



# Parasitoid communities attacking externally feeding folivorous Lepidoptera in New Guinea rainforest

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### **Annotation**

The host - parasitoid community of externally feeding folivorous Lepidoptera and their parasitoids was studied on 45 focal tree species in a New Guinea rainforest. The patterns of parasitisation rate, parasitoid species richness and parasitoid host specificity are described.

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## INTRODUCTION

### **Plant - herbivore - parasitoid food webs**

The study of food webs consisting of plants, their herbivores and parasitoids is a field of biology studying at least 75% or more of global terrestrial biodiversity (Price, 2002). Most of the global diversity which has been recently estimated at <10 million species of arthropods alone (Novotny *et al.*, 2007), has not been described and catalogued, even though the biologists are systematically working on this from the times of Karl Linné (Godfray *et al.*, 1999). Much more interesting and more laborious than mere cataloging of species is finding out how they interact in nature. Despite accelerating progress, this field is still in its early stage with many ideas how the species interactions should work, but severe limitation by the availability of experimental data (Godfray *et al.*, 1999; Janzen, 1983). Even when we omit parasitoids and concentrate on the plant - herbivore interactions, the diversity is so huge that we can find only few larger systems (those which cover more than several species) which have been studied in detail, permitting generalisations (Dyer *et al.*, 2007; Janzen, 1988; Novotny *et al.*, 2002b). The few general patterns found can still be contradictory as they are often documented from very few sites (Dyer *et al.*, 2007; Novotny *et al.*, 2006). Such studies are based on tens of thousands person-days spent collecting insects in the field, processing and identifying them (Novotny *et al.*, 2002a).

The host - parasitoid interaction has proven even more difficult to study due to several factors. The greatest problem is sample size, simply because there are fewer individuals in higher trophic levels. The rearing of parasitoids is also complicated by often difficult species identification of immature hosts, which is however necessary for unambiguous coupling of parasitoid with its host. The difficulties are however balanced by the attractivity of parasitoids so there are no fewer studies concentrating on them than on herbivores.

The boom of the study of parasitoid - host interactions is usually dated to the 1880s when the vedalia beetle (a predator) was introduced in California for the biological control of the cottony cushion scale on citrus trees (Hawkins & Sheehan, 1994). This event started an intense interest in the use of natural enemies to control insect pests which continues at a somewhat lower pace also during the last decades. Since the pioneer studies by Askew (1961) and Price (1970) the emphasis is shifting towards studying complex communities in natural habitats (Hawkins & Sheehan, 1994).

Among the first communities studied were inhabitants of galls with their parasitoids (Askew, 1961; Price, 1970) and miners with their parasitoids (Memmott *et al.*, 1994; Rott & Godfray, 2000). Both systems have proven amenable to study for the relative ease with which it is possible to sample and identify the insects, which is also the reason why gall and miner communities account for most of the studied systems (Lewis *et al.*, 2002; Rauf *et al.*, 2000; Schonrogge & Crawley, 2000; Valladares *et al.*,

2001). Other studies concentrated on Macrolepidoptera (Barbosa *et al.*, 2001; Gentry & Dyer, 2002; Lill *et al.*, 2002; Sheehan, 1994; Stireman & Singer, 2003), Tortricidoidea (Mills, 1993), sawflies (Price & Pschornwalcher, 1988), aphids (Muller *et al.*, 1999), grass feeding chalcids (Dawah *et al.*, 1995; Tschardtke *et al.*, 2001) or solitary bees and wasps (Tylianakis *et al.*, 2007).

Distinctly different approach to the study of host - parasitoid interactions was pioneered by Hawkins (1994), whose meta-analytical research introduced a number of general patterns and serves an important background to which any new work can be related.

### **Results of previous host - parasitoid studies**

The parasitoids occupy high positions in the food chain and the ecological and evolutionary forces affecting them mostly originate in lower levels of the food web (Price, 1992). Hawkins (1994) found the host feeding niche to be the single most important factor structuring host - parasitoid communities (see also Gentry & Dyer, 2002). Other factors were reported to be important, such as host plant (Lill *et al.*, 2002), host plant range of the herbivore, herbivore gregariousness, hairiness and aposematism (Stireman & Singer, 2003) and chemicals sequestered by the host (Gauld & Gaston, 1994; Gentry & Dyer, 2002). A correlation of climatic unpredictability with parasitoid rate had also been suggested (Stireman *et al.*, 2005). The differences in parasitoid host use inspired important theoretical developments, such as the concept of koinobiont - idiobiont (Askew & Shaw, 1985) or the concept of parasitoid guilds (Mills, 1994).

The species in natural communities are highly interconnected (Lewis *et al.*, 2002) and therefore apparent competition has been suggested to be important in host - parasitoid communities (Godfray *et al.*, 1999; Holt & Lawton, 1993). Its existence was recently also confirmed experimentally (Morris *et al.*, 2004).

Interesting results emerge when it is possible to compare two or more food web datasets which are ordered along some gradient. Tylianakis *et al.* (2007) have shown in such study that the evenness of the interactions declined with increasing habitat modification while the species richness stays constant.

The community structure was found to be different even when Tschardtke *et al.* (2001) compared grass feeding chalcid wasp communities in Great Britain and Germany. They found the British communities non-saturated (consider the contrast of great and numerous British naturalists with the comparatively poor biodiversity in their homeland).

The knowledge about natural systems can be also used in predicting the potential of natural enemies for biological control (Dyer & Gentry, 1999) or for assessing impact of species introduced for biological control on the native communities (Henneman & Memmott, 2001).

The dynamics of host - parasitoid communities is very interesting, but it proved very hard to study. The data from studied systems have to be usually pooled over several

years to produce one "snapshot" of the community with reasonable sample size. Moreover there is the problem of how to sample the community repeatedly without influencing its dynamics. Several community dynamics studies exist despite of these complications (Lewis *et al.*, 2002; Muller *et al.*, 1999; Valladares & Salvo, 2001) but extend only over 1, 2 or 3 years and therefore deal mostly with seasonal variation.

The question whether there are differences between tropical and temperate host - parasitoid communities is very intriguing (Godfray *et al.*, 1999), but the studies of this problem have usually dealt only with parasitoid species richness (Noyes, 1989), focusing particularly on decreasing species richness of Ichneumonidae along the latitudinal gradient (Janzen, 1981; Owen & Owen, 1974; Sime & Brower, 1998). Such results are interesting, but tell us little about the structure of host - parasitoid communities. The tropical Lepidoptera hosts have also been suggested to be "nastier" for predators and therefore better targets for parasitoids than their temperate counterparts (Gauld & Gaston, 1994). The parasitoid species richness per host species tends to be higher in temperate regions for externally feeding hosts (Hawkins, 1994). In the study of Stireman *et al.* (2005) the parasitization rate did not significantly correlate with latitude. Lewis *et al.* (2002) found the tropical miner parasitoids to be highly polyphagous, which is the case also for temperate leaf miner parasitoids (Hawkins, 1994; Rott & Godfray, 2000). The evidence for either similarity or distinctness of tropical and temperate host - parasitoid communities is contradictory in overall and the need of more data for both regions is evident.

### **Purpose of this study**

The purpose of this study is to describe patterns in parasitization of externally leaf feeding Lepidoptera reared in the mass rearing project of Novotny *et al.* (<http://www.entu.cas.cz/png/>).

The dataset is interesting in several aspects: (i) it is the first quantitative dataset covering both externally leaf feeding Macrolepidoptera and Microlepidoptera, (ii) both Hymenoptera and Diptera parasitoids are included and (iii) the study site lies in tropical rainforest with low seasonality. My aim is to describe parasitization rate, parasitoid species richness and parasitoid host specificity in this host - parasitoid community.

## METHODS

### Data gathering

The study area is in the vicinity of Madang town in Papua New Guinea. Average annual rainfall in this area is 3,600 mm, with a moderate dry season from July to September and mean air temperature 26.5°C (McAlpine *et al.*, 1983). The vegetation cover is species-rich evergreen rainforest. Fieldwork was conducted in primary and secondary lowland forests near Baitabag, Ohu and Mis Villages (145°41–7'E, 5°08–14'S, 0–200 m a.s.l.) during the years 1999-2004.

The insects were collected on 45 focal tree species (Appendix A) which were chosen to include representatives of main angiosperm lineages (monocotyledons, basal eudicots, euasterids I and II, and eurosids I and II; APG II, 2003) as well as locally common plants from primary and secondary forest and riverine habitats (Leps *et al.*, 2001). All but one species were native, the exception being *Piper aduncum* which was introduced from the Neotropics, but has already attained caterpillar community indistinguishable from native trees (Leps *et al.*, 2002).

All Lepidoptera caterpillars feeding externally on leaves were collected from the vegetation by local collectors. Sampling effort was standardized to approximately 1500m<sup>2</sup> of leaf area per plant species and each plant species was sampled over one year to control for seasonal effects. The number of tree inspections, that is, a particular tree sampled at a particular time, exceeded 1000 per plant species.

The caterpillars were brought to the rearing facility and provided with leaves of the plant they were collected on. Only the caterpillars that fed were retained, morphotyped by parataxonomists and reared until a moth or a parasitoid hatched or the caterpillar died. Hyperparasitoids were not distinguished from parasitoids.

Adult moths were morphotyped by parataxonomists and later identified by taxonomists. The morphospecies thus correspond to species, albeit sometimes undescribed. The identification and especially the matching of sexes was aided by ~4000 mitochondrial CO I sequences (barcodes). Reared parasitoids were morphotyped by the author and then sent to taxonomists specialized to particular groups for identification (see acknowledgements for the list of taxonomists). The identifications of only two subfamilies of Braconidae (Cheloninae and Macrocentrinae) came back in time to be included in the analysis, while other identifications are based on my morphospecies identifications only. Several hundreds of mitochondrial CO I barcodes are planned to help with the parasitoid identifications. Both moth and parasitoid specimens are stored in USNM as well as other major museums.

The parasitoids were connected with the host through the caterpillar morphospecies code. All moth specimens reared from a particular caterpillar morphospecies code were checked and if at least 95% of them belonged to one species then the parasitoids



reared from caterpillars of that code were marked as parasitising the corresponding moth species.

