Department
for Environment
Food & Rural Affairs

Too much information? Assessing the establishment potential of *Hyphantria cunea* in the UK with contradictory thermal data

Anastasia Korycinska & Richard Baker

International Pest Risk Research Group,

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Background to the work

- The first UK PRA on *Hyphantria cunea* was in 1991
- Two adults were caught in light traps in the UK in 2014, in separate locations and months
- This prompted a new UK Rapid PRA, focussing on the potential for establishment and impacts
- At least 12 published combinations of threshold temperatures for development and accumulated day degrees were identified
- In the time available, not all sources could be utilised for risk mapping and only a subset of thermal data was selected
    - How to select which data to include?
    - Generating multiple output maps: how to present to risk managers?

Adult *Hyphantria cunea* © Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org

Late instar larva of *Hyphantria cunea* © Pennsylvania Department of Conservation and Natural Resources - Forestry , Bugwood.org

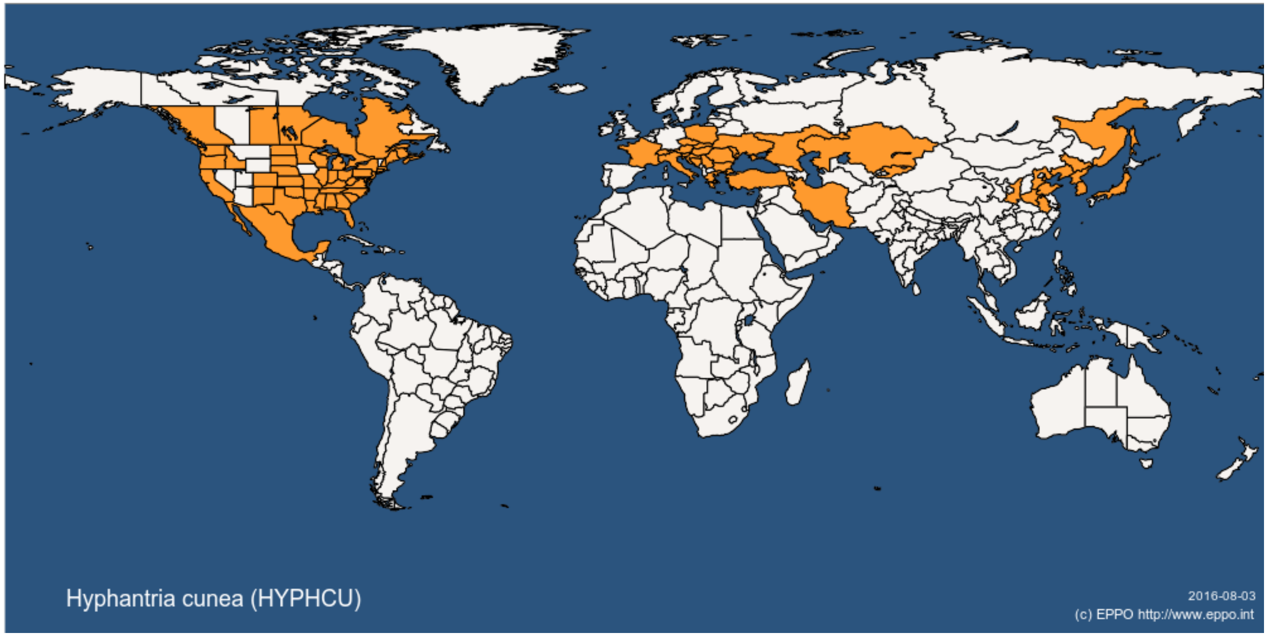
Hyphantria cunea: pest biology & distribution

Lepidoptera, Erebidae, Arctiinae

- Fall webworm, American white moth…
- Two forms – distinguishable as larvae
  - Black-headed: the invasive form
  - Red-headed: only in North America

Polyphagous on deciduous woody plants

- A number of preferred hosts
- In outbreak years, feeds on many additional species



