Gumleaf Skeletonizer (GLS) monitoring using pheromone baited moth traps 2011-2014

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Occasional Report

June 2014

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Parks and Wildlife

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The recommended reference for this publication is:
Janet D. Farr and Allan J. Wills, 2014, *Gumleaf Skeletonizer (GLS) monitoring using pheromone baited moth traps 2011-2014*, Department of Parks and Wildlife, Perth.

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Acknowledgments

We thank Trish Dumitro, Shannon Grigg, Kerry Ironside, Ian Jones, Melanie Schindler, Asako Takahashi, and Paul Van Heurck for assistance in moth trapping and larval collection. We Thank Dr Ian Abbott for critical review of an earlier draft of the report.

Summary

Gumleaf skeletonizer (GLS) can be an extensive and severe defoliator of jarrah and marri in the jarrah forest of southwest WA.

A GLS outbreak affecting jarrah forest in the South West and Warren management regions of Department of Parks and Wildlife was first detected in 2009/2010 and has been monitored between 2010 and 2014 using larval sampling and moth trapping.

As expected, high larval density results in capture of large numbers of moths. Moth trapping is the more cost effective method of gathering data and is the current method for long term GLS population monitoring.

Moth trapping indicates the period 2011-2014 to be a period of GLS population decline from a peak in 2010/2011.

Moth counts provided a statistically significant prediction for larval population densities the following spring.

There is strong evidence that density dependent mortality was operating during the period of outbreak recession. Larger populations showed greater mortality and tended to decrease while smaller populations tended to show population increase. The compensation point at low population densities tallies with the observed long period of low population densities.

The extensive 2009-1012 outbreak of GLS in Southwest and Warren Regions, continuing in small isolated patches until 2014 in Warren Region, follows the pattern of an earlier outbreak in the 1980s in the same locations. The outbreaks were relatively short-lived (several years) with a long interval between the outbreaks (22 years between peak population levels).

Capturing informative GLS population monitoring data requires a continued modest effort of moth trapping for an extended period of time.

1 Introduction

Gumleaf skeletonizer (GLS) can be an extensive and severe defoliator of jarrah and marri in the forests of southwest Western Australia (Farr 2002, Farr and Wills 2012). Outbreaks of GLS typically last for only a few years. Extensive and severe defoliation (Fig. 1) is likely to have effects on fauna which depend on the forest canopy for food and habitat.

Visible damage from GLS was reported around Donnelly Mill in the summer of 2009/2010. A roadside survey of visual estimates of damage at 45 long term GLS monitoring sites (Abbott 1992) was initiated in February 2010. These sites provided a regional framework for immediate gauging of the extent and severity of an outbreak of GLS. Data on larval populations from a previous outbreak in the 1980s were available for these sites (Strelein 1988, Farr 2002; Farr et al. 2004) and reappraisal and further monitoring of the sites was likely to be enhanced by earlier monitoring data. Two centres of outbreak were apparent: one focused on Yanmah and Wheatley blocks; and the other on Kinkin, Quillben and Dingup blocks (Farr and Wills 2010). In 2010/2011 the outbreak became more extensive and severe (Farr and Wills 2012)

Monitoring of GLS populations using pheromone trapping and/or larval sampling has continued since detection of the first signs of outbreak in the summer of 2009/2010. Of the two methods of population sampling, moth trapping is the more cost effective and has been adopted for long term monitoring of GLS populations in the Warren management region of the Department of Parks and Wildlife (Farr and Wills 2012). We report here the results of that monitoring for the period 2011 to 2014.

Figure 1 Severe defoliation of jarrah forest by GLS along Tamm Road, Kinkin forest block, January 2011

2 Methods

2.1 Pheromone trapping

GLS has been detected as an introduced pest in New Zealand, providing an imperative to monitor progress of invasion there (Suckling et al. 2005, Kriticos et al. 2007). This led to the development of a commercially available pheromone lure attracting male moths (Fig. 2) for use in a standard Delta trap system. Paired pheromone trapping and larval sampling was conducted to test the congruence of each method as estimators of GLS populations. The method of Farr and Wills (2012) using delta traps baited with a male GLS sex attractant pheromone was used to capture male moths between late January and early April of each trapping year. Nineteen sites were trapped in 2011; 35 sites were trapped in 2012; and 40 sites were trapped without paired larval sampling in 2013 and 2014 (Appendix 1).