In this way, 45.2% of parasitoid species and 45.5% of parasitoid specimens could be assigned with at least 95% confidence (usually much higher) to host species. Further 24.3% of species and 41.9% of parasitoid specimens could be safely assigned to host genera. Another 16.5% of species and 7.5% of specimens could be safely assigned to host family. Only 14.0% of species and 5.1% of specimens could not be safely associated with any host taxon. Such parasitoid species were mostly rare.

### **Data analysis**

A simplified concept of "most probable host" was used in the analyses, associating the parasitoid with the moth which made up highest proportion of the specimens reared. This inevitably brought some factual error in the dataset, but greatly simplified the data analysis.

The variables were used as follows:

Parasitisation rate as the proportion of parasitoid rearings from all successful rearings.

Parasitoid species richness as the number of parasitoid species attacking a particular host.

Parasitoid host specificity as the number of hosts recorded for a parasitoid.

Caterpillar feeding mode as a factor with two levels: semi concealed and free living.

Leaf rolling and web making caterpillars were regarded as semi concealed (mostly Tortricidae, Crambidae, Thyrididae, Choreutidae, Pyralidae, Gelechiidae, Elachistidae and Immidae) and all others as free living (mostly Geometridae, Noctuidae, Lymantriidae, Arctiidae, Nolidae, Nymphalidae, Lycaenidae, Lacturidae, Limacodidae and Sphingidae). Appendix B gives the list of host species together with their feeding mode.

Host taxonomy as a factor with six levels corresponding to taxonomic groups shown in Fig.1.

All variables were log transformed prior to analysis. Untransformed variables were used in the figures.

Regressions were performed with lm function in R environment (R Development Core Team, 2006)

## RESULTS

### General characteristics of the hosts

Altogether 49,019 externally feeding caterpillars were collected from 45 focal trees (Appendix A). The overall rearing success was 34% leading in 15,001 Lepidoptera hosts and 1,602 Hymenoptera and Diptera parasitoids reared (total parasitisation rate of 9.6%). The rearing success of the Lepidoptera species was highly variable with the mean of  $30.6 \pm 16.6$  (SD).

A total of 274 host species from 28 families were reared (Appendix B). The most species rich groups were Pyraloidea (Crambidae + Pyralidae) with 48 species followed by Geometridae (43), Tortricidae (39) and Noctuidae (37). These four groups make up 61% of the host species and the next most common families significantly lag behind them (Thyrididae with 16 and Choreutidae with 13 species) (see Appendix C for the complete list of families). The taxonomic composition of species reared in this study is compared to other sites where mass rearing of externally feeding caterpillars took place in Fig. 1.

The abundance of individual species was highly unequal with only 42 species reaching over 100 individuals (with a maximum of 892) and 150 species having only 10 or less reared individuals.

Of the 274 host species, 134 were free living and 140 were semi concealed. Although the proportion of species was about 50% for each feeding mode, the semi concealed hosts were much more common making 77.8% of reared caterpillar specimens, leaving only 22.2% to free living caterpillars. Also majority of common species were semi concealed feeders, so there were only ten free living species in the fifty most common hosts.

### General characteristics of the parasitoids

Altogether 1,602 parasitoid specimens of 266 species were reared from 105 host species. About two thirds of them were Hymenoptera and the other third were Diptera: Tachinidae. The Hymenoptera were mostly Ichneumonoidea but several Chalcidoidea and Bethyloidea parasitoids were also reared. Only one tenth of the Ichneumonoidea were Ichneumonidae with the rest being different subfamilies of Braconidae. Table 1 details the number of specimens reared and the number of species for each taxonomic group.

### Data analysis

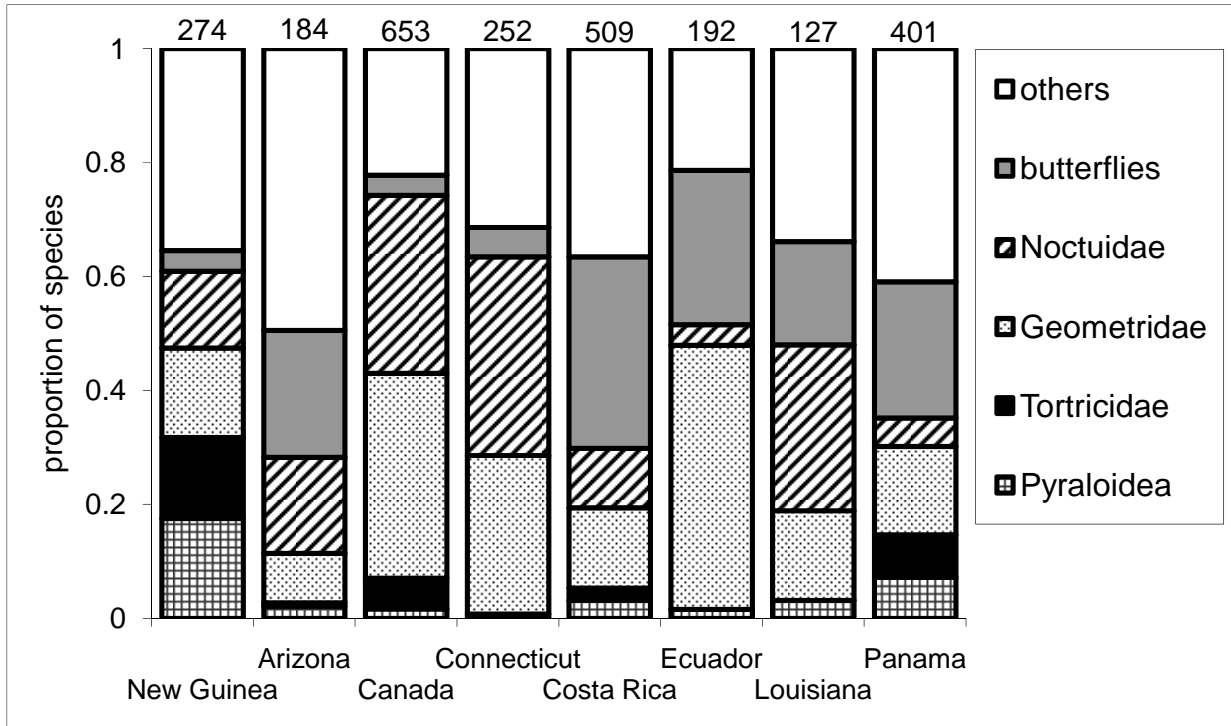
The statistical analyses were performed with the assumption of the most probable host (explained earlier in the methods) and with datasets restricted to more common species. Table 2 summarizes the restrictions imposed to the datasets and shows the proportion of the data satisfying the criteria.

**Table 1. Taxonomic affiliation of reared parasitoids.**

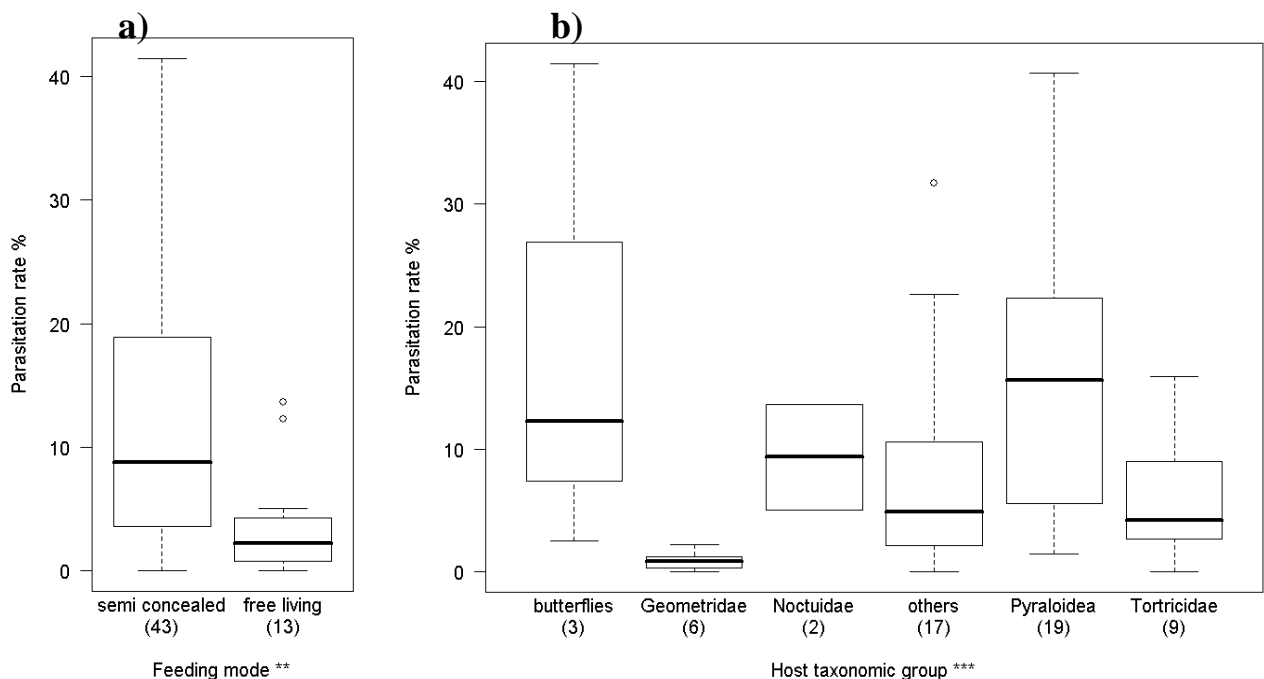
Taxonomy		Specimens	Species	
Hymenoptera	Braconidae	Microgastrinae	581	86
		Agathidinae	123	20
		Cardiochilinae	88	1
		Orgilinae	41	9
		Rogadinae	35	16
		Cheloninae	30	8
		Macrocentrinae	13	3
		Meteoridiinae	2	1
Hymenoptera	Ichneumonidae	99	19	
Hymenoptera	Chalcidoidea	12	7	
Hymenoptera	Bethylidae	8	2	
Diptera	Tachinidae	570	94	
		1602	266	

