Department for Environment Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Elasmopalpus lignosellus

January 2021

Summary and conclusions of the rapid PRA

Elasmopalpus lignosellus (the lesser cornstalk borer) (Lepidoptera: Pyralidae) is a polyphagous pest in the Americas. In February 2019, larvae of this pest were intercepted in asparagus from Peru. As a non-listed pest, this PRA was commissioned to better understand the risk this pest poses to the UK. It is still unclear if this pest could establish in the UK, but the risk was considered unlikely (with low confidence). It is, however, clear that this pest would not have a significant impact were it to establish.

Risk of entry

This pest has only ever been intercepted on asparagus, and trade in plants for planting from the Americas is relatively small, therefore plant produce was considered the most likely pathway. Entry by this pathway was only considered **moderately likely** with **medium** confidence due to the difficulties the pest would have transferring from produce to live hosts, i.e. the requirement for the moth to successfully pupate, mate and escape to the wider environment.

Risk of establishment

If *E. lignosellus* is able to establish in the UK, it would be limited to one generation per year. Two to four generations per year are cited in the literature, so it is unclear if this pest is suited to a univoltine (one generation per year) lifecycle. *Elasmopalpus lignosellus* requires warm nights to mate and oviposit, but the number of these nights were found to be limited in the UK. Risk of establishment outdoors and under temporary protection was considered **unlikely** with **low confidence**. Establishment within glasshouses was also considered **unlikely** with **medium confidence** due to the irrigation of substrates being largely unfavourable for this pest as the larvae are semi-subterranean, and due to a lack of reports of damage in glasshouse systems.

Economic, environmental and social impact

If this pest is able to establish outdoors, the relatively low summer temperatures and high rainfall experienced by the UK would keep individual numbers very low. Therefore an impact rating of **very small** with **medium confidence** is given for economic and environmental impact. The presence of the pest could have an impact on exports to countries where *E. lignosellus* is not established. Potential social impacts were considered **very small** with **high confidence**.

Endangered area

If *E. lignosellus* is able to establish outdoors, no economically important losses are expected, therefore there is no outdoor endangered area for this pest.

This pest is considered unlikely to establish on hosts grown under protection. However, incursions could cause short-term losses for growers. Those hosts more at risk would be those grown in sandy mediums that are not regularly watered.

Risk management options

Given that this pest is not established outside of the Americas, the prospect for continued exclusion from the UK is good.

Eradication under protection could be expensive (requiring all or part of the crop to be sacrificed), but quite straight forward as this moth does not have the attributes of a persistent pest.

Eradication or containment outdoors would be very difficult due to this pest's wide host range (which includes grasses and legumes) and likely ability to fly long distances. Population numbers would likely be low enough to avoid detection, allowing spread to new areas. Preliminary mapping suggests that if it were to establish, populations could be quite temporary in places, and small populations could die out completely following successive cold, wet years.

Key uncertainties and topics that would benefit from further investigation

Generally speaking, there is a lack of information on the natural history of this pest in the wider environment i.e. non-pest populations.

The US distribution of this pest stretches as far north as Maine in some references. These records are based on adult specimens, however, and may not be indicative of breeding populations. If the northern border of this pest's distribution was more certain or if there was information on the cold tolerance of this pest, the likelihood rating for establishment in the UK could be made with more confidence.

Images of the pest

Elasmopalpus lignosellus Female adult © Mark Dreiling, Bugwood.org https://www.ipmimages.org/browse/detail.cfm?imgnum=5470527

E. lignosellus silk-lined tunnel on *Zea mays* © John C. French Sr., Retired, Universities: Auburn, GA, Clemson and U of MO, Bugwood.org https://www.ipmimages.org/browse/detail.cfm?imgnum=1599981

Is there a need for a detailed PRA or for a more detailed analysis of particular sections of the PRA? If yes, select the PRA area (UK or EPPO) and the PRA scheme (UK or EPPO) to be used.

No	✓				
Yes		PRA area: UK or EPPO		PRA scheme: UK or EPPO	

Given the information assembled within the time scale required, is statutory action considered appropriate / justified?

Yes Statutory action ☐ No Statutory action ☑

The UK PRA concludes that this pest is ‘unlikely’ to establish, and were it able to establish, it would have a ‘very small’ economic/environmental impact. The potential impact on exports have been considered, but not thought a strong enough argument for statutory action.

Stage 1: Initiation

1. What is the name of the pest?

Elasmopalpus lignosellus (Zeller) is a moth in the family Pyralidae. It is commonly called the lesser corn stalk borer in the USA, or in the Caribbean, the sugarcane jumping borer.

The vast majority of scientific literature on this pest is under the current accepted scientific name *Elasmopalpus lignosellus*. Literature prior to 1919 may refer to a range of synonyms including *Elasmopalpus major, E. incautella, E. carbonella, E. anthracellus, Pempelia lignosella* and *Salebria lignosella* (CABI, 2019).

2. What initiated this rapid PRA?

In February 2019, larvae of *E. lignosellus*, at least one of which was live, were intercepted at Heathrow airport on asparagus imported from Peru. Because this is a potential pathway of entry for the pest, and because this pest causes a significant impact to crops in its native range, it was added to the UK Plant Health Risk Register (RR) in June 2019. The RR entry identified *E. lignosellus* as a potential risk to a number of UK hosts, but identified significant uncertainties surrounding the climatic suitability of the UK. A PRA was requested to better assess the risk of this pest to the UK.

3. What is the PRA area?

The PRA area is the United Kingdom of Great Britain and Northern Ireland.

Stage 2: Risk Assessment

4. What is the pest's status in Regulation (EU) 2016/2031[1] and its associated regulations, including Commission Implementing Decision (EU) 2019/2072[2], and in the lists of EPPO[3]?

Elasmopalpus lignosellus is not listed in EU Regulations.

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[1] http://data.europa.eu/eli/reg/2016/2031/oj
[2] http://data.europa.eu/eli/reg_impl/2019/2072/oj
[3] https://www.eppo.int/ACTIVITIES/quarantine_activities

Elasmopalpus lignosellus was added to the EPPO alert list in 2019 following interceptions of the pest on asparagus into the UK and Ireland (EPPO, 2019).

5. What is the pest's current geographical distribution?

Elasmopalpus lignosellus is recorded as present across most of South and Central America including much of the Caribbean. It is also present in the southern part of the United States and Hawaii (Table 1 and Fig. 1) (CABI, 2019; EPPO.GD, 2020). It is absent from several northern, central and western states of the US, there have, however, been adult specimens captured in the north east of the US and a few in Canada. These are likely migratory or perhaps had moved in trade, but this could not be confirmed. No information on the northern limit of the breeding distribution of *E. lignosellus* was found. What is clear is that, within the US, economic damage caused by this pest is restricted to the south-eastern states (South Carolina to Texas) (Gill *et al.*, 2017). There is an isolated report of this pest from Vietnam (Perez, 1980), but EPPO GD (Global Database) claims this is an unreliable record (EPPO.GD, 2020).

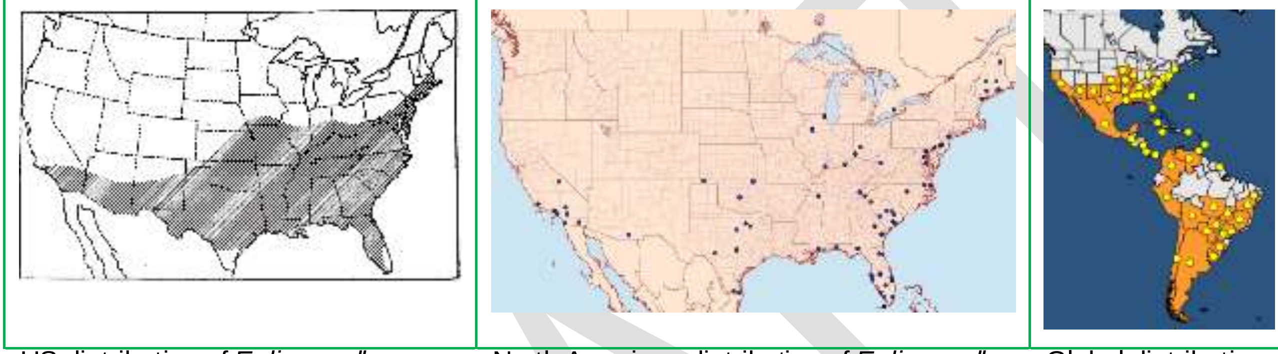
Table 1: Distribution of *Elasmopalpus lignosellus*	
North America:	Bermuda, Canada (Nova Scotia (Ferguson *et al.*, 1991), Ontario (MPG)), Cuba, Mexico, USA (Alabama, Arizona, Arkansas, California, Connecticut, Delaware, Florida, Georgia, Hawaii, Illinois (Luginbill & Ainslie, 1917), Iowa (Luginbill & Ainslie, 1917), Kansas, Louisiana, Maine (Brower, 1983; Gill *et al.*, 2017), Maryland, Massachusetts (Luginbill & Ainslie, 1917; Neunzig, 1979), Mississippi, Missouri, New Jersey (Luginbill & Ainslie, 1917; Neunzig, 1979), New Mexico, New York (CABI, 1960), North Carolina, Ohio (CABI, 1960), Oklahoma, South Carolina, Tennessee, Texas, Virginia)
Central America:	Barbados, Costa Rica, El Salvador, Guatemala, Jamaica, Nicaragua, Panama, Puerto Rico, Trinidad and Tobago, United States Virgin Islands
South America:	Argentina, Bolivia, Brazil, Chile, Colombia, French Guiana, Guyana, Paraguay, Peru, Uruguay, Venezuela
Europe:	
Africa:	
Asia:	
Oceania:	

Unless otherwise stated, distribution is taken from (CABI, 2019; EPPO.GD, 2020)
Underlined states/provinces are the more northerly

Status of *E. lignosellus* in the northern United States

Ferguson *et al.* (1991) state that *E. lignosellus* is widespread in the southern US and migrates northward as far as Canada in some seasons; it has been captured in Nova Scotia at least twice. Gill *et al.* (2017) state that this pest is more often observed in the south-eastern states, and that outside of this area, *E. lignosellus* is sporadic in nature, distributed from Maine to southern California. One of the datasheets on this pest states that it is common in the Atlantic and Gulf coast states (Bessin, 2004). In a list of the microlepidoptera of Maine, Brower (1983) lists 10 captures of *E. lignosellus*. Records for New Jersey and Massachusetts are cited in Neunzig (1979) which does not explicitly state whether the known distribution is based on larval records or just collected adult specimens. Iowa and Illinois are cited on a survey map, and again it is not clear what the records were (USDA, 1933). New York is cited within a CABI pest map, but is based on a museum specimen (CABI, 1960). Luginbill and Ainslie (1917) report that *E. lignosellus* has been 'taken at various points' in Illinois. They then go on to list museum specimens labelled with a number of states including Iowa and Massachusetts. They also cite a reference which states that *E. ligonsellus* will be found throughout the state of New Jersey.

Figure 1: Distribution maps of *Elasmopalpus lignosellus*



US distribution of *E. lignosellus* (Luginbill & Ainslie, 1917)

North American distribution of *E. lignosellus*. Complied using museum and state databases, literature, collector and photographer's records (MPG)

Global distribution of *E. lignosellus* (map does not include Hawaii) (EPPO.GD, 2020)

Migratory capability of *E. lignosellus*

When disturbed during the day, the flight pattern of *E. lignosellus* is short, jerky and just above the top of host plants (Dixon, 1982a). However, adult flight is primarily nocturnal when the adults mate (Holloway & Smith, 1975). No information was found on the long-distance flight capability of *E. lignosellus. Elasmopalpus lignosellus* has a wingspan of 16-24 mm (Dixon, 1982a) which is similar to *Hellula undalis* (Pyralidae), a moth capable of flying significant distances (Table 2). There is also a record of an *E. lignosellus* adult being captured by aeroplane in Texas at 300 m (Glick & Noble, 1961) which suggests this pest uses winds to migrate. Female moths are larger than males (Sanchez & Sanchez, 2010).

