Department
for Environment
Food & Rural Affairs

Met Office

The use of meteorological data to support outbreak modelling and the analysis of natural dispersal

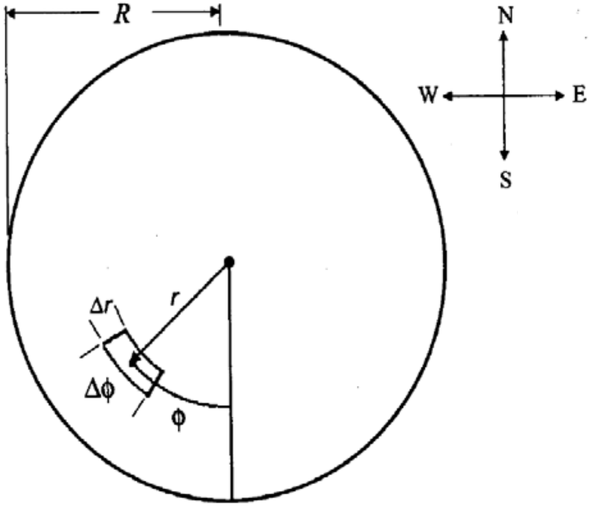
Dominic Eyre, M. Everatt and R. Baker, **Defra**
D. Hemming, P. Boorman, H. Champion, S. Millington, L. Burgin and N. Kaye, **Met Office**
Date: 19 August 2015

Tree trunk model

- A finite difference numerical model of two-dimensional heat flow within a circular horizontal section of a tree (based on Potter & Anderson, 2002) was created to estimate temperature at different depths within a tree trunk.
- The flow model estimates heat flows radially and around the tree trunk circumference between the grid of points where each defined radial and circumference intersect
- Values from Potter & Anderson (2002) for aspen *(Populus tremuloides)* for trunk density 700 kg m^{-3} and specific heat of 2500 J kg^{-1} K^{-1} were used

Equation used for calculating temperature within a tree

$$\rho c\frac{\delta T}{\delta t}=\frac{1}{r}\frac{\delta}{\delta r}\left(kr\frac{\delta T}{\delta r}\right)+\frac{1}{r}\frac{\delta}{\delta\phi}\left(\frac{k}{r}\frac{\delta T}{\delta\phi}\right)$$