**Table 2. Details for analysed datasets.**

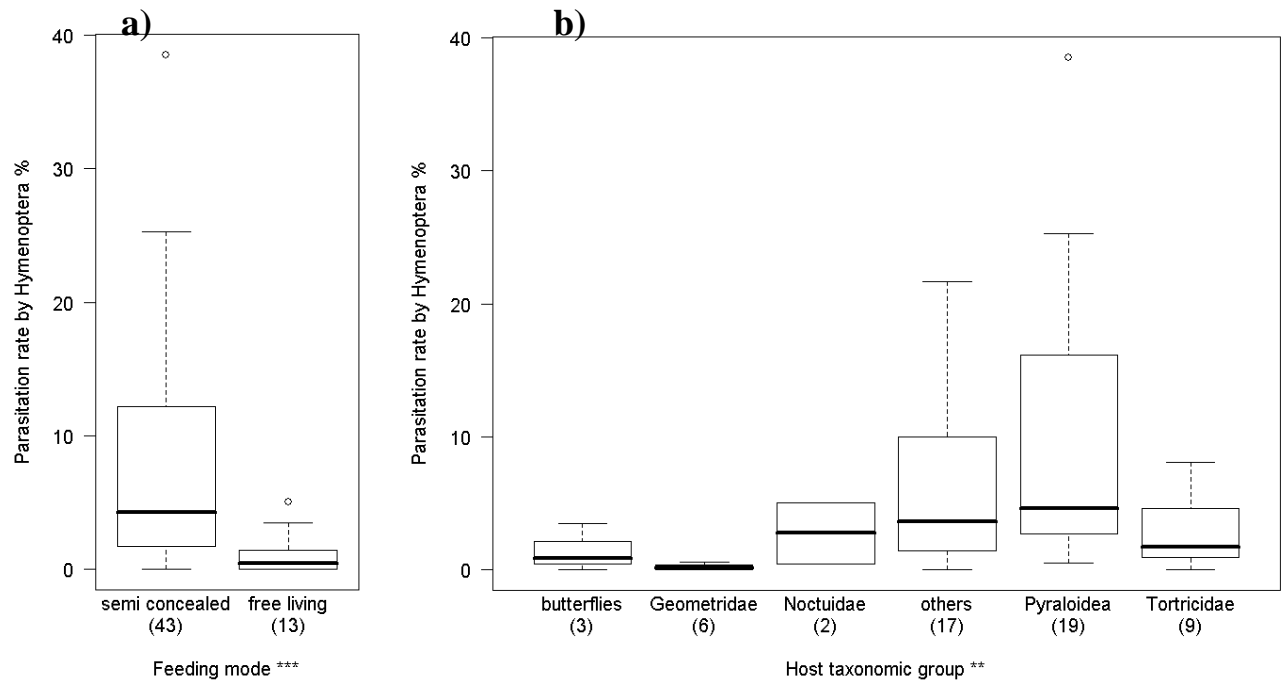
	Whole Dataset	Parasitisation rate analysis	Parasitoid species richness analysis	Parasitoid host specificity analysis
<b>the limit imposed</b>		50+ rearings	50+ rearings, host species with no parasitoids excluded	5+ reared parasitoids
<b>no. of host specimens</b>	15001	11743	11336	9651
<b>no. of parasitoid specimens</b>	1602	1465	1465	1300
<b>no. of host species</b>	274	56	52	60
<b>no. of parasitoid species</b>	266	203	203	58



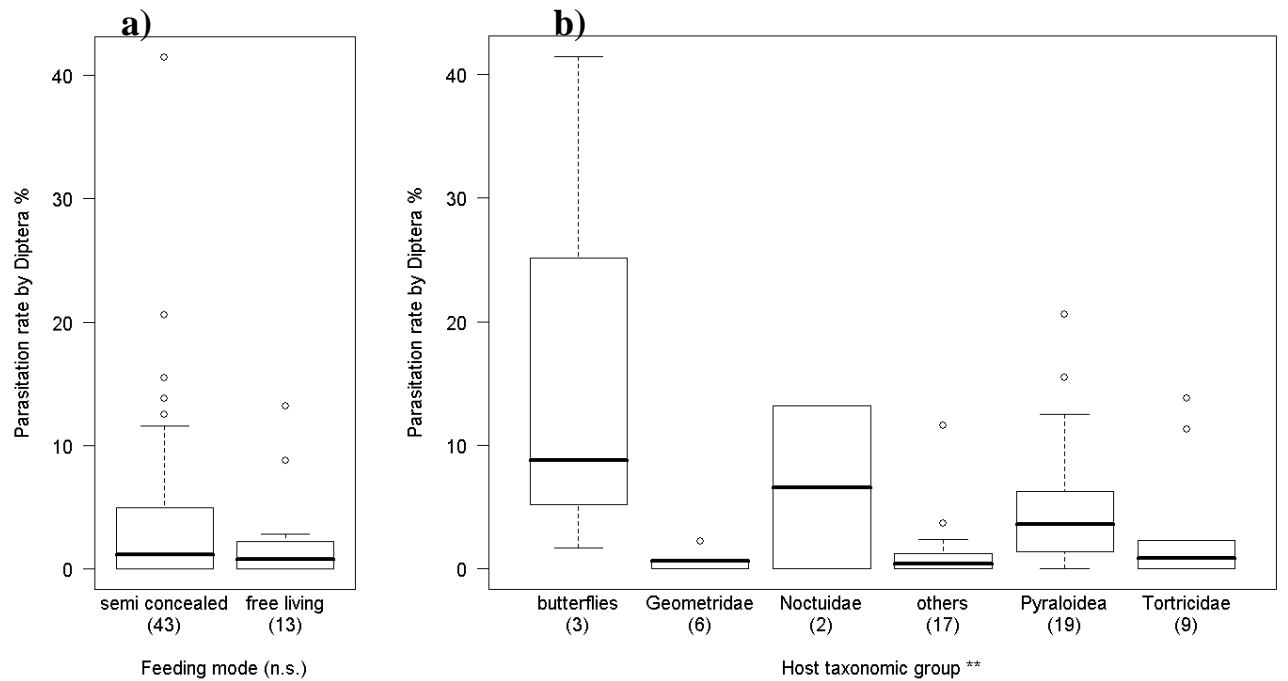
**Figure 1. Taxonomic composition of reared species in the most extensive Lepidoptera rearing programs.** The data used in this study are in the first column, the remaining data are from Dyer et al. (2007). Lepidoptera families representing less than 12% of species on the locality with their highest relative species richness were combined into category "others." Total number of species reared at each site is shown at the top of each bar.



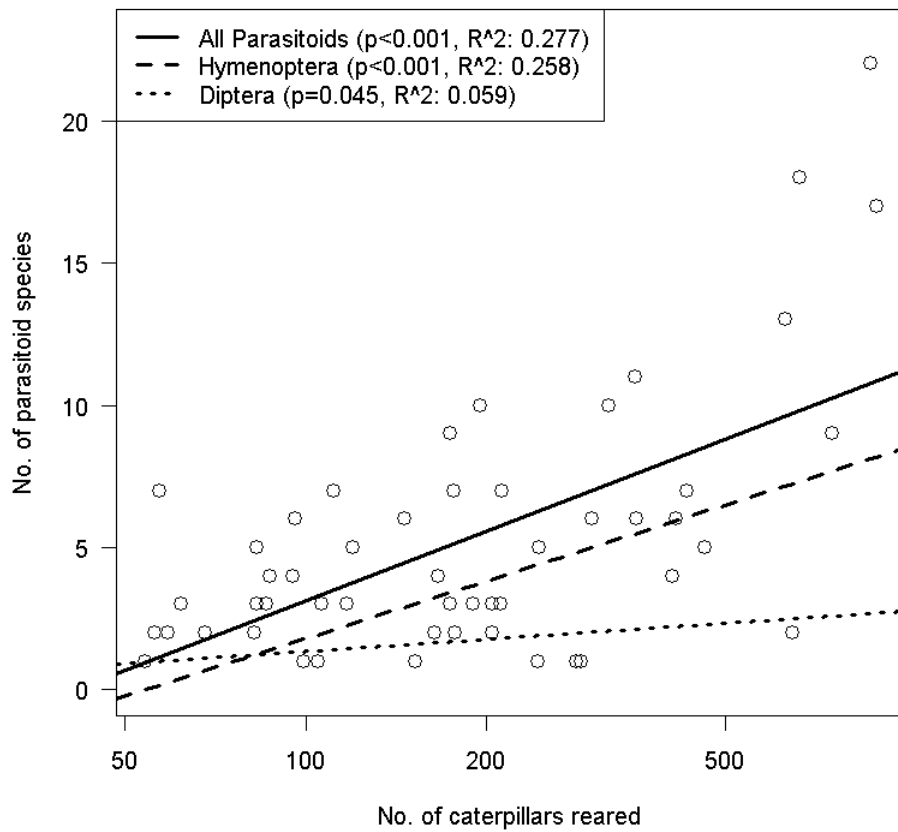
**Figure 2. Parasitization rate categorised by feeding mode (a) and host taxonomy (b).** The box shows first to third quartile with median as horizontal line, the whiskers show adjacent values and outliers are plotted as circles. Significance of a factor in linear model where the graphed factor is the only explanatory variable is marked as follows: '\*\*\*'  $p < 0.001$  '\*\*'  $p < 0.01$  '\*'  $p < 0.05$  '(n.s.)' not significant. The number of moth species in each category is shown in parentheses under the category name.