Table 2: Flight distances of species of Pyralidae						
Species	Distance (m)	Time	Sex	Wingspan	Method	Source
Chilo suppressalis	128	1 night	male	20-30 mm	mark & recapture	Kondo and Tankana (1994)
Hellula undalis	6,800	24 hrs	male	18-21 mm	mark & recapture	Shirai and Kawamoto (1990)
Hellula undalis	16,000	48 hrs	male	18-21 mm	mark & recapture	Shirai and Kawamoto (1990)
Cactoblastis cactorum	21,500	24 hrs	female	27-40 mm	flight mill	Sarvary *et al.* (2008)
Loxostege sticticalis	70,000	1 night	-	24-29 mm	flight mill	Kong *et al.* (2010)
Hellula undalis	500,000	-	-	18-21 mm	captured on ship	Reference in Shirai and Kawamoto (1990)

Elasmopalpus lignosellus was first discovered outside the continental US in 1986 infesting sugarcane in Hawaii (Gill *et al.*, 2017). This appears to be an introduction. *Elasmopalpus lignosellus* has not been introduced anywhere else.

6. Is the pest established or transient, or suspected to be established/transient in the UK/PRA Area?

There are no reports of *E. lignosellus* having established in the UK.

The pest has been intercepted many times in the last two years. As of 4th November 2020 there have been 21 live interceptions of larvae on asparagus imported by air to England, all originating from Peru. One interception has occurred via sea freight, also on asparagus from Peru to England. Ireland also intercepted this pest twice in 2019.

7. What are the pest's natural and experimental host plants; of these, which are of economic and/or environmental importance in the UK/PRA area?

Elasmopalpus lignosellus is highly polyphagous with over 100 reported hosts from over 30 families, many of which are agricultural crops (Appendix I, Table 1). It is most commonly associated with cereals, other grasses and legumes, particularly crabgrass (*Digitaria* spp.), maize (*Zea mays*), peanut (*Arachis hypogaea*), sorghum (*Sorghum* spp.), soybean (*Glycine max*) and sugarcane (*Saccharum officinarum*). Damage to trees (broadleaved and coniferous) is limited to seedlings (Craighead, 1950; Baker, 1972; Dixon, 1982b; a). Because of the very wide range of species reported as hosts of this pest, the host list in Appendix I, Table 1 should not be considered exhaustive. Some of the listed plants are not necessarily confirmed hosts, but have been assumed as such in the literature.

Many of the listed crop hosts are of significant economic importance to the UK. Asparagus (*Asparagus officinalis*), beet (*Beta vulgaris*), barley (*Hordeum vulgare*), brassicas including oilseed rape (*Brassica napus*), cabbage (*B. oleracea* var. *capitata*) and turnip (*B. rapa* subsp. *rapa*), common bean (*Phaseolus vulgaris*), maize, pea (*Pisum sativum*), potato

(*Solanum tuberosum*), oat (*Avena sativa*), radish (*Raphanus sativus*), soybean and wheat (*Triticum aestivum*) are all important field grown crops in the UK. Tomato (*Solanum lycopersicum*), sweet pepper (*Capsicum frutescens*) and strawberry (*Fragaria* X *ananassa*) are also important crops, but in the UK, commercially-grown tomatoes and peppers are mostly grown in replaceable, alternative substrates and so are not likely to be at risk from this pest. The larvae of *E. lignosellus* live under the soil surface journeying from silk-lined tunnels to within plant stems for feeding. *Elasmopalpus lignosellus* therefore requires soil or soil-like substrates to complete development.

In Florida, USA, where there were reports of damage on strawberries in the 1930s, the strawberries were grown in the ground with weeds and grasses (preferred hosts of this pest) allowed to grow around the strawberry plants (Stahl, 1930). Stahl (1930) suggests that when the weeds are cut, the strawberry plants are the only available food source. In the UK, strawberries are commercially grown in raised beds or tabletops. Even if grown in the soil, it is likely that efforts are made to keep the crops free from as many growing weeds as possible.

Grasses grown for biomass, *Miscanthus* spp. for example, are also potential hosts for this borer (Prasifka *et al.*, 2012).

The listed tree and shrub genera which are of significant economic or environmental importance to the UK include dogwood (*Cornus*), juniper (*Juniperus*) and pine (*Pinus*). Though the species listed as hosts are North American, given the recorded hosts of this pest are so varied, it seems likely that the UK's native species (*Cornus sanguinea*, *Juniperus communis* and *P. sylvestris*) and forestry species (e.g. *P. contorta* and *P. nigra*) could also be hosts under the right conditions. American planetree (*Platanus occidentalis*) is a listed host, and London plane (*P. x acerifolia,* thought to be a hybrid of *P. occidentalis* and *P. orientalis*) is a very common amenity tree in urban environments. These tree host records, however, all originate from the same report of damage to nursery seedlings in Florida in 1981 (Dixon, 1982b). The seedlings were grown in the ground (Dixon & Mayfield, 2012), and environmental conditions described were very suited to the pest (sandy soils, drought, and the use of susceptible cover crops). The records of attack on black locust trees (*Robinia pseudoacacia*) also appear to be limited to nursery seedlings in the southern states (Craighead, 1950; Baker, 1972). In the UK, a large portion of conifer and broadleaved species are field-grown for the forestry/woodland market. Given the particular set of circumstances that lead to tree seedling attacks in the US southern states (warm temperatures, drought, sandy soil and susceptible cover crops), it seems unlikely that tree hosts in outdoor nurseries or the wider environment in the UK would be at risk. It is less clear whether nursery seedlings grown under protection in the UK would be at risk from this pest. *Elasmopalpus lignosellus* has been intercepted by the US on hazel (*Corylus avellana*), but no other details on this interception are available (Appendix I, Table 1) (Solis, 2006).

8. Summary of pest biology and/or lifecycle

The timing of the lifecycle of *E. lignosellus* is very strongly determined by temperature, and reports of the duration of each life stage differ significantly between references. The durations given below are therefore all taken from the 21°C (considered room temperature) treatment from Sandhu *et al.* (2010). Total development (from egg lay to adult emergence) ranges from 23 days at 33°C to 121 days at 13°C (Sandhu *et al.*, 2010).

Eggs of *E. lignosellus* are usually deposited just below the surface of the soil close to host plants, though some can be found on the soil surface, on leaves or on stems (Gill *et al.*, 2017). The location of egg deposition varies by host species and soil type (Sandhu, 2010). The reported number of eggs deposited by females varies significantly between references, but the average is 140, with 420 reported on an artificial diet (Sandhu, 2010 and references therein). Egg development requires 4 days at a constant 21°C (Sandhu *et al.*, 2010).

Young larvae feed on plant roots and leaves, later constructing tunnels under the soil surface from sand, frass and detritus woven together with silk (Bessin, 2004). They leave the tunnel to feed in the basal stalk of the host, returning and constructing new tunnels as they mature (Gill *et al.*, 2017). A translation of a handbook on asparagus pests in Peru suggests that *E. lignosellus* larvae can build their silk tunnels within the asparagus stems when soil humidity is high (Sanchez & Sanchez, 2010). It is the larval feeding on plant stems and roots that causes the economic damage. Larval feeding can lead to wilting, withering of buds, stunted development and girdling (Gill *et al.*, 2017). Injuries to plants by *E. lignosellus* sometimes resemble those caused by *Diabrotica* (Coleoptera: Chrysomelidae) (Luginbill & Ainslie, 1917). Larvae can move from one plant to another, and from field weeds to crops (Isely & Miner, 1944). Larvae are highly active if disturbed, with the pest named the jumping borer in the Caribbean. The number of larval instars varies between four and nine. Larvae emerging in spring or summer typically have four or five larval instars whereas those emerging later have six or more (Luginbill & Ainslie, 1917; Gill *et al.*, 2017). Larval development (with six instars) requires 27 days at a constant 21°C (Sandhu *et al.*, 2010).

Pupation occurs at the end of the larval tunnels in cocoons made with soil and silk (Gill *et al.*, 2017), with pupal development taking 12 days at a constant 21°C (Sandhu *et al.*, 2010).

Elasmopalpus lignosellus overwinters in the larval stage (presumably within the larval tunnels) or in the pupal stage in the soil or in leafy debris on the soil surface (Baker, 1972; Bessin, 2004). The total development time from oviposition to adult is 50 days at a constant 21°C (Sandhu *et al.*, 2010) and the number of generations per year varies between two (Salvatore *et al.*, 2007) and four (Craighead, 1950; Baker, 1972).

Adults are most active at night when the temperature exceeds 27°C, relative humidity is high, and there is little air movement. These conditions are optimal for mating and oviposition. These activities cease below 18 - 20°C (Capinera, 2001). During the day, moths are found under the foliage of host plants. When disturbed, the flight pattern of the moths is short, jerky and just above the top of plants (Dixon, 1982a). Adult longevity under field conditions is estimated to be around ten days (Leuck, 1966; Gill *et al.*, 2017). In the laboratory, female longevity was approximately 20 days at 17°C (Mack & Backman, 1984). The dispersal distances of moths is not known (see discussion in Section 5 and Table 2).

There can be significant colour variation between individuals of this species, including between eggs, making identification difficult in the field. In the US, moths are difficult to distinguish from many other species (Capinera, 2001). Larval identification is problematic. For Lepidoptera generally, only the final instar larvae of economically important species are adequately described. This means that identification of earlier instars, or conclusively separating *E. lignosellus* larvae from other Pyralidae species from the same origins, is difficult.

9. What pathways provide opportunities for the pest to enter and transfer to a suitable host and what is the likelihood of entering the UK/PRA area?

Elasmopalpus lignosellus is thought to have been introduced to Hawaii where it was discovered in 1986 and has impacted sugarcane production (Chang & Ota, 1987 cited in Gill *et al.*, 2017). It is not known to have been introduced outside of the Americas.

There is clear evidence that this pest can move in trade, with large numbers of UK interceptions of live larvae within the base of asparagus stems from Peru (21 interceptions by air from Feb 2019 to Nov 2020, one by sea in Jan 2021). Whether these larvae could successfully pupate, mate and locate a living host is still uncertain.

The most viable pathway for this pest was considered to be produce with stems.

Plants for planting

Plants for planting have the potential to harbour eggs (in the soil and on the plant), larvae (in the soil or the stem), or pupae (in the soil or soil surface). When disturbed in the field, adults make short jerky flights. It therefore seems unlikely that adults would be found on the underside of any leaves. Plants for planting would likely come via air, and would be a viable route of entry for *E. lignosellus* as the pest would already be on a living host. However, according to Plant Health Regulations, these plants need to have been grown in nurseries, and certain grass species require an inspection prior to export. These measures reduce the likelihood of the plants being infested with this pest. There is also only a limited trade in plants for planting from the Americas and it has been reducing (five year mean [2014 to 2018] using all possibly relevant commodity codes = 11,200 kg/year, Eurostat). A portion of this trade will not be host species. Another portion will be plants in tissue culture, cuttings or bare-rooted plants which the pest is less likely to be associated with, or at least easier to spot during packing or inspection. Any containerised plants are likely to have been grown in compost and well-watered, which is known to be unfavourable to this pest. If followed, the measures concerning growing medium in Point 1, Schedule 7 of the Plant Health (EU Exit) Regulations 2020 would significantly reduce the risk of this pest being associated with containerised plants. These measures include options to use a) non-soil growing mediums; fumigation or heat treatment; or an effective systems approach, And to b) ensure growing mediums are kept free from pests; hygiene measures are used; or in the two weeks prior to export, plants are washed and replanted in growing mediums described in point a). Therefore entry via plants for planting at the present time was considered **unlikely** with **medium** confidence, though this could change with an increase in trade.