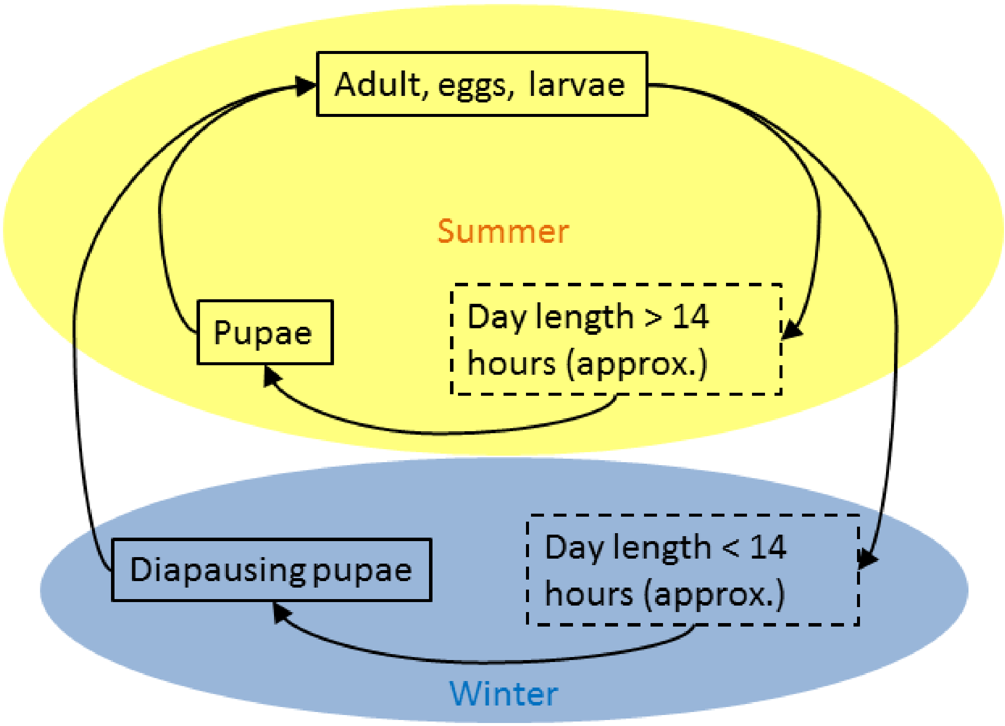
Map © EPPO Global database
https://gd.eppo.int/taxon/HYPHCU

Native to North America

- Introduced to Europe, 1940 in Hungary
- Now spread to much of southern & central Europe
- Also western parts of Asia, e.g. Azerbaijan, Kazakhstan
- Japan first recorded 1945
- Spread to mainland east Asia including Korea, north-east China, etc.

Development parameters: diapause

- Many published papers on lifecycle from native & invasive ranges
- Uni to multi-voltine lifecycles
  - Overwinters as diapausing pupa
- Diapause triggered by short day length
  - Critical day length ~14 hours (most work in Asia)
  - Exact value varies depends on population studied: Italian critical day length ~15.5 hours
  - Japanese switch from bivoltine to trivoltine extensively studied



***Hyphantria cunea* diapause**

- In northerly latitudes, only one generation per year (all pupae diapause)
- In more southerly locations, multiple (non-diapausing) generations are possible

Development parameters: thermal

- 12 different combinations of threshold temperature for development and accumulated day degrees found in the literature for the black-headed form
  - This is the type which is invasive in Europe and Asia
- ~~+ 1 set of values for the red-headed form in North America~~
  - Not considered further for European risk modelling

Parameter	Minimum	Maximum	Italian population	Number of studies
Threshold temperature for development	10	11.3	10	12
Accumulated day degrees: diapausing generation	686	1097	-	4
Accumulated day degrees: non-diapausing generation	567	1060	820-1060 (outdoor populations)	11

Selecting thermal development parameters

- Many papers, but few dealing with the diapausing generation (which overwinters)
  - Subset of 4 papers which include diapause examined more closely:

Threshold temperature for development	Accumulated day degrees (diapausing generation)	Accumulated day degrees (non-diapausing generation)	Origin
~~10~~	~~686~~	~~870~~	~~Kobe, Japan~~
10.7-10.9	1097	840	Kentucky, USA
10.5	982	830	New Brunswick, Canada
10	830	780	Gunma, Japan

- 3 papers concluded the diapausing generation requires more degree days than non-diapausing generation
- 1 paper concluded the opposite and was removed from analysis

Climate data

JRC-MARS dataset used for source climate data

- Daily minimum and maximum temperature
    - Other parameters available but not used in this analysis
- 25 x 25 km gridded dataset
- Interpolated to mean agricultural altitude
- Data for 2000 – 2014 inclusive
- Data analysed for all of geographical Europe
    - Except for European Russia and European Turkey
- 64,575,494 rows of climate data used

Hyphantria cunea nest © James B. Hanson, USDA Forest Service, Bugwood.org

This was an initial exploratory analysis: it was unclear if the UK was suitable for establishment at all

- Other datasets, e.g. Climond or higher-resolution UK data, not consulted
- More sophisticated modelling, e.g. using CLIMEX, not used

- Depending on the outputs of the preliminary analysis, more sophisticated modelling may be an option for the future

Approach taken

- Mapping based only on degree days for this preliminary analysis
  - Diapause not considered here, other than increased number of degree-days above threshold required
  - Using PRATIQUE Decision Support Scheme, sufficient data available to justify mapping:
    - Uncertainty over how suitable the UK might be
    - Climatic factors (temperature, day length) available from native, invasive and laboratory
    - Reasonable location data, though not always clear if breeding populations
- Nest-building larvae
  - Nests increase temperature experienced by other Lepidoptera
  - Effect of nest not considered here (little evidence of increased temperatures)
- Number of generations

  Univoltine = diapausing accumulated day degrees

  Bivoltine = diapausing accumulated day degrees + non-diapausing accumulated day degrees

  Trivoltine = diapausing accumulated day degrees + non-diapausing accumulated day degrees + non-diapausing accumulated day degrees
- PRATIQUE guidelines on representing uncertainty followed
  - Maps showing most likely outcomes plus extremes should be presented
  - In this case, all three sets of thermal thresholds used illustrated

