Project title:	Survey of earwig abundance in blackcurrant plantations in the main growing areas of the UK in 2016
Project number:	SF 168
Project leader:	Dr Michelle Fountain, NIAB EMR
Report:	Final Report 2017
Previous report:	None
Key staff:	Madeleine Cannon (NIAB EMR) Dr Phil Brain (NIAB EMR)
Location of project:	NIAB EMR, Grower sites
Industry Representative:	Harriet Roberts, Lucozade Ribena Suntory LTD, harriet.roberts@lrsuntory.com
Date project commenced:	April 2016
Date project completed (or expected completion date):	April 2017

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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CONTENTS

GROWER SUMMARY

Headline

- A survey of earwig abundance and its influencing factors has been carried out in blackcurrant plantations across the UK in 2016.

Background and expected deliverables

The common European earwig, *Forficula auricularia* L., is the most frequently encountered species of earwig in UK fruit plantations (Fitzgerald and Solomon, 1996; Solomon et al., 1999). Earwigs are omnivorous feeding on other arthropods, plants, pollen, microscopic algae and fungi, and are sometimes cannibalistic. They are important predators of many pests including scale insects (McLeod and Chant, 1952; Karsemeijer, 1973), psyllids (Lenfant et al., 1994; Solomon et al., 1999), woolly apple aphid, *Eriosoma lanigerum* Hausmann (Phillips, 1981; Ravensburg, 1981; Noppert et al., 1987; Mueller et al., 1988; Nicholas et al., 2005; Dib et al., 2010) and codling moth, *Cydia pomonella* L. (Glen, 1977). Hence, they also have the potential to be an important predator of soft bodied pests in blackcurrant plantations (aphids, sawfly eggs and larvae, midge larvae and caterpillars).

Research at NIAB EMR has shown large differences in earwig populations in apple and pear orchards (EMR, 2014: Annual report, p 20-21). Reports that earwigs are declining in some orchards (Gobin et al., 2008) have raised concern for this effective, natural enemy in apple and pear orchards, but to date there is no comparative data on the abundance of earwigs in blackcurrant plantations. Research by NIAB EMR and other researchers across Europe and New Zealand identified that earwigs can be adversely affected by applications of some insecticides (reviewed in Fountain and Harris (2015) and TF 220 (2015)). Little is known about the impact of insecticide applications on earwig populations in blackcurrant plantations.

Summary of the project and main conclusions

Five of the main UK blackcurrant growing regions were surveyed in 2016 to determine earwig abundance in blackcurrant crops. Ten plantations were surveyed in each region. In collaboration with Harriet Roberts, LRS, ten refuges (confidential design, see p.4 of the Science Section of this report) were deployed at the edge and centre of each plantation for a minimum of 45 days. Grower spray programmes for 2015 and 2016 were collected to examine effects of insecticide spray programmes on earwig abundance within each plantation. Toxicity scores of commonly used insecticides in blackcurrant crops were used and summed for each crop. Earwig numbers varied greatly between blackcurrant plantations within and between farms (mean 0 – 110 earwigs per refuge). However, no significant correlation between earwig abundance and the toxicity score of the insecticide spray programmes was found. Nonetheless, blackcurrant plantations which received an insecticide spray programme with an overall toxicity score greater than 14 had fewer earwigs (<20 earwigs per refuge) and with a score greater than 25 had no earwigs. Earwig numbers varied between plantations where insecticide spray programmes were similar. For example, the insecticide spray programmes for farm A had the same overall toxicity score on each of the plantations whilst mean earwig numbers varied from 3 to 63 earwigs per refuge per plantation. This suggests that other abiotic and biotic factors may have influenced earwig abundance in blackcurrant plantations in addition to spray programmes. Further studies are needed to determine what other factors influence earwig populations in blackcurrant.

Financial benefits

Approvals for chlorpyrifos and pirimicarb have been discontinued on blackcurrant, so a reliance on natural enemies is becoming increasingly prevalent. Earwigs have been recognised as effective at controlling pests in apple and pear orchards and increasing earwig numbers in blackcurrant could help to suppress many common blackcurrant pests. If earwigs are found to be sufficient at controlling pests then fewer insecticides will need to be applied reducing residue levels in the fruit and reducing the cost of insecticide inputs.

Action points for growers

- Assess earwig presence and abundance in blackcurrant plantations by tap sampling or using corrugated cardboard bottle refuges.
- Foster and encourage populations of earwigs by considering the choice and timing (females in canopy Apr, nymphs in canopy May – Sep) of insecticide products applied.
- Monitor pest incidence alongside general natural enemy numbers.

SCIENCE SECTION

Introduction

The common European earwig is an important predator of orchard pests including scale insects (McLeod and Chant, 1952; Karsemeijer, 1973), psyllids (Lenfant et al., 1994; Solomon et al., 1999), woolly apple aphid, *Eriosoma lanigerum* Hausmann (Phillips, 1981; Ravensburg, 1981; Noppert et al., 1987; Mueller et al., 1988; Nicholas et al., 2005; Dib et al., 2010) and codling moth, *Cydia pomonella* L. (Glen, 1977). A survey of earwig populations in top fruit orchards undertaken in South East England by NIAB EMR (EMR, 2014.) revealed significant variation in earwig populations between orchards and farms. Research at NIAB EMR and other research groups has looked to determine what factors (e.g., insecticides, herbicides, soil tillage, mowing) cause variation in earwig populations between orchards leading to recommendations on how to foster and maintain earwig populations in orchards. No previous survey of earwig populations in blackcurrant plantations has been undertaken in the UK.

The current AHDB-funded SF145 project has provided information on the phenology of earwigs within blackcurrant plantations. The data revealed that adult females were present in the canopy in early May. In apple and pear orchards females present in the orchard from April to May are likely to be foraging for food for the early stage nymphs in the nest (Moerkens et al., 2008). Nymphs were then present in the canopy from May (fruit set) until Mid-September. Finally, from Mid-September onwards only adult males or females were present (Figure 1). Hence, earwigs in blackcurrant plantations can be exposed to insecticide applications. Earwig nymphs have been found to be more susceptible to some insecticides than adults in lab and field studies (Fountain and Harris, 2015) therefore, insecticide toxicity and timing of spray applications may have an influence on earwig abundance.