Plants for planting	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

Plant produce for consumption

There is a very wide range of commodities derived from plants in this pest's host list. Only fruit or vegetables that have grown on the soil surface, below ground, or are imported with the lower stem or leaves attached would be likely to harbour the eggs or larvae of this pest. When disturbed in the field, adults make short, jerky flights. It therefore seems unlikely that after harvest adults would still be found on the underside of any leaves. Though eggs could enter the UK on leaves or stems, it seems unlikely that the emergent larvae would find the new environment favourable as well as locate enough resource (plant leaf and stem tissue) to complete development in any great number. Pupae could enter in packing boxes and other packing material, but again, this is not likely to occur in large numbers. Therefore, the larval stage feeding on the inner tissue of plant produce seems to be the most viable pathway for this pest. The only UK interceptions of this pest have been larvae feeding within asparagus. Plant species *E. lignosellus* has been intercepted on by the US include asparagus, pineapple, hazel, mint, sorghum, maize and coffee, though information on the exporting country, pest life stage and plant part was not available (Solis, 2006).

Table 3. Produce exports from the distribution of *E. lignosellus* (Eurostat in 100 kg)										
	produce with stems			root & tuber produce		leguminous produce				
year	asparagus	c.flower & broccoli	kale etc	carrots & turnips	sweet potatoes	soya beans	peas	beans	peanuts	other
2015	110491	682	544	2407	859663	6558172	59325	25978	2595	2251
2016	113082	470	507	2699	1207885	7038534	66041	27235	1262	4189
2017	107606	462	25	2128	1190059	7037353	65437	23808	2946	3829
2018	117048	545	11	2112	1073696	7766059	74960	25381	5073	1343
2019	122779	1937	1	2223	819548	5277172	80527	20953	3493	118
mean	**114201**	**819**	**218**	**2314**	**1030170**	**6735458**	**69258**	**24671**	**3074**	**2346**

Commodity codes and descriptions for Table 3

Commodity	**Commodity code**	**Full commodity description**
asparagus	07092000	Fresh or chilled asparagus
c.flower & broccoli	07041000	Fresh or chilled cauliflowers and headed broccoli
kale & similar	07049090	Kohlrabi, kale and similar edible brassicas, fresh or chilled (excl. cauliflowers, headed broccoli, Brussels sprouts, white and red cabbages)
carrots & turnips	07061000	Fresh or chilled carrots and turnips
sweet potatoes	07142010	Sweet potatoes, fresh, whole, for human consumption
soya beans	12019000	Soya beans, whether or not broken (excl. seed for sowing)
peas	07081000	Fresh or chilled peas "Pisum sativum", shelled or unshelled
beans	07082000	Fresh or chilled beans "Vigna spp., Phaseolus spp.", shelled or unshelled
peanuts	12024100	Groundnuts, in shell (excl. seed for sowing, roasted or otherwise cooked)
other	07089000	Fresh or chilled leguminous vegetables, shelled or unshelled (excl. peas "Pisum sativum" and beans "Vigna spp., Phaseolus spp."
Not included in table as < 500 (100 kg) in total for time period		
	12129300	Sugar cane, fresh, chilled, frozen or dried, whether or not ground
	12130000	Cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets
	07069090	Fresh or chilled salad beetroot, salsify, radishes and similar edible roots (excl. carrots, turnips, celeriac and horse-radish)

Produce with stems: There is significant trade in vegetables with stems from the Americas. The UK imports approximately 11 M kg of asparagus each year (Table 3), the bulk of which comes from Peru and Mexico, though during the British asparagus season, some may also be imported from Italy and Spain (Chinn, C. pers. comms., 2020). Approximately 30% of imported asparagus is imported via containerised sea freight, with the rest being airfreight (Chinn, C. pers. comms., 2020). As of 4th November 2020 there have been 21 UK interceptions of larvae on asparagus imported by air, all originating from Peru. In January 2021 there was also an interception on Peruvian asparagus entering the UK via sea freight. There is also a significant quantity of brassicas with stem parts imported from the distribution area of *E. lignosellus* (Table 3). Imports of sugarcane and cereal straw are negligible from this area.

Root and tuber produce: Potato (USDA, 1933), sweet potato (Gill *et al.*, 2017), radish (Carbonell, 1977 cited in Sandhu, 2010) and turnip (Luginbill & Ainslie, 1917) are all listed as hosts, however either the original source of information could not be accessed or no reference to the pest infesting the actual produce was found. Turnip is listed by a few secondary sources, but the exact wording in a primary source Luginbill and Ainslie (1917) is "Athens, Ga., October, 1889 (Thomas I. Todd), feeding on the leaves". Though larvae have been noted to feed on roots, this assessment assumes that root and tuber produce itself is not likely to be infested. Were these commodities found to be a viable pathway for this pest, however, the commodity volumes are significant; approximately 100 M kg of sweet potato per year (Table 3).

Leguminous produce: *Elasmopalpus lignosellus* is known to infest peanuts (groundnuts) in the field (Isely & Miner, 1944) (Figure 2), and approximately 300,000 kg of peanuts are imported into the UK 'in shell' each year (Table 3). It is very unlikely that shelled produce would be infested by live larvae. Commodity codes for other leguminous produce (soya beans, peas and beans) do not differentiate between shelled and unshelled produce, so the volumes of shelled imports are uncertain. It is also not clear whether peas and beans in shell are likely to suffer infestation from the larval stage of this pest as peas and beans grow above the surface of the ground (though some contact with the ground might occur). One interception on string beans (*Phaseolus* sp.) being imported from Mexico into the US for consumption did occur in 1943 (USDA, 1944).

Figure 2: *Elasmopalpus lignosellus* in damaged peanut pod

Cereal grains and other seeds: It is very unlikely that cereal grains, seeds or maize cobs would harbour eggs or larvae as this pest lays eggs in the soil or close to the ground, and larvae do not attack the top parts of the plant.

In order for transfer to a living host to occur, larvae need to survive any post-import processing (at packing houses or in domestic properties), pupate, and the emergent adults would need to mate and the female moth would need to successfully locate a host. Whether pupation can occur within the asparagus stems is not known, but if possible, this would decrease the chances of detection. As this pest is so polyphagous, it would not be difficult to find a suitable host (transfer to crops might then occur after establishment on wild hosts). The climatic environment and physical barriers of buildings, however, may be a limiting factor. Interceptions in 2019 were made from February to November. Any individuals that successfully emerge as adults during autumn or winter months in the UK would be unlikely to produce another generation due to low temperatures.

Asparagus packing and growing in the UK: There are approximately 3000 acres of land used for commercial asparagus crops in the south of the UK (Chinn, C. pers. comms., 2020). Several packing houses in the south of the UK receive pre-graded imported asparagus for labelling and distribution to wholesale and retail (Chinn, C. pers. comms., 2020). Some of these may be located in proximity to where asparagus and other host crops are grown, so transfer from imported asparagus to growing asparagus (and other host crops) could occur. It is also likely that during the ‘shoulders’ of the UK asparagus production season, UK and imported produce would be in close proximity during distribution (Chinn, C. pers. comms., 2020). Packing boxes and equipment might be returned to suppliers from packing houses containing the pest, again facilitating transfer of the pest to a living crop host.

Because of the likelihood of larval association with some of the produce discussed, particularly asparagus, and the high volumes imported, plant produce was rated as a **moderately likely** route of entry with **medium** confidence. Limiting the likelihood of this pathway is the requirement for the larvae to successfully pupate, mate and transfer to a host in a suitable environment.

Plant produce	Very unlikely ☐	Unlikely ☐	Moderately likely ☑	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

Cut flowers

Reference to *Gladiolus* sp. as a host is made in (Sandhu, 2010), but the original source could not be accessed. The five year mean for gladioli imports from the distribution area of *E. lignosellus* is 16,800 kg / year. For the last two years, however, there have been no imports of this flower (Table 4).

Table 4. Flower exports from the distribution of *E. lignosellus* (Eurostat in 100 kg)		
year	**gladioli 06031910***	**all other cut flowers**
2015	106	80094
2016	702	73829
2017	33	74152
2018	0	74251
2019	0	76571
mean	**168**	**75779**

*Full description: Fresh cut gladioli and buds, of a kind suitable for bouquets or for ornamental purposes

The UK does import a lot of cut flowers from the Americas (approximately 8 M kg / year), in particular from Colombia and Ecuador. As no reports of this pest on flower crops were found, and with no interception data for cut flowers, it is assumed that cut flowers are an **unlikely** pathway with **high** confidence.

Cut flowers	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

Natural spread

This pest is not present outside of the Americas. Natural spread of this pest into the UK was rated as **very unlikely** with **high** confidence.

Natural spread	Very unlikely ☑	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

10. If the pest needs a vector, is it present in the UK/PRA area?

Elasmopalpus lignosellus is a free living organism and does not require a vector to move/spread.

11. How likely is the pest to establish outdoors or under protection in the UK/PRA area?

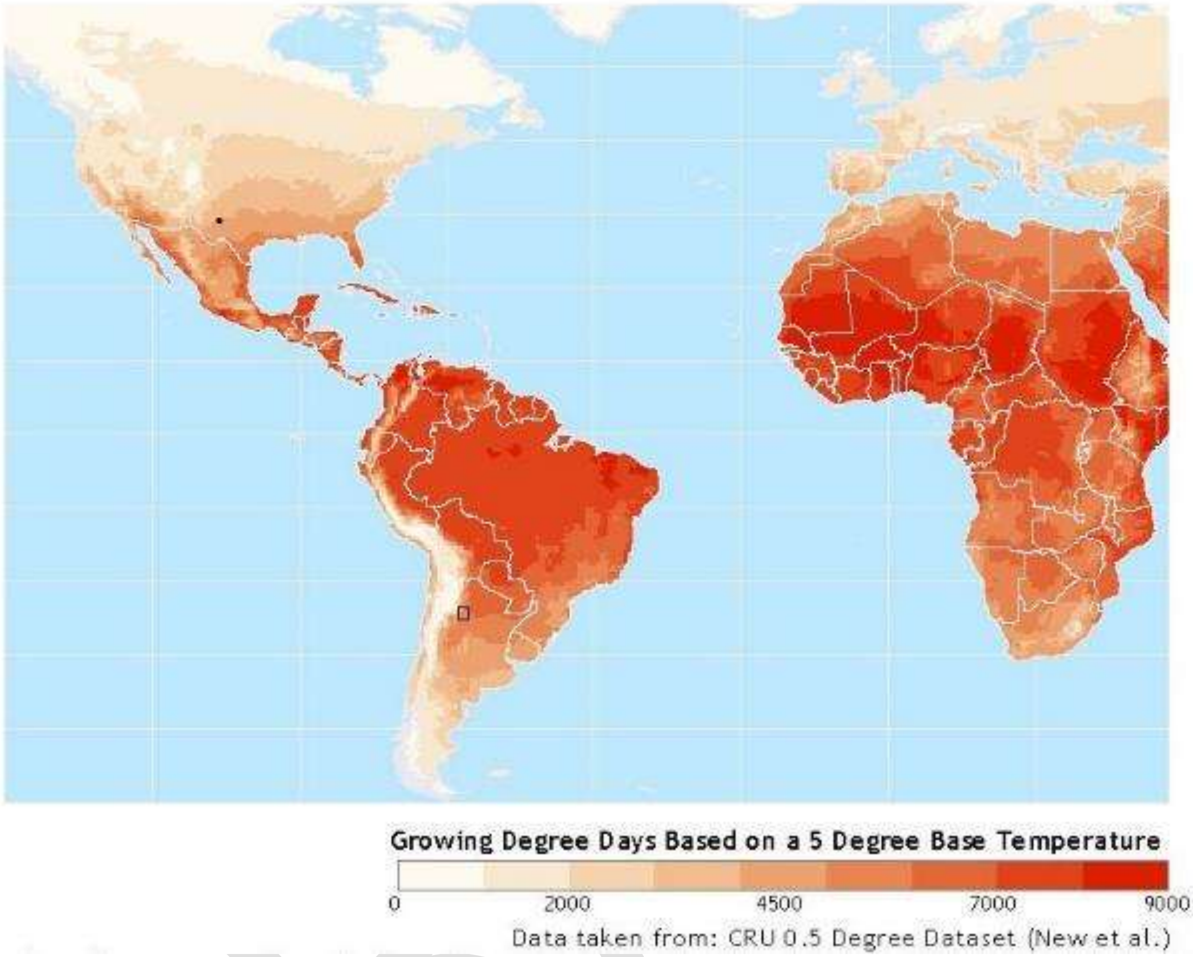
Hosts

As this pest is so polyphagous, preferring grasses (including cereals) and common garden and crop legumes, host distribution was not considered a limiting factor in the pest's potential to establish outdoors or under protection in the UK.

