THE EFFECT OF MOTH TRAP TYPE ON CATCH SIZE AND COMPOSITION IN BRITISH LEPIDOPTERA

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ABSTRACT

Light trapping is a common method for collecting flying insects, particularly Lepidoptera. Many trap designs are employed for this purpose and it is therefore important to know how they differ in their sampling of the flying insect fauna. Here we compare three Robinson-type trap designs, each of which employs a 125W mercury vapour bulb. The first uses a standard bulb; the second uses the same bulb with the addition of a Pyrex beaker, often deployed to prevent bulbs from cracking in the rain, and the third uses a bulb coated with a substance that absorbs visible wavelengths of light (also known as a black light). The black light trap caught fewer moths than either of the other traps, and had lower macromoth species richness and diversity than the standard + beaker trap. This lower species richness could be accounted for by the smaller number of moths caught by the black light trap. Furthermore the black light caught a different composition of both species and families to the other two trap types. Electromagnetic spectra of the three trap types showed the black light trap lacked peaks in the visible spectrum present in both of the other traps. We therefore conclude that the addition of a beaker to a Robinson-type trap does not make catches incomparable, but use of a black light does. These differences are probably due to lower total emission of radiation in the black light trap, thus catching fewer moths overall, and the lack of visible radiation produced, meaning that moths most sensitive to visible wavelengths are not attracted.

INTRODUCTION

Light trapping has long been used as a method for collecting Lepidoptera for a variety of purposes, from biodiversity monitoring (Conrad *et al*., 2006) to pest detection (Hendricks *et al*., 1975). In recent years the analysis of long-term light trapping datasets has revealed drastic declines in many species of British moth (Conrad *et al*., 2006). With such a wide range of uses it is important to know what affects the catch of a moth trap.

A variety of factors are known to affect the numbers and identities of moths caught in a trap. The phase of the moon affects the catch, as does the temperature and degree of cloud cover (Yela & Holyoak, 1997). These factors are not generally under the control of the person carrying out the survey and cannot be manipulated directly. Those which can be controlled include the placement and design of the trap. The height of the trap above the ground can affect the catch (Baker & Sadovy, 1978), but the majority of traps are set at, or near to, ground level. Perhaps the single most important feature is that of trap design.

A wide range of designs are currently used (Muirhead-Thomson, 1991) making comparisons between studies problematic. The Rothamsted trap has an incandescent tungsten filled 200W bulb and often uses a killing jar as the receptacle for insects. The Robinson trap, on the other hand, uses a mercury vapour bulb, and insects are kept alive. The portable Heath trap uses a low wattage strip light and can therefore be run from a car battery (Majerus, 2002). Black lights, which emit predominantly ultraviolet wavelength light, can be used in a variety of traps where light pollution may be an issue, or where the target group is attracted mainly to those wavelengths. Taylor and French (1974) found that a Robinson-type trap caught four times as many moths as a Rothamsted-type trap, demonstrating the large effect trap type can have on catch size. The use of planes of material in proximity to the light source (baffles) to intercept insects is also common (Southwood, 1987). Yela and Holyoak (1997) claim that the most important factor affecting catch size is that of light intensity, with more moths being caught at higher intensities. But this cannot be the only important factor as Williams (1951) found that a 125W ultraviolet bulb caught greater numbers of moths than a 200W standard bulb. Blomberg *et al.* (1976) showed that a black light trap caught fewer moths than a mercury vapour light trap, but there is no mention of the locations of the two traps being rotated between nights, and the black light bulb was considerably less powerful (125W) than the mercury vapour light bulb (160W). So the wide range of trap designs employed is likely to catch differing samples of moths. To our knowledge there is no study which assesses the efficiency of commonly used Robinson-type traps with different bulb set-ups.

This study compares three such trap set-ups. All three traps are of Robinson-type and use three pin bayonet fitting 125W mercury vapour bulbs (supplier: Watkins and Doncaster Entomological Suppliers). One uses a standard bulb only (standard, S), one uses a standard bulb with the addition of a Pyrex beaker to protect it from cracking in the rain (standard + beaker, Bk), and one uses a standard 125W mercury vapour black light bulb (black light, Bl). This consists of a standard bulb coated with a substance which absorbs most visible wavelengths, as supplied by Watkins and Doncaster Entomological Suppliers. We hypothesise that the reduction in visible wavelengths in the black light treatment may reduce catch, while the addition of a beaker might either absorb certain wavelengths, thus reducing the catch, or act as a baffle increasing the catch.