Risk map for *H. cunea* in Europe

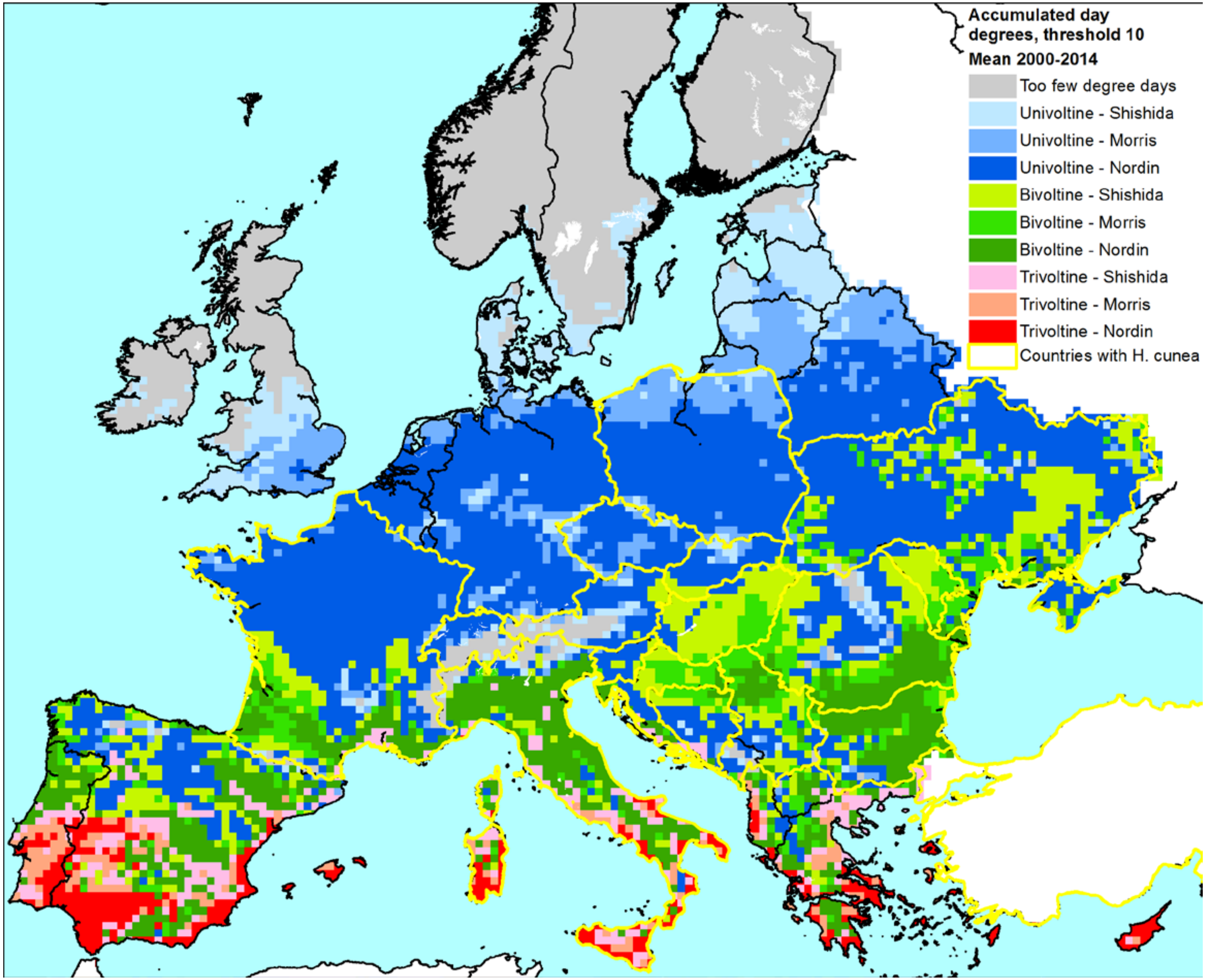
Grey = unsuitable

Blue = univoltine

Green = bivoltine

Red = trivoltine

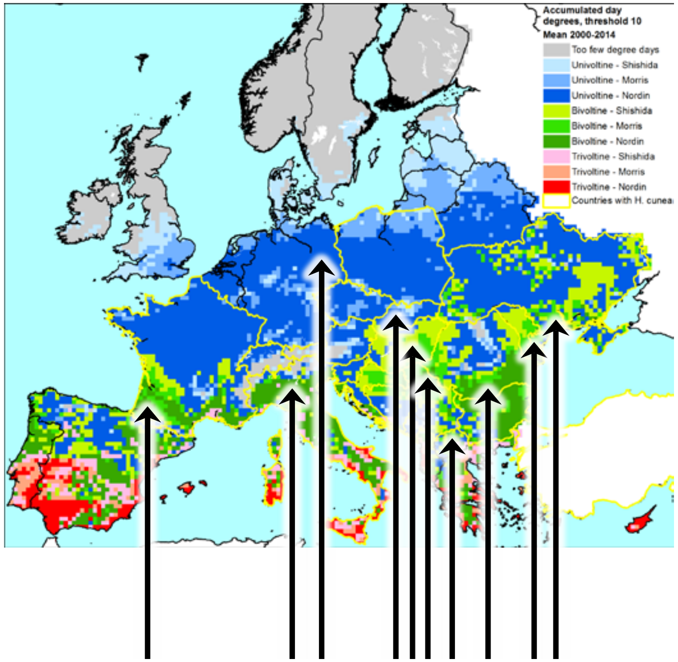
The darker the colours, the greater the number of sources agree the area is suitable



“Validation” of map

- Historical data on number of generations in Europe compared with predicted data