$\rho = density.(kg.m^{-3})$

$c = specifc.heat.(J.kg^{-k}K^{-1})$

$T = temperature.(K)$

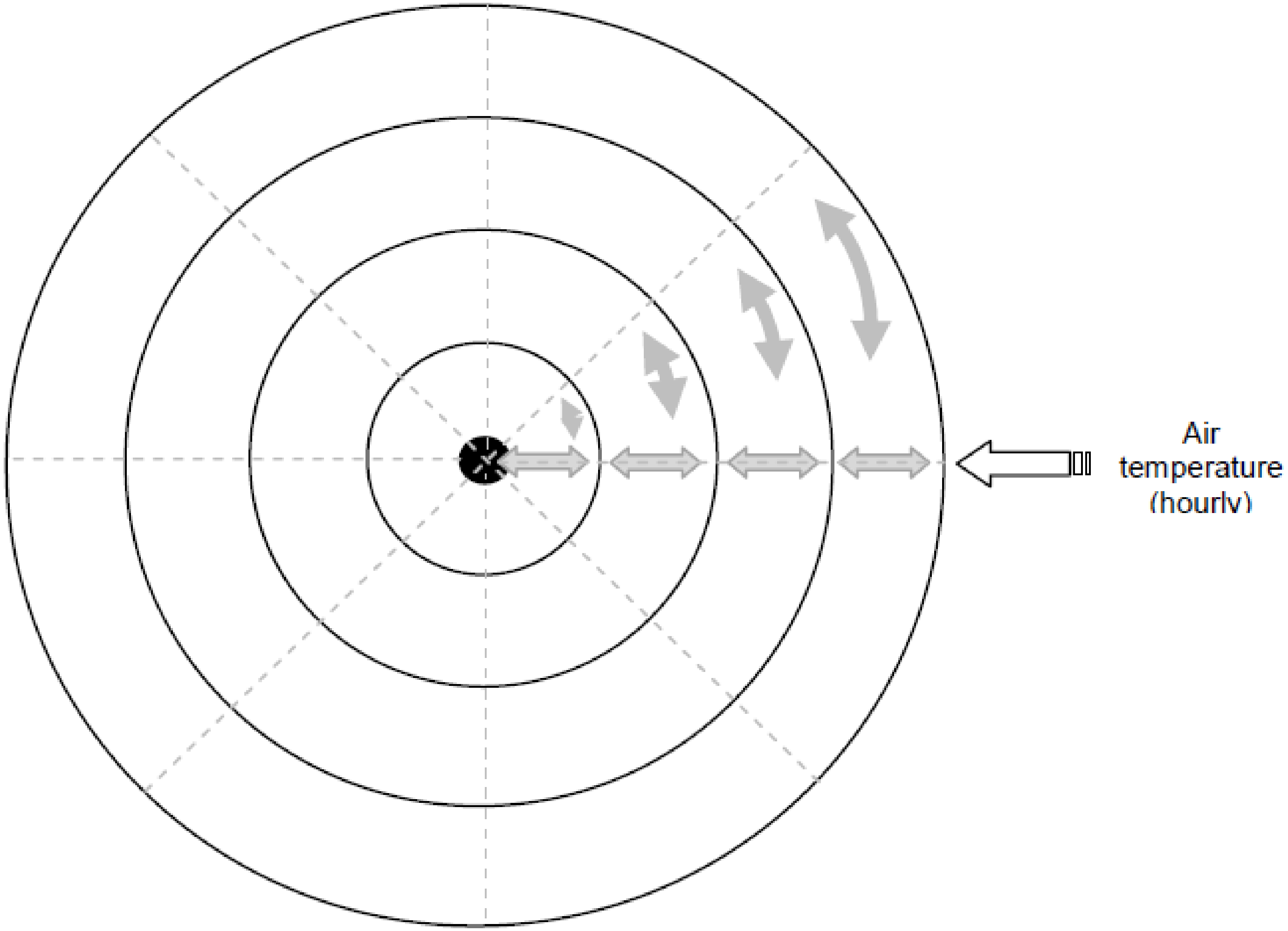
$t - time.(s)$

$k = thermal.conductivity.(W.^{-1}.K^{-1})$

$r = dis\tan ce.from.centre.(m)$

$\phi = azimuth.angle.from.south = 0$

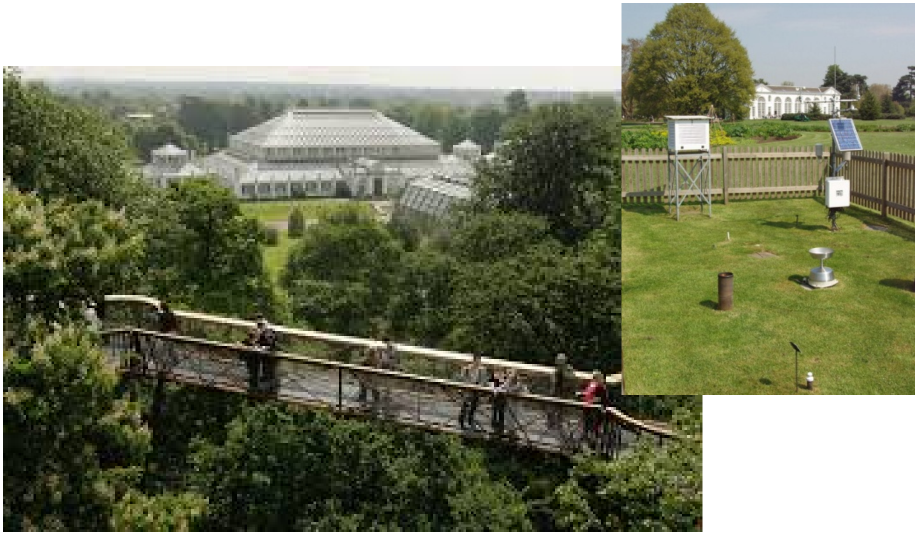
Schematic of the Tree Trunk Temperature model. Arrows represent direction of heat flow between sections in a tree trunk cross section. The same flows apply for each segment. For the initial model, air temperature is assumed to equal bark temperature and is uniform around the tree trunk.