METHODS

Study site

The three traps were placed in an equilateral triangle of side 4.5m by the weather station of Juniper Hall Field Centre, adjacent to a field and also to the field centre gardens. While the close proximity of the traps probably led to some mixing of the moths attracted to the different lights this meant that we could be confident that the same moth community was being sampled by all three traps. They were run for six nights between 20.00 BST and 06.00 BST from 29 June to 4 July 2001. The traps were not run on the night of 1 July. The traps were rotated each night to control for any effects of position on moth catch. Although the traps were run for only a short period of time we feel that since the traps were all in close proximity, observed differences were due to trap design rather than trap location (we were unable to test for this due to small sample size). The weather was warm and dry during the study period with a daytime maximum temperature range of 21.4°C–28.5°C and a night time minimum range of 10.6°C–15.1°C. Cloud cover at 09.00 BST ranged from 0/10 to 8/10 and the total rainfall for the period was 0.6mm.

Identification

Macrolepidoptera were identified to species using Skinner (1998). Microlepidoptera were identified to family using Chinery (1993) and Goater (1986). Note that the micromoth family Pyralidae is employed *sensu lato* to include the subfamilies Pyralinae, Pyraustinae and Crambinae (Goater, 1986).

Statistical methods

Differences across trap types in total moth abundance and macromoth species richness per trap were tested using ANOVA. Moth abundance was logged as population processes are inherently multiplicative (Ian Woiwod, pers.com.). Logged moth abundance was included as a covariate in the analysis of species richness. All residuals were normally distributed with homogeneous variances. Tukey's pairwise comparisons were used to compare individual trap types with each other. Diversity was calculated using Fisher's α (Fisher *et al*., 1943) as this index is not biased by small sample size and has good site discriminant ability when used on light trap macrolepidoptera data (Taylor *et al*., 1976). The index was calculated for the accumulated data for each trap type as this helps to reduce biases caused by small sample size. Fisher standard errors for the diversity index were calculated analytically for the accumulated data (Taylor *et al*., 1976; Magurran, 1988). Pairwise differences in diversity were tested using t-tests (assuming unequal variance). Differences in family composition across the three trap types were tested using chi-square tests on the data summed across all six nights, with an initial test across all three trap types being followed by pairwise tests between trap types. Less abundant families were collapsed into "other" for these tests to avoid expected values less than five. EstimateS 7.5 was used to calculate Fisher's α and its standard error (Colwell, 2004). The ordination technique Detrended Correspondence Analysis (DCA) was used to assess differences in family composition and macrolepidoptera species composition. Species occurring in only a single trap on a single night were excluded from these ordination analyses. Minitab 13.31 was used for all statistical analyses with the exception of the ordinations, which were carried out in Community Analysis Package 1.50.

Electromagnetic Spectra

300-850nm electromagnetic spectra of all three traps were taken using a UV/visible spectrometer in order to relate differences in the wavelengths of emitted light to their moth catches. Total radiation emitted across all wavelengths was calculated by summing the area beneath the spectra.

RESULTS

Abundance, species richness and diversity

In total 4168 moths were caught in the three traps over six nights. These consisted of 689 macromoths (eight families, 95 species, see Appendices 1 and 2) and 3479 micromoths (five families, see Appendix 2). Fewer moths were caught in the black light trap than in either of the other traps (Fig. 1a, ANOVA: $F_{2,15} = 18.05$, $P < 0.001$, Tukey's pairwise comparisons: S-Bl, $P = 0.002$; S-Bk, $P = 0.290$; Bl-Bk, $P < 0.001$). There was no difference in the numbers of macromoths caught by the different trap types (Fig. 1b, ANOVA: $F_{2,15} = 3.54$, $P = 0.055$), although the trend was similar to