In addition, other abiotic and biotic factors may also influence earwig populations including, soil type, surrounding habitat, predation etc.

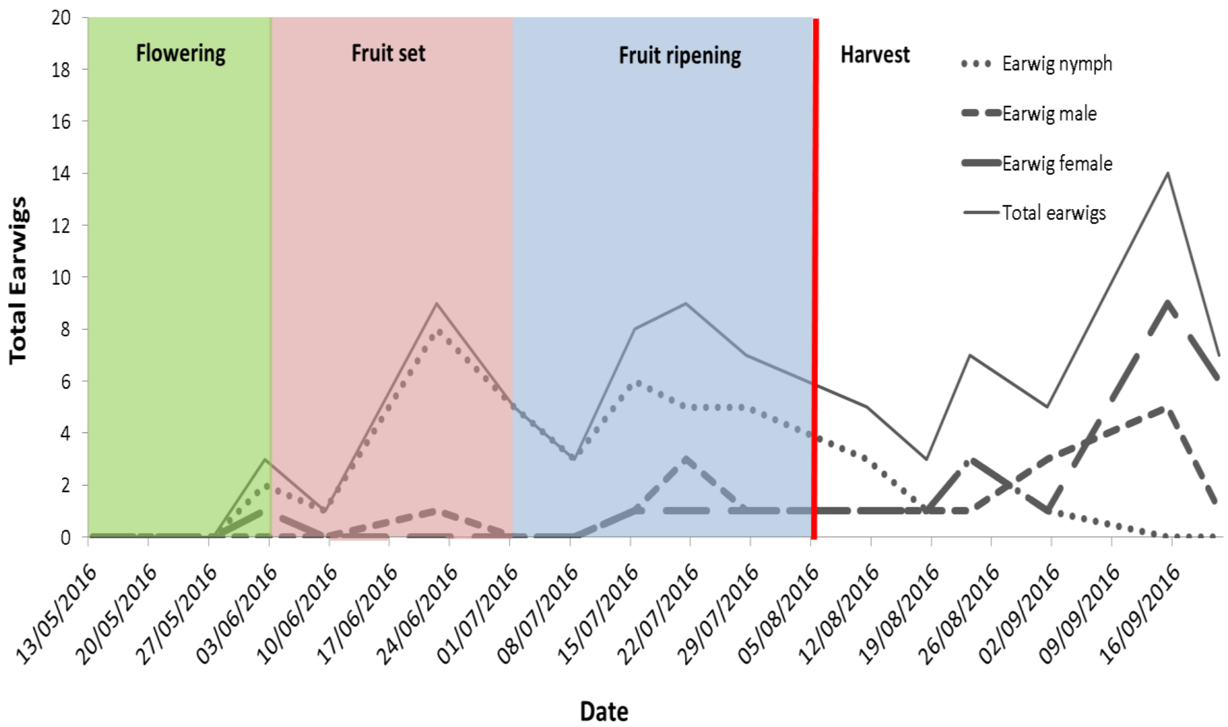

Figure 1. Earwig female, male and nymph numbers in a blackcurrant plantation in the South East monitored every 1- 2 weeks over 20 weeks in 2016 (SF 145).

This project surveyed earwig populations in blackcurrant plantations across the UK and attempted to establish if insecticide spray programmes, plantation age or the surrounding habitat impacted earwig abundance.

Materials and Methods

In collaboration with Harriet Roberts earwig refuges were deployed in ten mature blackcurrant plantations (>4 years old) in each of the five main blackcurrant growing regions (South East, East Anglia, West Midlands, Somerset and Scotland). Ten earwig refuges were deployed per plantation, five at the edge, adjacent to semi-natural habitat (Figure 2), where possible, and five in the centre of each plantation, (500 refuges deployed across the UK). Refuges were deployed in April and left in the plantations for a minimum of 45 days. The design of the refuges is not detailed in this report as they are part of an Innovate UK project at NIAB EMR with Worldwide Fruit and Russel IPM.

Figure 2. Blackcurrant plantation with refuges deployed at the edge of the plantation adjacent to hedgerow, location marked with red and white tape

From June to July earwig refuges were removed from the crop and placed into individual sealed bags. All refuges and their contents were frozen in a -20^{o}C freezer at NIAB EMR. Refuges were opened and the total numbers of earwig nymphs (L1, L2, L3, L4), males and females recorded in each refuge (Figure 7, Appendix). Some earwig refuges were lost or destroyed by machinery therefore the mean numbers of earwigs per refuge were calculated to estimate earwig abundance at the edge and centre of each plantation.

Significant differences in the mean number of earwigs per refuge between plantations and farms was analysed using an ANOVA in GENSTAT V 14.1 with treatments being region, farm, plantation + position with the position x region, farm, plantation interaction used as the estimate of variance.

The difference between the number of earwigs per refuge between the edge and centre of all combined plantations was analysed using ANOVA in GENSTAT 14.1 with the treatment being the position (edge/centre) of the refuge in the plantation.

Grower spray programmes from 2015 up until the earwig refuges were collected in (~19 months) were requested for each plantation. Insecticides applied to the plantation during those dates were given a toxicity score. The toxicity score was based on the percentage mortality of earwigs after exposure to the insecticide (1 = Harmless (<25%), 2 = Slightly harmful (25-50%), 3 = Moderately harmful (51-75%), 4 = Harmful (>75%)). This data is summarized in reports TF 220 and TF 196, Table 1, Appendix. Where no data was available for earwigs the Biobest side effects manual (http://www.biobestgroup.com/en/side-effect-manual, accessed in April 2017) was used to produce a toxicity score for each insecticide based on the toxicity to other relevant terrestrial Insecta; *Anthocoris nemoralis*, Coleoptera and *Orius* spp. (Table 2, Appendix). Each plantation was given an overall toxicity score by summing each individual spray event. Data on the age of the plantation and adjacent habitat was also recorded for each of the 50 plantations. Farms were labelled A to K and plantations numbered 1-50.