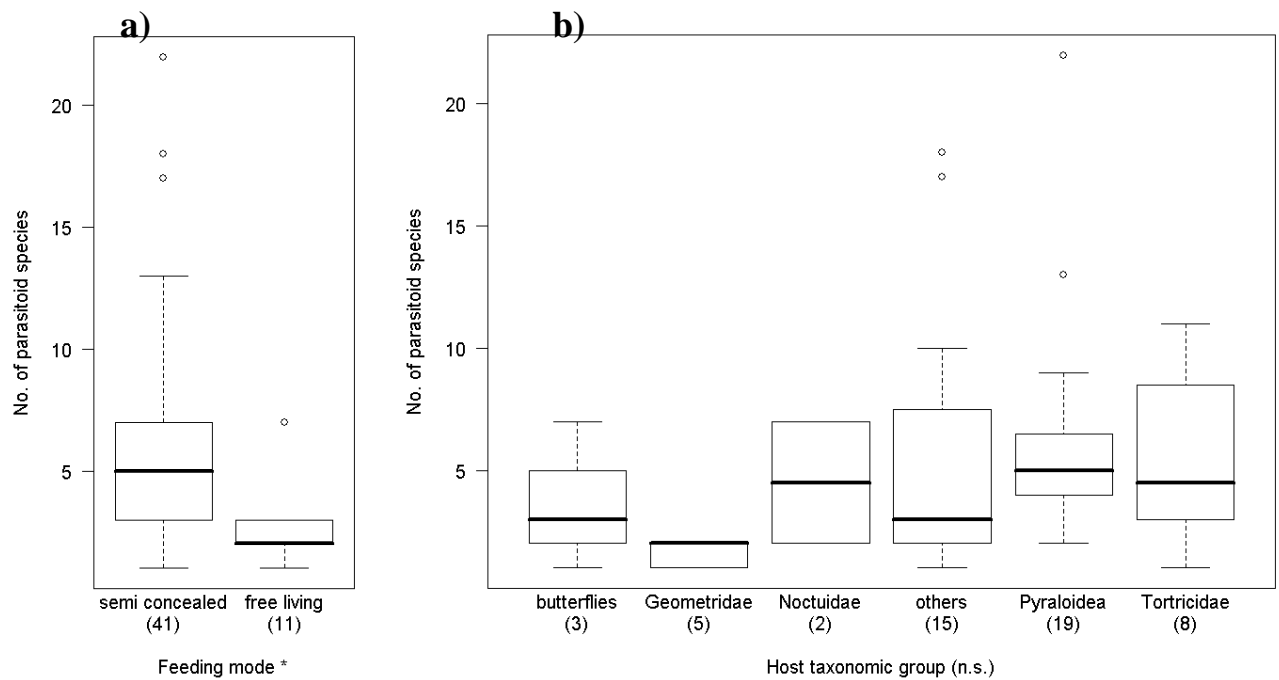
**Figure 3. Parasitization rate by Hymenoptera categorised by feeding mode (a) and host taxonomy (b).** The symbols are explained in legend to Fig. 2.



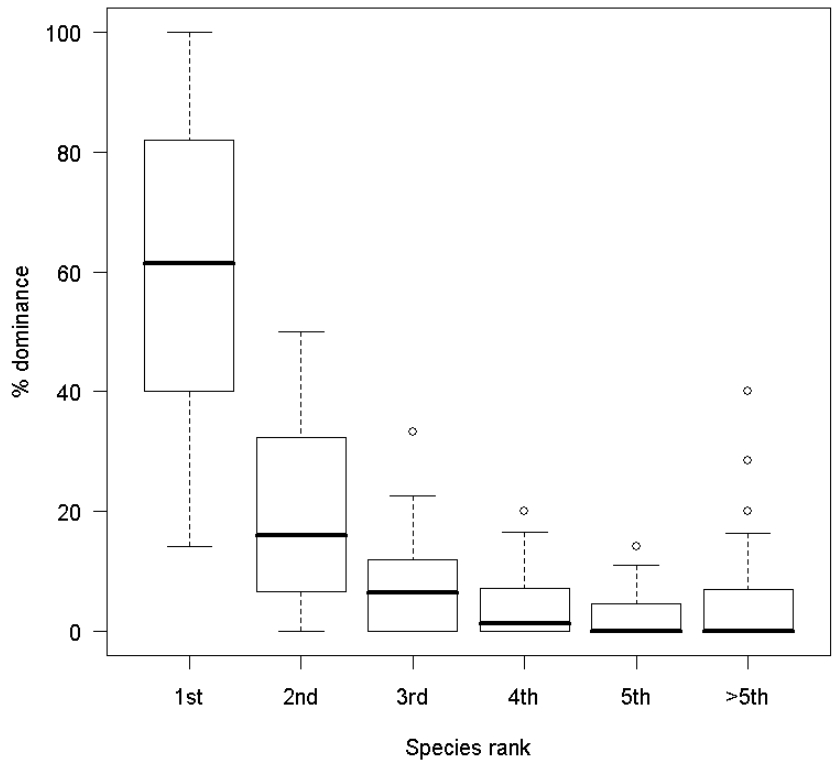
**Figure 4. Parasitization rate by Diptera categorised by feeding mode (a) and host taxonomy (b).** The symbols are explained in legend to Fig. 2.



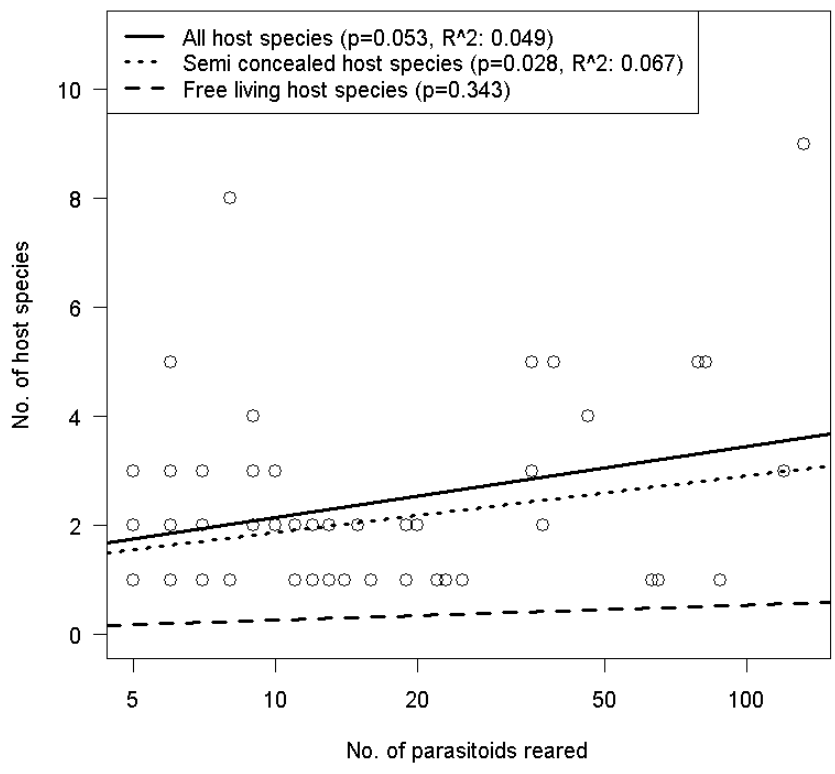
**Figure 5. The relationship between sample size and parasitoid species richness.** Both points and regression line are shown for total parasitoid species richness while only regression lines are shown for Hymenoptera and Diptera parasitoid species richness.



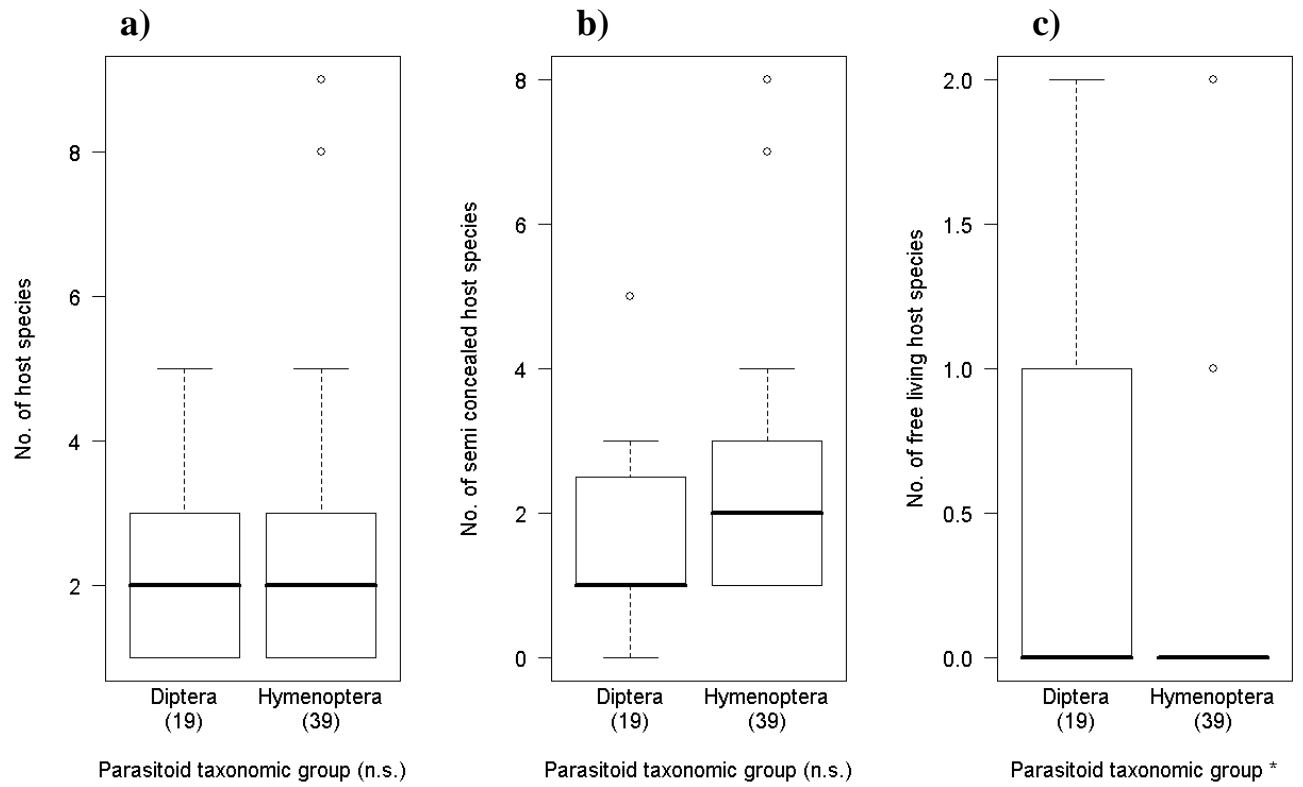
**Figure 6. Parasitoid species richness categorised by feeding mode (a) and host taxonomy (b).** The symbols are explained in legend to Fig. 2.



**Figure 7. Dominance in parasitoid communities feeding on particular Lepidoptera host species.** The proportion of individuals represented by the most abundant parasitoid species (1–5) and by all remaining species combined (rank > 5) is reported for 52 most common Lepidoptera host species (medians with first and third quartiles as boxes, adjacent values as whiskers, outliers as circles).



**Figure 8. The relationship between sample size and parasitoid host specificity.** Both points and regression line are shown for overall host specificity while only regression lines are shown for semi concealed and free living host specificity.



**Figure 9. Host specificity (a), semi concealed host specificity (b) and free living host specificity (c) for different parasitoid taxa.** The symbols are explained in legend to Fig. 2. Note different scale on y axes.