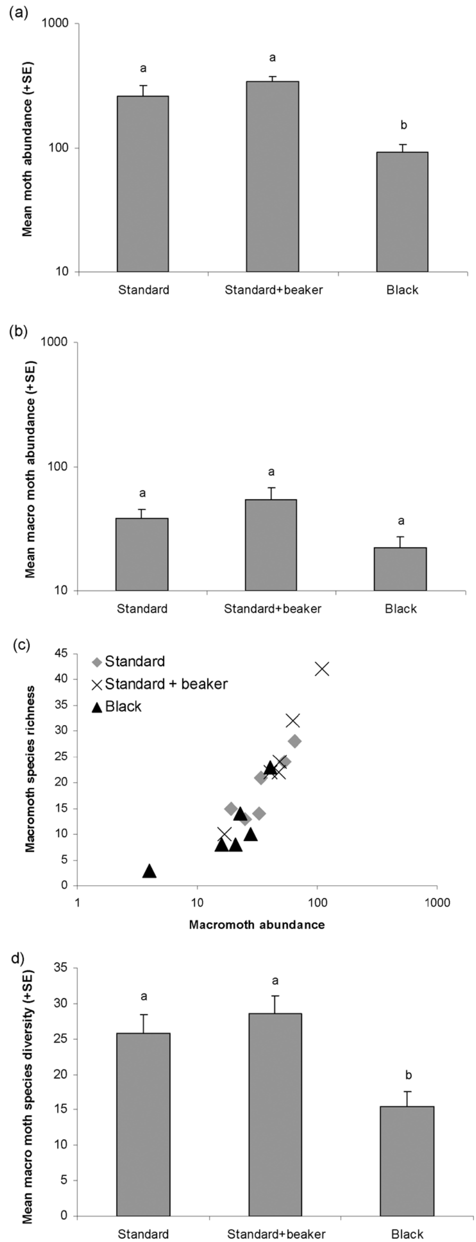


Fig. 1. Comparisons between the three trap types of: (a) total moth abundance, (b) macromoth abundance, (c) macromoth species richness in relation to macromoth abundance, (d) macromoth species diversity (Fisher's α index). Different letters indicate significantly different means.

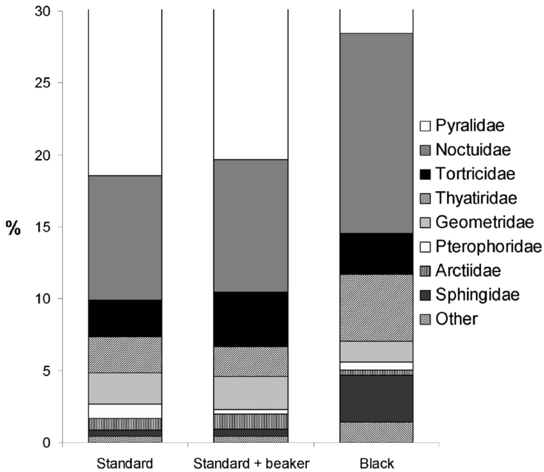
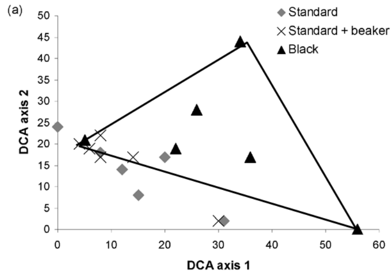


Fig. 2. Relative abundances of moths of different families found in the three trap types summed over all six nights. Note that the y-axis ends at 30%, as the majority of moths caught in all three trap types were pyralids. Families with less than ten individuals in total were summed as "other". These were: Coleophoridae, Drepanidae, Hepialidae, Notodontidae and Tisheriidae.

that seen for total moth abundance. Absolute macromoth species richness was higher in the standard + beaker trap than in the black light trap, while the standard trap did not differ in species richness from either of the other two trap types (ANOVA: $F_{2,15} = 4.63$, $P = 0.027$, Tukey's pairwise comparisons: S-Bl, $P = 0.227$; S-Bk, $P = 0.414$; Bl-Bk, $P = 0.022$). But once macromoth abundance had been taken into account macromoth species richness did not differ among trap types (Fig. 1c, ANCOVA: $F_{2,14} = 0.91$, $P > 0.05$, see Appendix 1 for details of the species caught). The macromoth diversity (Fisher's α) was lower in the black light trap than that in both the standard trap and the standard + beaker trap, while the diversity of the standard and standard + beaker traps did not differ (Fig. 1d, T-tests: S-Bl, $t = 7.30$, d.f. = 10, $P < 0.001$; S-Bk, $t = 1.86$, d.f. = 10, $P = 0.090$; Bl-Bk, $t = 9.67$, d.f. = 10, $P < 0.001$).