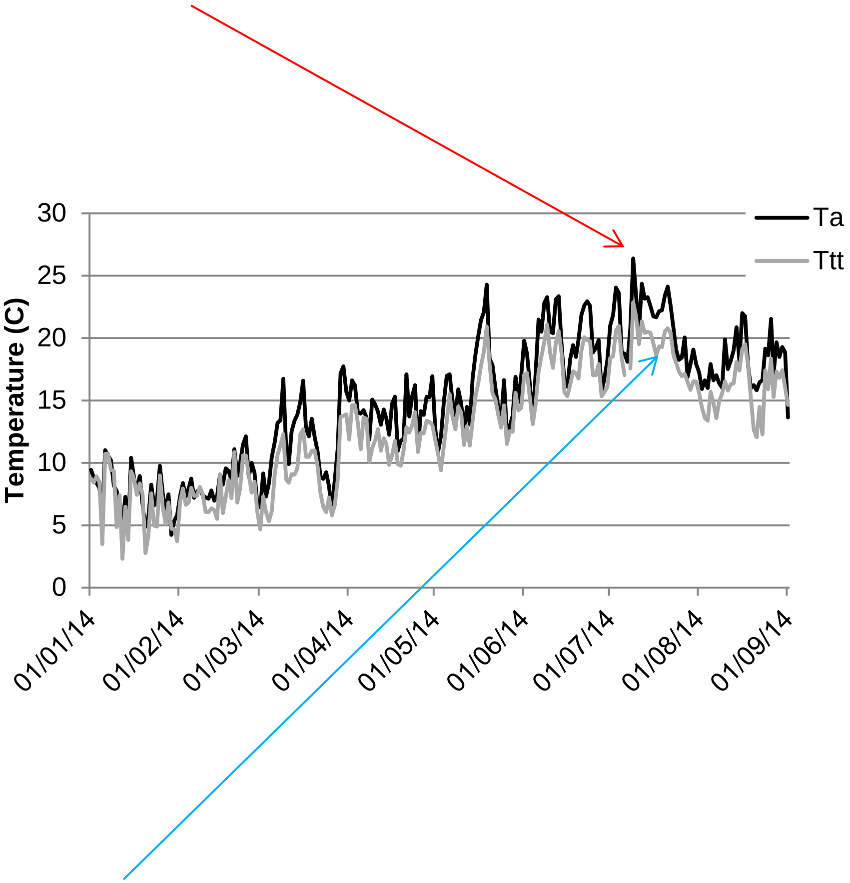
Exercise Rubicon

Modelling emergence date

using daily air and tree trunk temperature at Kew Gardens



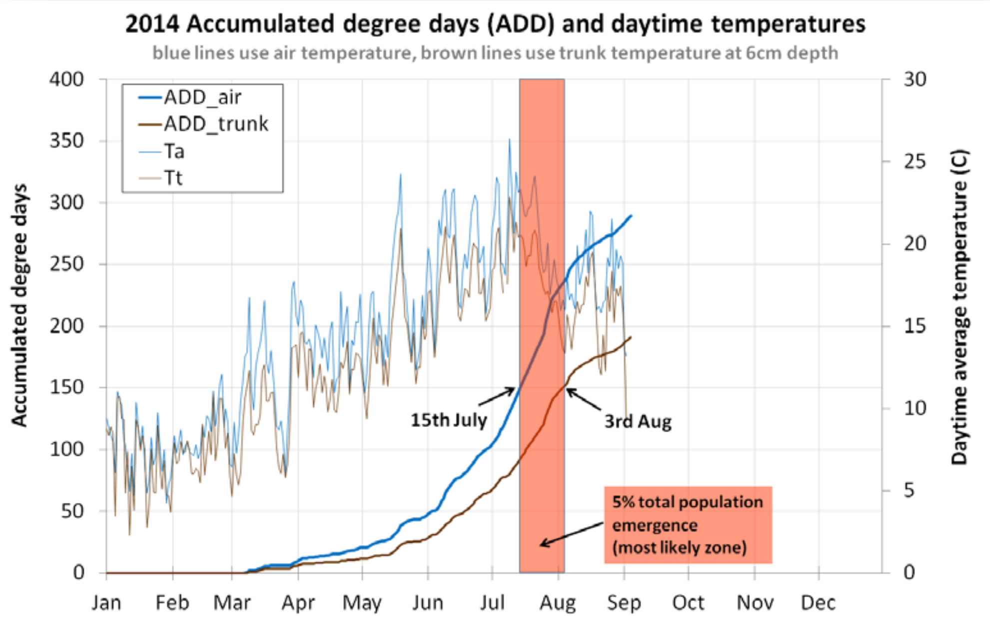
Air temperature Ta



Trunk temperature modelled at 6cm depth Ttt

Modelling emergence date

applying degree day model

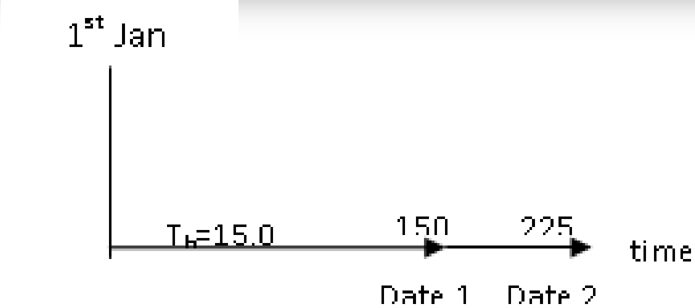


First generation

Emergence at original infestation location - Kew

Year 1

Estimate emergence date from emergence year degree day calculation



The degree days (DD) model is applied to daily data as follows:

$$Tmax \le Tb;\ DD = 0$$

$$Tmax > Tb\ \&\ Tmin \ge Tb;\ DD = \frac{(Tmax+Tmin)}{2} - Tb$$

$$Tmax > Tb\ \&\ Tmin < Tb;\ DD = \frac{(Tmax-Tb)}{4}$$

Where, T_{max} and T_{min} are daily temperature extremes and T_b is a base temperature which varies with application, e.g. species or lifecycle stage

Kew emergence date estimates

results for 5% adult emergence each year 2010-2014

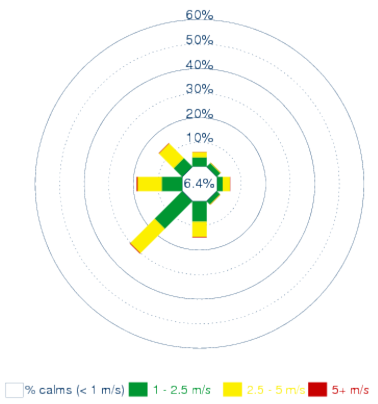
	AIR TEMPERATURE T_A	TREE TRUNK TEMPERATURE T_{TT}
	DATE 1 FOR 150DD (5% ADULT EMERGENCE)	DATE 1 FOR 150DD (5% ADULT EMERGENCE)
2010	11 JUL	3 AUG
2011	20 JUL	16 AUG
2012	6 AUG	22 AUG
2013	22 JUL	5 AUG
2014	15 JUL	3 AUG

Risk of spread using wind roses – Kew Gardens

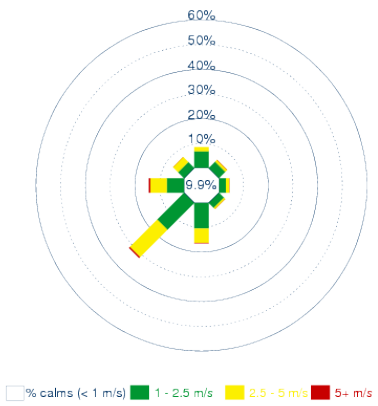
July-Sept 2010 - 2014

- Wind roses (combining wind speed and direction) created for five years using hourly observations from Kew
- 1 Jul to 30 Sep assumed to be the most likely window for adult emergence
- Typically show light to moderate winds from the south-west
- Used to produce ‘hazard zones’ on the GIS based Kew Tree Tool