An ANOVA was done in GENSTAT V 14.1 to determine significant differences in the overall insecticide toxicity score between years, regions, farms and plantations.

A linear regression analysis was carried out to determine whether there was a significant correlation between earwig abundance and overall insecticide programme toxicity score and plantation age.

Results

A total of 184 male, 331 female, 21 L1 nymph, 536 L2 nymph, 1747 L3 nymph and 3617 L4 nymph earwigs were found in the refuges; a total of 6436 earwigs overall.

There was a significant difference in the number of earwigs per refuge between farms in the same region, for example in the South East, farm I had a mean of 61.7 earwigs per refuge, meanwhile farm J had significantly lower numbers of earwigs per refuge (mean of 8.88) (P < 0.001, l.s.d. = 16.863, s.e.d. = 8.378, Figure 3).

In addition, significant differences in the mean number of earwigs per refuge were found between plantations on same farms (I, K and A) (P < 0.001, l.s.d. = 16.863, s.e.d. = 8.378, Figure 3). At farm A, for example, plantations 3 and 4 had significantly higher numbers of earwigs per refuge (63 and 42 earwigs per refuge, respectively) than plantation 5 (2.6 earwigs per refuge).

Significantly more earwigs were found at the centre (14.9) than the edge of the plantations (11.3) (P < 0.001, s.e.d. = 1.68, l.s.d. = 3.37).

Although we recorded the habitat (hedgerow type) adjacent to the edge of the plantation analysis could not be done due to the low replication and variability in some habitat types and variability between hedgerow species. Adjacent habitat types are shown in Figure 3 and no obvious link can be seen between earwig numbers and hedgerow type.

The following insecticides (active ingredients) with the following toxicity scores were applied to blackcurrant plantations in 2015/16; thiacloprid (2.8), lambda cyhalothrin (4), spinosad (3.5), pirimicarb (1), chlorpyrifos (3.5), tebufenpyrad (3.3) and pymetrozine (1.5) (Table 1). The mean toxicity score of the insecticide products being applied per plantation in 2015 was 8.53, significantly higher than in 2016 where the mean toxicity score was 7.32 (P < 0.017, l.s.d. = 0.994, s.e.d. = 0.495).

The overall toxicity score for insecticide use from 2015-2016 did not vary significantly between plantations at farms A, B, G, H, J and K (Figure 4, $P < 0.001$, l.s.d. = 5.214, s.e.d. = 2.596). The probability of there being no dependency of mean earwig numbers per refuge on the overall toxicity score of the insecticide programmes was greater than 0.481 (Figure 5). Hence, there was no significant relationship between the overall toxicity score of the insecticide programmes and the numbers of earwigs per refuge. However, when the overall toxicity score exceeded 14 the mean numbers of earwigs per refuge were always below 20. Furthermore, in plantations that had a toxicity score of 25 or greater, virtually no earwigs were found. Lower insecticide toxicity scores allowed for greater mean numbers of earwigs per refuge (max. 115 earwigs per refuge). The R^2 value was 0.23 suggesting that 23% of the variation in the mean number of earwigs per refuge can be attributed to the variation in the overall toxicity of the insecticide programme.

There was no significant correlation between earwig abundance and plantation age (P = 0.077, R^2 value = 0.071, y = 1.4839x + 0.3853, Figure 6).