### **Parasitisation rate**

The overall parasitisation rate was 5.6% (2.5 – 15.7, median with lower and upper quartile) and the rate caused by Hymenoptera (3.1%, 0.6 – 7.6) was significantly higher than that caused by Diptera (1.1%, 0.0 – 3.9) ( $p = 0.031$ , double sided Wilcoxon test).

The variable most strongly correlated with parasitisation rate was number of parasitoid species ( $p < 0.001$ ,  $R^2 = 0.438$ ). Number of specimens reared from a moth species was not correlated with parasitisation rate ( $p = 0.578$ ). The caterpillar feeding mode significantly influenced parasitisation rate ( $p = 0.002$ ,  $R^2 = 0.155$ ) with semi concealed hosts suffering higher parasitisation rate than free living (8.7%, 3.6 – 18.9 or 2.3%, 0.8 – 4.3 respectively, Fig. 2a). The effect of host taxonomy was highly significant ( $p < 0.001$ ,  $R^2 = 0.271$ , Fig. 2b) with Geometridae being significantly different from all other groups at 0.05 significance level. The effects of host feeding mode and taxonomy were complementary to some degree, but the combined model was significantly better than either feeding mode or taxonomy alone (ANOVA,  $p < 0.01$  in both cases) and explained more variance than the single models ( $p < 0.001$ ,  $R^2 = 0.351$ ).

Parasitisation rate caused by Hymenoptera was most strongly correlated with number of Hymenoptera parasitoid species ( $p < 0.001$ ,  $R^2 = 0.580$ ) and the effect of number of reared specimens was not significant ( $p = 0.368$ ). The caterpillar feeding mode significantly influenced Hymenoptera parasitisation rate ( $p < 0.001$ ,  $R^2 = 0.199$ ) with semi concealed hosts suffering higher Hymenoptera parasitisation rate than free living (4.3%, 1.7 – 12.2 or 0.5%, 0.0 – 1.4 respectively, Fig. 3a). The effect of host taxonomy was significant ( $p = 0.002$ ,  $R^2 = 0.241$ , Fig. 3b). The effects of host feeding mode and taxonomy were highly complementary, so the combined model was not significantly better than either feeding mode or taxonomy alone (ANOVA,  $p = 0.108$  or  $p = 0.127$  respectively).

Parasitisation rate caused by Diptera was most strongly correlated with number of Diptera parasitoid species ( $p < 0.001$ ,  $R^2 = 0.512$ ) and the effect of number of reared specimens was not significant ( $p = 0.790$ ). The caterpillar feeding mode did not significantly influence Diptera parasitisation rate ( $p = 0.417$ ) with semi concealed hosts suffering slightly higher Diptera parasitisation rate than free living (1.1%, 0.1 – 5.0 or 0.8%, 0.0 – 2.3 respectively, Fig. 4a). The effect of host taxonomy was highly significant ( $p = 0.005$ ,  $R^2 = 0.209$ , Fig. 4b). The combined model of host feeding mode and taxonomy showed same results as the single models alone.

### **Parasitoid species richness**

The overall number of parasitoid species was 4 (2 – 7) and number of Hymenoptera species (2, 1 – 4) was significantly higher than number of Diptera species (1, 1 – 2) ( $p < 0.001$ , double sided Wilcoxon test).

Number of parasitoid species was most strongly correlated with number of caterpillars reared ( $p < 0.001$ ,  $R^2 = 0.277$ , Fig. 5). The effect of parasitisation rate was also significant and very strong ( $p < 0.001$ ,  $R^2 = 0.271$ ). These two effects combined into the effect of number of reared parasitoids ( $p < 0.001$ ,  $R^2 = 0.596$ ). This was found out by trying all combinations of the three variables in the models. The caterpillar feeding mode significantly influenced number of parasitoid species, but explained very low proportion of the variability ( $p = 0.028$ ,  $R^2 = 0.075$ , Fig. 6a). The semi concealed hosts had more parasitoid species than free living (5, 3 – 7 or 2, 2 – 3 respectively). The feeding mode was still significant when considered together with number of caterpillars reared but not when considered together with both number of caterpillars reared and parasitisation rate. The effect of host taxonomy was not significant ( $p = 0.112$ , Fig. 6b).

Number of Hymenoptera parasitoid species showed the same relationships with number of caterpillars reared ( $p < 0.001$ ,  $R^2 = 0.258$ , Fig. 5), parasitisation rate ( $p < 0.001$ ,  $R^2 = 0.185$ ) and number of reared parasitoids ( $p < 0.001$ ,  $R^2 = 0.470$ ) as total number of parasitoid species. The effect of caterpillar feeding mode was highly significant and explained much bigger proportion of variance than in the case of number of parasitoid species ( $p < 0.001$ ,  $R^2 = 0.193$ ). The semi concealed hosts had more Hymenoptera parasitoid species than free living (3, 2 – 5 or 1, 1 – 1 respectively). The effect of host taxonomy was significant ( $p = 0.018$ ,  $R^2 = 0.167$ ). The effects of host feeding mode and taxonomy were highly complementary, so the combined model was not significantly better than either feeding mode or taxonomy alone (ANOVA,  $p = 0.685$  or  $p = 0.414$  respectively).

Number of caterpillars reared had significant effect on number of Diptera parasitoid species, but explained very small proportion of the variability ( $p = 0.045$ ,  $R^2 = 0.059$ , Fig. 5). The effect of parasitisation rate was significant and strong ( $p = 0.002$ ,  $R^2 = 0.165$ ) and number of parasitoids reared explained significantly bigger proportion of variability than number of caterpillars reared and parasitisation rate combined ( $p < 0.001$ ,  $R^2 = 0.261$ ). Neither caterpillar feeding mode nor host taxonomy were significant ( $p = 0.772$  or  $p = 0.165$  respectively).

### **Dominance in parasitoid communities on particular hosts**

The proportion of individuals represented by the most abundant parasitoid species feeding on particular Lepidoptera host species is shown in Fig. 7. The most abundant parasitoid was responsible for 61.4% (40.0 – 80.2) of the total parasitisation.

### **Parasitoid host specificity**

The overall number of host species was 2 (1 – 3) and number of semi concealed species (2, 1 – 3) was significantly higher than number of free living species (0, 0 – 0) ( $p < 0.001$ , double sided Wilcoxon test).

The effect of number of parasitoids reared on parasitoid host specificity was not significant, but close to 0.05 significance level ( $p=0.053$ ,  $R^2=0.049$ , Fig. 8).

Parasitoid taxonomy did not significantly influence the parasitoid host specificity (2, 1 – 3 for both groups,  $p=0.821$ , Fig. 9a).

Semi concealed host specificity was significantly influenced by number of reared parasitoids ( $p=0.028$ ,  $R^2=0.067$ , Fig. 8). The effect of parasitoid taxonomy was not significant ( $p=0.113$ , Fig. 9b), but Diptera had fewer species of semi concealed hosts than Hymenoptera (1, 1 – 2.5 or 2, 1 – 3 respectively).

Free living host specificity was not affected by number of parasitoids reared ( $p=0.343$ , Fig. 8), but the effect of parasitoid taxonomy was significant ( $p=0.016$ ,  $R^2=0.084$ , Fig. 9c) with Diptera having more species of free living hosts than Hymenoptera (0, 0 – 1 or 0, 0 – 0 respectively).

From the 19 Diptera species with more than 5 parasitoids reared 9 had only one host (6 semi concealed, 3 free living - but those had only 5 or 6 parasitoid specimens reared), 5 were confined to semi concealed hosts, none was confined to free living hosts and 5 parasitized both semi concealed and free living hosts.

From the 39 Hymenoptera species with more than 5 parasitoids reared 15 had only one host (all semi concealed) 19 were confined to semi concealed hosts, none was confined to free living hosts and 5 parasitized both semi concealed and free living hosts.

## DISCUSSION

### Methodological issues

The studies of host - parasitoid interactions are hindered by many problems which lead to possible bias in their results.

Due to great diversity of both moths and parasitoids and the unevenness of their abundance with many species and interactions being very rare, it is largely impossible to sample all caterpillars and their parasitoids at any site and especially in a tropical rainforest. Even though it took tens of thousands of person days of work to amass this dataset, we still expect to find many new species and interaction if the collecting continues. It would be unimaginable to compile such dataset without the help of local collectors and parataxonomists (Basset *et al.*, 2004).

Main problem which complicates the understanding of general patterns in caterpillar - parasitoid interaction is the bias to economically important species (Hawkins, 1994) and to the study of bigger host species i.e. Macrolepidoptera, despite the numerical dominance of Microlepidoptera in natural communities (Novotny *et al.*, 2006). I am not aware of any community study, other than ours, which quantitatively sampled parasitoids from both Macrolepidoptera and Microlepidoptera feeding externally on leaves. Leaf feeding caterpillars of Macrolepidoptera mostly forage freely on the vegetation while caterpillars of Microlepidoptera mostly feed in semi concealed situations (Powell *et al.*, 1999). Both groups interact through shared parasitoids and considering the former without the latter might lead to biased conclusions. The uniqueness of this study in this regard means also a lack of truly comparable results from other studies.

Other problems are common to all rearing surveys, the most serious of them being the reality that usually more than 50% of the caterpillars die in the rearing process. This severely lowers the yield / waste ratio and opens the possibility of skewed results due to possible differential survival of parasitized and parasitoid free caterpillars. Dissecting the dead caterpillars is a very labor intensive task and still leaves open the possibility that the parasitoid larva would be overlooked.

Further, the caterpillars are protected from parasitation from the moment of collection which again can skew the results (with the exception of possible accidental of introducing microtype eggs of Tachinidae, Stireman *et al.*, 2006). Eggs and pupae are rarely found and the pupation takes place in much wider range of microhabitats than the feeding. Current taxonomy of eggs and pupae often makes the species determination impossible. Due to all these reasons eggs and pupae were not sampled in our and similar studies. These effects limit the scope of the study to egg-larval, larval and larval-pupal parasitoids and the results underestimate both the total parasitation rate suffered by the host and number of parasitoid species attacking the host. Parasitoid life forms which attack mainly eggs and pupae are very rare in our

dataset and their general importance cannot be judged from our data, namely idiobionts (Askew & Shaw, 1985), ectoparasitoids and hyperparasitoids. As far as what can be inferred from the biology of parasitoid groups which were reared in this study, only a very small proportion could be hyperparasitoids (Bolton & Gauld, 1996), namely some Chalcidoidea and some Ichneumonidae.