Region & Country	Observed	Predicted
Bordeaux, SE France	2 Exceptionally 3	2
Germany (experimental)	1 2nd failed	1
Hungary	2	2
Northern Italy	2	2
Macedonia	3	2 (3 in south)
Moldova	2 (Partial 3rd)	2
Bucharest, Romania	2	2
Serbia (north)	2	2
Slovakia	1, 2 or 3 depending on author	1 (north) 2 (south) 3 not possible
Odessa, Ukraine	2	2



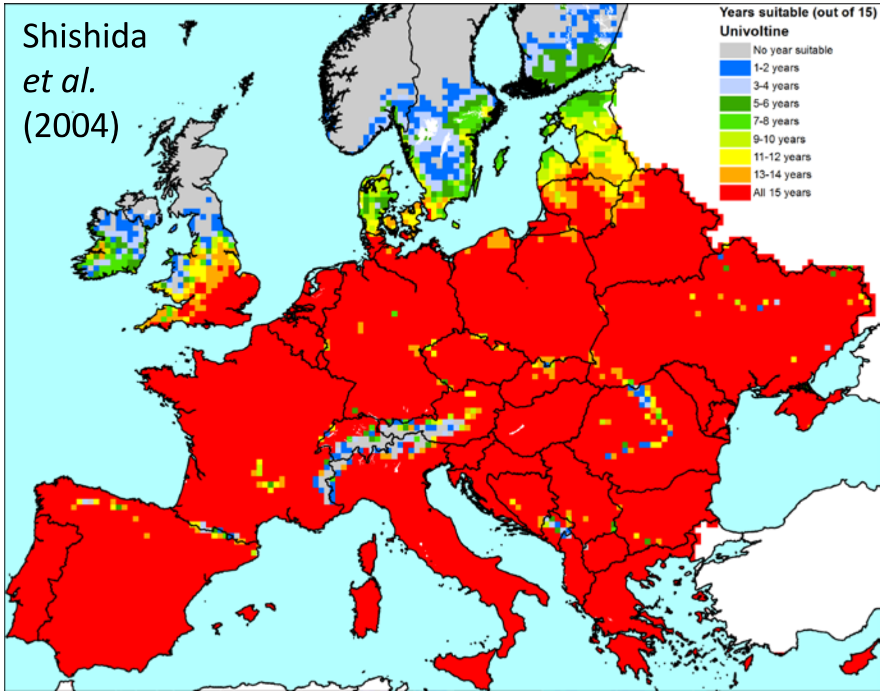
Areas with data on number of generations marked with arrows

Annual variability

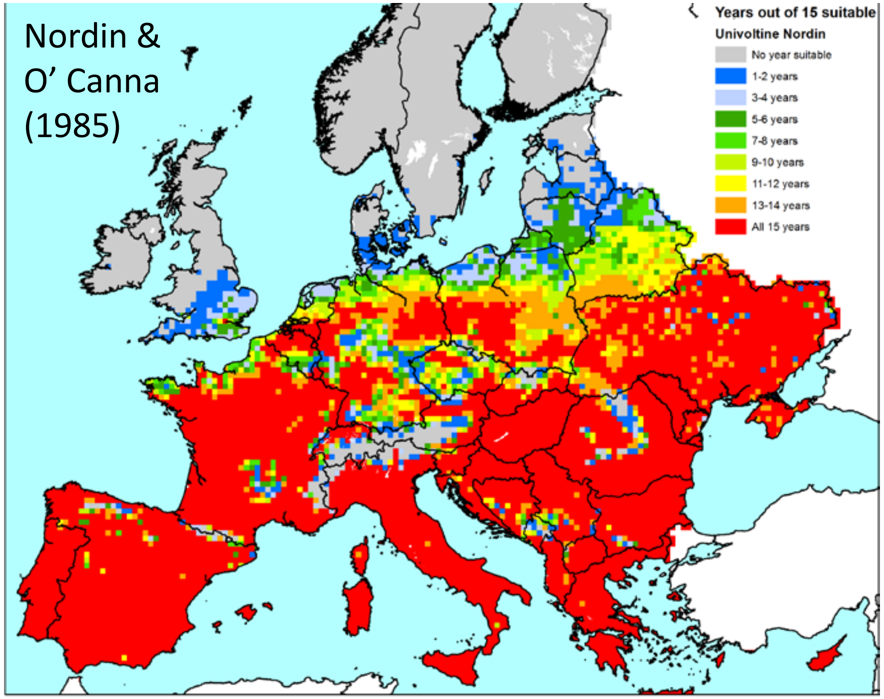
- Previous map averaged 15 years' data
- Annual variation important for establishment risks
- For each set of thresholds used, the number of years suitable (accumulated day degrees over threshold reached or exceeded) was calculated
  - Date range 2000 – 2014 inclusive = 15 years
    - 15/15 years threshold reached
    - ….
    - 0/15 years threshold reached
- Currently, no attempt made to identify consecutive unsuitable years
  - These may have more of an impact on establishment
  - The insect may be able to persist through one marginally unsuitable year, but not survive two or more consecutive poor years

