Exploring nature-based solutions to oak processionary moth

1. *Carcelia iliaca*. (Photo: David Humphries)

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Oak processionary moth (OPM) became established in the west of London in 2006. At the time the outlook seemed rather bleak, and perhaps rightly so.

Reports from northern Europe, where the moth had been re-establishing itself[1] since the 1990s, were of a significant new pest defoliating trees and causing major human health issues. Could this be another nail in the coffin for our native oaks? What would become of the already threatened population of ancient oaks? Would health services be inundated by patients with rashes, and would parks be forced to temporarily close during the summer?

Certainly, in the early days some sites had serious problems with very large numbers of caterpillars and nests. But has this pattern been reproduced as the moth has spread? At the start of the outbreak Defra drew up a zone that was already affected by OPM, a zone where it was being actively surveyed for and an area that was free from OPM. Since then, the advice for those in the area where OPM is established has been modified a number of times and it now states that a risk-based approach should be adopted. So, what might the future of OPM management look like?

I am not going to dwell much on OPM itself because there is plenty of information out there already.[2] However, whilst I can't speak for everyone, I think that it may be helpful to share some of our experiences of managing OPM on a busy North London open space.

When it first became clear that OPM had established itself, Ted Green, along with other voices from the ecology community, pointed out that we already had a natural parasite community and that we should experiment with non-intervention to see what would happen. This advice is as good today as it was then. Butterfly Conservation has published a document criticising some of the initial concerns (see references).

When the moth's arrival was first announced I was working for contracting firms in the south-west of England and so OPM was something I was aware of but only at a distance. Fast forward to 2014 and I had started working in London on Hampstead Heath – the realisation of a long-term ambition to focus on conservation arboriculture and veteran tree work. Unfortunately, in the following year we discovered OPM for the first time on two of our three sites. This resulted in Statutory Plant Health Notices (SPHN) and an obligation to remove and destroy all nests and then spray any trees within a 50-metre radius of nests for the following 2 years. For the next few years, spring and summer became a chaotic scramble to try to deal with the situation.

We can only guess the number of oak trees across the 500 acres that make up our sites: Hampstead Heath, Highgate Wood and Queens Park. Perhaps a reasonable estimate would be 3,000–4,000. In the first few years the OPM population grew exponentially until we could no longer reasonably remove all the nests and concerns were being raised by some stakeholders that the spraying would be detrimental to butterflies and other moths on the sites.

But then something interesting happened. The number of nests grew from 15 in 2015 to nearly 200 in 2017 to 2,000 in 2018, and then in 2019 the numbers dropped to 1,000. Since then, they have fallen further and appear to have stabilised at 300–400 in the following years. (See fig. 2)

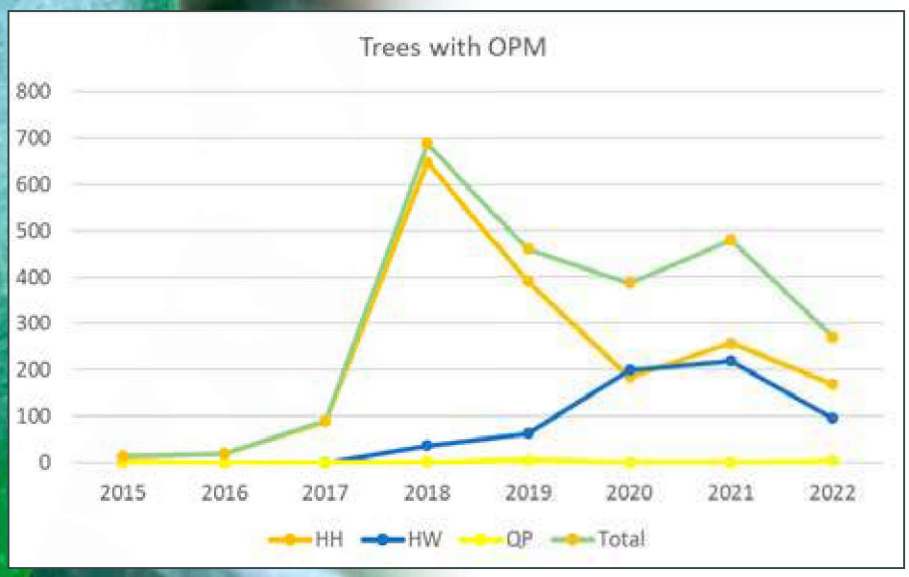
Why did this happen? Why did the feared inundation not play out? My answer to these questions is simple: I don't know, but I would like to try and find out.