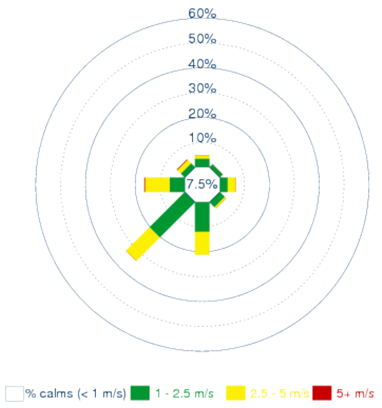
Wind rose at Kew 1 Jul - 30 Sep 2010



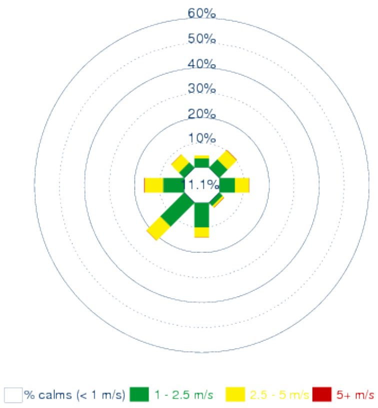
Wind rose at Kew 1 Jul - 30 Sep 2011



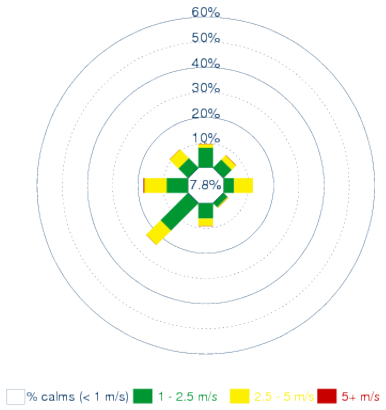
Wind rose at Kew 1 Jul - 30 Sep 2012



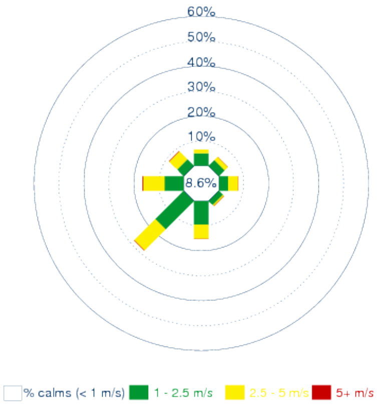
Wind rose at Kew 1 Jul - 30 Sep 2013



Wind rose at Kew 1 Jul - 30 Sep 2014



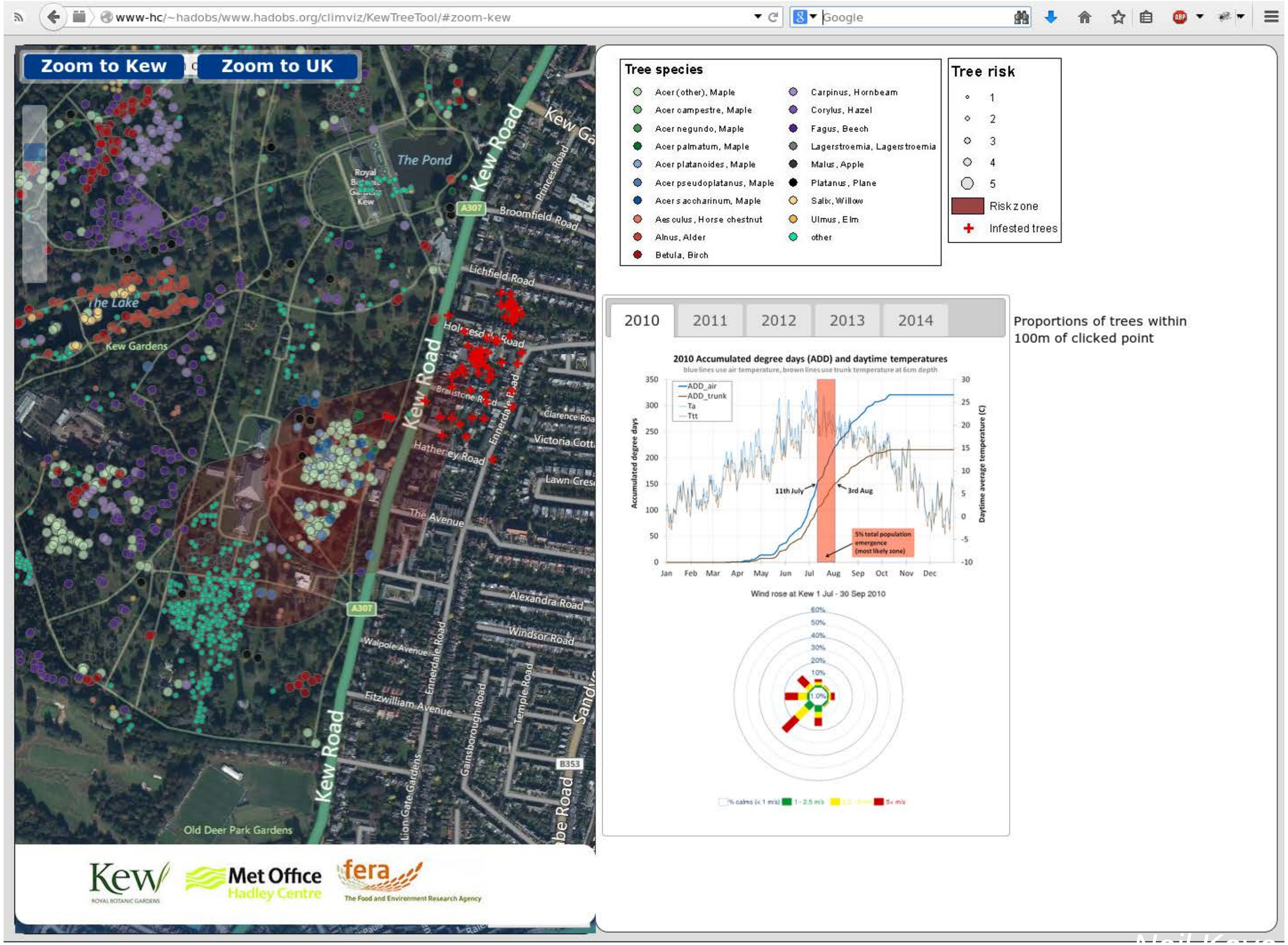
Wind rose at Kew 1 Jul - 30 Sep 2010-2014



Department for Environment, Food & Rural Affairs

Demo interactive web tool

(not publically available)



Tree species

- Acer (other), Maple
- Acer campestre, Maple
- Acer negundo, Maple
- Acer palmatum, Maple
- Acer platanoides, Maple
- Acer pseudoplatanus, Maple
- Acer saccharinum, Maple
- Aesculus, Horse chestnut
- Alnus, Alder
- Betula, Birch
- Carpinus, Hornbeam
- Corylus, Hazel
- Fagus, Beech
- Lagerstroemia, Lagerstroemia
- Malus, Apple
- Platanus, Plane
- Salix, Willow
- Ulmus, Elm
- other