Temperature (outdoors)

Baker (1972) states that up to four generations per year are reported for the 'Deep South' and Gill *et al.* (2017) states that there are three to four generations annually of *E. lignosellus* in the southeast of the US, but only three in the southwest. In Tucumán, Argentina, *E. lignosellus* is reported to complete two or three generations each year, with "overlapping activity" during September to December (Salvatore *et al.*, 2007). It is not known if *E. lignosellus* has one generation annually within its current distribution. Figure 3 shows that the annual accumulation of degree days in much of the UK is equivalent to that in the most northerly US states where *E. lignosellus* moths (but not necessarily breeding populations) have been observed.

Figure 3. Annual accumulated Growing Degree Days



Dot = Seminole, Gains County, Texas, USA, altitude = 1005 m. Three to four *E. lignosellus* generations per year are reported for the southern states.
Square = Tucumán Province, Argentina, altitude varies greatly. Two to three *E. lignosellus* generations per year are reported for this area.
Used by permission of The Center for Sustainability and the Global Environment (SAGE), Nelson Institute for Environmental Studies, University of Wisconsin-Madison
https://nelson.wisc.edu/sage/data-and-models/atlas/maps.php?datasetid=31&includerelatedlinks=1&dataset=31

Three sets of temperature-dependent developmental parameters were found in the literature for *E. lignosellus* (Table 5). The parameters reported in Mack *et al.* (1987) were used for this assessment. The reasoning behind this decision is described in Appendix II.

Table 5. Estimated temperature parameters for oviposition to adult development of *Elasmopalpus lignosellus*

LDT (°C)	Degree-Days	Details and source
13.0	530.0	parameters for 'one generation' (unpublished in Berberet *et al*. 1982)
14.5	439.6	egg to pupal stages, estimated by linear regression, reared on an artificial diet in the laboratory (Mack *et al*., 1987)
9.5	543.5	'total development', estimated by linear regression, reared on sugarcane in the laboratory (Sandhu *et al*. 2010)

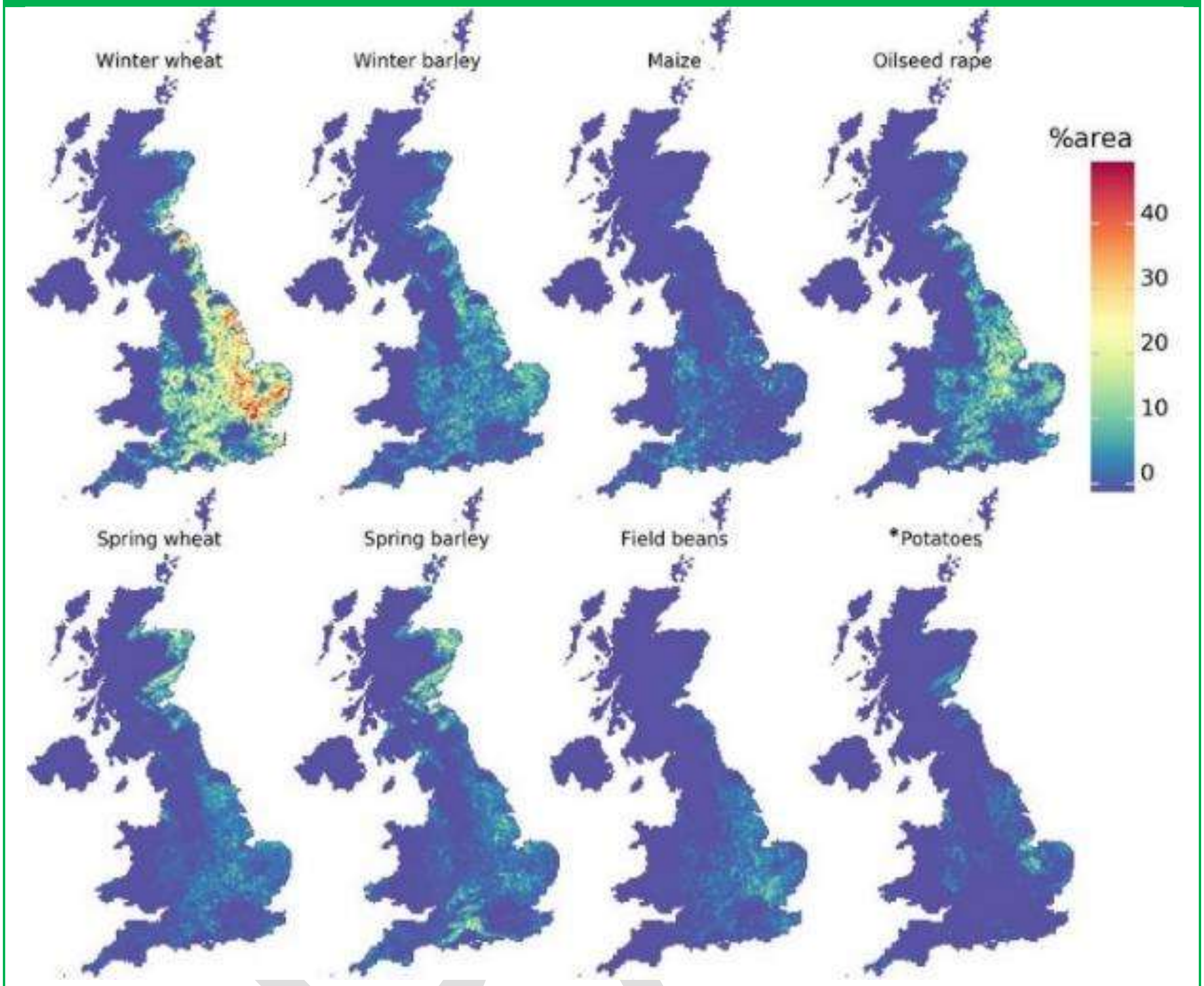
LDT = Lower Developmental Threshold Temperature

Figure 4. Estimated number of *Elasmopalpus lignosellus* generations within a calendar year (Jan to Dec) in the UK

LDT = Lower Developmental Threshold Temperature, DD = Degree Days

Egg to adult development: Figure 4 shows the estimated number of generations *E. lignosellus* would have in the UK in a cool year, such as 2002, and a warm year, such as 2006. Neither year would have resulted in more than one generation per year. For the purpose of this assessment, it is assumed that any generation requiring more than a year to develop would perish. In the Americas, *E. lignosellus* has multiple generations per year and is known to suffer increased larval mortality when soil moisture is high due to wet weather or irrigation (Schaaf, 1972; Viana & Costa, 1995; Salvatore *et al.*, 2007; Nuessly & Webb, 2017). Any generation that takes a year or longer to develop is going to have an extended larval developmental period. That extended period means larvae might be more likely to be predated or succumb to disease. The calculations used to create the map assume that egg development begins on the first of January. Though this would not occur in the field, the relatively high LDT (lower developmental threshold temperature) of 14.5°C means that significant development would not begin to occur in the model until well into Spring (a more likely time for egg development to begin). The calculations are also based on air temperatures recorded at 1.25 m above ground. Ground or just below-ground temperatures experienced by *E. lignosellus* might be slightly different to these.

Figure 5. Land cover maps of UK crops that are *Elasmopalpus lignosellus* hosts



Adapted from Bourhis *et al.* (2020)
https://www.biorxiv.org/content/10.1101/2020.05.14.095539v3
*Potato only a potential host (see Appendix I, Table 1)

Mating: Leuck (1966) cited in Gianessi (2009) states that copulation takes place only at night and only occurs when temperatures are above 70 degrees F (21°C). Table 6 shows the number of nights (taken as 20:00 to 05:00) where temperatures were recorded at or above 21°C at two locations during two growing seasons (one from a cool year and one from a warm year). Locations in Hampshire and Cambridge were chosen as establishment of the pest is more likely in the south and east of England (Figure 4), and these are two areas where abundant crop hosts are grown (wheat, barley and oil seed rape, Figure 5). Air temperatures were recorded by Met Office stations which are positioned on flat open ground. It should therefore be noted that warmer microclimates could exist in the field. During the cooler year (2002), there would have been few opportunities to mate (Table 6; Appendix III). In order to take advantage of those few opportunities male and female moths would need to have emerged at least within a couple of weeks of each other; adult longevity under field conditions is estimated to be around ten days in South Georgia (Leuck, 1966; Gill *et al.*, 2017), but Mack and Backman (1984) found that female longevity increased with decreasing temperature, and at 17°C was approximately 20 days.

Table 6. No. of nights (20:00 to 05:00) where temperatures of ≥ 21°C were recorded

	2002 Cool year		2006 Warm year	
Month	Hampshire	Cambridgeshire	Hampshire	Cambridgeshire
April	0	0	0	0
May	0	0	0	0
June	0	0	5	4
July	3	4	15	14
August	0	2	3	2
September	0	0	1	2
October	0	0	0	0

Hampshire - Middle Wallop, Cambridgeshire - Monks Wood
Weather data (Met.Office, 2012)

Oviposition: Mack and Backman (1984) state that 17°C is the minimum temperature for oviposition. Table 7 shows the number of nights (taken as 20:00 to 05:00) where temperatures were recorded at or above 17°C at the same time and locations as described above. Only the months of July and August would have had many opportunities for oviposition across both cool and warm years. In June of the cooler year (2002), temperatures were usually only above 17°C for the first few hours of the night (Appendix III).

Table 7. No. of nights (20:00 to 05:00) where temperatures of ≥ 17°C were recorded

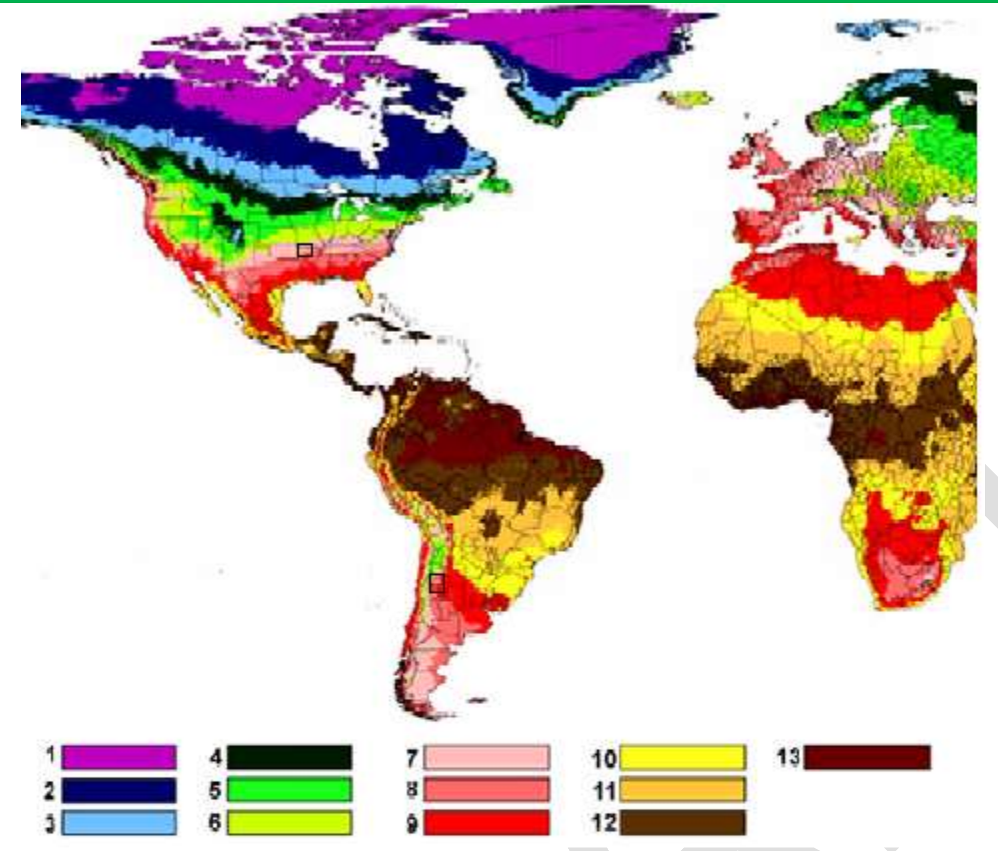
	2002 Cool year		2006 Warm year	
Month	Hampshire	Cambridgeshire	Hampshire	Cambridgeshire
April	0	0	0	0
May	2	1	1	1
June	3	6	15	11
July	13	14	28	28
August	18	11	11	5
September	5	2	12	15
October	0	0	0	0

Hampshire - Middle Wallop, Cambridgeshire - Monks Wood
Weather data (Met.Office, 2012)

Night temperatures in England could therefore be a limiting factor to the establishment of *E. lignosellus*.