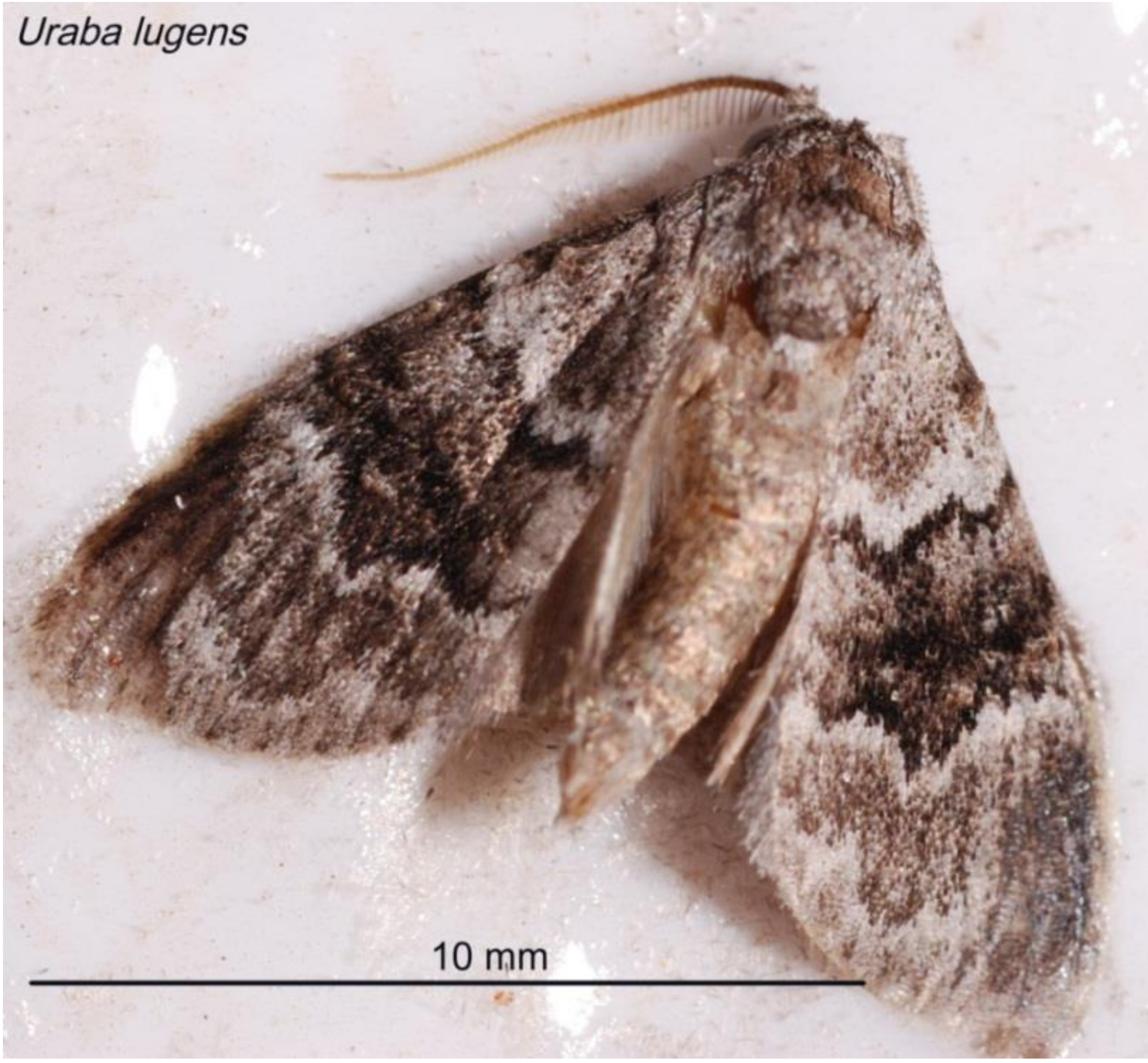

Figure 2 Male Gumleaf Skeletonizer moth

2.2 Larval sampling

In November 2010 and November 2011, branch clipping samples collected using a truck-mounted cherrypicker were taken from a selection of the 45 long-term locations as well as an additional 17 sites to quantify GLS larval populations on single trees across an extensive area of the Warren region (Appendix 1). Larval samples were collected from jarrah crowns at heights up to 14 metres. Pairs of branches from single trees at each sample site were clipped, bagged and stored in a refrigerated trailer for later processing. All larvae (Fig.3) were removed and counted. All leaves including petioles were removed and oven dried to a stable dry weight. Population densities were calculated as number of larvae per kilogram of dry leaf weight on the branches and the two samples from each tree averaged (Farr 2002).

Figure 3 Gumleaf Skeletonizer larva showing characteristic retained head capsules and feeding damage removing mesophyll leaf tissue down to vascular structure

3 Results

3.1 Male moth flight period

Two male moths were captured on the most north eastern site at the north end of Northern Road in early December 2011 followed by a period of no captures on any sites until early February 2012, with a peak in moth captures in early March (Fig. 4). This indicates minor bivoltinism (two generations per year) with a mostly univoltine (one generation) life cycle. Earlier modelling work by Farr (2002) indicated bivoltinism under suitable temperature conditions. Moth trapping between the last week of January and the first week of April covered the main period of male GLS activity. Trapping in 2013 and 2014 was completed between the last week in January and the first working days after April 25th.