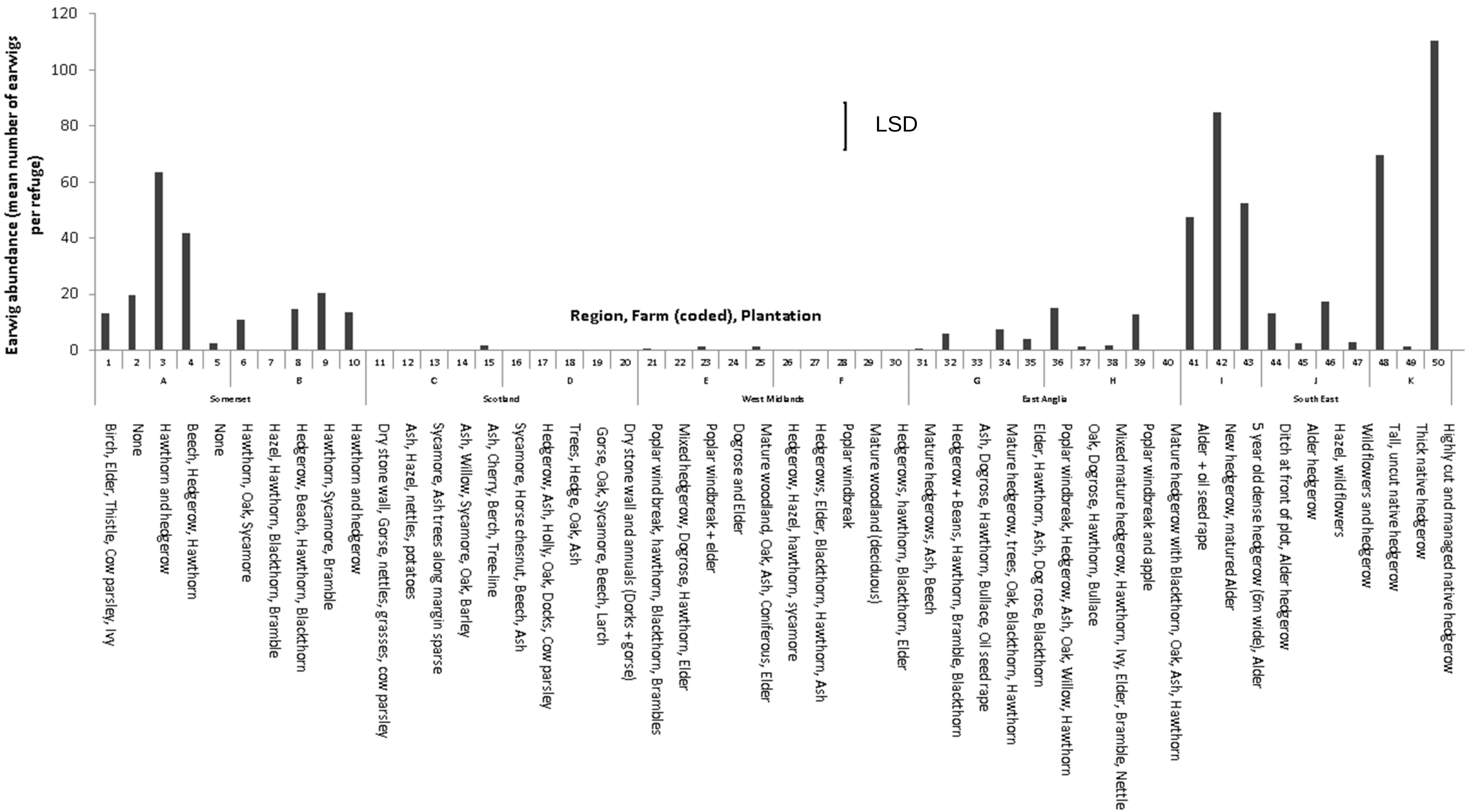

Figure 3. Mean number of earwigs per refuge in each blackcurrant plantation at ten farms and five regions across the UK. Adjacent plantation habitat type is shown below ($P < 0.001$, l.s.d. = 16.863, s.e.d. = 8.378)

Table 1. Earwig toxicity scores of insecticide products applied to surveyed blackcurrant plantations from 2015 to 2016. The toxicity score was based on the percentage mortality of the insect after exposure to the insecticide (1 = Harmless (<25%), 2 = Slightly harmful (25-50%), 3 = Moderately harmful (51-75%), 4 = Harmful (>75%)).

Product	Active ingredient	Common European Earwig		Orius spp	Coleoptera	*Anthocoris nemoralis*		Final toxicity score
		Toxicity score	Average Toxicity Score	Toxicity Scores			Average toxicity score	
Aphox	Pirimicarb	1[1], 1[3]	1	1.5[7]	2.5[7]	1[7]	1.7	1[1, 3]
Hallmark with Zeon	Lambda-cyhalothrin	Not tested	Not tested	4[7]	4[7]	4[7]	4.0	4.0[7]
Calypso	Thiacloprid	3[1],4[4],1[5], 3[6]	2.8	4[7]	3.5[7]	4[7]	3.8	2.8[1,4,5,6]
Cyren 480 EC	Chlorpyrifos	3[1],4[5]	3.5	3[7]	3[7]	4[7]	3.3	3.5[1,5]
Tracer	Spinosad	4[1],4[2], 4[4], 2[5]	3.5	4[7]	1[7]	2[7]	2.3	3.5[1,2,4,5]
Plenum	Pymetrozine	Not tested	Not tested	2[7]	1.5[7]	1[7]	1.5	1.5[7]
Masai	Tebufenpyrad	Not tested	Not tested	4[7]	3.5[7]	3[7]	3.3	3.3[7]

1 Peusens and Gobin (2008); 2 Peusens., et al (2009), 3 Ffrench-Constant and Vickerman (1985), 4 Shaw and Wallis (2010), 5 Fountain and Harris (2015), 6 TF 220 (2015), 7 Biobest side effects manual (2016)