Unfortunately, no information on the cold tolerance of *E. lignosellus* was found, but some areas of the pest's distribution are within Plant Hardiness Zone 8 which is the zone attributed to the area at risk in the UK (England). Plant Hardiness Zones are determined by average annual extreme minimum temperatures (Fig. 6).

Figure 6. Plant Hardiness Zones (1 to 12) comparison map



Adapted from Magarey *et al.* (2008)
http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-90162008000700009&lng=en&tlng=en
Squares show, NW Arkansas, US and Tucumán Province where *E. lignosellus* has been recorded as a pest.

Temperature (under protection)

Though the higher temperatures within glasshouses would be favourable for this pest, the larval and pupal stages develop in soil. Glasshouse crops grown in alternative substrates such as rock wool would therefore not be at risk from this pest. Frequent irrigation of crops which creates moist soils, discourage female moths from laying eggs and also suppresses larval populations (Gill *et al.*, 2017). Glasshouse crops grown in soil/compost mixtures are likely to be well irrigated. It is therefore assumed that any incursions on such crops would be slow to establish and be easily eradicated by the destruction of the plants and soil mix they were grown in.

Most soft fruits are commercially grown under some sort of protection in the UK (Defra, 2011). *Rubus* (spp. including raspberries and blackberries), *Ribes* (spp. including blackcurrant) and *Vaccinium* (spp. including blueberries) are, however, not listed as hosts of *E. lignosellus*. Strawberry is listed as a host (Appendix I, Table 1). Where strawberries are grown in the ground, and Spanish tunnels (large temporary ploytunnels) are used, the tunnels extend the season for plant growth and would therefore favour the temperature-dependent development of *E. lignosellus*. The plastic is usually removed in the winter.

Therefore the pest would still need to overwinter successfully outdoors in order to establish (due to a lack of data, cold tolerance is assumed not to be a limiting factor to *E. lignosellus* establishment). Raised, plastic covered hills used for strawberry production and similar systems would also encourage faster development of the larvae and pupae by raising the temperature of the soil. As discussed in Section 7, records of attack on strawberries are limited to instances where grasses (preferred hosts) were allowed to grow over the strawberry crop or were cut just before the strawberries were planted, so the strawberry plants were the only available food source. As protected crops are high value, they are likely to be more intensively managed systems than outdoor crops. In strawberries, *E. lignosellus* causes dried young leaves in the crown. It is assumed that in well managed crops, attacked plants would be rogued out, and incursions noticed early. In less well managed systems or gardens and allotments, establishment in tunnels might be more likely. Fruit crop systems might be closed at each end or also employ other protective covers / netting to keep insects out which would prevent the moth spreading from system to system. Most asparagus is grown in open fields without irrigation, though Spanish tunnels with irrigation and mini tunnels are used by larger growers to extend the asparagus season (approximately 25%) (Chinn, C. pers. comms., 2020). Again, protection would favour the development of *E. lignosellus* on asparagus which is grown as a perennial crop (for approximately 13 years if conditions are favourable).

Other covers used in the UK for growing vegetables, for example fleece / mulching plastics, are only temporarily on the crop and may even act as a barrier to keep the moth out. Methods and timings differ depending on crop, location and farm, therefore it is difficult to generalise.

Rainfall/irrigation

Many sources state that *E. lignosellus* is a dry weather pest and that rainfall or irrigation significantly reduces larval survival or attack (Schaaf, 1972; Bessin, 2004; Salvatore *et al.*, 2007; Gill *et al.*, 2017). When comparing sugarcane plots under different management systems, Salvatore *et al.* (2007) found that those that were irrigated suffered almost no attacks by *E. lignosellus* (0.18% of shoots attacked), whilst those under a conventional system had 24.85% of shoots attacked. Soil moisture also affects the behaviour of larvae and ovipositing females (Carrola, 1984 cited in Mack *et al*., 1987). In saturated soil, larvae are more likely to abandon their subterranean habit, and females lay more eggs on the soil surface and plant foliage rather than in the soil. This can lead to increased mortality by predators in the US. In a handbook on cultivating asparagus in Peru, it suggests that when the water content of the soil is high, larvae construct a silk tunnel in the stem of the asparagus at 20 to 25 cm (Sanchez & Sanchez, 2010).

Whether the amount of rainfall the UK receives is too much for *E. lignosellus* populations to endure is not clear, but the pest does infest irrigated peanut fields (especially prior to canopy closure) in Georgia, so it is not the case that rainfall and irrigation necessarily prevent establishment, but rather that they do not favour the pests development. Though the larvae do not survive well in moist conditions, one or two rainfall events does not eliminate infestations (UGA, 2020b).

Summary of establishment

If *E. lignosellus* is able to establish in the UK, outdoor temperatures would likely limit its distribution to England with the potential to develop in parts of Wales during warmer years. The most limiting factor to the successful establishment of *E. lignosellus* appears to be night temperatures. The occasional 'cool' year might be enough to devastate populations in some areas, but urban heat islands could act as population refuges. The risk of establishment outdoors was therefore considered **unlikely** with **low confidence**. The confidence was low because of the uncertainty associated with the upper limits of this pest's distribution in the US and whether its biology is suited to a univoltine (one generation per year) lifecycle.

The risk of establishment on crops under temporary protection was considered similar to that for outdoor establishment. Though the temperatures in these systems improve the chances of establishment (especially if they allow two generations a year), other factors, such as the temporal nature and scattered distribution of these systems, as well as netting, might act as barriers to establishment and spread. So an **unlikely** rating is given. A confidence rating of **low** is given because of the changing nature of these systems and uncertainty associated with the upper limits of this pest's distribution in the US.

Establishment within glasshouses was considered **unlikely** with **medium confidence** due to the irrigation of substrates being largely unfavourable for this pest, and due to a lack of reports of damage in glasshouse systems. It was also considered that incursions on potted plants would be easy to eradicate, though potentially costly.

Outdoors	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		
Under protection - temporary structures	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely	Very likely
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		
Under protection - glass	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

12. How quickly could the pest spread in the UK/PRA area?

Natural spread: Adult *E. lignosellus* have been caught in Canada and many of the northern US states (Table 1). These are assumed to be migrant moths. There is very little information on the flight capability of *E. lignosellus*. *Elasmopalpus lignosellus* has a wingspan of 16-24 mm (Dixon, 1982a). Table 2 in Section 5 contains flight distances of similar moths. As suggested previously, this moth may also use winds to migrate. If *E. lignosellus* is able to establish in the UK, egg to adult development is expected to occur within a year (Fig. 4). It is therefore assumed that this pest could spread **very quickly**. This assumption is made with **medium** confidence due to a lack of flight distance data.

Spread with trade: This moth is not known to be a horticultural pest, though there have been a few reports of it causing much damage to nursery tree seedlings in the southern states (Craighead, 1950; Baker, 1972; Dixon, 1982b; a). As suggested in the previous section, association with traded plants that are usually grown in compost mixes and are generally well-watered is probably not likely. Infested produce with stems (e.g. asparagus) or any field crop hosts that are transported long distances for processing (cereals or biomass grasses) could move larvae. *Elasmopalpus lignosellus* was introduced to Hawaii (Chang & Ota, 1987 cited in Gill *et al.*, 2017) where it is a pest of sugarcane, but it is not known by which means it was introduced. It is possible that the moths caught in the more northerly states of the US are the result of movements with trade, but no evidence supporting this could be found. Spread with trade was therefore considered unlikely, but could occur very occasionally. Spread with trade was therefore given a rating of **moderate pace** with **low confidence**.

Natural Spread	Very slowly ☐	Slowly ☐	Moderate pace ☐	Quickly ☐	Very quickly ☑
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

With trade	Very slowly ☐	Slowly ☐	Moderate pace ☑	Quickly ☐	Very quickly ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		

13. What is the pest's economic, environmental and social impact within its existing distribution?

Economic: Elasmopalpus lignosellus is an important pest of economically important crops in its native range. Impacts vary significantly by region, host, soil type, weather and crop management practices including weed control, crop rotation and irrigation. In some areas in the US, *E. lignosellus* is an intermittent pest, only occurring during dry years. In the south-eastern coastal states (Gulf and Atlantic coast) where the soil is more sandy, *E.*

lignosellus appears to be more persistent (Bessin, 2004; Gill *et al.*, 2017). Though the preference for sandy/well-drained soils is often mentioned, severe damage to sweet corn on heavy organic soil does occur in Florida (Nuessly & Webb, 2017). In 2014, *E. lignosellus* was ranked by growers as the 4th most destructive pest of peanut in Georgia, USA (Hollis, 2014). A few years later, the peanut entomologist working with those growers described *E. lignosellus* as the *most* economically important pest of peanut in Georgia (UGA, 2020a). This pest has occasionally caused large-scale damage in forest nurseries in the southern states (Dixon, 1982a; b; Dixon & Mayfield, 2012).

In Peru, *Spodoptera frugiperda* (fall armyworm) and *E. lignosellus* are the main lepidopteran pests of green and white asparagus production (Flores Villanueva, 2016). In Argentina, *E. lignosellus* is one of the most important pests of sugarcane in the Tucumán region (Salvatore *et al.*, 2007). In a paper on pest control in sugarcane in Costa Rica, *E. lignosellus* is listed as a secondary pest (Fernandez, 2000).

Environmental: Field weeds are described as favoured hosts which act as reservoirs for crops (Stahl, 1930; Isely & Miner, 1944), but no records of impacts on particular wild hosts or habitats were found. Alongside cultural control and *Bt* crop varieties, granular or liquid pesticides are recommended to control this pest (Gill *et al.*, 2017). These may have an impact on other arthropods.

Social: A few references to the 'lesser cornstalk borer' (*E. lignosellus*) as a pest of garden plants were found, but it was not clear if these were written from experience or just reviews of potential garden pests (Parrish, 2017; Allman). No records on other social impacts were found.

Because of the number of crops affected, and the area across which this pest has an impact, the impact was assessed as **large**, with **high** confidence.