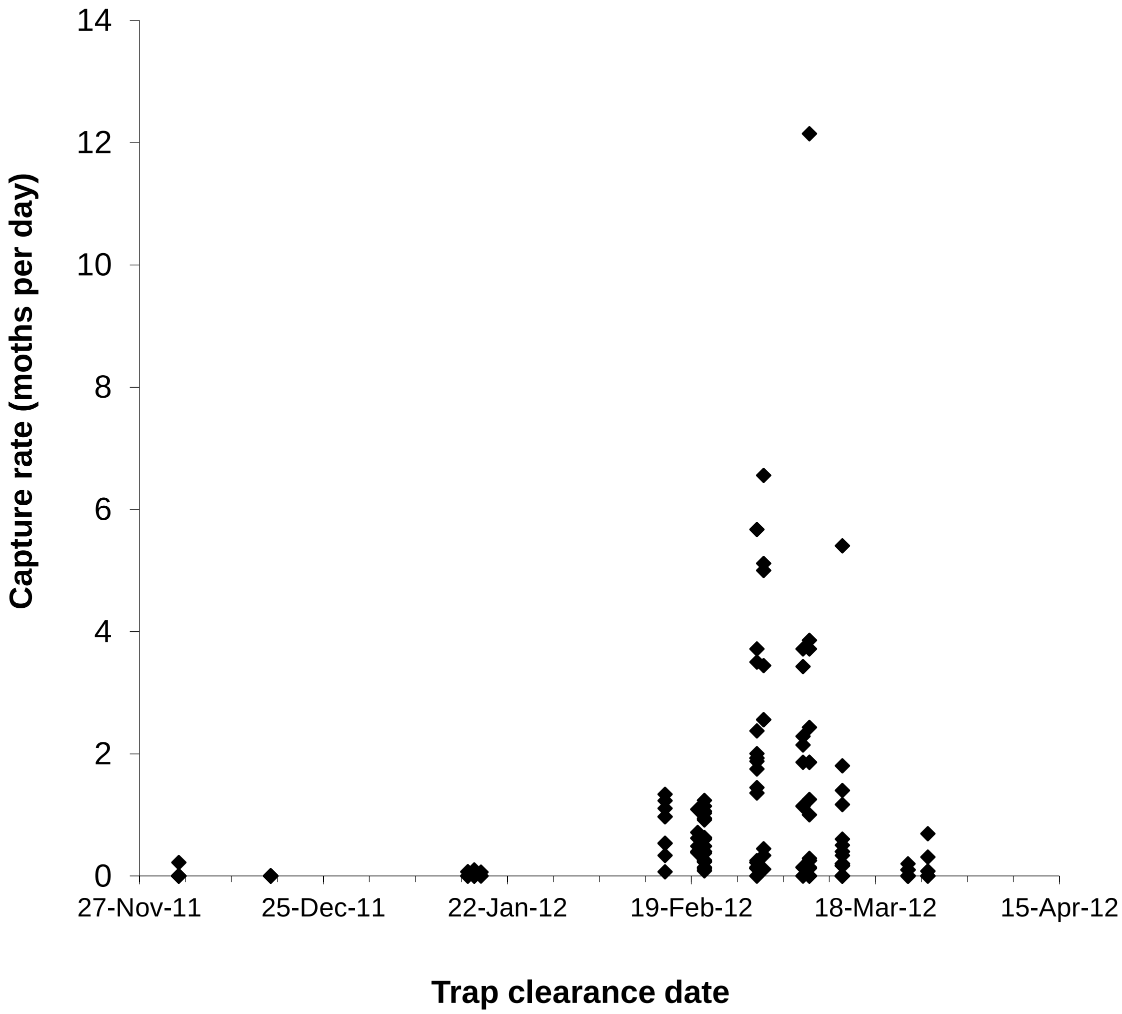

Figure 4 Trap catch rates for summer of 2011/2012 indicate a main male moth flight period between first week of February and first week of April.

3.2 Moths trapped and preceding larval density

Summer moth trap catches were positively correlated with the larval density of the preceding November (Fig. 5). Combined data for 2011 and 2012 yielded a model for predicted number of moths such that Moths = 28.8($\log_{10}$(larvae kg-1 foliage+1))+8.7, where r^2= 0.75, and p<0.0000003.

Applying the model to a wider set of data indicated that pheromone trap failure was relatively common with four sites showing fewer than expected trap catches given high larval population densities at the sites (Fig. 6). One site showed an unusually abundant trap catch. The reasons for poor performance of traps at some sites remains unclear but may be related to density and height of understorey vegetation, the slope of the site, or a combination of these factors.

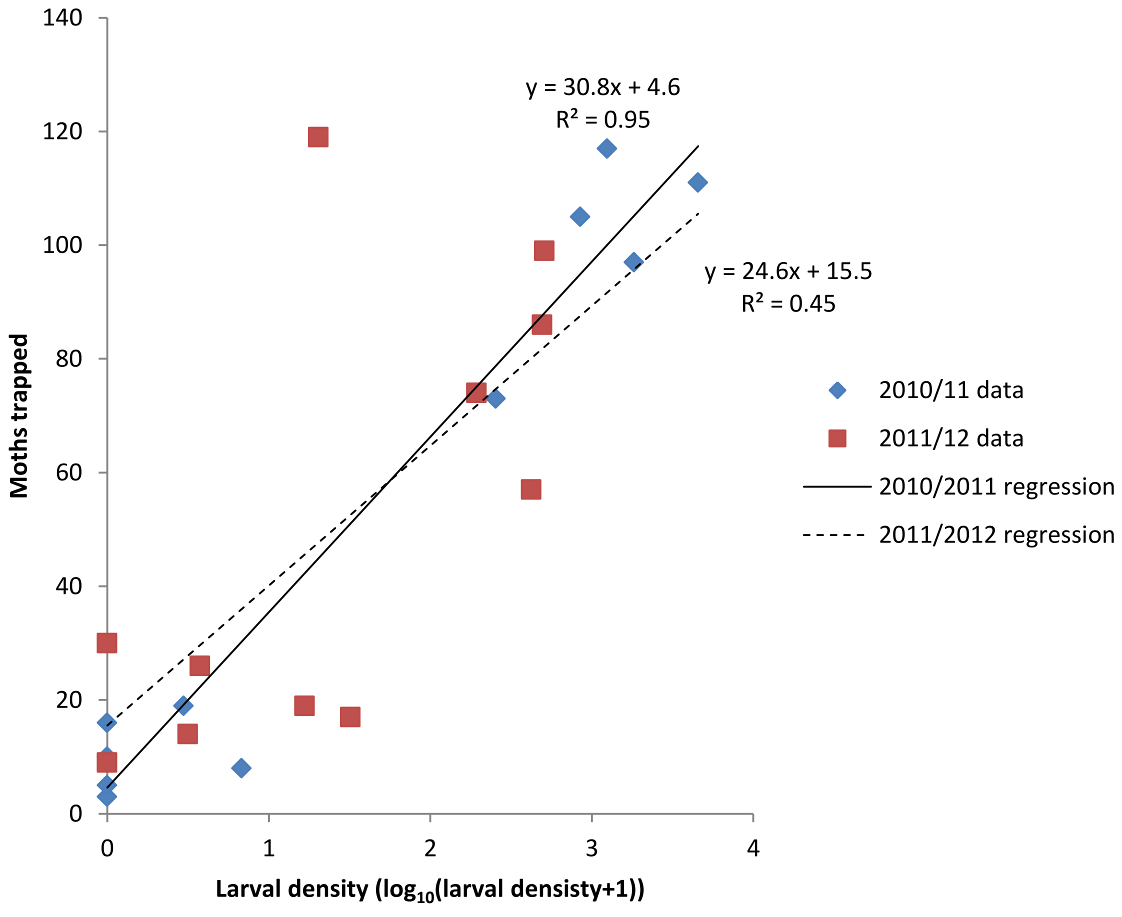

Figure 5 Relationship between number of moths trapped and antecedent larval density for sites trapped in both 2011 and 2012 (excludes sites UL 02 and UL 04).