Tree risk

- 1
- 2
- 3
- 4
- 5
- Risk zone
- ✚ Infested trees

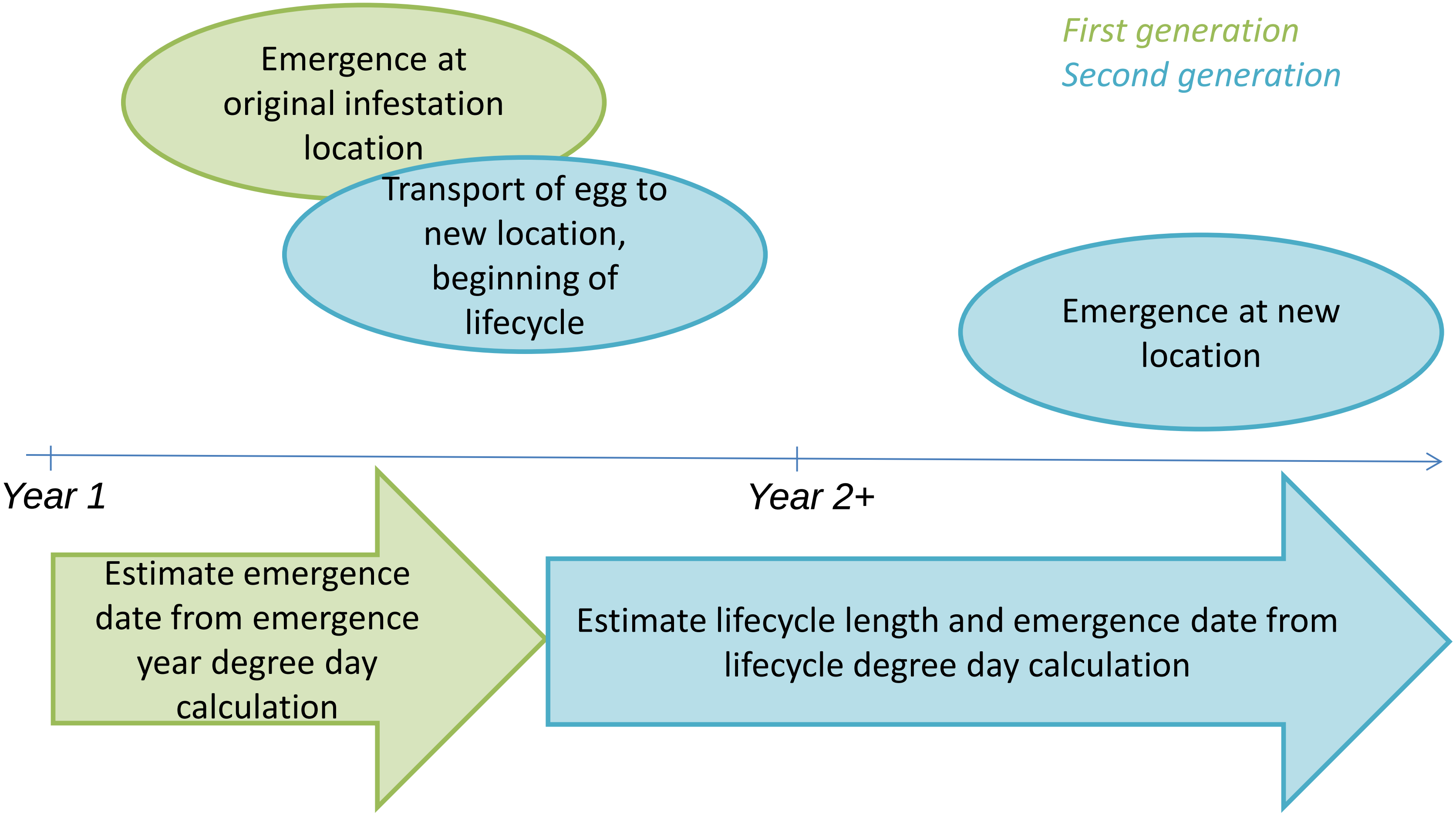
Proportions of trees within 100m of clicked point

Neil Kaye

Department for Environment, Food & Rural Affairs

Modelling emergence date & lifecycle

UK-wide model



First generation
Second generation

Emergence at original infestation location

Transport of egg to new location, beginning of lifecycle

Emergence at new location

Year 1

Year 2+

Estimate emergence date from emergence year degree day calculation

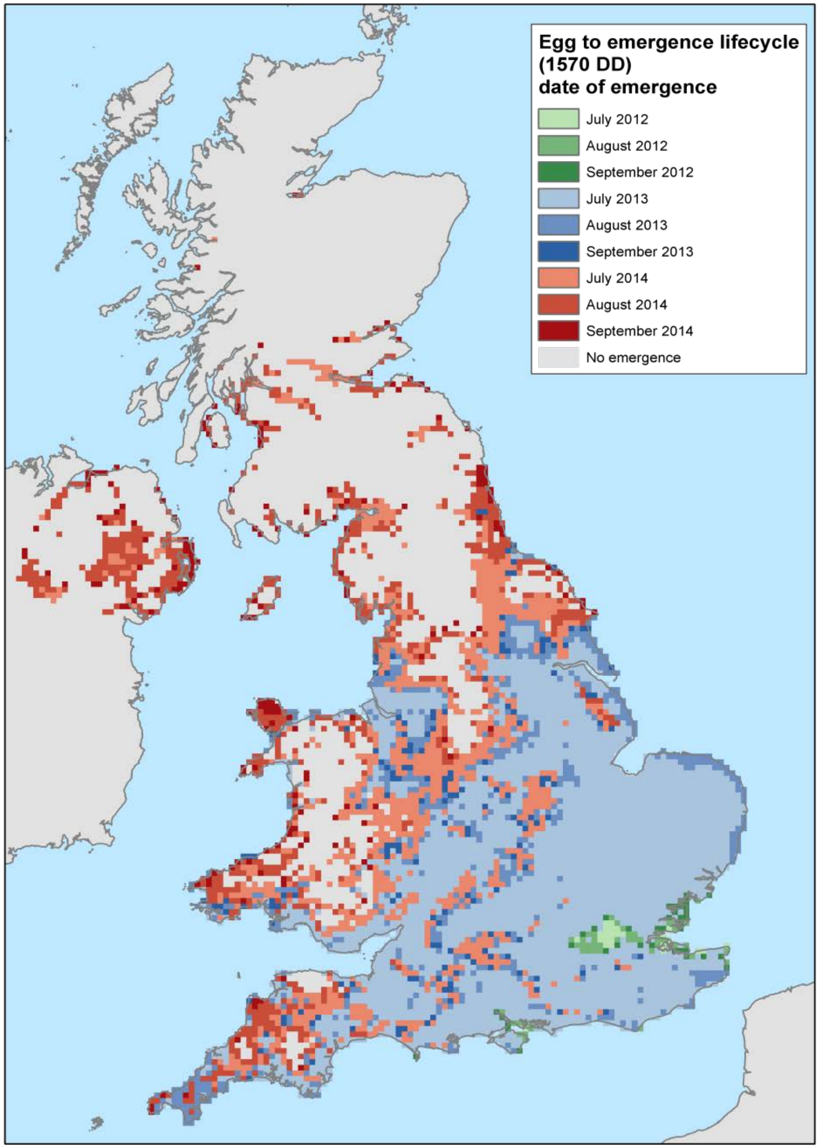
Estimate lifecycle length and emergence date from lifecycle degree day calculation