Taxonomy of both hosts and parasitoids is a major challenge in rearing surveys and requires cooperation with many specialists. The species limits should be explored with both morphological and molecular methods (Hajibabaei *et al.*, 2006; Janzen *et al.*, 2005; Smith *et al.*, 2007). Our data match this standard in Lepidoptera taxonomy (Miller *et al.*, 2003), and we are working on the parasitoid taxonomy to meet the standard as well. However in this analysis only small proportion of parasitoid material was formally identified by specialists and the majority of the data is based on my morphospecies assignments.

Proper morphotyping of the caterpillars is needed for the parasitoid to be correctly associated with the host. The resulting 87.4% of parasitoid specimens being safely associated with at least host genera is satisfying when we consider the difficult taxonomy of microlepidoptera caterpillars.

The "most probable host" assumption which was used to circumvent the imperfect matching of parasitoids with hosts is a possible source of analytical bias, which however does not systematically decrease or increase the analyzed variables but brings some noise to the analysis (i.e. among closely related host species, some are analyzed as having more parasitoids than they probably do, but others are analyzed as having less parasitoids than they probably do).

Some possibly important factors were not yet analyzed which lowers the interpretational power of the study, the most important of them being the effect of the host plant (Lill *et al.*, 2002).

I report patterns of parasitism for Hymenoptera and Diptera, but it is important to keep in mind that the Diptera parasitoids come only from the family Tachinidae and the patterns reported for Hymenoptera are mostly driven by Ichneumonoidea and especially Braconidae (Table 1).

### **Parasitization rate**

The overall parasitization rate reported in this study is one of the lowest reported for complex system of externally feeding caterpillars and their parasitoids (Stireman *et al.*, 2005). It becomes the lowest ever reported when we consider the fact that the parasitization rate reported in other papers is based mostly on Macrolepidoptera which are more comparable to our free living hosts. No clear hypothesis lends itself for the explanation of this fact. Our data point does not fit the negative correlation of

parasitisation rate on climatic variability of Stireman *et al.*, (2005), scoring both low parasitisation rate and low climatic variability. Latitude was not significant predictor of parasitisation rate (Stireman *et al.*, 2005), and this issue cannot be solved without adding many more data points. Some other factors such as habitat or history should be also considered, although the parasitisation rate on a site with climate similar to our study area was 26% (Gentry & Dyer, 2002; Stireman *et al.*, 2005) compared to 9.6% in our study.

Higher parasitisation rate of the semi concealed caterpillars compared to free living caterpillars (Fig. 2a) was reported also in Gentry & Dyer, (2002). Similar relationship was reported also for parasitoid species richness by Hawkins (1994). The difference can be explained by the biology of these two groups of hosts. The semi concealed feeders should be better hosts for parasitoids for several reasons: (i) they are more common (Novotny *et al.*, 2006), (ii) they suffer lower predation (Jeffries & Lawton, 1984) (iii) they are less mobile and therefore more apparent to parasitoids since they tend to stay near the plant tissue they damage, which makes them more easily locatable by chemical signals released when the leaf is damaged (Gentry & Dyer, 2002; Hawkins, 1994).

The differential parasitisation of Hymenoptera and Diptera where Hymenoptera parasitize mostly semi concealed feeders, while Diptera parasitize both types of hosts with very similar intensity (Fig. 3a and 4a) was reported before by Hawkins (1994) for parasitoid species richness and the part concerning Macrolepidoptera (mostly free living hosts) also by e.g. (Janzen, 1995; Sheehan, 1994). The minimal parasitism of free living by Hymenoptera can be explained by the experimental results of Gentry & Dyer (2002) that the Hymenoptera parasitoids are heavily deterred by the caterpillar's regurgitating, dropping and biting. The Hymenoptera parasitoids possess a piercing ovipositor which gives them the possibility to directly attack semi concealed hosts (Bolton & Gauld, 1996; Eggleton & Belshaw, 1993).

The Diptera parasitoids rarely have a piercing structure and have to rely on other means of reaching the host. Some oviposit on their host's integument and hatching larvae burrow into the host. Others oviposit or larviposit near a host, and are either consumed as eggs or search out their host as first instar larvae (Eggleton & Belshaw, 1993; Feener & Brown, 1997). We have to wait for the identifications to be more specific about the ovipositing behavior of Diptera in our study.

The Diptera reach very similar parasitisation rates in semi concealed and free living hosts. This means that they fail to use the semi concealed hosts (who are generally better suited for parasitisation) with higher efficiency. This is probably due to the limitations of the ovipositing behavior. On the other hand, the indirect oviposition of Diptera opens the way for them to parasitize free living hosts.

The taxonomic distribution of Diptera hosts gives indirect support to the assumption that Diptera have problems with attacking smaller hosts (Fig. 4b, note that category

"others" is composed almost exclusively of small sized caterpillars of Choreutidae, Gelechiidae and Thyrididae). This hypothesis needs to be tested directly with caterpillar body size. It brings up the question of what happens to the undersized host which eats a Tachinidae egg but is not big enough to support the parasitoid's development. This might be a parasitoid induced source of mortality for small semi concealed as well as free living hosts.

The active determent of the directly ovipositing parasitoid by the caterpillar together with the inability of Diptera to develop inside a small host would also explain the unusually low parasitisation rate of Geometridae (Fig. 2b).

According to our results, the two principal parasitoid groups, Hymenoptera and Diptera, do not appear to be in direct competition as the lack of parasitisation by one group is not compensated by the increase of the other. Stireman *et al.* (2005) also found the parasitisation rate of Hymenoptera and Diptera uncoupled.

### **Parasitoid species richness**

The strong correlation of parasitoid species richness with number of reared hosts (Fig. 5) is typical for mass rearing studies (Lewis *et al.*, 2002; Sheehan, 1994).

When the hosts are not sampled quantitatively it is usually regarded as sampling artifact (Hawkins, 1994). However in our study, considerable effort was spend to make the sampling effort constant over a tree species and therefore the number of caterpillars reared can be regarded as being close to the real caterpillar relative abundance on that tree (not the overall relative abundance in the habitat as the trees differ very much in the abundance, Novotny *et al.*, 2004) This suggests that the more common caterpillar species really do have more parasitoid species, probably because they represent a bigger resource than rare host species. This pattern is similar to that found for British tree species and their insect herbivores as tree species more common in Britain also host more herbivore species (Kelly & Southwood, 1999).

The parasitisation rate and parasitoid species richness are strongly correlated in our data, which was shown by the regressions of one on the other. This pattern suggests that additional parasitoid species may increase overall parasitisation rate.

The ecological variables explained low proportion of the variability in parasitoid species richness in both (Sheehan, 1994) and our study. Semi concealed hosts had more parasitoid species than free living hosts (Fig. 6a, Hawkins, 1994), the same pattern as with parasitisation rate. The pattern with Hymenoptera having much more semi concealed host species than free living host species and Diptera having similar number of host species in both type of hosts is also a parallel to the same pattern found for parasitisation rate. I expect the same forces (mentioned before) to drive this pattern for both parasitisation rate and parasitisation species richness. The insignificance of host taxonomy (Fig. 6b) in the analysis cannot be taken as a proof of nonexistent

differences, and would be better tested with balanced categories, which were however not provided by the quantitative sampling.

### **Dominance in parasitoid communities on particular hosts**

The most abundant parasitoid on particular host was typically responsible for more than 50% of total parasitization of that host, leaving just about 20% of parasitizations to the second most abundant parasitoid and about 10% to the third (Fig. 7). Interestingly, similar pattern of high dominance of the most abundant species was found also in the communities of caterpillars feeding on a single host plant species (Novotny *et al.*, 2002c).

### **Parasitoid host specificity**

The host specificity decreases very slowly with the number of reared parasitoids (Fig. 8), which suggests that we can't expect many more additional hosts for the parasitoids studied here even with additional sampling on the same tree species. I don't expect the common parasitoid species in our analysis to have regular hosts outside the studied community, as the Lepidoptera are by far the most common leaf feeding herbivores on the study site (Novotny *et al.*, 2002a) and miners reared from same tree species as the caterpillars in this study have completely different parasitoids (our unpublished data).

New hosts would be likely found if the sampling was extended to other plant species. The host specificity reported here is slightly underestimated due to the use of "most probable host" assumption in the analysis.

The finding that Hymenoptera and Diptera host specificity are identical (Fig. 9a) is novel and unexpected, although it was previously mentioned for Macrolepidoptera by Stireman *et al.* (2006) as a preliminary result of Janzen & Hallwachs (2005). However Janzen & Hallwachs's (2005) result refers mostly to free living caterpillars, where we found the Hymenoptera to be more host specific. This is possibly also due to very low parasitization rate of Hymenoptera on the free living hosts (Fig. 9c). Tachinidae are known to have wider host range than Hymenoptera (Eggleton & Belshaw, 1993; Feener & Brown, 1997; Stireman *et al.*, 2006) on the level of whole groups. It was generally assumed that they will be more generalist than Hymenoptera on the community level as well, but we show that this is not true for communities of externally leaf feeding Lepidoptera and their parasitoids. The Tachinidae could have easily been more generalist in the host use considering the diversity of the hosts studied (Appendix C), but they are not. The general idea that Hymenoptera are more host specific in caterpillar communities might be partially an artifact as many studies focused disproportionately on free feeding hosts.

Both Tachinidae and Hymenoptera have mechanisms to overcome the immunity reaction of the host, and the differences in this trait were thought to explain the lower host specificity of Tachinidae (Stireman *et al.*, 2006). Many Tachinidae form a



respiratory funnel which allows them to overcome the host's encapsulation response (Stireman *et al.*, 2006). On the other hand, Hymenoptera produce venoms and immune-suppressant substances such as polyDNA viruses (Bolton & Gauld, 1996; Qucke, 1997) which can be injected in the host with an ovipositor. The absence of the difference in host specificity reported here leads to the hypotheses that the way how the parasitoid overcomes the host's immunity reaction is either not important for the structure of host ranges in the studied system, or both groups of parasitoids are approximately equally good at it.