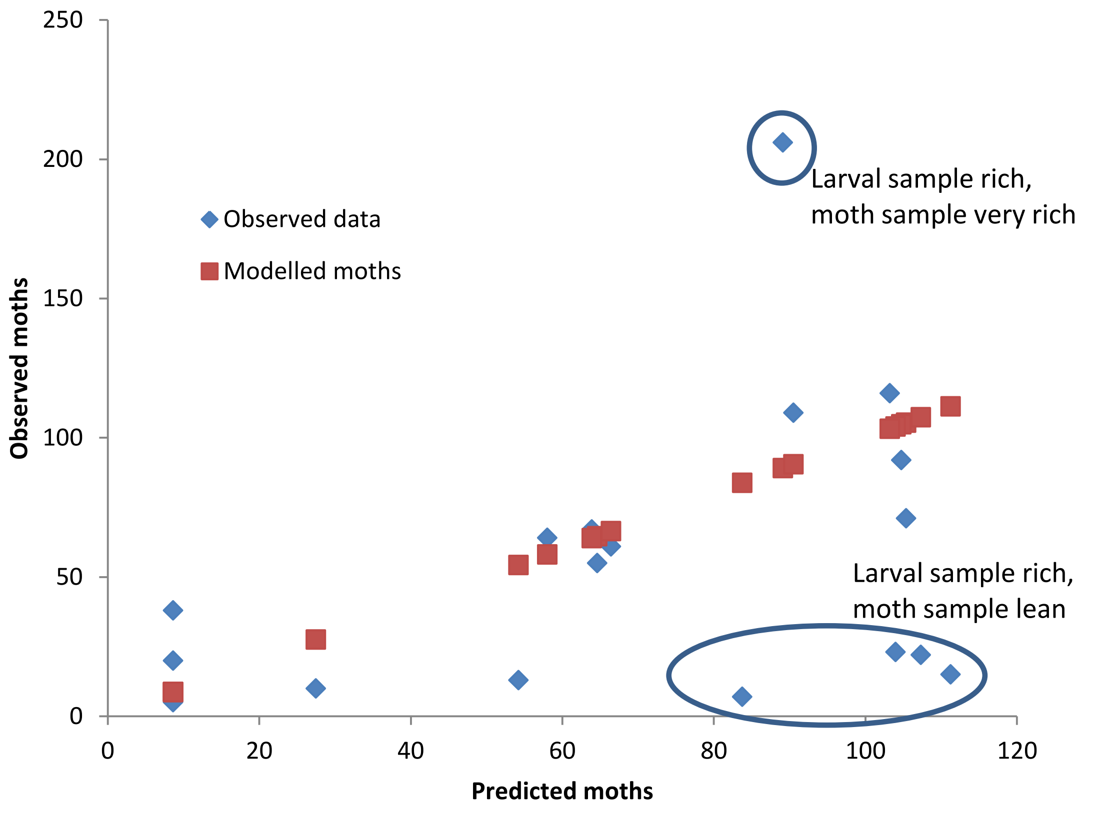

Figure 6 Observed versus predicted moths on all other sites trapped in 2012 not represented in Fig. 2. Model for predicted moths is Moths = 28.8(log$_{10}$(larvae kg^{-1} foliage+1))+8.7, based on combined data in Fig. 5, where r^2= 0.75, p<0.0000003.

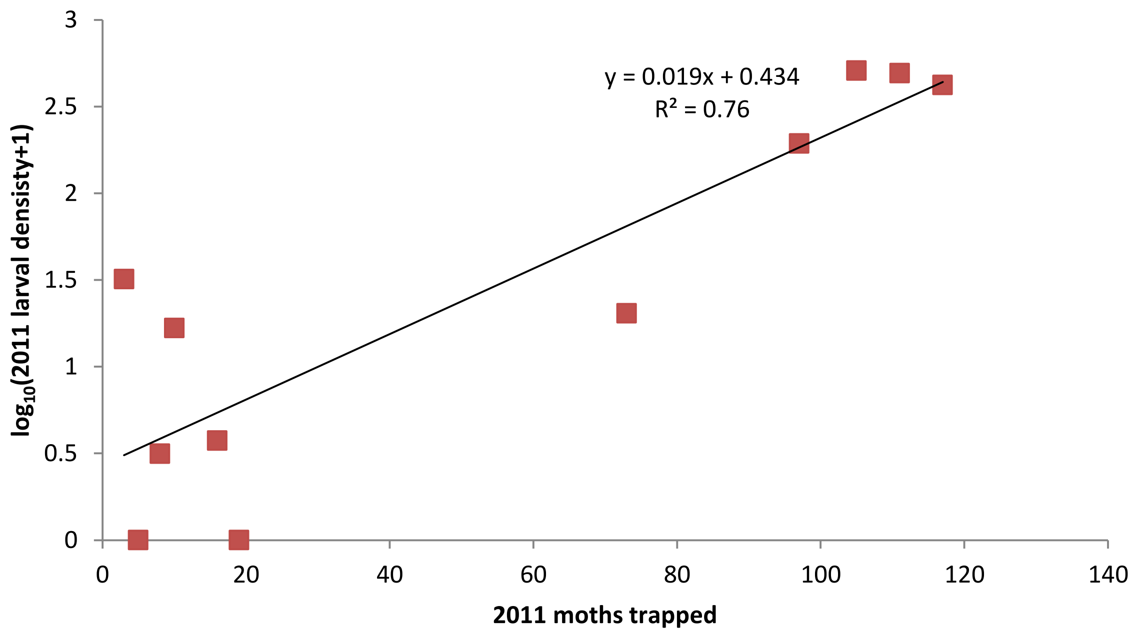

Figure 7 Relationship between November larval populations and antecedent moth trap catches (excludes sites UL 02 and UL 04). r^2= 0.76, p<0.0005.

3.3 Larval density and preceding moth catch

At the range of larval densities and moth trap catches obtained in 2011 there was a positive correlation between November larval densities and the preceding moth trap catch (Fig. 7). The model for predicted larval density was Log_{10}(Larval density +1) = 0.019(Moths trapped) + 0.434, where r^2= 0.76, and p<0.0005. At a sufficiently broad range of population densities, moth catch is a robust predictor of subsequent larval densities.

3.4 Overview of moth trap catches

Traps were set in 2011 on a transect covering a rainfall gradient between Easter forest block in high rainfall and Corbal and Dwalgan forest blocks to the northeast in a lower rainfall area. Greatest trap catches (> 120 moths) were initially in the high rainfall end of this transect (Fig. 8). Populations at these sites decreased in the following year, while some sites of intermediate population (60-120 moths) remained intermediate with increases or decreases within this range. Two sites of relatively low population (< 60 moths) in 2011 increased to intermediate in 2012. All sites on this transect returned catches of 62 or fewer moths in 2013 and 2014. Moth trapping on this transect appears to have defined a period of outbreak recession from 2011 to 2014.

In 2012 and 2013 the network of traps was extended to the south and southeast. This extended series of traps also showed outbreak recession from 2012 to 2014 (Fig. 9). However, in 2014 three sites returned trap catches in excess of 110 moths. It is not clear whether these spikes represent signs of incipient outbreak or stochastic variation.