Family and species composition

The representation of the moth families differed across the three trap types ($\chi^2 = 96.1$, d.f = 16, $P < 0.001$, Fig. 2, see Appendix 2 for family abundances). The catch of the black light trap differed from that of the other two trap designs (S-Bl, $\chi^2 = 58.5$, d.f = 8, $P < 0.001$; Bl-Bk, $\chi^2 = 68.4$, d.f = 8, $P < 0.001$), while those of the other two trap designs were not different (S-Bk, $\chi^2 = 14.3$, d.f = 8, $P = 0.075$). There was a greater proportion of sphingids, thyatirids and noctuids, and a smaller proportion of pyralids in the black light trap. The high proportion of pyralids caught in all trap types was due mainly to large numbers of grass moths (i.e. *Crambus* spp.). These differences in family composition are also clearly shown in the ordination. The



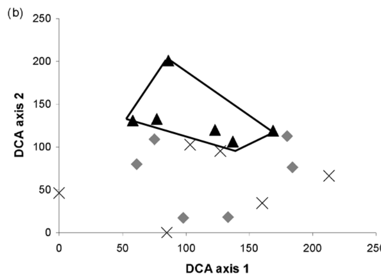


Fig. 3. Ordinations (DCAs) of: (a) family composition and (b) macromoth species composition. Points in close proximity represent traps with a similar moth community, while those far apart represent those with a dissimilar moth community. Polygons show the distribution of the black light trap points. Families and species represented at only one trap on only one night were excluded from the analyses.

points representing black light trap catches cluster in the upper right of the plot (with the exception of a single point) showing that the family composition of this trap differs from that of the other two trap types (Fig. 3a). The family compositions of the standard and standard + beaker traps are similar, as shown by overlapping sets of points representing the catches of these two trap types. The different trap types show a similar pattern to that seen at the family level in terms of macromoth species composition (Fig. 3b). Here the black light catch is completely distinct from the catches of the other two trap types, which are again similar to one another. A Venn diagram of the macromoth species caught in the three trap types shows that the majority of species caught were present either in the standard trap or the standard + beaker trap or both (Fig. 4).

Electromagnetic spectra

The electromagnetic spectra from the standard and standard + beaker traps both show a single peak in the ultraviolet region at 366nm and then further large peaks in the visible region at 405nm, 436nm, 546nm, 578nm and 618nm with a smaller peak on the border of the visible and infrared regions at 698nm (Fig. 5). The spectrum for the black light shows only the 366nm peak in the ultraviolet region, all other peaks being absent. The total amount of radiation emitted was similar for the standard trap and the standard + beaker trap at 0.206μW/cm^2 and 0.253μW/cm^2 respectively, and considerably less for the black light trap at 0.012μW/cm^2.

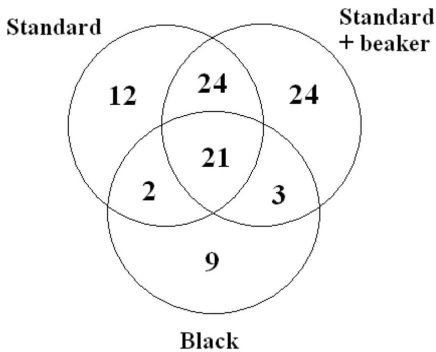


Fig. 4. Venn diagram showing macromoth species caught in the three trap types.

Discussion

The black light trap caught fewer moths overall, catching only 36% and 27% of the numbers caught in the standard and standard + beaker traps, respectively. There were also fewer macromoth species and a lower macromoth diversity in the black light trap compared to the standard + beaker trap. The smaller number of species in the black light trap is what would be expected if one was sampling fewer individuals from the same population as the other two traps. But this does not explain the differences between catches entirely as the black light trap caught a different set of species and families from the other two trap types. So not only will the use of a black light trap give fewer moths, but it gives a different impression of the moth community. Furthermore, out of the 95 species of macromoth caught in total only nine were unique to the black light trap and all of these were singletons. Therefore the use of a black light in place of a standard mercury vapour bulb does not catch extra species of macromoth, but instead catches a characteristic subset of those species caught using the standard set-up.