From the 58 parasitoid species with five or more reared specimens, nearly all species were either confined to semi concealed hosts or attacked both semi concealed and free living host. No Hymenoptera species was specialized to a free living host, and only three species specialized to free living hosts were found among Diptera. However, those three species had only 5 or 6 specimens reared and it is therefore probable that some semi concealed hosts would be recorded for them if the sampling continued.

The semi concealed hosts therefore seem to drive the host - parasitoid interaction of folivorous externally feeding Lepidoptera and their parasitoids. Generally, this is not very surprising as they are much more common in the nature and better suited for parasitism. This pattern can be also thought of as a case of apparent competition (Jeffries & Lawton, 1984) between two guilds of caterpillars. If this pattern is shown to be general it also implies that analyses of parasitism patterns based only on Macrolepidoptera are not appropriate, because they describe a pattern which is mostly a side effect of parasitism of semi concealed hosts. This in turn applies for instance to evolutionary considerations on the adaptive significance of oviposition behavior (Stireman *et al.*, 2006).

## CONCLUSIONS

A number of important patterns in host - parasitoid interaction of folivorous externally feeding Lepidoptera and their parasitoids is reported based on extensive rearing survey in Papua New Guinea rainforest.

Feeding mode of the host caterpillar seems to be the most important determinant of host - parasitoid interactions in the studied system with semi concealed hosts (mostly Microlepidoptera) being much more common and having higher parasitisation rate and more parasitoid species than free living hosts (mostly Macrolepidoptera).

The two principal parasitoid groups use semi concealed and free living hosts differently with Hymenoptera parasitising almost exclusively semi concealed hosts and Diptera using both groups of hosts with similar parasitisation rate. This pattern is explained by (i) the overall dominance of semi concealed hosts in the nature, (ii) the effectivity of free living caterpillar defenses and (iii) the differences in parasitoid ovipositor and oviposition traits.

Host specificity was found to be the same in Hymenoptera and Diptera, despite the generally lower host specificity of Tachinidae reported in the literature, so the physiological mechanisms of overcoming the host's immunity reaction probably don't play as important role as expected in the differences in host specificity in the studied system.

Near absence of parasitoids specialized on free living hosts suggests that semi concealed hosts drive the host - parasitoid interaction in the studied system and the parasitisation of free living hosts is mostly a side effect of parasitisation of semi concealed hosts.

Further quantitative studies covering both Macrolepidoptera and Microlepidoptera are needed to evaluate the generality of these results.

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## APPENDIX A. List of plant species sampled.

Plant Species	Plant Family	Plant Code
<i>Aglaia cucullata</i> (Roxb.) Pellegr.	Meliaceae	AGL
<i>Barringtonia</i> sp.	Lecythidaceae	BAR
<i>Cordyline terminalis</i> P. Beauv.	Agavaceae	COR
<i>Ficus bernaysii</i> King	Moraceae	BER
<i>Ficus</i> cf. <i>erythrosperma</i> Miq.	Moraceae	ERY
<i>Ficus</i> cf. <i>ternatana</i> Miq.	Moraceae	TER
<i>Ficus conocephalifolia</i> Ridley	Moraceae	CON
<i>Ficus copiosa</i> Steud.	Moraceae	COP
<i>Ficus dammaropsis</i> Diels	Moraceae	DAM
<i>Ficus gul</i> K. Schum. & Laut.	Moraceae	GUL
<i>Ficus hispidioides</i> S. Moore	Moraceae	HIS
<i>Ficus mollior</i> F. Muell. ex Benth.	Moraceae	MOL
<i>Ficus pachyrrhachis</i> K. Schum. & Laut.	Moraceae	PAR
<i>Ficus phaeosyce</i> Laut. & K. Schum.	Moraceae	PHA
<i>Ficus pungens</i> Reinw. ex Blume	Moraceae	PUN
<i>Ficus subtrinervia</i> Laut. et K. Schum.	Moraceae	PAS
<i>Ficus wassa</i> Roxb.	Moraceae	WAS
<i>Geunsia farinosa</i> Blume	Verbenaceae	GEU
<i>Heliconia papuana</i> W.J. Kress	Heliconiaceae	HEL
<i>Hibiscus tiliaceus</i> L.	Malvaceae	HYB
<i>Hornstedtia scottiana</i> (F. Muell.) K. Schum.	Zingiberaceae	HOR
<i>Kleinhovia hospita</i> L.	Malvaceae	KLE
<i>Leea indica</i> Merrill	Vitaceae	LEE
<i>Litsea timoriana</i> Span.	Lauraceae	LIT
<i>Lunasia amara</i> Blanco	Rutaceae	LUN
<i>Macaranga aleuritoides</i> F. Muell.	Euphorbiaceae	MAA
<i>Macaranga</i> cf. <i>brachytricha</i> A. Shaw	Euphorbiaceae	MAF
<i>Macaranga clavata</i> Warb.	Euphorbiaceae	MAX
<i>Macaranga ducis</i> Whitmore	Euphorbiaceae	MAP
<i>Macaranga fallacina</i> Pax & Hoffm.	Euphorbiaceae	MAS
<i>Macaranga novoguineensis</i> J. J. Smith	Euphorbiaceae	MAU
<i>Macaranga quadriglandulosa</i> Warb.	Euphorbiaceae	MAQ
<i>Maniltoa</i> cf. <i>plurijuga</i> Merrill & Perry	Fabaceae	MAN
<i>Myristica</i> cf. <i>sepicana</i> D.B. Foreman	Myristicaceae	MYL
<i>Piper aduncum</i> L.	Piperaceae	PAD
<i>Piper macropiper</i> Pennant	Piperaceae	PMV
<i>Pouteria</i> sp.	Sapotaceae	POU
<i>Psychotria micrococca</i> (Laut. & Schum.) Val.	Rubiaceae	PSS
<i>Psychotria ramuensis</i> Sohmer	Rubiaceae	PSL
<i>Syzygium longipes</i> (Warb.) Merrill & Perry	Myrtaceae	SSW
<i>Syzygium malaccense</i> Merr. & Perry	Myrtaceae	SRS
<i>Syzygium</i> sp.	Myrtaceae	SRB
<i>Syzygium</i> sp.2	Myrtaceae	SYW
<i>Teijsmanniodendron</i> sp.	Verbenaceae	TEI
<i>Trichospermum pleiostigma</i> (F. Muell.) Kostermans	Malvaceae	TRI

## APPENDIX B. List of Lepidoptera species reared.

Moth Family	Moth Category	Moth Genus	Moth Species	Moth Author	Feeding Mode	Code
Arctiidae	others	<i>Asura</i>	<i>pallida?</i>	Rotschild	free living	XXXX073
Arctiidae	others	<i>Chamaita</i>	<i>metamelaena</i>	Hampson 1900	free living	LYMA035
Arctiidae	others	<i>Darantasia</i>	<i>caerulescens</i>	Druce	free living	ARCT002
Arctiidae	others	<i>Eugoa</i>	sp. near <i>perfasciata</i>	Rothchild	free living	ARCT010
Arctiidae	others	<i>Spilosoma</i>	<i>niceta</i>	Stoll	free living	NOCT049
Arctiidae	others	<i>Trichalis</i>	sp. near <i>aereoplagiata</i>	Rothchild	free living	ARCT011
Arctiidae	others	unknown	sp.		free living	ARCT012
Arctiidae	others	unknown	sp.		free living	LYMA073
Choreutidae	others	<i>Brenthia</i>	n. sp.		semi concealed	CHOR001
Choreutidae	others	<i>Brenthia</i>	sp.		semi concealed	CHOR002
Choreutidae	others	<i>Brenthia</i>	sp.		semi concealed	CHOR008
Choreutidae	others	<i>Brenthia</i>	sp.		semi concealed	CHOR012
Choreutidae	others	<i>Brenthia</i>	sp.		semi concealed	CHOR016
Choreutidae	others	<i>Choreutis</i>	<i>basalis</i>	(Felder & Rogenhofer)	semi concealed	TORT012
Choreutidae	others	<i>Choreutis</i>	<i>chi?</i>	(Durrant)	semi concealed	TORT013
Choreutidae	others	<i>Choreutis</i>	<i>lutescens</i>	(Felder & Rogenhofer)	semi concealed	TORT006
Choreutidae	others	<i>Choreutis</i>	sp.		semi concealed	CHOR011
Choreutidae	others	<i>Choreutis</i>	sp. cf. <i>anthorma</i>	(Meyrick)	semi concealed	TORT005
Choreutidae	others	<i>Saphta</i>	sp. cf. <i>exanthista</i> & <i>divitiosa</i>	(Meyrick) / Walker	semi concealed	TORT009
Choreutidae	others	unknown	sp.		semi concealed	CHOR013
Choreutidae	others	unknown	sp.		semi concealed	CHOR014
Crambidae	Pyraloidea	<i>Agrotera</i>	<i>ignepictoides</i>	Rothschild	semi concealed	CRAM065
Crambidae	Pyraloidea	<i>Agrotera</i>	sp. 1 nr. <i>basinotata</i>		semi concealed	CRAM098
Crambidae	Pyraloidea	<i>Agrotera</i>	sp. nr. but not <i>effertalis</i>	Walker	semi concealed	PYRA012
Crambidae	Pyraloidea	<i>Chalcidoptera</i>	<i>emissalis</i>	(Walker)	semi concealed	CRAM068
Crambidae	Pyraloidea	<i>Coelorhyncidia</i>	<i>nitidalis</i>	Hampson	semi concealed	PYRA008
Crambidae	Pyraloidea	<i>Coelorhyncidia</i>	<i>purpurea</i>	Hampson	semi concealed	CRAM044
Crambidae	Pyraloidea	<i>Coelorhyncidia</i>	sp.		semi concealed	CRAM041
Crambidae	Pyraloidea	<i>Cydalima</i>	<i>diaphanalis</i> complex		semi concealed	CRAM069
Crambidae	Pyraloidea	<i>Diaphania</i>	<i>indica</i>	(Saunders)	semi concealed	CRAM063
Crambidae	Pyraloidea	<i>Eutectona</i>	sp.		semi concealed	PYRA003
Crambidae	Pyraloidea	<i>Glyphodes</i>	<i>doleschalii</i>	Lederer	semi concealed	CRAM016
Crambidae	Pyraloidea	<i>Glyphodes</i>	<i>eurygania</i>	Druce	semi concealed	CRAM017
Crambidae	Pyraloidea	<i>Glyphodes</i>	<i>margaritaria</i>	(Cramer)	semi concealed	CRAM003
Crambidae	Pyraloidea	<i>Glyphodes</i>	sp. cf. <i>stolalis</i>	Guenee	semi concealed	CRAM008
Crambidae	Pyraloidea	<i>Haritalodes</i>	<i>adjunctalis</i>	Leraut 2005	semi concealed	CRAM012
Crambidae	Pyraloidea	<i>Herpetogramma</i>	<i>bractealis</i>	(Kenrick)	semi concealed	PYRA025
Crambidae	Pyraloidea	<i>Herpetogramma</i>	nr. <i>licarsisalis</i>	(Walker) 1859	semi concealed	CRAM066
Crambidae	Pyraloidea	<i>Musotima</i>	sp.		semi concealed	CRAM077
Crambidae	Pyraloidea	<i>Nacoleia</i>	<i>octasema</i>	(Meyrick)	semi concealed	PYRA026
Crambidae	Pyraloidea	<i>Orthospila</i>	sp. A	(Walker)	semi concealed	CRAM013
Crambidae	Pyraloidea	<i>Orthospila</i>	sp. C	(Walker)	semi concealed	CRAM051
Crambidae	Pyraloidea	<i>Pagyda</i>	nr. but not <i>ochrealis</i>	Whalley	semi concealed	PYRA013
Crambidae	Pyraloidea	<i>Parotis</i>	sp. nr. <i>marginata</i>	(Hampson)	semi concealed	GEOM001
Crambidae	Pyraloidea	<i>Parotis</i>	<i>suralis</i>	(Lederer)	semi concealed	CRAM037
Crambidae	Pyraloidea	<i>Pleuroptya</i>	<i>sabinusalis</i>	(Walker)	semi concealed	CRAM011
Crambidae	Pyraloidea	<i>Pleuroptya</i>	<i>sellalis</i>	(Guenee) 1854	semi concealed	CRAM076
Crambidae	Pyraloidea	<i>Pseudocera</i>	nr. <i>trissosticha</i>		semi concealed	CRAM067
Crambidae	Pyraloidea	<i>Pycnarmon</i>	<i>argenticincta</i>	Hampson	semi concealed	CRAM034
Crambidae	Pyraloidea	<i>Pycnarmon</i>	<i>jaguaralis papualis</i>	Munroe	semi concealed	CRAM023