3.5 Evidence of density dependent mortality

Four years of moth trapping data across a range of population levels allows an indication of whether density dependent mortality is operating to regulate GLS populations during outbreak abatement. Non-zero slope for the regression depicted in Fig. 10 indicates density dependent mortality. In the absence of conditions favourable to regional population increases, small populations tended to increase while large populations tended to decrease. The compensation point is around 28 moths trapped in a season, a moth catch that corresponds to sub-outbreak larval population densities. This indicates that population densities tend to fall to levels generating larval damage which may be invisible to ground observers.

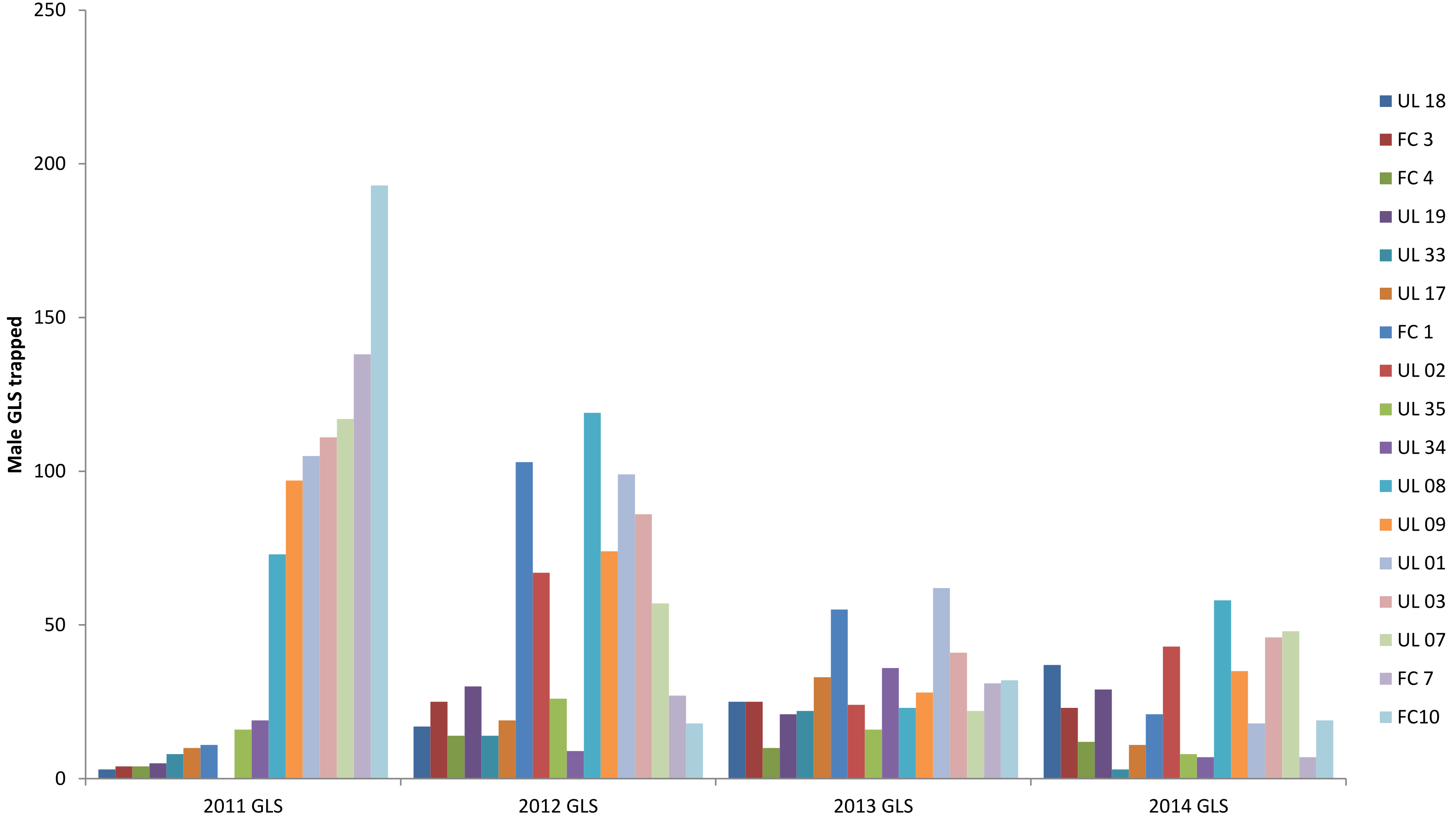

Figure 8 Whole season (February to April) male GLS catches for sites trapped initially in 2011. Sites ranked according to 2011 trap catches.