Natural predation

In continental Europe great tits have been widely reported to eat OPM caterpillars in significant numbers, from when the caterpillars are newly hatched and throughout their growth stages. From 2017 onwards the birds were seen on Hampstead Heath plucking caterpillars from

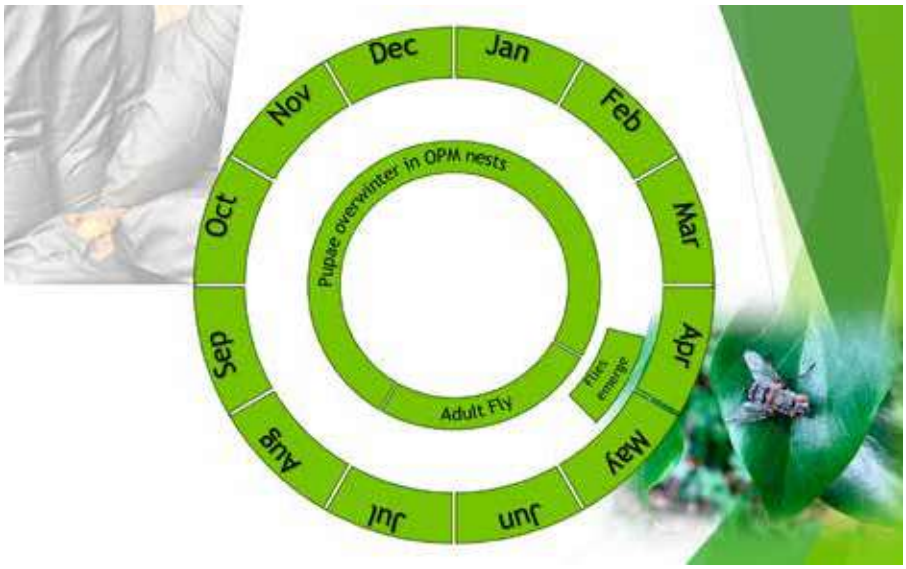
1. Groenen and Meurisse (2012) demonstrated that OPM was present throughout Europe before 1920. In the 20th century it receded south only to re-establish itself due to climate fluctuations. It is likely its spread over geological boundaries was aided by human movement of oak trees.

2. www.gov.uk/guidance/managing-oak-processionary-moth-in-england



2. OPM populations on Hampstead Heath (HH), in Highgate Wood (HW) and in Queens Park (QP) and a total per year.

3. Great tit eating an OPM caterpillar. (Photo: Adrian Brooker)



4. *Carcelia* life cycle.

processions and from the outside of nests. They have even been seen in groups attacking the pupating nests by partially removing them and accessing the pupae from the back of the nests. Hampstead Heath's ecologist, Adrian Brooker, photographed an adult great tit stripping the skins off caterpillars and eating the insides (image 3).

Enter the parasitoids

The Oxford Dictionary defines a parasitoid as: 'an insect whose larvae live as parasites which eventually kill their hosts, e.g. an ichneumon wasp'.

In 2014 *Carcelia iliaca*, a host-specific parasitoid tachinid fly (a big black fly whose only host is OPM), was first found in Richmond Park. *Carcelia* is not native to the UK, and it is not known how it got here. The flies lay their eggs directly onto the caterpillars but can also lay fully incubated eggs on nest webbing. When the larvae emerge, they actively seek out OPM caterpillars and thus access those hidden with the nest (Tschorsnig & Wagenhoff, 2012).

The fly larvae burrow into the caterpillars and eat them from the inside. The caterpillars are mostly still able to live, feed and most importantly build nests and pupae. During the OPM pupation period, the *Carcelia* larvae completely consume the caterpillar and in this way they can overwinter, safely tucked up inside the protective webbed nest, defended by millions of microscopic urticating hairs.

The following spring, usually within a week or two of the OPM caterpillar emergence, the *Carcelia* flies emerge and the cycle repeats (image 4).

If you watch processions or clusters of OPM caterpillars in late spring/early summer, you may well be able to observe *Carcelia* trying to lay its eggs. The caterpillars become visibly agitated by a fly's presence, performing what looks like a Mexican wave to chase the fly away (www.youtube.com/shorts/xiw8JswJ97k).

Presence of *Carcelia* confirmed

In the autumn of 2018, whilst removing an OPM nest to allow some routine tree work, I noticed some large maggots in the pupae within the nest. Each intact pupae had a single maggot inside.