Modelled lifecycle emergence dates UK-wide

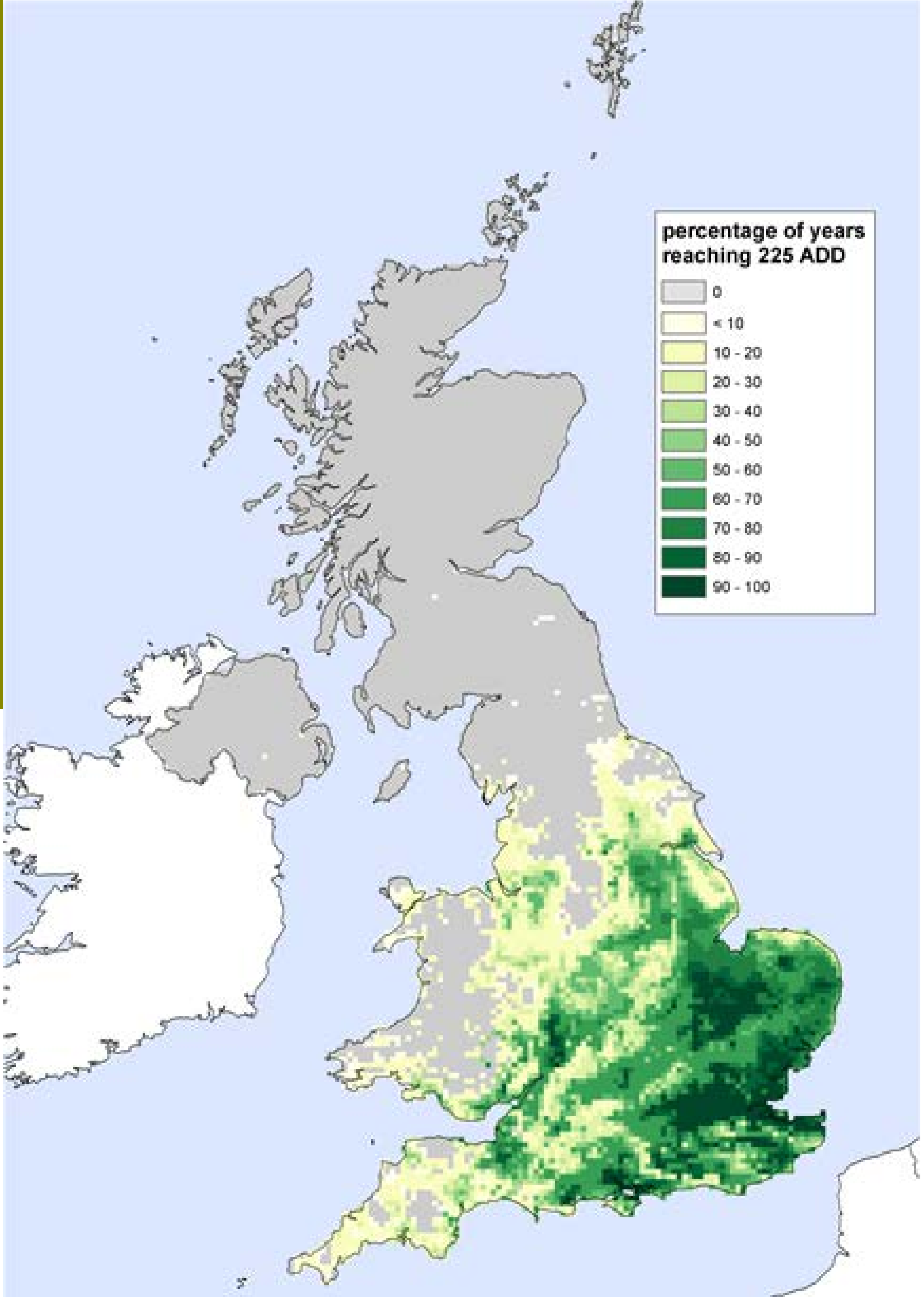
- Earliest emergence dates Greater London and the Thames gateway July and September 2012

- Large areas of south and east England showed emergence dates between July and September 2013

- Latest emergence dates July and September 2014 in the more exposed/cooler regions of southern and central England, and more moderate areas of Wales, N Ireland and England. A few locations in southern Scotland