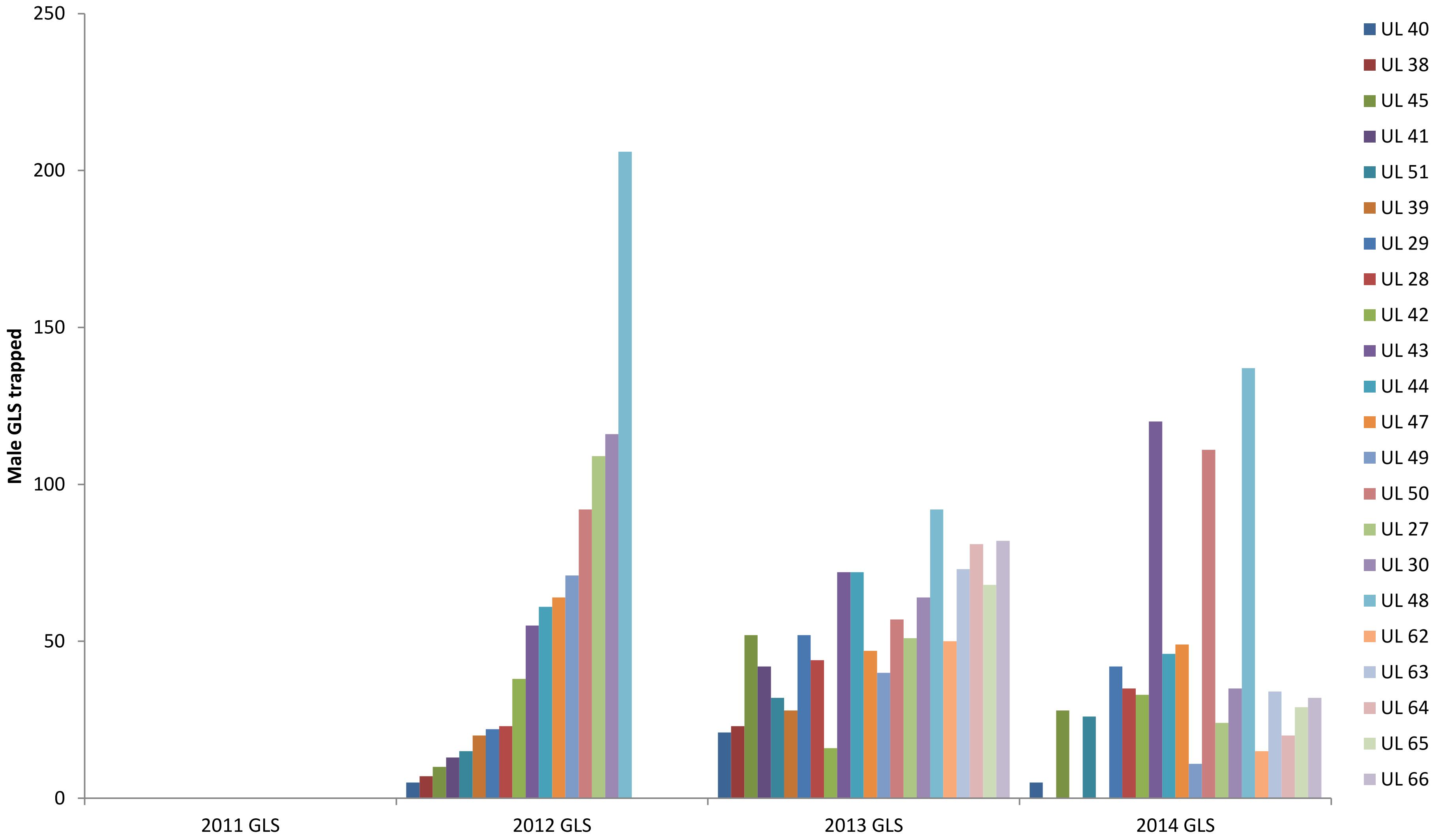

Figure 9 Whole season (February to April) male GLS catches for sites trapped initially in 2012 or 2013. Sites ranked according to 2012 trap catches.

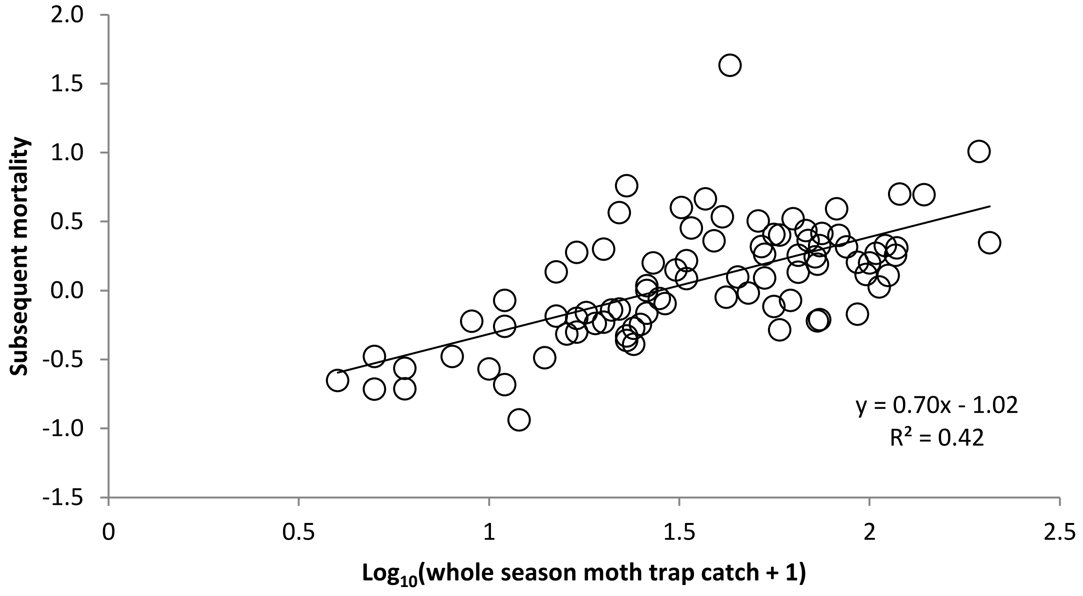

Figure 10 Relationship between initial year $\log_{10}$ GLS male moth captures and mortality determined by difference from following year $\log_{10}$ GLS moth captures. Data are from 2011-2014, a period of declining moth captures. Negative mortality values indicate population increase.

4 Discussion

The conditions driving GLS population growth to outbreak levels remain unknown. The one year lagged response between the time when high populations of GLS became evident and the initiation of systematic moth trapping meant that the population increase phase of the outbreak was not covered in the trapping data. The moth trapping data captures the peak of outbreak and its subsequent abatement. This is an important consideration when interpreting the moth trap data.

Male moth flight period of late January to late March from pheromone traps conforms to the flight period of combined male and female moth data from light trap catches presented by Strelein (1988). Strelein did not differentiate the male and female components of his light trap catches, or cover the early summer period when bivoltinism might be indicated. A temperature driven switch to bivoltinism has been postulated as a mechanism for accelerating population growth (Farr 2002). There was evidence that bivoltinism was not an important component of the GLS lifecycle in moth trapping conducted in 2011/2012 and the good correlation between larval populations and subsequent moth populations tends to indicate bivoltinism was not important in 2010 larval populations. However, the moth trapping data do not exclude a voltinism switch as a population driver because the period of population increase was not captured in moth data.

Moth counts provide a statistically significant prediction for larval population densities the following spring, under the conditions of declining outbreak experienced 2011-2014. This relationship might not be applicable during periods of outbreak development as factors limiting population growth during periods of population decline may be different from limiting factors during periods of outbreak development.

There is strong evidence that density dependent mortality was operating during the period of outbreak recession. Larger populations showed greater mortality and smaller populations tended to show population increase (Fig. 10). The compensation point, at low population densities, tallies with the observed long period of low population densities (Farr 2002). The mechanism behind the density dependent mortality is unknown. During outbreak development this form of density dependent mortality is likely to break down with mortality becoming density independent or survival increasing at greater population densities.