By a stroke of good fortune, at about the same time we were discussing concerns over the use of *Bacillus thuringiensis* (BT), a bacterial insecticide used for the treatment of OPM which is also toxic to butterflies and other moths and to some other insect species. Currently BT is the least damaging spray available. Some of our stakeholders were concerned at the lack of available data about damage to non-target species and questioned whether the spraying was necessary or effective in the long run. One of our volunteers, Jeff Waage, is an entomologist and a professor at the

5 and 6. *Carcelia* larvae inside dead OPM caterpillar skins. (Photos: Jack O'Brien)

7. Carcelia Iliaca. (Photo: Alasdair Nicoll)

University of London; he was formerly Director of the International Institute of Biological Control, a Commonwealth organisation. We discussed the subject of *Carcelia* and Jeff created a plan to firstly prove the presence of the fly and secondly estimate what percentage of the caterpillars were being parasitised.

In late 2018 we collected a few OPM nests and overwintered them in mosquito cages. The following spring flies emerged and were later positively identified as *Carcelia iliaca*. Having identified the presence of the fly on one of our sites, the next step was to try to establish if it could be a significant predator. So, we formulated four questions.

1. Could *Carcelia* be a significant enough parasitoid to naturally control OPM?
2. Is there a direct link between population cycles of OPM and *Carcelia*?
3. Can the significant drop and apparent levelling out of our OPM population be attributed to *Carcelia*?
4. If *Carcelia* could be an effective control, how long does it take for the *Carcelia* population to establish itself after OPM arrives?

A positive answer to question 3 is hard to prove. If the answers to questions 1 and 2 are 'yes', then I would be comfortable in saying the answer to question 3 is 'probably'.

To address question 4 and establish whether *Carcelia* could be a significant natural population control method for OPM, Jeff advised us on how to set up a relatively

8. Jeff Waage counting *Carcelia*. (Photo: Alasdair Nicoll)

9. OPM nests in mosquito cages. (Photo: Alasdair Nicoll)

simple method of estimating the percentage of OPM caterpillars being predated:

1. Collect OPM nests once pupation has started. This is normally sometime in July, and we took nests from 5 locations around our sites.
2. Place 2 or 3 nests from each site into a mosquito cage.
3. Count the moths that emerge from the nests. This normally happens by mid-September.
4. Count the *Carcelia* that emerge from the nests in the spring of the following year (April).
5. From this, a simple calculation gives the percentage of OPM that have been parasitised by *Carcelia* in each of the cages and an average percentage for the 5 sites.

There are of course pros and cons to this method.

Pros:
- It is a simple method of estimating parasitism rates.
- The method is easily repeatable.

Cons:
- Not all the pupae necessarily hatch: some die, whether they contain a moth or a fly. As with any organism, there are likely to be a broad range of bacteria, fungi, viruses and other parasites effecting OPM and *Carcelia*.
- In the early days, we were unsure if it was possible that more than one *Carcelia* fly could parasitise a single caterpillar. Known as superparasitism, this has been observed in Germany with the rare tachinid fly *Phorocera grandis* (Tschorsnig & Wagenhoff, 2012). Dr James Kitson of FERA has dissected lots of OPM nests and while twins and triplets were seen it was by no means common.
- There are likely to be other parasitoids in the nests. On the continent, there are a variety of parasitoids, the significant one being another host-specific tachinid fly, *Pales processionea*. This is the major parasitoid of OPM in continental Europe. Its presence in the UK has been confirmed but numbers are not well monitored.
- There is a significant risk of exposure to the urticating hairs for those who come into repeated close contact with OPM nests. Rummaging around in cages full of nests requires appropriate PPE and diligence when removing it.
- Storing OPM nests can present some risk of exposure. The nests need to be stored safely and any waste material disposed of correctly for incineration.

Cons aside, this method has allowed us to come up with approximate parasitism rates annually between 2019 and 2022. The results for 2023 will be available later this year.

Results

The average percentages of OPM parasitised by *Carcelia* in the nests studied were:

2019 83.1%
2020 81.7%
2021 60%
2022 82%

The parasitism rates have ranged between 16% and 95% in individual nests, but the majority of the nests studied have had a rate of between 70% and 80%. Having been given access to the results of similar studies from around London and the surrounding counties, I have yet to see evidence of an OPM nest that does not contain *Carcelia*.

To establish if there is a direct link between populations of *Carcelia* and OPM will take longer, and the factors involved are likely to be complicated. OPM populations fluctuate and can occasionally have boom years. The conditions which contribute to a boom year are not well understood; it is likely that some are climatic, but could changes in populations of the moth's natural enemies also contribute?