Impacts	Very small	☐	Small	☐	Medium	☐	Large	✓	Very large	☐
Confidence	High Confidence	✓	Medium Confidence	☐	Low Confidence	☐				

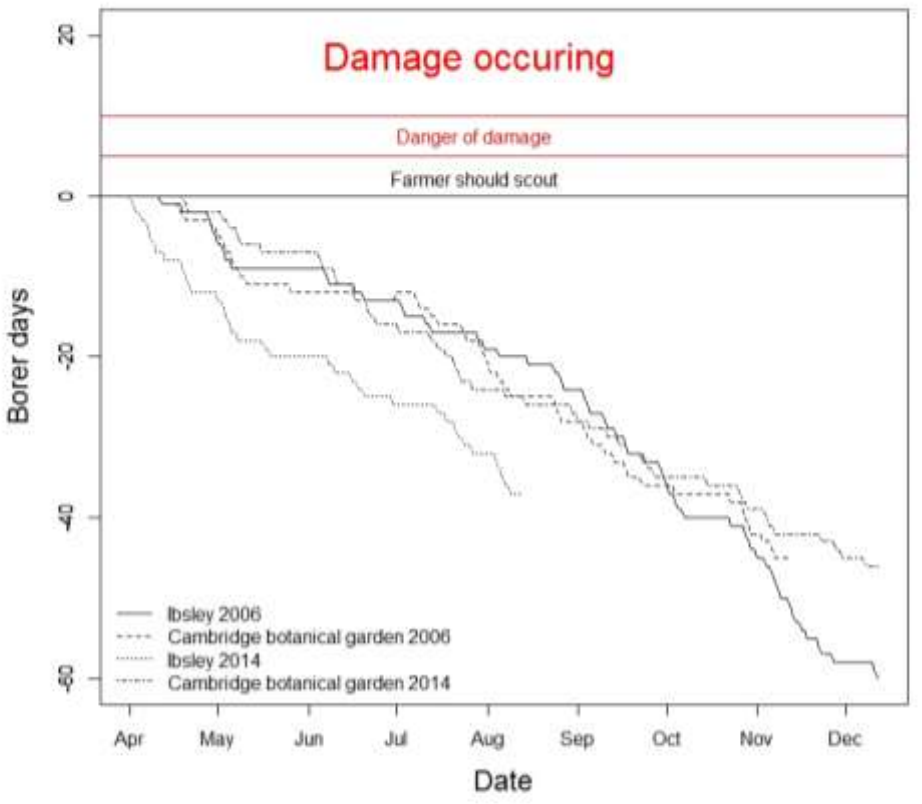
14. What is the pest's potential to cause economic, environmental and social impacts in the UK/PRA area?

Economic: In order to reach economically damaging levels, *E. lignosellus* requires hot, dry weather, and preferably well drained/sandy soils. Wet conditions in the growing season or irrigation leads to sharp increases in larval mortality (Bessin, 2004). Mack *et al.* (1993) developed a formula that calculates the number of 'borer days' (the cumulative effect of weather on larval abundance) since planting a peanut crop.

$$Borer\ days = \sum (H - W)$$

Where *H* is the number of days where the maximum temperature is ≥ 35°C and rainfall is < 2.5 mm (hot, dry days), and *W* is the number of days where the maximum temperature is < 35°C and rainfall is ≥ 2.5 mm ('normal', but wet days). If the number of 'borer days' reaches > 10, the number of larvae within a peanut crop is likely to be at a damaging level. Though this formula was intended for peanut crops, it can give a rough idea of whether this pest would cause damage to crops in the UK. Using recorded weather data from Cambridge and Hampshire during two warm years (2006 and 2014), it is clear that should this pest establish in the UK, it would not reach economically damaging levels (Fig. 7).

Figure 7. Calculated 'borer days' for two locations in England during two warm years (2006 and 2014)



Assuming crop sewn on 20th April (typical sew date for maize)
'Borer days' (Mack *et al.*, 1993)
Weather data (Met.Office, 2012)

If this pest was able to establish, the relatively low summer temperatures and high rainfall experienced by the UK would keep individual numbers very low. Therefore an impact rating of **very small** with **medium confidence** is given for economic impact. A medium confidence rating was given as there is some uncertainty over the damage it might cause under protection were it to establish. The presence of the pest could also have an impact on exports to countries where *E. lignosellus* is not established, but commenting on such impacts is beyond the scope of this PRA. An impact rating of **very small** with **medium confidence** is given for environmental impacts due to potential unknown effects on rarer plants in the wider environment. No social impacts are expected, so this impact was rated **very small** with **high confidence**.

Economic Impacts	Very small ☑	Small ☐	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		
Environ - mental Impacts	Very small ☑	Small ☐	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		
Social Impacts	Very small ☑	Small ☐	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

15. What is the pest's potential as a vector of plant pathogens?

This pest is not known to vector any plant pathogens.

Like many pests that cause mechanical wounds to plants, attacks by this pest do leave plants more susceptible to secondary bacterial and fungal infections, including aflatoxins (Bowen & Mack, 1993).

16. What is the area endangered by the pest?

If *E. lignosellus* is able to establish outdoors, its distribution is expected to be limited to England and possibly parts of Wales, with distribution area fluctuating year by year (Fig. 4). As no economically important losses are expected, there is no outdoor endangered area for this pest.

This pest is considered unlikely to establish on hosts grown under protection. However, incursions could cause short-term losses for growers. Those hosts more at risk would be those grown in sandy mediums that are not regularly watered.

Stage 3: Pest Risk Management

17. What are the risk management options for the UK/PRA area?

Exclusion: As yet, the UK has only intercepted this pest on asparagus from Peru. Solis (2006) lists a few more hosts that the pest has been intercepted on by the US. This extended list is likely to be a result of the much larger volumes of plants and plant products the US imports from Central and South America (https://resourcetrade.earth/data). Given that this pest is not established outside of the Americas, the prospect for continued exclusion from the UK is good. Information on the cold tolerance of this pest might help inform methods for reducing the risk of spreading this pest on produce.

Eradication (under protection): The larval stage of this pest is cryptic; it usually feeds below ground and within the stem of plants, which could make it difficult to detect initially. However, it is unlikely to be a 'persistent' pest under protection. Though there are overlapping generations in the field, in a glasshouse, a young population is more likely to be in sync. Larvae are relatively large, and if all affected plants are destroyed and soil sifted, a population in the larval stage could be easily eradicated. If adults and eggs are present, eradication might require treatment with an insecticide or bioinsecticide if the crop cannot be sacrificed.

Eradication or containment (outdoors): Because of this pest's wide host range (which includes grasses and legumes) and likely ability to fly long distances, once established outdoors, it could be very difficult to eradicate or contain. Numbers would likely be low enough to avoid detection, allowing spread to new areas. Preliminary mapping (Fig. 4) suggests that if it were to establish, populations could be quite temporary in places, and small populations could die out completely following successive cold, wet years. Where this moth is a pest, pheromone traps have been successfully used to monitor populations. Whether traps could be used to monitor/detect populations with low numbers is less clear.

Irrigation, modifying planting date, mulching, weed control, granular and liquid pesticides, as well transgenic *Bt* (*Bacillus thuringiensis*) crops all contribute to controlling field populations (Gill *et al.*, 2017; UGA, 2020b).

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19. Appendix

I Hosts

Table 1: Hosts and potential hosts* of *Elasmopalpus lignosellus*

*Some records may have been observations of larval feeding (not confirmation that the pest can complete its lifecycle on the listed plant)

**Source is not necessarily the original reference

Highlighted in green are major hosts

Highlighted in grey are interceptions by the USA

Family	Genus/Species	Common name	Country/area	Source**
Amaranthaceae	*Beta vulgaris*	beet		(Gill *et al.*, 2017)
Annonaceae	*Annona muricata*		Puerto Rico	(Robinson *et al.*, 2010)
Araucariaceae	*Araucaria angustifolia*		Brazil	(Robinson *et al.*, 2010)
Asparagaceae	*Asparagus officinalis*	asparagus	Peru	(Flores Villanueva, 2016)
Asparagaceae	*Asparagus officinalis*	asparagus	USA [int.]	(Solis, 2006)
Asparagaceae	*Gladiolus*	gladiolus		(Sandhu, 2010)
Brassicaceae	*Brassica napus*	oilseed rape		(Sandhu, 2010)
Brassicaceae	*Brassica oleracea var. capitata*	cabbage		(Gill *et al.*, 2017)
Brassicaceae	*Brassica rapa*		New World	(Robinson *et al.*, 2010)
Brassicaceae	*Brassica rapa subsp. rapa*	turnip		(CABI, 2019)
Brassicaceae	*Matthiola*	stock		(Sandhu, 2010)
Brassicaceae	*Raphanus sativus*	radish		(Sandhu, 2010)
Bromeliaceae	*Ananas comosus*	pineapple	USA [int.]	(Solis, 2006)
Chenopodiaceae			USA	(Robinson *et al.*, 2010)
Convolvulaceae	*Convolvulus arvensis*		New World	(Robinson *et al.*, 2010)
Convolvulaceae	*Ipomoea batatas*	sweet potato		(Gill *et al.*, 2017)
Convolvulaceae			USA	(Robinson *et al.*, 2010)
Cornaceae	*Cornus florida*	flowering dogwood		(Dixon, 1982a; CABI, 2019)
Corylaceae	*Corylus avellana*	hazel	USA [int.]	(Solis, 2006)
Cucurbitaceae			USA	(Robinson *et al.*, 2010)
Cucurbitaceae	*Cucumis melo*	muskmelon		(Gill *et al.*, 2017)
Cupressaceae	*Cupressus*		Pantropical	(Robinson *et al.*, 2010)
Cupressaceae	*Cupressus arizonica*	Arizona cypress		(Dixon, 1982b)
Cupressaceae	*Juniperus virginiana*	red cedar		(Dixon, 1982a)
Cyperaceae	*Cyperus esculentus*		New World	(Robinson *et al.*, 2010)
Cyperaceae	*Cyperus esculentus*	yellow nutsedge		(CABI, 2019)
Cyperaceae	*Cyperus rotundus*	java grass		(Sandhu, 2010)
Cyperaceae			USA	(Robinson *et al.*, 2010)
Fabaceae	*Arachis hypogaea*	groundnut / peanut	New World	(Dixon, 1982b; Robinson *et al.*, 2010)
Fabaceae	*Cajanus cajan*	pigeon pea		(CABI, 2019)
Fabaceae	*Dolichos*		Brazil	(Robinson *et al.*, 2010)

Fabaceae	*Glycine max*	soyabean	Pantropical	(Dixon, 1982b; Robinson *et al.*, 2010)
Fabaceae	*Lupinus*		USA	(Robinson *et al.*, 2010)
Fabaceae	*Medicago sativa*	alfalfa	USA	(Robinson *et al.*, 2010)
Fabaceae	*Mimosa pigra*		USA [int.]	(Solis, 2006)
Fabaceae	*Phaseolus*	beans	New World	(USDA, 1933; Isely & Miner, 1944)
Fabaceae	*Phaseolus*	beans	Mexico, USA [int]	(USDA, 1944)
Fabaceae	*Phaseolus vulgaris*	common bean	Pantropical	(Robinson *et al.*, 2010)
Fabaceae	*Pisum sativum*	pea	Puerto Rico	(Robinson *et al.*, 2010)
Fabaceae	*Pisum sativum*	pea	USA	(USDA, 1933; Robinson *et al.*, 2010)
Fabaceae	*Robinia pseudoacacia*	black locust	New World	(Craighead, 1950; Baker, 1972)
Fabaceae	*Trifolium incarnatum*	crimson clover		(Sandhu, 2010)
Fabaceae	*Vicia faba*	broadbean	Brazil	(Robinson *et al.*, 2010)
Fabaceae	*Vigna luteola*	cowpea		(Sandhu, 2010)
Fabaceae	*Vigna mungo*	cowpea	USA	(USDA, 1933; Robinson *et al.*, 2010)
Fabaceae	*Vigna unguiculata*	cowpea	New World	(Robinson *et al.*, 2010)
Iridaceae			USA	(Robinson *et al.*, 2010)
Labiatae	*Mentha*	mint	USA [int.]	(Solis, 2006)
Linaceae	*Linum usitatissimum*	flax	New World	(Robinson *et al.*, 2010)
Malvaceae	*Gossypium*		New World	(Robinson *et al.*, 2010)
Malvaceae	*Gossypium hirsutum*	cotton		(CABI, 2019)
Malvaceae	*Gossypium herbaceum*		Brazil	(Robinson *et al.*, 2010)
Malvaceae	*Gossypium thurberi*		USA	(Robinson *et al.*, 2010)
Malvaceae	*Sida*		USA [int.]	(Solis, 2006)
Marantaceae	*Maranta*		USA [int.]	(Solis, 2006)
Nyssaceae	*Nyssa sylvatica*	tupelo		(Dixon, 1982a)
Pinaceae	*Pinus*	pines		(CABI, 2019)
Pinaceae	*Pinus clausa*	sand pine		(Dixon, 1982a)
Pinaceae	*Pinus elliottii*	slash pine		(Dixon, 1982a)
Pinaceae	*Pinus taeda*	loblolly pine		(Dixon, 1982a)
Platanaceae	*Platanus occidentalis*	American planetree		(Dixon, 1982a; CABI, 2019)
Poaceae	*Alopecurus pratensis*	meadow foxtail		(Sandhu, 2010)
Poaceae	*Aristida stricta*	wiregrass		(Gill *et al.*, 2017)
Poaceae	*Avena fatua*	common wild oat		(Gill *et al.*, 2017)
Poaceae	*Avena sativa*	oat		(Gill *et al.*, 2017)
Poaceae	*Bambusa*		New World	(Robinson *et al.*, 2010)
Poaceae	*Chloris gayana*	rhodes grass		(Sandhu, 2010)
Poaceae	*Cynodon dactylon*	Bermuda grass		(Gill *et al.*, 2017)
Poaceae	*Digitaria*	crabgrass	New World	(Dixon, 1982b; Robinson *et al.*, 2010)