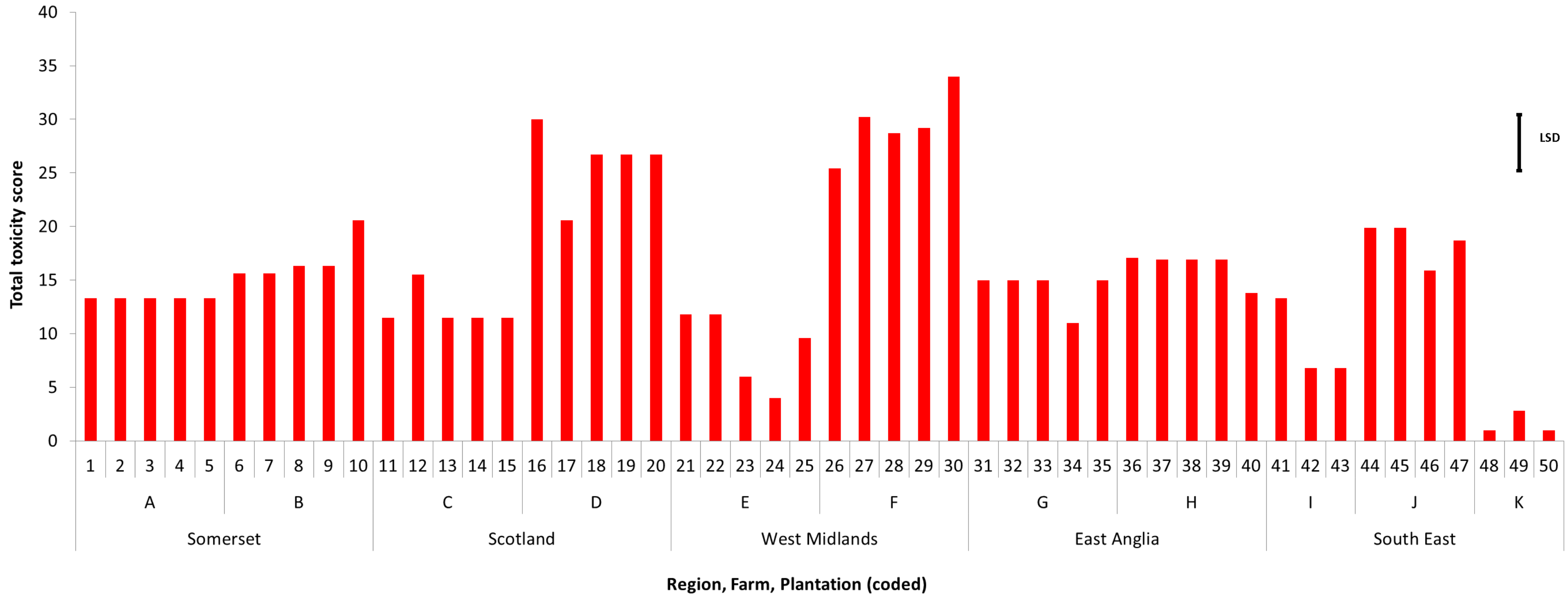

Figure 4. Overall toxicity score of insecticides applied to each blackcurrant plantation in sites across the UK ($P < 0.001$, l.s.d. = 5.214, s.e.d. = 2.596)

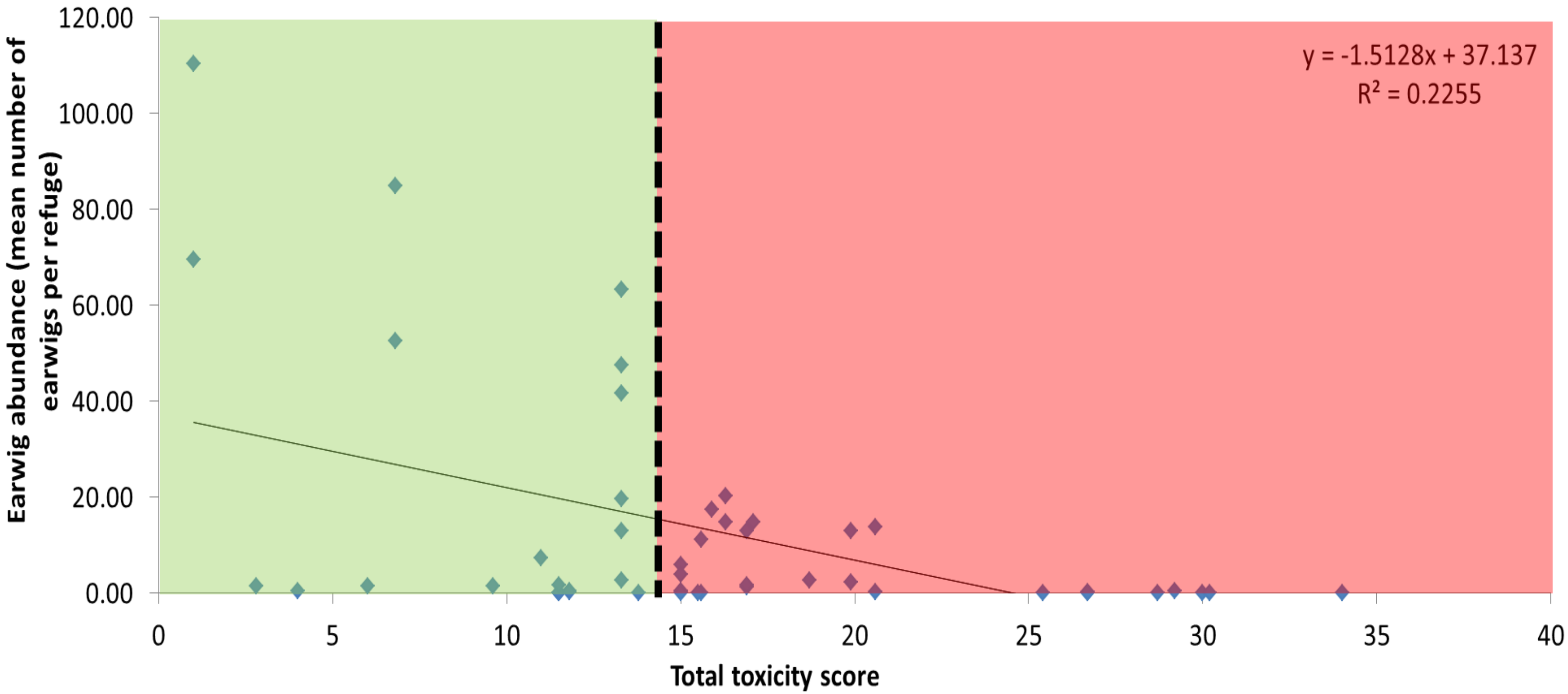

Figure 5. Correlation between overall toxicity score of insecticides applied to each plantation and earwig abundance (*F pr. = 0.481*, R^2 = 0.2255, y = 37.137 – 1.5128x). The green area shows sites which scored below 14 and where there is a wide range of earwig abundance per plantation. The red area shows toxicity scores above 14 where the abundance of earwig rarely reaches above 20 per refuge. Once the score is above 25 virtually no earwigs are detected