Univoltine annual variation maps

Most precautionary (Lowest thermal thresholds)



Least precautionary (Highest thermal thresholds)



Red = every year suitable
Orange = most years suitable
Green = some years suitable
Blue = few years suitable
Grey = no year suitable

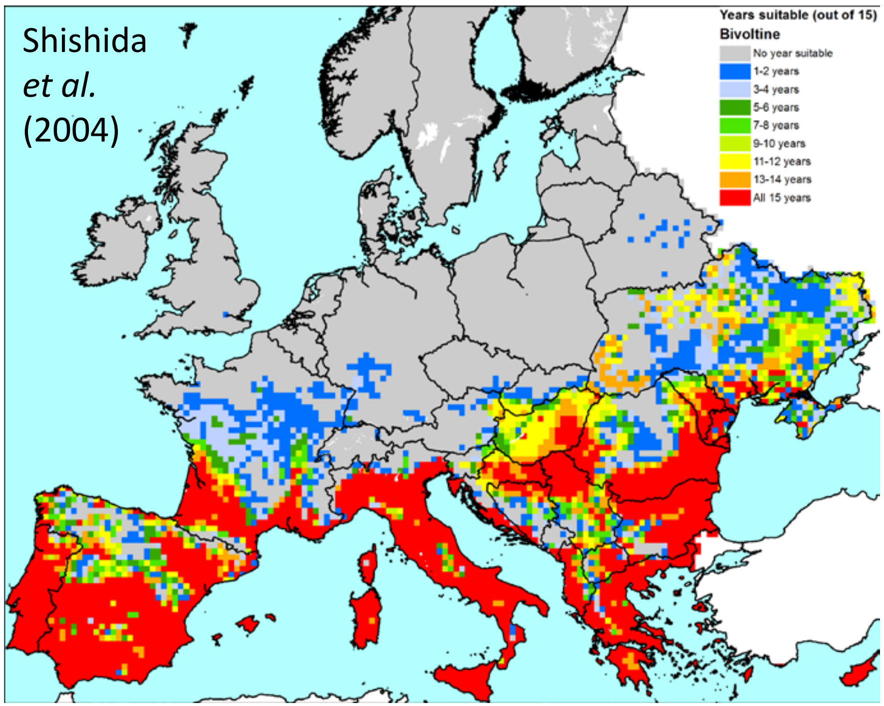
Bivoltine annual variation maps

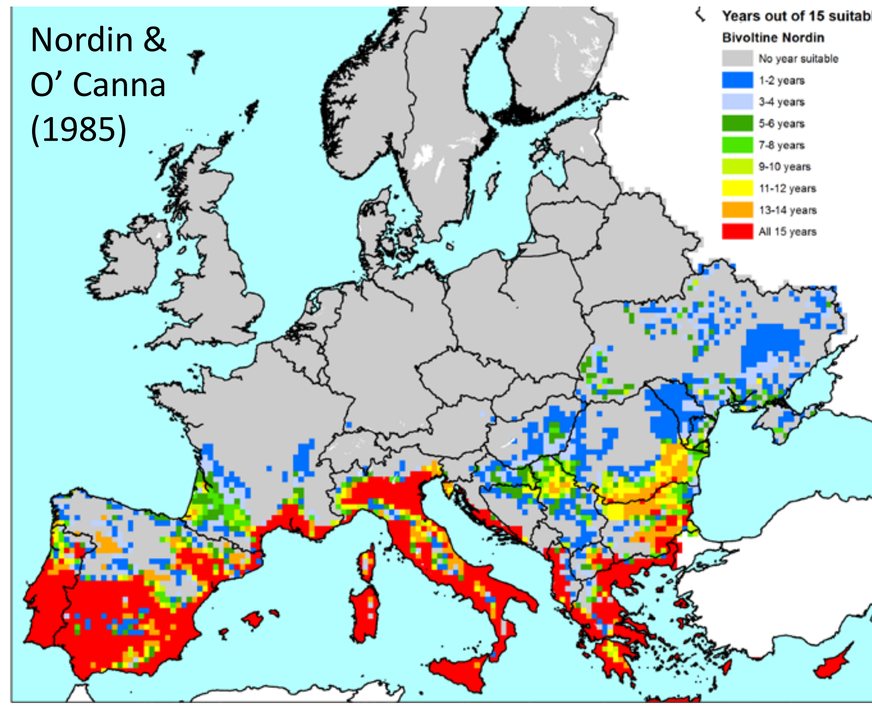
Most precautionary

(Lowest thermal thresholds)

Least precautionary

(Highest thermal thresholds)





Red = every year suitable
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Impacts and voltinism

- Univoltine populations known from Canada
  - Few recorded impacts from univoltine populations
- European (and Asian) populations all multivoltine
  - Second generation considered most damaging
  - Fewer impacts recorded in native North America
  - Japanese population has switched from bivoltine to trivoltine in some areas
  - European population has spread west and east, but limited in northerly expansion
  - High levels of damage immediately after introduction/colonisation
  - In Western Europe (e.g. France, Italy), the pest appears to persist at a low level, but no recent reports of outbreaks have been found
  - In Eastern Europe (e.g. Hungary, Romania, Slovakia), recent outbreaks have been recorded
  - In Asia, impacts have been reported from countries including China, Kazakhstan and South Korea

Is the UK at risk of establishment?

Yes

- Parts of England may be suitable for univoltine populations (depending on source data)
- It is unclear if European populations capable of switching to univoltine lifecycles
  - Univoltine Canadian populations have been reared as multivoltine under laboratory conditions
  - No evidence found of multivoltine populations switching to univoltine, experimental or natural
  - No records of any univoltine populations in introduced range
    - Are univoltine populations present but unrecorded?