Is it possible to explain the differences observed in terms of the electromagnetic spectra of the different bulbs? The addition of the beaker does not change the spectrum of the bulb, and this is reflected in the fact that no differences were observed in abundance, species richness, or composition between the standard trap and the standard + beaker trap. Nor does it seem to act as a baffle, although there is a non-significant increase in the overall moth catch of 32% ($P = 0.29$). It is possible that the small catch size of the black light trap is partly due to the reduction in total radiation emitted, as found by Yela and Holyoak (1997). But the difference in community composition between the black light trap and the other two traps, particularly with respect to the pyralids, indicates that the black light is attracting a particular subset of the taxa found in those two traps. Hendricks *et al.* (1975) found that some noctuid pests preferred fluorescent black lights while others preferred green lights, so this is not without precedent. One possibility is that those moths most sensitive to visible wavelengths of light are not attracted to the black light trap.

Certain wavelengths repel some species, as may be the case with the sphingids in this study. There were a greater number of them in the black light trap than the other two traps, indicating that perhaps the visible light emitted by the other traps deters

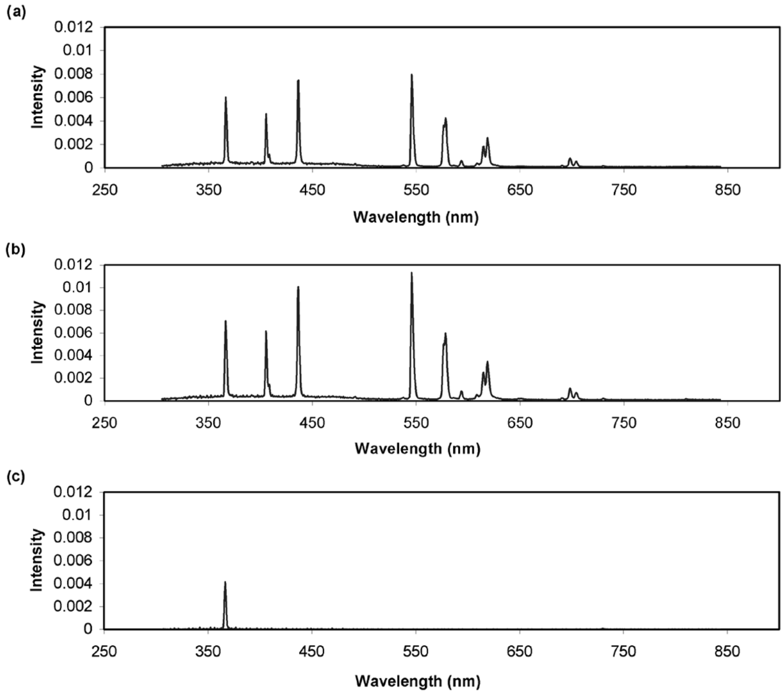


Fig. 5. Electromagnetic spectra (300–850nm) of (a) standard trap, (b) standard + beaker trap and (c) black light trap. This range includes ultraviolet radiation (200–380nm), visible light (380–750nm) and infrared radiation (750nm and above). The unit of intensity is μW/nm/cm^2.

them from entering. Hsiao (1972) has shown that when moths approach very close to a bright light source they are often repelled by it, so this explanation seems likely. It is possible that each species has sets of wavelengths to which it is most attracted or repelled.

In conclusion, the addition of a beaker to a standard Robinson-type trap does not affect the moth catch significantly, whereas painting the bulb with a visible light-reducing coating reduces the total moth catch and macromoth species richness and diversity, catching only a subset of the moths caught by the other two traps. Observation of electromagnetic spectra in relation to this suggests that species respond in different ways to certain wavelengths of light, with species attracted by visible light not being present in the black light trap. Comparative studies of such responses, in conjunction with studies of the species' ecology may shed light on the unsolved mystery of why moths are attracted to light.

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Appendix 1. Macromoth species caught summed over all six nights

		Standard	Standard + beaker	Black
Hepialidae				
Hepialus humuli (L.).	Ghost Moth	3	1	1
Hepialus lupulinus (L.)	Common Swift	0	1	0
Thyatiridae				
Habrosyne pyritoides (Hufn.)	Buff Arches	38	35	26
Tetheella fluctuosa (Hb.)	Satin Lutestring	0	1	0
Thyatira batis (L.)	Peach Blossom	1	6	0