The observed density dependent mortality might operate through a feed forward mechanism whereby larval populations initiate plant host responses by feeding that induces host qualities which lead to reduction in the fitness of larvae. This response would be proportional to the extent of damage caused by larval populations. GLS larvae are known to prefer mature foliage, and defoliation through larval feeding, fire or silviculture, leads to a greater proportion of young foliage in canopies (Farr 2002, Farr et al. 2004). A simple mechanism such as this might be expected to result in short period population cycles. Another density dependent mortality mechanism that leads to the pattern observed in Fig. 10 might be increased susceptibility of larvae to pathogens as population density increases (e.g. Reilly and Hejek 2007). Literature reviews of immune responses to population density indicate the direction of response varies between insect species (e.g. Shlichta and Smilich 2012). More complex examples for other Lepidoptera species involving both induced plant host responses and insect susceptibility to pathogens are to be found in the scientific literature (e.g. Sarfraz et al. 2013, Elderd et al. 2013).

Negative mortalities (population growth) at low population densities indicate that mate availability is not likely to be a limiting factor at the low population densities encountered in the current trapping.

The extensive 2009-1012 outbreak of GLS in Southwest and Warren Regions follows the pattern of an earlier outbreak in the 1980s in the same locations. The outbreaks were relatively short-lived (a few years) with a long interval (decades) between the outbreaks. The onset of outbreaks is at present unpredictable. Data for the population increase phase of outbreak are particularly scant. Moth trapping is applicable across the whole range of population densities and remains sensitive to population fluctuations at densities where damage indications are not visible.

Capturing informative GLS population data requires a continued modest effort of moth trapping for an extended period of time. Moth trapping across the strategic network of monitoring sites is likely to detect onset of outbreak populations in GLS.

Appendices

Appendix 1

Monitoring sites and types of data gathered

Site	Location	Historical larval count	Nov 2010 Larval count	Jan 2011 NDVI/LAI	2011 Moths	Nov 2011 Larval count	2012 Moths	2013 Moths	2014 Moths	Historical and modern data
FC 1	S34 04 33.9 E116 19 38.1			Yes	Yes		Yes	Yes	Yes	
FC 3	S34 05 21.2 E116 22 05.1			Yes	Yes		Yes	Yes	Yes	
FC 4	S34 05 16.8 E116 21 30.5			Yes	Yes		Yes	Yes	Yes	
FC 7	S34 07 11.0 E116 03 25.9			Yes	Yes		Yes	Yes	Yes	
FC 9	S34 12 42.3 E115 47 41.1			Yes	Yes					
FC10	S34 05 19.5 E116 04 54.0			Yes	Yes		Yes	Yes	Yes	
UL 01	S34 07 49.3 E116 00 01.9	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 02	S34 09 32.7 E115 59 44.6	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 03	S34 07 37.1 E115 59 07.8	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes

Site	Location	Historical larval count	Nov 2010 Larval count	Jan 2011 NDVI/LAI	2011 Moths	Nov 2011 Larval count	2012 Moths	2013 Moths	2014 Moths	Historical and modern data
UL 04	S34 06 34.3 E115 57 15.2	Yes	Yes		Yes		Yes	Yes	Yes	
UL 05	S34 12 12.8 E115 54 54.1	Yes	Yes							
UL 06	S34 13 16.0 E115 52 09.4	Yes	Yes							
UL 07	S34 07 41.1 E116 12 48.2	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 08	S34 06 27.8 E116 15 08.1	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 09	S34 05 30.9 E116 12 37.8	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 11	S34 20 41.5 E116 16 22.6	Yes	Yes							
UL 12	S34 23 22.4 E116 16 37.9	Yes	Yes							
UL 13	S34 24 53.5 E116 16 07.0	Yes	Yes							
UL 14	S34 26 25.7 E116 13 24.5	Yes	Yes							
UL 15	S34 08 11.8 E116 27 30.7	Yes	Yes							
UL 16	S34 06 25.4 E116 29 08.7	Yes	Yes							
UL 17	S34 06 03.6 E116 30 58.3	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes

Site	Location	Historical larval count	Nov 2010 Larval count	Jan 2011 NDVI/LAI	2011 Moths	Nov 2011 Larval count	2012 Moths	2013 Moths	2014 Moths	Historical and modern data
UL 18	S34 10 41.7 E116 36 47.9	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 19	S34 11 59.9 E116 35 16.2	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 20	S34 13 09.0 E116 34 39.4	Yes	Yes							
UL 21	S34 14 24.1 E116 33 17.7	Yes	Yes							
UL 22	S34 16 04.4 E116 32 23.7	Yes	Yes							
UL 23	S34 18 43.8 E116 31 38.6	Yes	Yes							
UL 24	S34 19 31.3 E116 31 26.5	Yes	Yes							
UL 25	S34 22 14.0 E116 31 54.6	Yes	Yes							
UL 26	S34 19 06.4 E116 28 20.7	Yes	Yes							
UL 27	S34 21 11.9 E116 28 09.6	Yes	Yes			Yes	Yes	Yes	Yes	Yes
UL 28	S34 23 01.9 E116 25 57.1	Yes	Yes			Yes	Yes	Yes	Yes	Yes
UL 29	S34 23 41.4 E116 24 04.4	Yes	Yes			Yes	Yes	Yes	Yes	Yes
UL 30	S34 25 35.8 E116 23 02.7	Yes	Yes			Yes	Yes	Yes	Yes	Yes

Site	Location	Historical larval count	Nov 2010 Larval count	Jan 2011 NDVI/LAI	2011 Moths	Nov 2011 Larval count	2012 Moths	2013 Moths	2014 Moths	Historical and modern data
UL 31	S34 34 48.4 E116 44 00.1	Yes	Yes							
UL 32	S34 35 20.9 E116 47 26.2	Yes	Yes							
UL 33	S34 36 48.0 E116 51 02.8	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 34	S34 34 32.3 E116 40 11.3	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 35	S34 34 54.8 E116 36 25.6	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
UL 36	S34 05 21.2 E116 22 05.1	Yes	Yes							
UL 37	S34 05 16.8 E116 21 30.5	Yes	Yes							
UL 38	S34 07 11.0 E116 03 25.9	Yes	Yes			Yes	Yes	Yes		Yes
UL 39	S34 12 42.3 E115 47 41.1	Yes	Yes			Yes	Yes	Yes		Yes
UL 40	S34 05 19.5 E116 04 54.0	Yes	Yes			Yes	Yes	Yes	Yes	Yes
UL 41	S34 07 49.3 E116 00 01.9	Yes	Yes			Yes	Yes	Yes	Yes	Yes
UL 42	S34 09 32.7 E115 59 44.6	Yes	Yes			Yes	Yes	Yes	Yes	Yes
UL 43	S34 07 37.1 E115 59 07.8	Yes	Yes			Yes	Yes	Yes	Yes	Yes