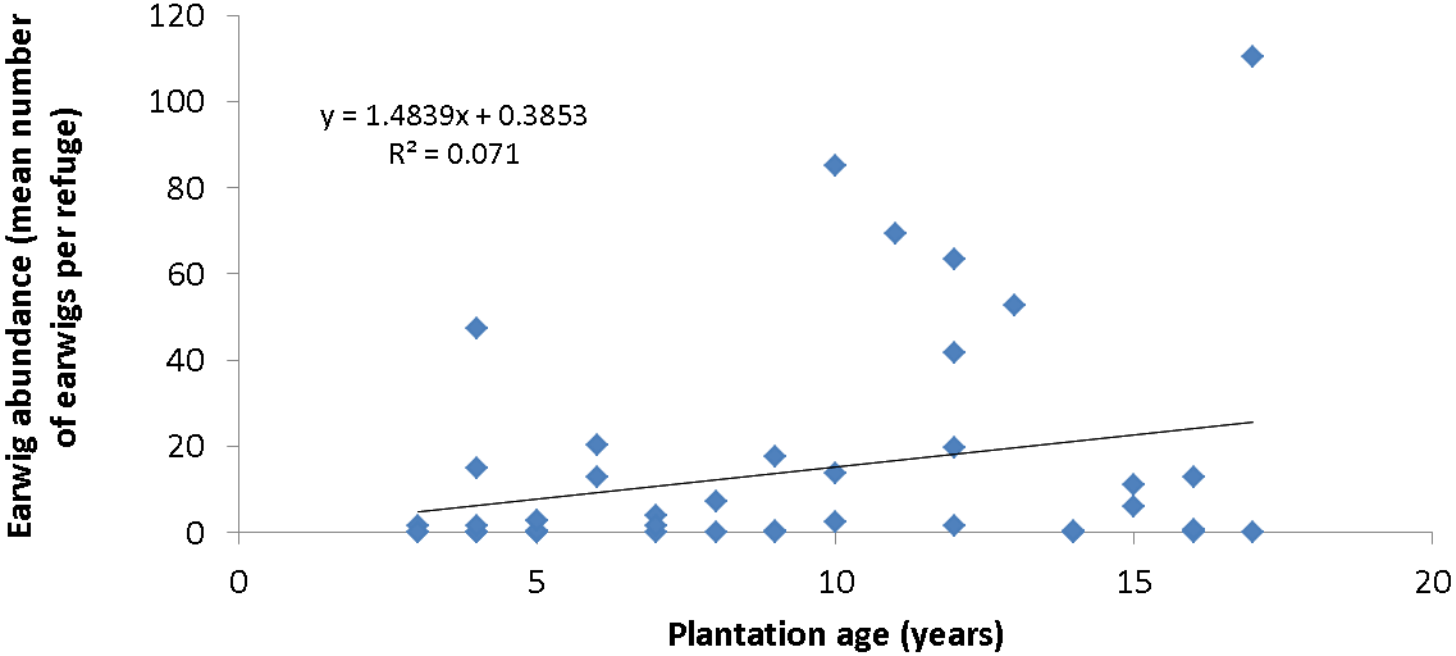

Figure 6. Correlation between earwig abundance in blackcurrant plantation and plantation age (*F pr. = 0.077*, R^2 value = 0.071, y = 1.4839x + 0.3853)

Discussion

Low earwig numbers were observed at the sites surveyed in Scotland, the West Midlands and East Anglia. However, fewer than three sites were surveyed in each region and therefore differences cannot be attributed to regional effects. To establish regional differences in earwig abundance between blackcurrant plantations more sites would need to be surveyed. Significant variation in earwig abundance was observed between farms and between plantations on the same farm. This variation in earwig abundance has also been observed in tree fruit orchards (Helsen et al., 2004; Moerkins et al., 2009; Gobin et al., 2008; EMR, 2014). Insecticide applications have been partly implicated in this variation in earwig populations between orchards (Fountain and Harris, 2015; Shaw and Wallis, 2010; Vogt et al., 2010). In this study it was observed that mean earwig numbers did not surpass 21 per refuge when the overall insecticide toxicity score exceeded 14. Furthermore, in plantations that had a toxicity score of 25 or greater, virtually no earwigs were found. In general plantations with a score of greater than 25 always applied more than three insecticide applications per year and 2 or more applications of broad spectrum insecticides such as thiacloprid, chlorpyrifos and lambda cyhalothrin per year. This shows that the use of broad spectrum insecticide applications may be a contributing factor in reduced earwig abundance in blackcurrant plantations.

However, variation in earwig abundance between plantations with the same overall insecticide toxicity score was observed. Farm A had an overall toxicity score of 13.3 at all five plantations surveyed, however 63 earwigs were found in one plantation whilst 2.6 were observed in another plantation at this same farm. Furthermore only 23% of the variation in earwig numbers is accounted for by the toxicity of the insecticides being applied. Due to the parameters of this study we were not able to incorporate important variables into the toxicity scoring system such as; application timing, insecticide dosage and historical spray programme. A more significant correlation between the insecticide toxicity score and reduced earwig abundance may be established with these variables incorporated.

The insecticide spray programme is unlikely to account for all the variation in earwig numbers, other abiotic and biotic factors may be influencing earwig numbers in blackcurrant plantations. Earwig abundance was not significantly influenced by the plantation age in this study. However, it has been found that management practices in tree fruit orchards, such as, insecticide application timing and dosage, herbicide use, mowing regime and soil tillage may influence earwig populations (Moerkens et al., 2012; Horton et al., 2003). Other factors outside of the growers control may also influence earwig abundance such as cold winter temperatures, crop age, waterlogging, soil type, rainfall, migration, starvation, pathogens, parasitoids and predation (Moerkens et al., 2012; Moerkens et al., 2010; Moerkens et al., 2008; Moerkens et al., 2009). This survey provides initial data that can be utilised to establish the toxicity of a growers insecticide spray programme to earwig abundance. Further investigation into the data could look to determine the influence of other factors such as insecticide application time and dosage, herbicide application, winter temperatures, rainfall, soil type and management practices.

The mean total toxicity score of insecticide application to blackcurrant plantations decreased in 2016. This is, in part, due to the loss of chlorpyrifos approval (insecticide toxicity score = 3.5) in blackcurrant crops. However, there was also a marked decrease in the number of insecticides applied to the crops, in 2015 (140 insecticide applications in total) compared to 2016 (111 applications). The reliance on natural enemies for pest control in blackcurrant plantations is likely to become increasingly important. A greater understanding of the interaction between pest and natural enemies in blackcurrants is, therefore, needed.

Conclusions

1. Earwig populations varied significantly between blackcurrant crops across the five main growing regions of the UK
2. There was no significant overall correlation between earwig abundance and the toxicity of insecticide spray programmes. However, plantations with insecticide toxicity score greater than 25 had no earwigs in the refugia
3. Other unknown biotic and abiotic factors are likely to have an influence of earwig abundance in blackcurrant plantations
4. The mean toxicity of the insecticide spray programmes being applied to each plantation decreased in 2016

Knowledge and Technology Transfer

SWD and earwigs in blackcurrant. Michelle Fountain, LRSuntory Conference, Chase Hotel Ross on Wye, 02 Nov 2016.

