work (10 days times 8h/d)	80				*assumption*
Average GP visit cost (£/visit)	£46				*Department of Health Unit Costs for GPs*

Average wage (£/h)	£15.11				
Average cost of hospitalisation (£/case)	£246				
Total cost of visiting GP (£)	£13,187	£13,187	£619,773	£5,670,267	
Total cost of hospitalisation (£)	£1,481	£1,481	£69,603	£636,796	
Total cost of work absence (£)	£5,198	£5,198	£244,298	£2,235,071	
Total simulated annual health cost (£)	**£0.02m**	**£0.06m**	**£3.14m**	**£8.41m**	

Assuming an infection rate of 0.01% the health impact of OPM infection under the deterministic scenario was estimated at £0.02m (£19.9k) per year. Using the most-likely values, the average health impact of OPM infection was calculated by the stochastic model at £3.14m with a standard deviation of £1.9m. The estimated cost due to health impacts varied from a minimum of £64.5k to a maximum of £8.4m per year (see Figure A4.3 and Table A4.4 for details).

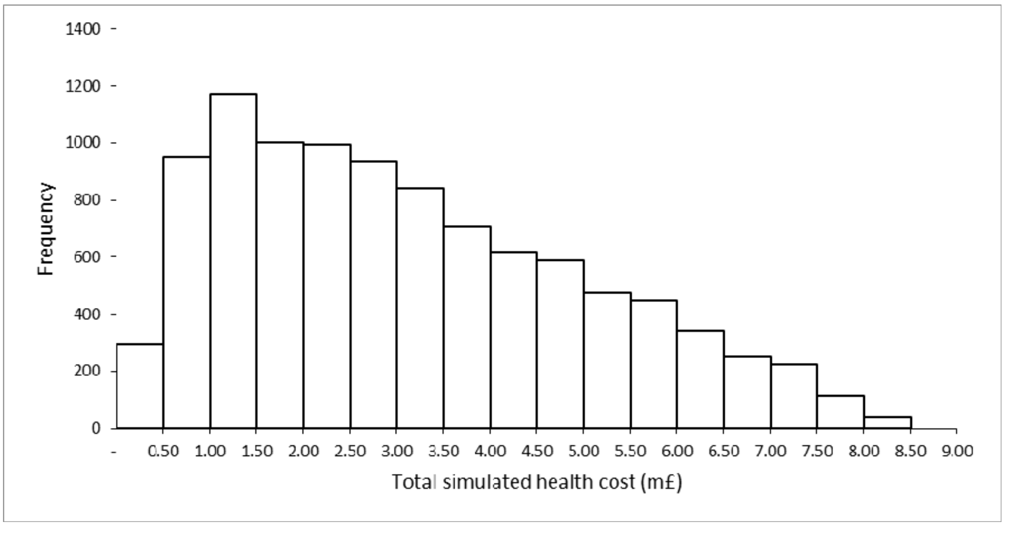

Figure A4.3 Histogram distribution of simulated total health cost of OPM in London.

The vertical axis in Figure A4.3 represents the frequency (i.e. number of observations) for a specific range of health cost values. The horizontal axis represents ranges (intervals) of health cost values. The height of the column shows the frequency for a specific range of health burden.

Table A4.4 presents descriptive statistics of 10,000 iterations (i.e. simulated observations) of the results that are graphically illustrated in Figure A4.3. The central tendency (i.e. average value) of the health burden was at £3.1m and the distribution has a tail to the right hand side with a maximum value estimated at £8.4m.

Table A4.4 Statistics of the results of 10,000 iterations of the stochastic simulation model of the total health cost (£) of OPM in London.

Descriptive statistics				
Mean	3,139,661		Median	2,806,627
St. Dev.	1,903,275		Third Quartile	4,483,066
Mean St. Error	19,032		Maximum	8,407,778
Minimum	64,546		Skewness	0.5612
First Quartile	1,538,757			

Comparison of potential management costs and potential health care costs

The potential range of costs and benefits were compared by dividing avoided/prevented health cost (that is considered as the benefit of implementing risk-based management) by the total cost of the approach. Ratios were estimated under three scenarios wherein the following levels of efficacy of management in preventing human cases were assumed: 100% (i.e. relative to and avoiding total notional baseline health burden)[24] , 80% and 50% efficacy of a risk-based approach in reducing human cases. Note that the estimated ratios are only partial as data for some inputs were either unavailable or based on crude assumptions. This caveat must be considered in relation to any interpretation of these results.

Results show that under the assumption of a 100% efficacy for a risk-based management approach, 76% of the projected cases (i.e. simulations) had a ratio below one, indicating that the expected benefit did not exceed the incurred cost of implementing risk-based management. For the remaining 24% of the simulated cases ratios were between one and four indicating that benefits of OPM management in terms of avoided human infections exceed the costs. The proportion of simulated cases with ratios smaller than one for 80% and 50% assumed efficacy rates were 87% and 97% respectively, indicating only 13% and 3% of the cases were economically justifiable. Figure A4.5 presents cumulative distribution of simulated benefit/cost ratios under the three assumed efficacy levels for the risk-based management.

[24] i.e. the baseline impacts currently happening under our data assumptions. These baseline cases are assumed not to be reported in existing data.

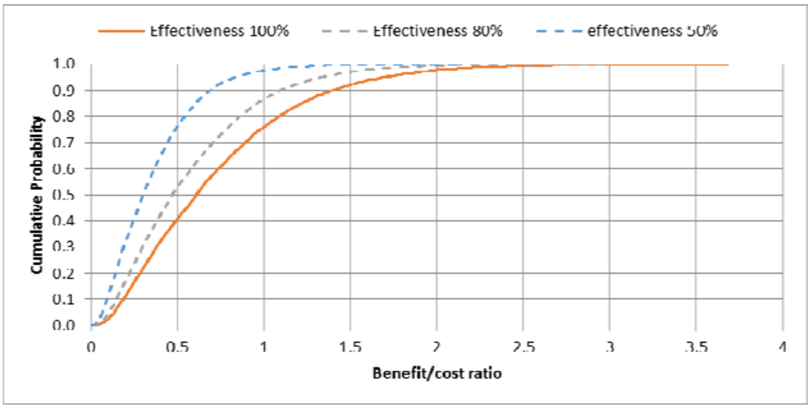

Figure A4.5 Cumulative distribution of simulated ratios under three assumed efficacy rates of 100%, 80% and 50% for a risk-based approach in reducing human cases.