Of course, the parasitism rates tell us how many OPM will not emerge as moths. Any *Carcelia* must then survive the winter and they themselves are vulnerable to predation, especially by birds and probably by other insects. I have seen nests where the entire contents have been plundered, probably by birds.

This raises another question: if you suitably protect the nests that need to be removed for risk-based reasons and allow the parasitoids to escape, could this be used as a method to naturally control OPM? It could be implemented either in sites of higher OPM populations or in newly colonised sites to assist in natural predation.

There are some ethical considerations. For example, will releasing *Carcelia* impact other Lepidoptera populations? However, *Carcelia* is an obligate parasite of OPM, and this means it only uses OPM as a host.

So, what we must ask ourselves is this: If 70–80% of caterpillars in a nest contain *Carcelia* flies, each female fly being able to lay hundreds of eggs, why would we remove and burn any of those nests unless they present a significant risk? By far the highest risk of acute and chronic exposure is to those engaged in nest removal, the next highest being to those who regularly work in or around oak trees.

In the Netherlands Storix, a company with whom we are collaborating on parasitoid monitoring, has devised a complex nature-based system of OPM management. This may be one way of working with nature rather than trying to fight it. Our work with Storix has certainly deepened our understanding of OPM parasitism and how best to monitor it. The parasites need to eat, and whilst the larvae of *Carcelia* can eat the host caterpillar, the adult flies need nectar. Their preferred source is plants of the Umbelliferae family (cow parsley, hogweed, hemlock, pignut and others) but they will feed on other spring and summer flowers. The flora and fauna in the UK do differ from those on the continent, but there is still a great deal to learn from experience in the Netherlands.

What else is eating OPM? The unexpected results

As part of the monitoring process, we have also noticed other parasitoids, much less numerous but still present. *Pales processioneae* was first confirmed on Hampstead Heath in 2020 with the help of Kyle Miller during work he was carrying out for his PhD at Newcastle University. On the continent *Pales* is the most significant parasitoid of OPM. Its life cycle is more

10. Putting OPM nests into mosquito cages. (Photo: David Humphries)

11 and 12. Suiting up to count moths with Storix. (Photos: Alasdair Nicoll)

complex than *Carcelia*'s and not well understood. At the time of writing, I have received confirmation of the presence of *Pales* at Epping Forest, Burnham Beeches and Ashtead Common. As well as flies we have also found at least two species of ichneumon wasps. At this time the levels of parasitism of these other species are unknown. However, the increasing numbers of known natural predators of OPM demonstrate that despite its defences, the caterpillar is a delicious treat for a growing number of species.

Going forward: risk-based approach

In 2020, along with site managers from other organisations, we began trialling a risk-based approach for the Forestry Commission. This meant that we were no longer obligated to spray or to remove nests. Spraying was phased out over the next few years and the number of nests we removed dropped dramatically; we only took down low nests in busier areas. There was a slight increase in nests in 2021, but nothing dramatic and certainly no return to the numbers we had at the peak.

What are the real risks from OPM? There is no real data available for the UK. So far, we have had a very small number of confirmed reports of rashes. Indeed, the vast majority of rashes we are aware of have been on contractors removing nests and my long-suffering colleagues who have assisted in nest rummaging. In our experience, the risk is predominantly to the occupational health of those working around the nests.

OPM continues to spread at a steady rate despite the spraying of trees and the removal and incineration of nests. If this is the case and a nest poses no significant risk, why burn all of the parasites contained within it? They are our natural control. With the current trend towards reduced mowing regimes, an increase in available nectar should assist in boosting parasitoid populations. The Tree Council has developed an OPM Toolkit for local authorities that helps to guide landowners and those with duty of care to build a risk-based approach to managing OPM (see references).

The phrase 'tree time' is one that is increasingly used. It challenges us to consider that some of our well-intentioned actions can have long-term consequences and that we should consider whether action or inaction is appropriate.

To paraphrase Professor Tom Wessels' phrase about the concern amongst ecologists regarding established introduced species, they are here now and we will not eradicate them. In time they will be a normal integrated part of the ecosystem.

Although OPM has been introduced to the UK and has never been native here, in time the moths will become part of the UK ecosystem, along with the things that eat them. Perhaps it is time we shifted the focus of our strategy towards living with them.

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Alasdair Nicoll is a Senior Arborist at Hampstead Heath, which is managed by the City of London Corporation. He aspires to spend more time managing veteran trees and less time on OPM.

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