The role of earwigs and other predators for pest control in blackcurrants. Madeleine Cannon, ADHB Soft Fruit Day, NIAB EMR, 23 November 2016.

References

Biobest side effects manual (2016) [online]. Available at: http://www.biobestgroup.com/en/side-effect-manual [Accessed on: 25 April 2017].

Dib, H., Sauphanor, B., Capowiez, Y. (2010). Effect of codling moth exclusion nets on the rosy apple aphid, *Dysaphis plantaginea*, and its control by natural enemies. Crop Prot. 29, 1502–1513.

EMR (2014) Annual report, p.20-21 [online]. Available at https://horticulture.ahdb.org.uk/sites/default/files/research_papers/TF%20220_Report_Annual_2015.pdf [Accessed on: 22 April 2017].

Ffrench-Constant,R.H., Vickerman, G.P. (1985) Soil contact toxicity of insecticides to the European earwig *Forficula auricularia* (Dermaptera). Entomophaga. 30, 271–278.

Fitzgerald, J.D., Solomon, M.G. (1996) Artificial refuges for enhancing populations of natural enemies of pests in apples and pear orchards. APRC News. 12, 16–17.

Fountain, M.T., Harris, A.J. (2015) Non-target consequences of insecticides used in apple and pear orchards on *Forficula auricularia* L. (Dermaptera: Forficulidae). Bio Control. 91, 27-33.

Glen, D.M. (1977) Predation of codling moth eggs, *Cydia pomonella*, the predators responsible and their alternative prey. J. Appl. Ecol. 14, 445–456.

Gobin, B., Moerkens, R., Leirs, H., Peusens, G. (2008) Earwigs in fruit orchards: phenology predicts predation effect and vulnerability to side-effects of orchard management. Pesticides Beneficial Organ. 35, 35–39.

Horton, D.R., Broers, D.A., Lewis, R.R., Granatstein, D., Zack, R.S., Unruh, T.R., Moldenke, A.R., Brown, J.J. (2003) Effects of mowing frequency on densities of natural enemies in three Pacific Northwest pear orchards. Entomologia Experimentalis et Applicata. 106, 135-145.

Karsemeijer, M.M.D. (1973) Observations on the enemies of the oyster shell scale, *Lepidosaphes ulmi*, on apple in The Netherlands. J. Plant Pathol. 79, 122–124.

Lenfant, C., Lyoussoufi, A., Chen, X., Darcier, F.F., Sauphanor, B. (1994) Potential of Forficula auricularia L. as a predator of pear-psylla *Cacopsylla pyri* (L). Entomol. Exp. Appl. 73, 51–60.

McLeod, J.H., Chant, D.A. (1952) Notes on the parasitism and food habits of the European earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae). Can. Entomol. 84, 343–345.

Moerkens, R., Gobin, B., Peusens, G., Helsen, H., Hilton, R., Dib, H., Suckling, D.M., Leirs, H. (2011) Optimizing biocontrol using phenological day degree models: the European earwig in pipfruit orchards. Agric. For. Entomol. 13, 301–312.

Moerkens, R., Leirs, H., Peusens, G., Gobin, B. (2009) Are populations of European earwigs, *Forficula auricularia*, density dependent? Entomol. Exp. Appl. 130, 198–206.

Moerkens, R., Leirs, H., Peusens, G., Gobin, B. (2010) Dispersal of single- and doublebrood populations of the European earwig, *Forficula auricularia*: a mark recapture experiment. Entomol. Exp. Appl. 137, 19–27.

Moerkens, R., Leirs, H., Peusens, G., Belien, T. & Gobin, B. (2012) Natural and human causes of earwig mortality during winter: temperature, parasitoids and soil tillage. J. Appl. Entomol. 136, 490–500.

Mueller, T.F., Blommers, L.H.M., Mols, P.J.M. (1988) Earwig (Forficula auricularia) predation on the woolly apple aphid, *Eriosoma lanigerum*. Entomol. Exp. Appl. 47, 145–152.

Nicholas, A.H., Spooner-Hart, R.N., Vickers, R.A. (2005) Abundance and natural control of the woolly aphid *Eriosoma lanigerum* in an Australian apple orchard IPM program. Biocontrol. 50, 271–291.

Noppert, F., Smits, J.D., Mols, P.J.M. (1987) A laboratory evaluation of the European earwig (Forficula auricularia L.) as a predator of woolly apple aphid (*Eriosoma*

lanigerum Hausm.). Mededelingen van de Faculteit Landbouuwwetenschappen Rijksuniversiteit Gent. 52, 413–422.
Phillips, M.L. (1981) The ecology of the common earwig *Forficula auricularia* in apple orchards (Ph.D. thesis), University of Bristol.
Peusens, G., Gobin, B. (2008) Side effects of pesticides on the European earwig *Forficula auricularia* L. (Dermaptera: Forficulidae). Pesticides Beneficial Organ. 35, 40–43.
Peusens, G., Moerkens, R., Beliën, T., Gobin, B. (2009) Side effects of plant protection products and biological interactions on the European earwig *Forficula auricularia* L. Commun. Agric. Appl. Bio. Sci. 74, 411–417.
Ravensberg, W.J. (1981) The natural enemies of the woolly apple aphid, *Eriosoma lanigerum*, and their susceptibility to diflubenzuron. Mededelingen van de Faculteit Landbouuwwetenschappen Rijksuniversiteit Gent. 46, 437–441.
Shaw, P.W., Wallis, D.R. (2010) Susceptibility of the European earwig, *Forficula auricularia*, to insecticide residues on apple leaves. New Zealand Plant Prot. 63, 55–59.
Solomon, M.G., Fitzgerald, J.D., Jolly, R.L. (1999). Artificial refuges and flowering plants to enhance predator populations in orchards. 22, 31–37.
TF 220 (2015) Further development of earwig-safe spray programmes for apple and pear orchards (TF 220) Annual report [online]. Available at: https://horticulture.ahdb.org.uk/sites/default/files/research_papers/TF%20220_Report_Annual_2015.pdf [Accessed on: 20 March 2017].