    - Or is some factor preventing the invasive populations switching to a univoltine lifecycle?
- Thus, unclear to what extent the UK is at risk
  - Introduction of univoltine Canadian populations a risk
  - But the risk posed by introduction of multivoltine (European, Asian or North American) populations is unknown

Summary and conclusions

- Some selection of multiple data sources is necessary to limit the numbers of datasets analysed, at least for a preliminary analysis
  - But need to be transparent about exclusions and reasoning for them
- In this case, the selection criteria were based on
  - Biology (need to model diapause)
  - Consistency (one source did not agree with others)
- For risk mapping, a precautionary approach is often justified
  - But the variation must also be presented (i.e., including or at least discussing the less precautionary data)
- For risk managers, such maps can be helpful in visually representing the extent of potential risk, but they are best used in response to particular questions, with caveats to explain the context
- In this particular case, the maps illustrated the range of potential scenarios, which helped to inform discussion about technically justified and proportionate risk management options

Further information and future work

Further details of this work are available in the updated UK PRA

- It can be requested from either of the authors of this presentation
- In due course, it will be freely published online

Possible future work options:

- A more refined analysis which explores the sensitivity of policy decisions to the available data sets
- More advanced modelling, e.g. with CLIMEX?
- Diapause more explicitly modelled (i.e., not just increased number of accumulated day degrees)?
- Utilise other climate datasets and/or model a longer time period?
- Further discussion with policy makers on representing uncertainty
    - What is most helpful in terms of decision-making?