Site	Location	Historical larval count	Nov 2010 Larval count	Jan 2011 NDVI/LAI	2011 Moths	Nov 2011 Larval count	2012 Moths	2013 Moths	2014 Moths	Historical and modern data
UL 44	S34 06 34.3 E115 57 15.2	Yes	Yes			Yes	Yes	Yes	Yes	Yes
UL 45	S34 12 12.8 E115 54 54.1	Yes	Yes			Yes	Yes	Yes	Yes	Yes
UL 46	S34 13 16.0 E115 52 09.4		Yes							
UL 47	S34 07 41.1 E116 12 48.2		Yes			Yes	Yes	Yes	Yes	
UL 48	S34 06 27.8 E116 15 08.1		Yes			Yes	Yes	Yes	Yes	
UL 49	S34 05 30.9 E116 12 37.8		Yes			Yes	Yes	Yes	Yes	
UL 50	S34 20 41.5 E116 16 22.6		Yes			Yes	Yes	Yes	Yes	
UL 51	S34 23 22.4 E116 16 37.9		Yes			Yes	Yes	Yes	Yes	
UL 52	S34 24 53.5 E116 16 07.0		Yes							
UL 53	S34 26 25.7 E116 13 24.5		Yes							
UL 54	S34 08 11.8 E116 27 30.7		Yes							
UL 55	S34 06 25.4 E116 29 08.7		Yes							
UL 56	S34 06 03.6 E116 30 58.3		Yes							

Site	Location	Historical larval count	Nov 2010 Larval count	Jan 2011 NDVI/LAI	2011 Moths	Nov 2011 Larval count	2012 Moths	2013 Moths	2014 Moths	Historical and modern data
UL 57	S34 10 41.7 E116 36 47.9		Yes							
UL 58	S34 11 59.9 E116 35 16.2		Yes							
UL 59	S34 13 09.0 E116 34 39.4		Yes							
UL 60	S34 14 24.1 E116 33 17.7		Yes							
UL 61	S34 16 04.4 E116 32 23.7		Yes							
UL 62	S34 18 43.8 E116 31 38.6		Yes					Yes	Yes	
UL 63	S34 19 31.3 E116 31 26.5							Yes	Yes	
UL 64	S34 22 14.0 E116 31 54.6							Yes	Yes	
UL 65	S34 19 06.4 E116 28 20.7							Yes	Yes	
UL 66	S34 21 11.9 E116 28 09.6							Yes	Yes	

Glossary

Bivoltine	“Life cycle with two generations per year”
Outbreak	“Rapid population growth and/or high population density”
Pheromone	“Signal chemical that induces a particular behaviour”
Univoltine	“Life cycle with single generation per year”

References

Abbott I (1992) Records of outbreaks of defoliating insects in jarrah forests, south-west Western Australia, from 1960 to 1990. Technical Report No. 28, pp. 1–29.

Elderd BD, Rehill BJ, Dwyer G, (2013) Induced plant defenses, host–pathogen interactions,and forest insect outbreaks. www.pnas.org/cgi/doi/10.1073/pnas.1300759110

Farr JD (2002) Biology of the gumleaf skeletoniser, Uraba lugens Walker (Lepidoptera: Noctuidae), in the southern jarrah forest of Western Australia. Australian Journal of Entomology 41, pp. 60–69.

Farr JD, Swain D, Metcalf F (2004) Spatial analysis of an outbreak of Uraba lugens (Lepidoptera: Noctuidae) in the southwest of Western Australia: does logging, vegetation type or fire influence outbreaks? Australian Forestry 67, pp. 101–113.

Farr J, Wills A (2010) Gumleaf skeletoniser (Uraba lugens) outbreak, February 2010: preliminary survey of the extent and severity of gumleaf skeletonizer outbreak in Warren region, February 2010. Department of Environment and Conservation, Kensington, WA. 7 p.

Farr JD, Wills AJ (2012) Field testing Desire® Delta trap and GLS sex pheromone lure system for measuring outbreak and basal populations of Uraba lugens Walker (Lepidotera: Nolidae). Australian Journal of Forestry 75, pp. 175–179.

Kriticos DJ, Potter KJB, Alexander NS, Gibb AR, Suckling DM (2007) Using a pheromone lure survey to establish the native and potential distribution of an invasive Lepidopteran, Uraba lugens. Journal of Applied Ecology 44, 853-863.

Reilly JR, Hajek AE (2008) Density-Dependent Resistance of the Gypsy Moth Lymantria dispar to its Nucleopolyhedrovirus, and the Consequences for Population Dynamics: Oecologia 154(4), pp. 691-701.

Sarfraz RM, Cory JS, Myer JH (2013) Life-history consequences and disease resistance of western tent caterpillars in response to localised, herbivore-induced changes in alder leaf quality. Ecological Entomology 38, 61–67. DOI: 10.1111/j.1365-2311.2012.01404.x

Shlichta JG and Smilanich AM (2012) Immune Responses and Their Potential Role in Insect Outbreaks. In: Insect Outbreaks Revisited, First Edition. Edited by Pedro Barbosa, Deborah K. Letourneau and Anurag A. Agrawal. Blackwell Publishing Ltd.

Strelein GJ (1988) Gumleaf skeletoniser moth,Uraba lugens, in the forests of Western Australia. Australian Forestry 51, 197-204.

Suckling DM, Gibb AR, Dentener PR, Seldon DS, Clare GK, Jamieson L, Baird D, Kriticos DJ, El-Sayed, AM (2005) Uraba lugens (Lepidoptera: Nolidae) in New Zealand: Pheromone trapping for delineation and phenology. Journal of Economic Entomology 98, 1187-1192.