Poaceae	*Digitaria eriantha*	digitgrass		(Sandhu, 2010)
Poaceae	*Digitaria sanguinalis*	large crabgrass		(CABI, 2019)
Poaceae	*Echinochloa crus-galli*		Pantropical	(Robinson *et al.*, 2010)
Poaceae	*Echinochloa crus-galli*	barnyard grass		(CABI, 2019)
Poaceae	*Eleusine*		New World	(Robinson *et al.*, 2010)
Poaceae	*Eleusine indica*	indian goosegrass		(Gill *et al.*, 2017)
Poaceae	*Hordeum vulgare*	barley		(Sandhu, 2010)
Poaceae	*Luziola fluitans*	watergrass		(Gill *et al.*, 2017)
Poaceae	*Oryza sativa*		Pantropical	(Robinson *et al.*, 2010)
Poaceae	*Oryza sativa*	rice		(CABI, 2019)
Poaceae	*Panicum*		New World	(Robinson *et al.*, 2010)
Poaceae	*Paspalum*		USA	(Robinson *et al.*, 2010)
Poaceae	*Saccharum*		New World	(Robinson *et al.*, 2010)
Poaceae	*Saccharum officinarum*	sugarcane	New World	(Sandu, 2010; Robinson *et al.*, 2010)
Poaceae	*Secale cereale*	rye		(Gill *et al.*, 2017)
Poaceae	*Sorghum*		New World	(Robinson *et al.*, 2010)
Poaceae	*Sorghum*	sorghum	USA [int.]	(Solis, 2006)
Poaceae	*Sorghum bicolor*	sorghum	Brazil	(Robinson *et al.*, 2010)
Poaceae	*Sorghum halepense*	Johnson grass	New World	(Robinson *et al.*, 2010)
Poaceae	*Sorghum subglabrescens*	sorghum		(Sandhu, 2010)
Poaceae	*Sorghum sudanense*	Sudan grass		(CABI, 2019)
Poaceae	*Sorghum x drummondii*		USA	(Robinson *et al.*, 2010)
Poaceae	*Triticum*	wheat	Pantropical	(Robinson *et al.*, 2010)
Poaceae	*Triticum aestivum*	wheat	New World	(Robinson *et al.*, 2010)
Poaceae	*Zea*		Nearctic	(Robinson *et al.*, 2010)
Poaceae	*Zea mays*	maize	New World	(Dixon, 1982b; Robinson *et al.*, 2010)
Poaceae	*Zea mays*	maize	USA [int.]	(Solis, 2006)
Poaceae	*Zea mexicana*		Puerto Rico	(Robinson *et al.*, 2010)
Polygonaceae	*Fagopyrum esculentum*	buckwheat		(Sandhu, 2010)
Rosaceae	*Fragaria*		Nearctic	(Robinson *et al.*, 2010)
Rosaceae	*Fragaria vesca*		Brazil	(Robinson *et al.*, 2010)
Rosaceae	*Fragaria virginiana*	wild strawberry		(Sandhu, 2010)
Rosaceae	*Fragaria X ananassa*	strawberry	USA	(Stahl, 1930; USDA, 1933)
Rubiaceae	*Coffea arabica*	coffee	USA [int.]	(Solis, 2006)
Rutaceae			USA	(Robinson *et al.*, 2010)
Solanaceae	*Capsicum annuum*	chilli pepper		(Gill *et al.*, 2017)
Solanaceae	*Capsicum frutescens*	sweet pepper		(Sandhu, 2010)
Solanaceae	*Solanum lycopersicum*	tomato		(Gill *et al.*, 2017)
Solanaceae	*Solanum tuberosum*	potato	USA	(USDA, 1933)
Taxodiaceae	*Taxodium distichum*	bald cypress		(Dixon, 1982a; CABI, 2019)

II Developmental parameters

Three sets of temperature-dependent developmental parameters were found in the literature for *E. lignosellus* (copy of Table 5).

Copy of Table 5: Estimated temperature parameters for oviposition to adult development of *Elasmopalpus lignosellus*

LDT (°C)	Degree-Days	Details and source
13.0	530.0	parameters for 'one generation' (unpublished in Berberet *et al*. 1982)
14.5	439.6	egg to pupal stages, estimated by linear regression, reared on an artificial diet in the laboratory (Mack *et al*. 1987)
9.5	543.5	'total development', estimated by linear regression, reared on sugarcane in the laboratory (Sandhu *et al*. 2010)

LDT = Lower Developmental Threshold Temperature

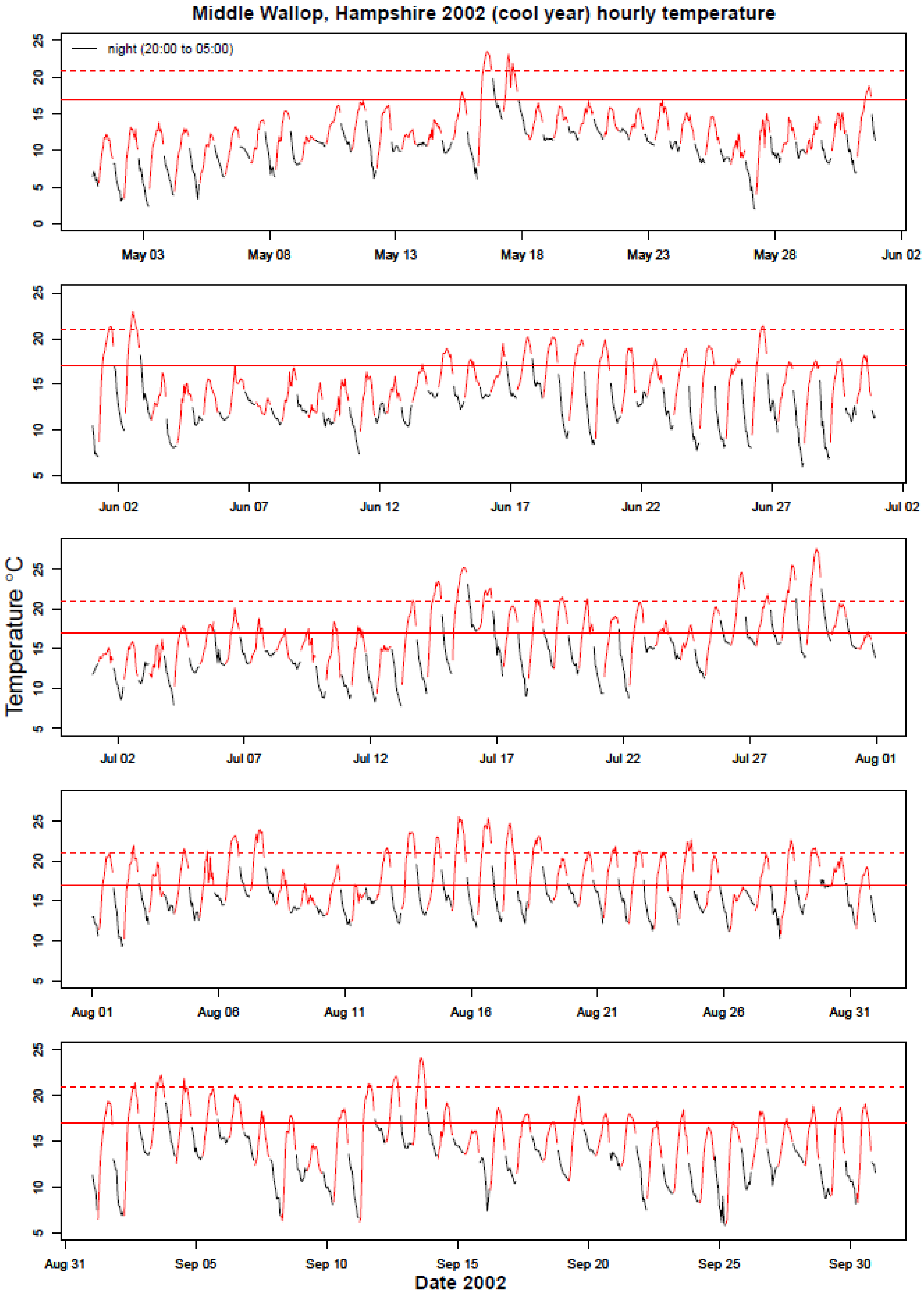
The parameters cited in Berberet *et al.* (1982) were not used in this assessment as there was not enough information made available on how they were obtained. Those estimated by Mack *et al.* (1987) and Sandhu *et al.* (2010) are quite different; even the estimates for the pupal stage which should, in theory, be independent of diet are very different. To decide which set of parameters to favour for mapping *E. lignosellus* generation times in the UK, daily temperature records for Seminole, Gaines County, Texas were downloaded for 2019 and the two sets of parameters compared. Using daily mean temperature (min+max/2), an initial oviposition date of the 15th March, and the parameters estimated by Mack *et al.* (1987), *E. lignosellus* would have developed through three complete generations and a partial generation (therefore a potential four generations from Spring to Spring). Using Sandhu *et al.* (2010) parameters, *E. lignosellus* would have developed through a potential five generations Spring to Spring. Using initial oviposition dates of the 15th April and the 15th May gave the same results, though the fifth generation produced by the Sandhu *et al.* (2010) parameters and May oviposition date began in mid-November which is possibly unlikely to occur in the field. As up to four generations per year are reported for the southern states, Mack *et al.* (1987) parameters were assumed to be the more reliable for this analysis.