Appendix

Table 2. Toxicity scores of insecticides commonly used in blackcurrant plantations on *Anthocoris nemoralis*, Coleoptera and *Orius* spp (side effects manual produced by Biobest (2016)). The toxicity score was based on the percentage mortality of the insect after exposure to the insecticide (1 = Harmless (<25%), 2 = Slightly harmful (25-50%), 3 = Moderately harmful (51-75%), 4 = Harmful (>75%)). insecticide (1 = Harmless (<25%), 2 = Slightly harmful (25-50%), 3 = Moderately harmful (51-75%), 4 = Harmful (>75%)).

		chlorpyrifos	lambda-cyhalothrin	pirimicarb		pymetrozine		spinosad		tebufenpyrad	thiacloprid	
		s	s	s	f	s	i	s	i	s	s	i
Anthocoris nemoralis	nymph	4	4	1	?	1	?	2	1	3	4	2
	adult	4	4	1	?	1	?	2	1	3	4	1
	persist	?	?	-	?	-	?	3 d	-	?	?	3 d
Coleoptera	larva	3	4	1	2	?	2	1	1	3	4	4
	adult	3	4	4	4	?	1	1	1	4	3	2
	persist	?	>8 w	1 w	?	?	?	-	-	?	?	?
Orius spp.	nymph	2	4	2	2	2	1	4	2	4	4	2
	adult	4	4	1	2	2	1	4	1	3	4	3
	persist	?	>8 w	5 d	?	1 w	1 w	2 w	?	2 w	2 w	>2 w

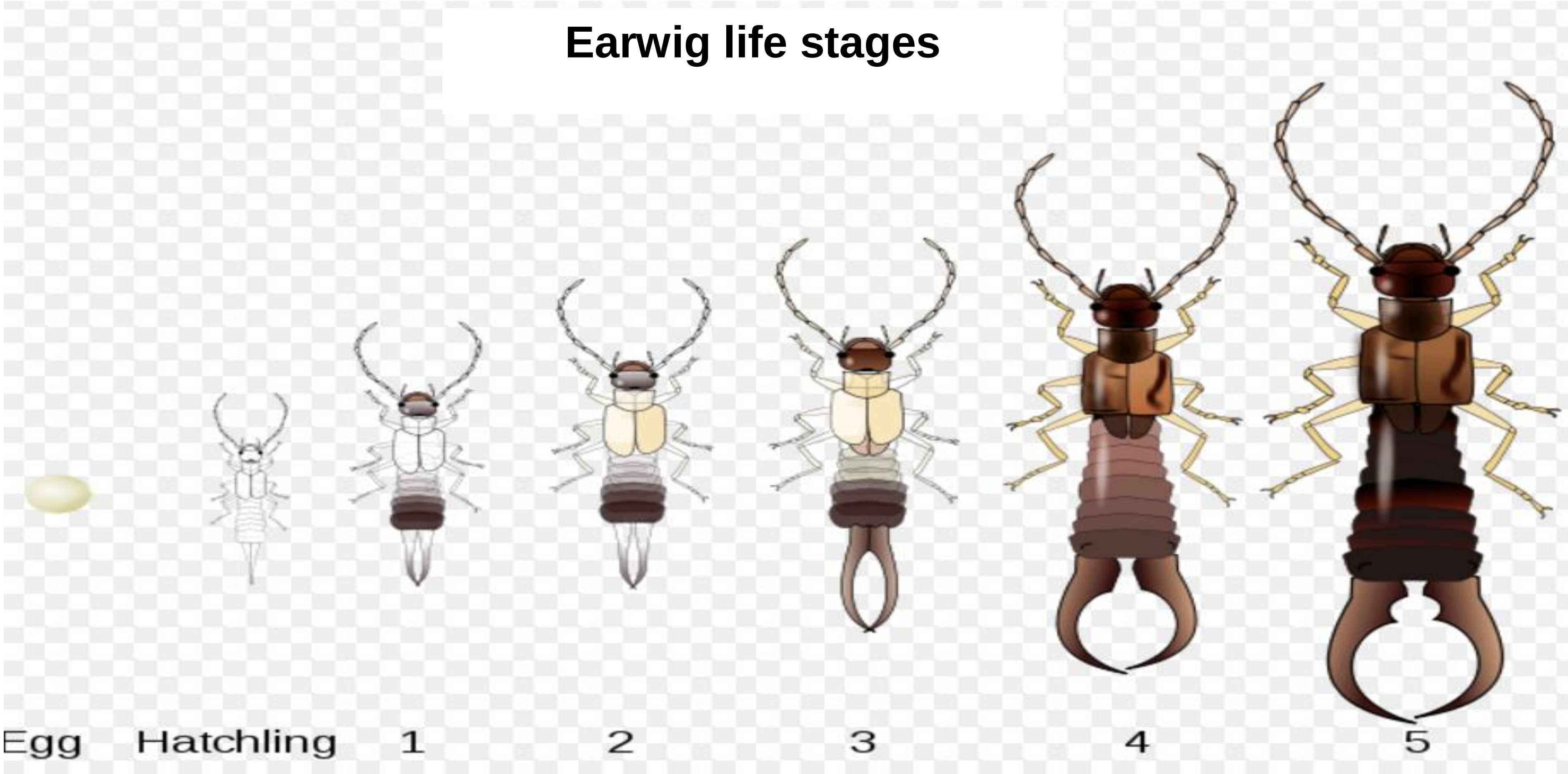

Figure 7. Earwig life stages (https://en.wikipedia.org/wiki/File:Earwig_life_cycle_Sideways.svg)