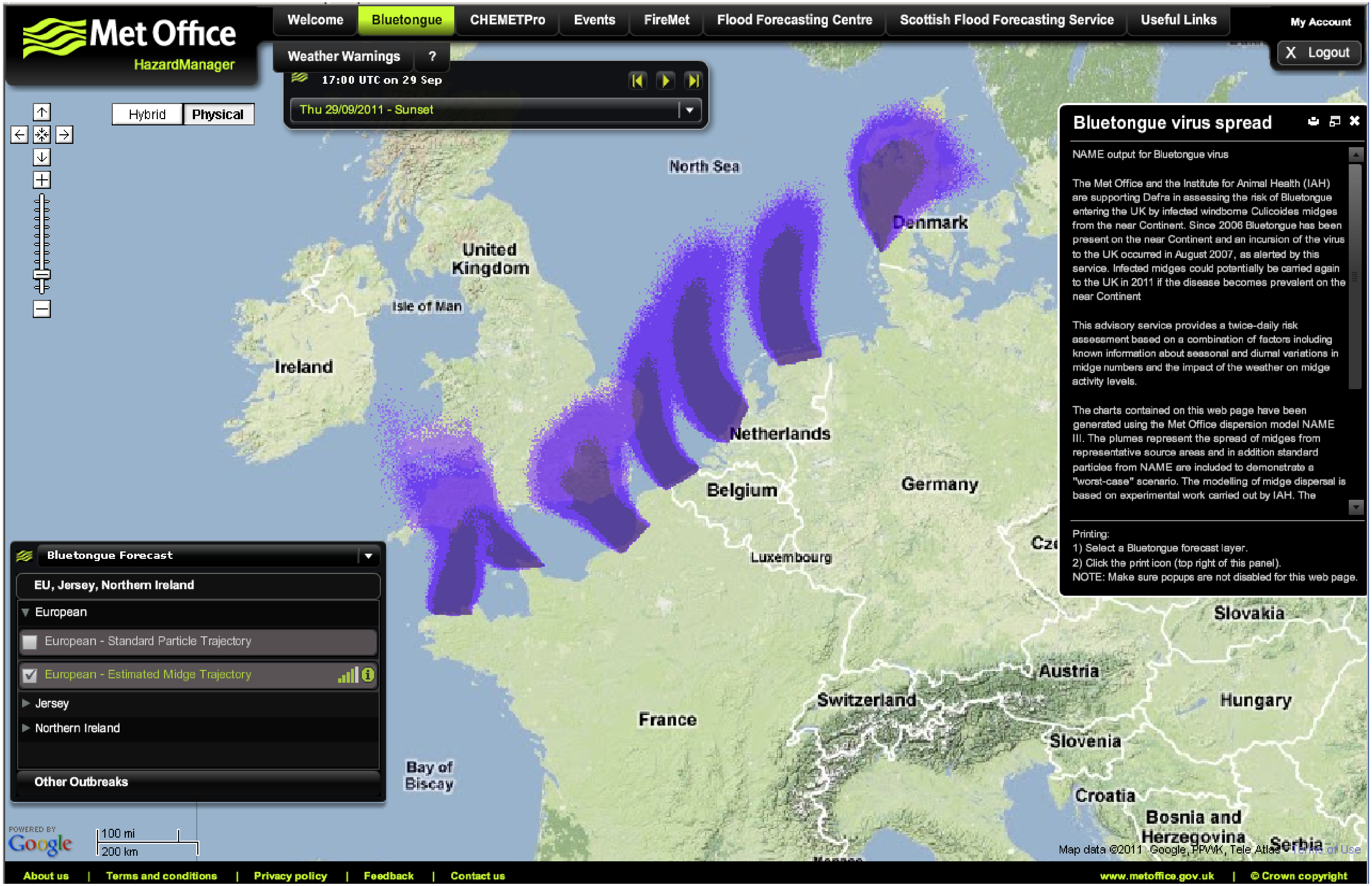
Proportion of years reaching threshold for 50% emergence



Potential use of the NAME model for modelling pest and pathogen spread

- NAME = Numerical Atmospheric-dispersion Modelling Environment
- Uses the Met Office's Unified Model at 1.5km resolution in UK, 4km in Europe and 17 km for the rest of the world
- NAME was developed by the Met Office following the explosions at Chernobyl in 1986
- Has since expanded its scope to simulate a range of atmospheric dispersion phenomena and their associated chemical and physical processes e.g. the eruption of the Icelandic volcano Eyjafjallajökull in 2010
- Was used to predict presence of blue-tongue vectors in the UK in 2007 and is now used as an early warning system

Output from bluetounge early warning hazard manager tool



Bluetongue virus spread

NAME output for Bluetongue virus

The Met Office and the Institute for Animal Health (IAH) are supporting Defra in assessing the risk of Bluetongue entering the UK by infected windborne Culicoides midges from the near Continent. Since 2006 Bluetongue has been present on the near Continent and an incursion of the virus to the UK occurred in August 2007, as alerted by this service. Infected midges could potentially be carried again to the UK in 2011 if the disease becomes prevalent on the near Continent

This advisory service provides a twice-daily risk assessment based on a combination of factors including known information about seasonal and diurnal variations in midge numbers and the impact of the weather on midge activity levels.

The charts contained on this web page have been generated using the Met Office dispersion model NAME III. The plumes represent the spread of midges from representative source areas and in addition standard particles from NAME are included to demonstrate a "worst-case" scenario. The modelling of midge dispersal is based on experimental work carried out by IAH. The

Printing:
1) Select a Bluetongue forecast layer.
2) Click the print icon (top right of this panel).
NOTE: Make sure popups are not disabled for this web page.