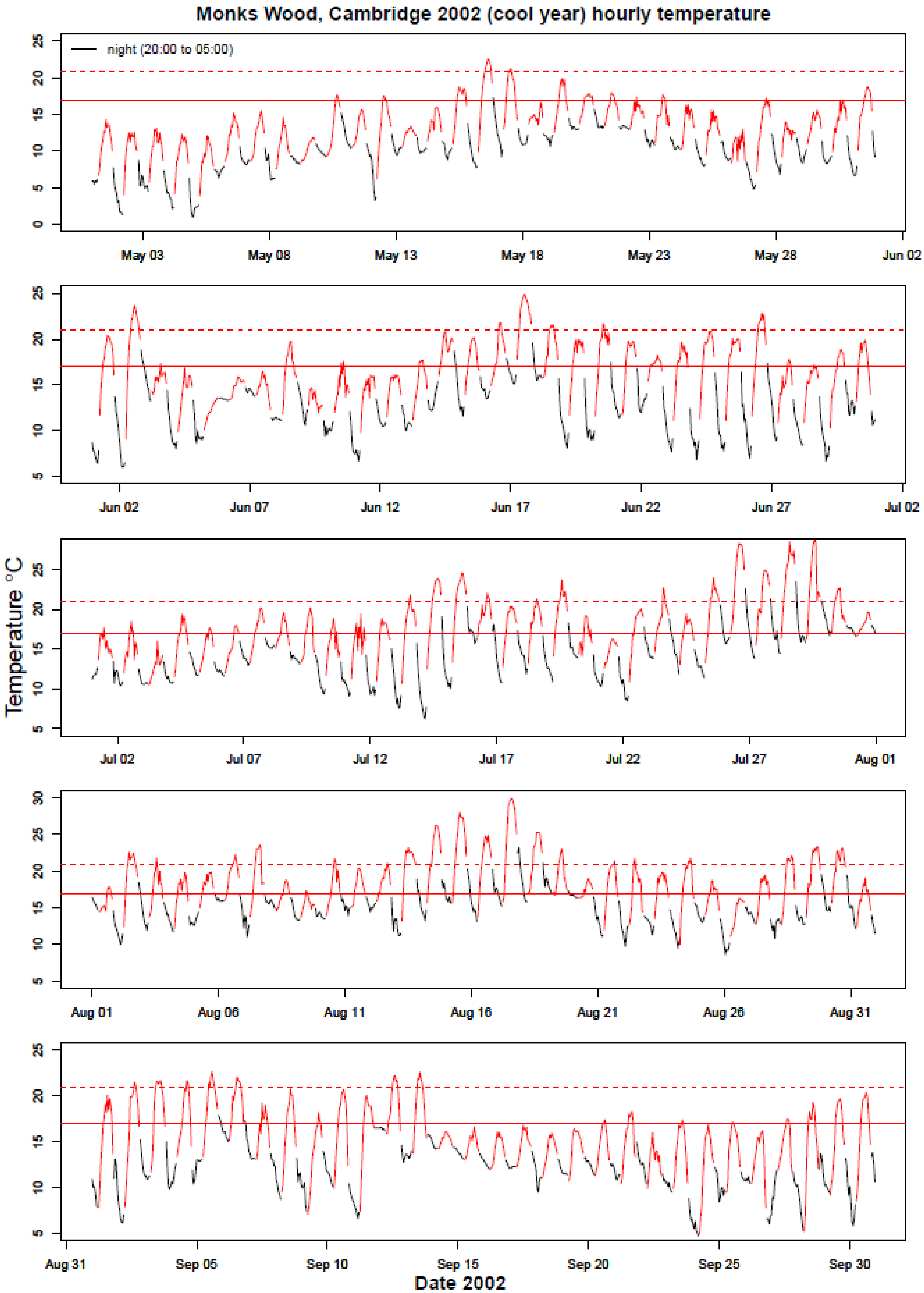
III Number of ‘warm’ nights in England

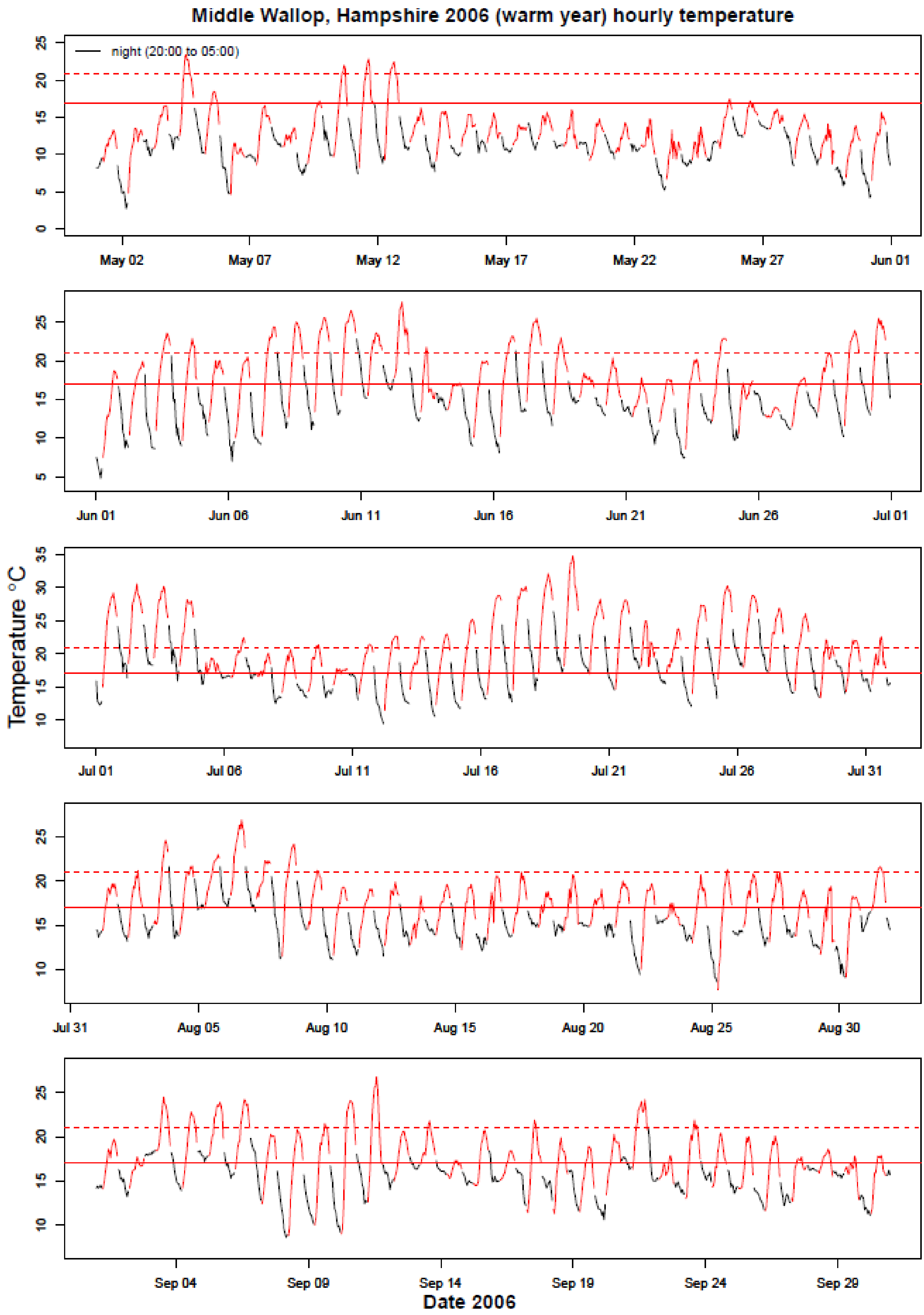
Red dotted line = minimum temperature for mating (°C)

Red line = minimum temperature for ovipositing (°C)

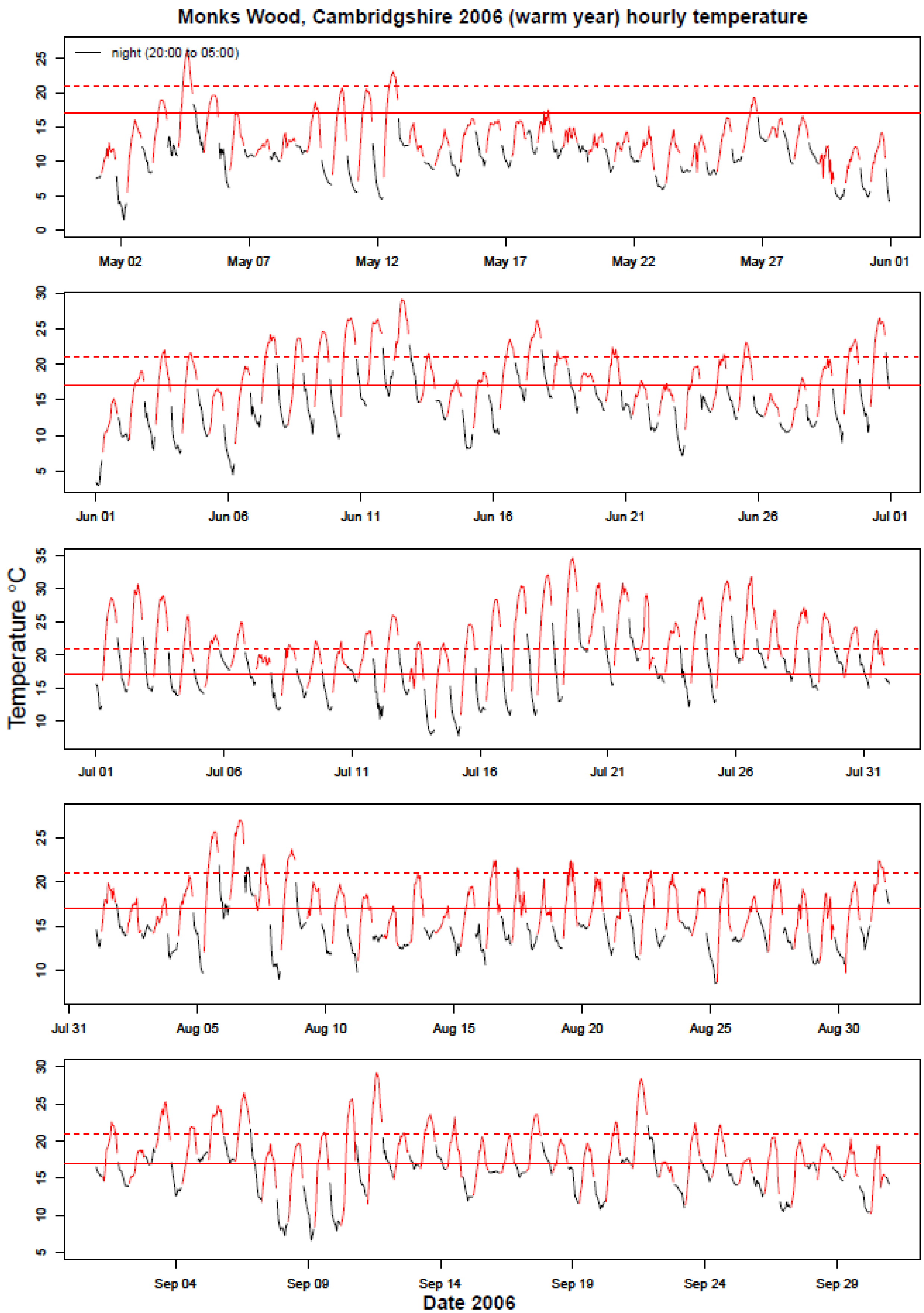
Hourly temperatures, red = day, black = night. There is a gap where data points are not joined (this is not missing data).




Monks Wood, Cambridge 2002 (cool year) hourly temperature
night (20:00 to 05:00)
Temperature °C
May 03
May 08
May 13
May 18
May 23
May 28
Jun 02
Jun 07
Jun 12
Jun 17
Jun 22
Jun 27
Jul 02
Jul 07
Jul 12
Jul 17
Jul 22
Jul 27
Aug 01
Aug 06
Aug 11
Aug 16
Aug 21
Aug 26
Aug 31
Sep 05
Sep 10
Sep 15
Sep 20
Sep 25
Sep 30
Date 2002



Middle Wallop, Hampshire 2006 (warm year) hourly temperature
night (20:00 to 05:00)
May 02
May 07
May 12
May 17
May 22
May 27
Jun 01
Jun 06
Jun 11
Jun 16
Jun 21
Jun 26
Jul 01
Jul 06
Jul 11
Jul 16
Jul 21
Jul 26
Jul 31
Aug 05
Aug 10
Aug 15
Aug 20
Aug 25
Aug 30
Sep 04
Sep 09
Sep 14
Sep 19
Sep 24
Sep 29
Temperature °C
Date 2006



Monks Wood, Cambridgeshire 2006 (warm year) hourly temperature
night (20:00 to 05:00)
Temperature °C
May 02
May 07
May 12
May 17
May 22
May 27
Jun 01
Jun 06
Jun 11
Jun 16
Jun 21
Jun 26
Jul 01
Jul 06
Jul 11
Jul 16
Jul 21
Jul 26
Jul 31
Aug 05
Aug 10
Aug 15
Aug 20
Aug 25
Aug 30
Sep 04
Sep 09
Sep 14
Sep 19
Sep 24
Sep 29
Date 2006

Name of Pest Risk Analysts(s)

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