Appendix 1. *(Continued)*

		Standard	Standard + beaker	Black
Drepanidae				
Drepana falcataria (L.)	Pebble Hooktip	0	1	0
Geometridae				
Alcis repandata (L.)	Mottled Beauty	1	3	0
Apeira syringaria (L.)	Lilac Beauty	1	1	0
Biston betularia (L.)	Peppered Moth	2	4	1
Campaea margaritata (L.)	Light Emerald	6	8	0
Camptogramma bilineata (L.)	Yellow Shell	0	1	0
Chloroclysta truncata (Hufn.)	Common Marbled Carpet	1	1	0
Cidaria fulvata (Forst.)	Barred Yellow	1	0	0
Epirrhoe rivata (Hb.)	Wood Carpet	0	0	1
Eulithis pyraliata (D. & S.)	Barred Straw	0	3	0
Eulithis testata (L.)	The Chevron	1	0	0
Eupithecia pimpinellata (Hb.)	Pimpernel Pug	1	1	0
Eupithecia satyrata (Hb.)	Satyr Pug	0	1	0
Eupithecia subfuscata (Haw.)	Grey Pug	0	0	1
Eupithecia succenturiata (L.)	Bordered Pug	0	3	0
Eupithecia tantillaria Boisd.	Dwarf Pug	1	2	1
Eupithecia tenuiata (Hb.)	Slender Pug	0	1	0
Eupithecia valerianata (Hb.)	Valerian Pug	1	0	0
Eupithecia venosata (Fabr.)	Netted Pug	1	0	0
Eupithecia vulgata (Haw.)	Common Pug	0	1	0
Hemithea aestivaria (Hb.)	Common Emerald	0	0	1
Horisme tersata (D. & S.)	The Fern	0	2	0
Idaea aversata (L.)	Riband Wave	6	3	1
Idaea biselata (Hufn.)	Small Fan-footed Wave	2	0	1
Idaea dimidiata (Hufn.)	Single-dotted Wave	1	2	0
Idaea straminata (Borkh.)	Plain Wave	1	0	0
Idaea trigeminata (Haw.)	Treble Brown Spot	0	2	0
Lomaspilis marginata (L.)	Clouded Border	1	2	0
Lomographa temerata (D. & S.)	Clouded silver	1	0	0
*Melanthia procellata (*D. & S.)	Pretty Chalk Carpet	1	0	1
Pasiphila rectangulata (L.)	Green Pug	1	0	0
Peribatodes rhomboidaria (D. & S.)	Willow Beauty	2	4	0
Philereme vetulata (D. & S.)	Brown Scallop	0	1	0
Xanthorhoe fluctuata (L.)	Garden Carpet	0	1	0
Sphingidae				
Deilephila elpenor (L.)	Elephant Hawk-moth	2	4	2
Deilephila porcellus (L.)	Small Elephant Hawk-moth	2	1	6
Laothoe populi (L.)	Poplar Hawk-moth	0	2	2
Mimas tiliae (L.)	Lime Hawk-moth	0	1	1
Smerinthus ocellata (L.)	Eyed Hawk-moth	0	0	1
Sphinx ligustri (L.)	Privet Hawk-moth	3	2	6
Notodontidae				
Notodonta dromedarius (L.)	Iron Prominent	0	1	0
Stauropus fagi (L.)	Lobster Moth	1	3	1