The flight boundary layer

- The flight boundary layer is a conceptual layer which occupies a layer above the earth’s surface and is defined as an area where the wind speed is lower the flight speed of an invertebrate
- In the FBL invertebrates have complete control over their flight direction and so is the area in which food-finding and made location can take place
- The height of the FBL varies with meteorological conditions, topography, land cover, etc.
- For small weak flying invertebrates the flight boundary layer may be only a few metres high, but the layer could be hundreds of metres for larger stronger flying invertebrates

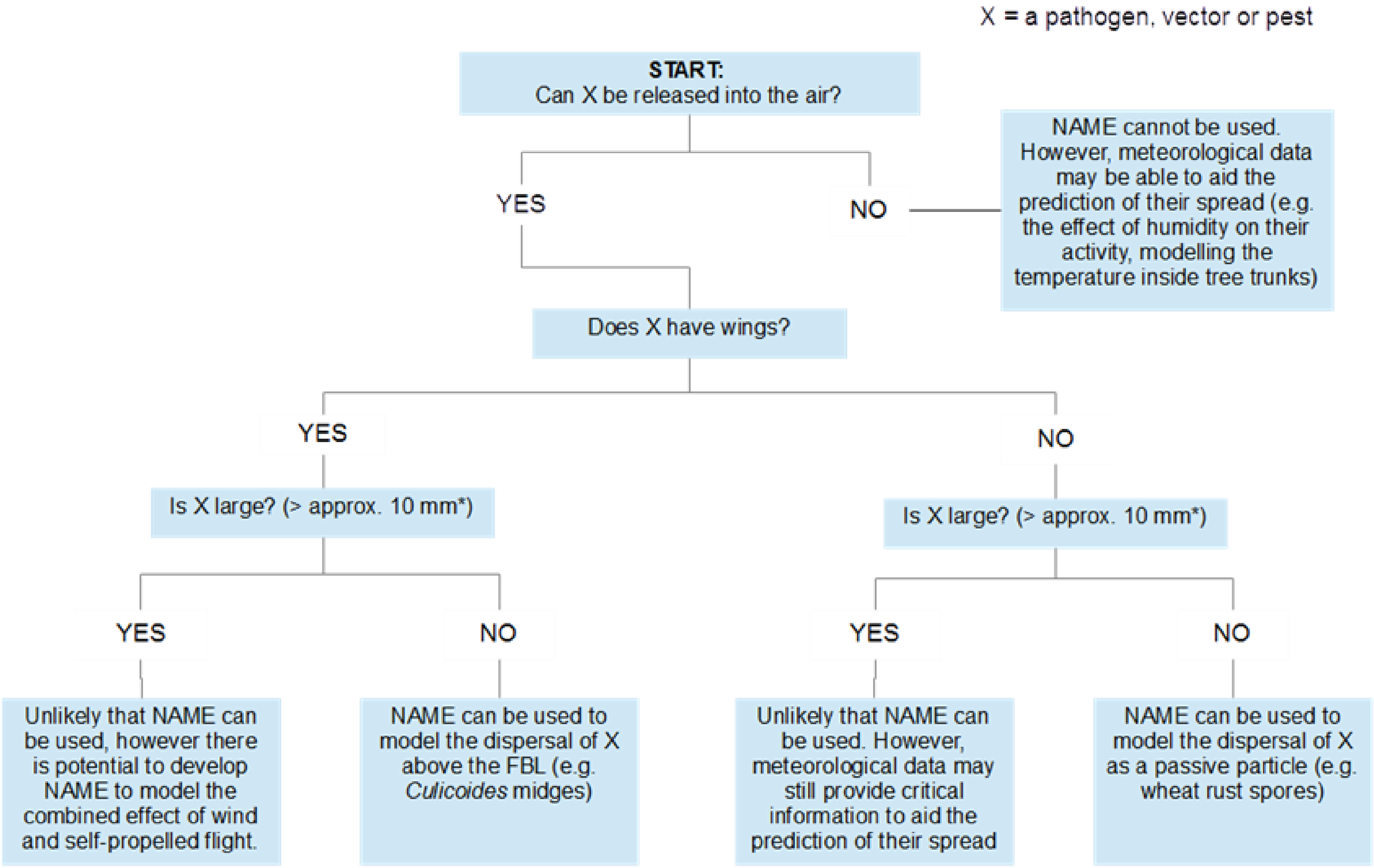
Dispersal groupings

Name	Characteristics	Examples
Passive particles	No control of movement in the air or landing, although some plants and pathogens will release seeds and spores only in certain conditions.	Seeds, pollen and many pathogens
Wingless invertebrates or 'aerial plankton'	Have some control over take-off and landing, but little control in the air.	Some scale insects, linyphiid spiders, mites
Small winged invertebrates	Can exert control over their dispersal when above the FBL. Can select altitude with favourable wind speed and temperature.	Invertebrates less than 10 mm long
Large winged invertebrates	Better able to influence the direction of flight when above the FBL, but can be blown off course.	Many moths and butterflies, dragonflies

Creation of initial shortlist from UK plant health risk register

- Selecting species with a risk * value score of at least 12
- Species that are considered at least moderately likely of being able to establish in the UK
- Species considered to have some chance of being able to disperse aerially (therefore excluding some taxa such as nematodes)

Decision tree for the use of NAME



X = a pathogen, vector or pest

START:
Can X be released into the air?

YES

NO

NAME cannot be used. However, meteorological data may be able to aid the prediction of their spread (e.g. the effect of humidity on their activity, modelling the temperature inside tree trunks)

Does X have wings?

YES

NO

Is X large? (> approx. 10 mm*)

Is X large? (> approx. 10 mm*)

YES

NO

YES

NO

Unlikely that NAME can be used, however there is potential to develop NAME to model the combined effect of wind and self-propelled flight.

NAME can be used to model the dispersal of X above the FBL (e.g. *Culicoides* midges)

Unlikely that NAME can be used. However, meteorological data may still provide critical information to aid the prediction of their spread

NAME can be used to model the dispersal of X as a passive particle (e.g. wheat rust spores)

Results of shortlisting

- There were *c.* 750 species on the PH risk register at the time of the analysis
- 184 species passed the initial screen
- 133 of the 184 fell into categories that would be more suitable for modelling using NAME
- 21 of the species have been recorded within 250 km of the UK e.g. *Circulifer tenellus* (the beet leafhopper) a vector of diseases of sugarbeet. There is evidence that this pest has spread naturally over long distances

Conclusions

- There is potential for closer co-operation with the Met Office
- Microclimatic environments are not often considered for pest risk mapping and modelling
- Heat flow models have the potential to increase understanding of differences in development rates in different locations
- The NAME model could be used to evaluate the risk of natural spread of pests across the English channel and over land within countries and continents. This can lead to the development of early warning systems, inform survey activities plus outbreak management.