Appendix 1. *(Continued)*

		Standard	Standard + beaker	Black
Arctiidae				
Eilema lurideola (Zink.)	Common Footman	0	4	0
Spilosoma lubricipeda (L.)	White Ermine	2	3	0
Spilosoma luteum (Hufn.)	Buff Ermine	8	11	2
Tyria jacobaeae (L.)	The Cinnabar	2	4	0
Noctuidae				
Abrostola tripartita (Hufn.)	The Spectacle	1	1	2
Acronicta leporina (L.)	The Miller	1	1	0
Acronicta psi (L.)	Grey Dagger	0	1	0
Agrotis clavis (Hufn.)	Heart and Club	14	21	8
Agrotis exclamationis (L.)	Heart and Dart	41	54	30
Apamea lithoxylaea (D. & S.)	Light Arches	7	7	6
Apamea monoglypha (Hufn.)	Dark Arches	9	12	7
Apamea remissa (Hb.)	Dusky Brocade	0	0	1
Autographa gamma (L.)	Silver Y	1	0	0
Autographa pulchrina (Haw.)	Beautiful Golden Y	2	3	0
Axylia putris (L.)	The Flame	3	0	0
Blepharita adusta (Esp.)	Dark Brocade	1	0	0
Charanyca trigrammica (Hufn.)	Treble Lines	1	2	0
Craniophora ligustri (D. & S.)	The Coronet	1	6	2
Diachrysia chrysitis (L.)	Burnished Brass	1	6	0
Diarsia mendica (Fabr.)	Ingrailed Clay	0	0	1
Euxoa nigricans (L.)	Garden Dart	1	3	2
Hada plebeja (L.)	The Shears	0	4	1
Herminia grisealis (D. & S.)	Small Fan-foot	1	2	0
Hoplodrina blanda (D. & S.)	The Rustic	3	7	8
*Hypena proboscidalis (*L.)	The Snout	6	10	0
Lacanobia oleracea (L.)	Bright-lined Brown-eye	1	1	0
Lacanobia w-latinum (Hufn.)	Light Brocade	0	0	1
Laspeyria flexula (D. & S.)	Beautiful Hooktip	0	2	0
Lygephila pastinum (Treit.)	The Blackneck	0	1	0
Melanchra persicariae (L.)	Dot Moth	3	2	0
Melanchra pisi (L.)	Brom moth	0	2	0
Mesapamea secalis (L.)	Common Rustic	0	0	1
Mythimna comma (L.)	Shoulder-Striped Wainscoat	1	1	3
Mythimna ferrago (Fabr.)	The Clay	2	0	0
Mythimna impura (Hb.)	Smokey Wainscot	11	10	0
Mythimna obsoleta (Hb.)	Obscure Wainscoat	0	0	1
Mythimna pallens (L.)	Common Wainscot	1	4	0
Noctua pronuba (L.)	Large Yellow Underwing	3	5	0
Ochropleura plecta (L.)	Flame Shoulder	3	3	0
Oligia strigilis (L.)	Marbled Minor	9	12	2
Photedes minima (Haw.)	Small Dotted Buff	0	1	0
Polia trimaculosa (Esp.).	Silvery Arches	0	1	0
Protodeltote pygarga (Hufn.)	Marbled White-spot	0	1	0
Pseudoips prasinana (L.).	Green Silver Lines	0	1	0
Rivula sericealis (Scop.)	Straw Dot	3	7	0
Rusina ferruginea (Esp.)	Brown Rustic	1	0	0
Xestia c-nigrum (L.)	Setacious Hebrew Character	0	2	0
Xestia triangulum (Hufn.)	Double Square-spot	2	3	1
Total abundance		229	327	133
Total species richness		59	72	35

Appendix 2. Numbers of individuals of each moth family caught summed over six nights

	Standard	Standard + beaker	Black
Hepialidae	3	2	1
Thyatiridae	39	42	26
Drepanidae	0	1	0
Geometridae	33	47	8
Sphingidae	7	10	18
Notodontidae	1	4	1
Arctiidae	12	22	2
Noctuidae	134	199	77
Coleophoridae	3	2	4
Pterophoridae	16	6	3
Pyralidae	1266	1646	397
Tisheriidae	0	0	2
Tortricidae	40	78	16
Totals	1554	2059	555

SHORT COMMUNICATION

Physatocheila smreczynskii **China (Hemiptera: Tingidae) in the Tamar Valley of Cornwall and Devon**. – The apple-tree lacebug has a very restricted distribution across the southern English counties. It has been known in Devon for some time – 'not common' (Bignell, 1906) – but no details of the old Devon records have yet been found and there appear to be no subsequent records. The discovery of a population at Slew Orchard, Sydenham Damerel (SX4074), 23.viii.2004, is therefore worth reporting. This orchard is predominantly old cherries but also includes a few old apple trees. Another population was found on a group of three remnant old orchard apple trees at Haye Farm, Bohetherick, St Dominick (SX4167), in East Cornwall, 20.vii.2006.

In both cases the lacebugs were associated with a very small number of apple trees. The St Dominick area has many other remnant orchards but no other populations could be found. Similarly in south Devon in 2004, two other areas of apple orchards failed to produce any lacebugs. This suggests that the species is capable of surviving on small groups of old apple trees but is of very restricted occurrence and relatively immobile – it appears not to readily colonise other apple trees even when relatively close by. The St Dominick site is the second known from Cornwall (Alexander, 2005).

The Slew survey was part of a wider English Nature commissioned project on orchard wildlife, while the St Dominick work was part of a survey of the National Trust's Cotehele Estate. There is now a Tamar Orchards project. The increasing interest in the conservation of traditional orchards is good news. – KEITH N.A. ALEXANDER, 59 Sweetbrier Lane, Heavitree, Exeter EX1 3AQ.

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