<b>Moth Family</b>	<b>Moth Category</b>	<b>Moth Genus</b>	<b>Moth Species</b>	<b>Moth Author</b>	<b>Feeding Mode</b>	<b>Code</b>
Crambidae	Pyraloidea	<i>Syllepte</i>	<i>ochrisalis</i>	S. E. Miller	semi concealed	CRAM079
Crambidae	Pyraloidea	<i>Talanga</i>	<i>deliciosa</i>	(Butler)	semi concealed	CRAM005
Crambidae	Pyraloidea	<i>Talanga</i>	<i>excelsalis</i> <i>moresbyensis</i>	(Strand)	semi concealed	CRAM002
Crambidae	Pyraloidea	<i>Talanga</i>	<i>polyzonalis</i>	(Hampson)	semi concealed	CRAM009
Crambidae	Pyraloidea	<i>Talanga</i>	<i>sexpunctalis</i>	(Moore)	semi concealed	CRAM006
Crambidae	Pyraloidea	unknown	sp.		semi concealed	CRAM075
Crambidae	Pyraloidea	unknown	sp.		semi concealed	CRAM078
Crambidae	Pyraloidea	unknown	sp.		semi concealed	CRAM092
Elachistidae	others	gen. nr. <i>Peritomenta</i>	sp.		semi concealed	XXXX093
Elachistidae	others	<i>Peritomenta</i>	sp.		semi concealed	XXXX097
Elachistidae	others	unknown	sp.		semi concealed	TORT167
Elachistidae	others	unknown	sp.		free living	XXXX109
Elachistidae	others	unknown	sp.		semi concealed	XXXX117
Gelechiidae	others	<i>Anarsia</i>	sp.		semi concealed	XXXX116
Gelechiidae	others	<i>Dichomeris</i>	<i>ochreoviridella</i>	(Pagenstecher)	semi concealed	XXXX048
Gelechiidae	others	<i>Dichomeris</i>	sp.		semi concealed	XXXX068
Gelechiidae	others	<i>Dichomeris</i>	sp.		semi concealed	XXXX095
Gelechiidae	others	<i>Idiophantis</i>	n. sp.		semi concealed	TORT163
Gelechiidae	others	unknown	sp.		semi concealed	XXXX120
Gelechioidea (sf)	others	unknown	sp.		semi concealed	TORT200
Gelechioidea (sf)	others	unknown	sp.		semi concealed	TORT202
Gelechioidea (sf)	others	unknown	sp.		semi concealed	XXXX126
Geometridae	Geometridae	<i>Hypomecis</i>	<i>infaustaria</i>	Walker	free living	GEOM023
Geometridae	Geometridae	<i>Agathiopsis</i>	<i>maculata</i>	Warren	free living	GEOM130
Geometridae	Geometridae	<i>Amblychia</i>	<i>angeronaria</i>	Guenee	free living	GEOM082
Geometridae	Geometridae	<i>Catoria</i>	<i>delectaria</i>	(Walker, 1866)	free living	GEOM009
Geometridae	Geometridae	<i>Chrysochloroma</i>	<i>electrica</i> or <i>saturata</i>	Warren	free living	GEOM122
Geometridae	Geometridae	<i>Chrysocraspeda</i>	<i>rothschildi</i> ?	Warren	free living	GEOM120
Geometridae	Geometridae	<i>Chrysocraspeda</i>	sp.		free living	GEOM118
Geometridae	Geometridae	<i>Chrysocraspeda</i>	sp. nr. <i>inundata</i>	Warren	free living	GEOM110
Geometridae	Geometridae	<i>Cleora</i>	<i>decisaria</i>	(Walker) 1866	free living	GEOM019
Geometridae	Geometridae	<i>Cleora</i>	<i>repetita</i>	Butler 1882	free living	GEOM021
Geometridae	Geometridae	<i>Craspedosis</i>	<i>ovalis</i>	Warren 1896	free living	GEOM105
Geometridae	Geometridae	<i>Cyclophora</i>	<i>glomerata</i>	Warren	free living	GEOM135
Geometridae	Geometridae	<i>Derambila</i>	<i>stigicosta</i>	Warren	free living	PYRA023
Geometridae	Geometridae	<i>Dysgnathia</i>	sp. near <i>albolineata</i>	Bethune-Baker), 1906	free living	GEOM107
Geometridae	Geometridae	<i>Ectropis</i>	<i>bhurmitra</i>	(Walker) 1860	free living	GEOM015
Geometridae	Geometridae	<i>Eucyclodes</i>	<i>absona</i>	(Warren)	free living	GEOM111
Geometridae	Geometridae	<i>Eucyclodes</i>	<i>albilauta</i>	(Warren) 1897	free living	GEOM022
Geometridae	Geometridae	<i>Eucyclodes</i>	sp. nr. <i>griseonotata</i>	Warren	free living	GEOM102
Geometridae	Geometridae	<i>Hyposidra</i>	<i>incomptaria</i>	Walker 1866	free living	GEOM012
Geometridae	Geometridae	<i>Hyposidra</i>	<i>talaca</i>	Walker	free living	GEOM016
Geometridae	Geometridae	<i>Oenospila</i>	sp. nr. <i>flavilinea</i>		free living	GEOM150
Geometridae	Geometridae	<i>Paradromula</i>	<i>xylinopa</i>	Meyrick 1899	free living	GEOM053
Geometridae	Geometridae	<i>Paradromulia</i>	nr. but not <i>lignifascia</i>	Warren	free living	GEOM134
Geometridae	Geometridae	<i>Perixera</i>	<i>ampligutta</i>	Warren 1896	free living	GEOM031
Geometridae	Geometridae	<i>Perixera</i>	<i>ceramis</i>	(Meyrick)	free living	GEOM104
Geometridae	Geometridae	<i>Pingasa</i>	<i>lariaria</i> or nr.	(Walker)	free living	GEOM144
Geometridae	Geometridae	<i>Pingasa</i>	sp.	Stoll 1782	free living	GEOM006
Geometridae	Geometridae	<i>Scopula</i>	<i>amala</i>	Meyrick 1899	free living	GEOM051
Geometridae	Geometridae	<i>Symmacra</i>	<i>solidaria ochrea</i>	Warren 1897	free living	GEOM034

Moth Family	Moth Category	Moth Genus	Moth Species	Moth Author	Feeding Mode	Code
Geometridae	Geometridae	<i>Thalassodes</i> (s.l.)	<i>albifusa</i>	(Warren) 1906	free living	GEOM013
Geometridae	Geometridae	<i>Tiruvaca</i>	<i>subcostalis</i>	(Walker)	free living	GEOM113
Geometridae	Geometridae	unknown	sp.		free living	GEOM079
Geometridae	Geometridae	unknown	sp.		free living	GEOM101
Geometridae	Geometridae	unknown	sp.		free living	GEOM109
Geometridae	Geometridae	unknown	sp.		free living	GEOM115
Geometridae	Geometridae	unknown	sp.		free living	GEOM116
Geometridae	Geometridae	unknown	sp.		free living	GEOM124
Geometridae	Geometridae	unknown	sp.		free living	GEOM133
Geometridae	Geometridae	unknown	sp.		free living	GEOM138
Geometridae	Geometridae	unknown	sp.		free living	GEOM145
Geometridae	Geometridae	unknown	sp.		free living	GEOM146
Geometridae	Geometridae	unknown	sp.		free living	GEOM151
Geometridae	Geometridae	<i>Zeugma</i>	<i>recusataria</i>	Walker 1862	free living	GEOM100
Gracillariidae	others	unknown	sp.		semi concealed	XXXX111
Hesperiidae	butterflies	<i>Chaetocneme</i>	<i>lunula</i>		free living	HESP005
Hesperiidae	butterflies	<i>Notocrypta</i>	<i>renardi</i>	Oberthur 1878	free living	HESP006
Hesperiidae	butterflies	<i>Sabera</i>	sp.		semi concealed	HESP007
Hyblaenidae	others	<i>Hyblaea</i>	<i>amboinae</i>	Felder	semi concealed	HYBL003
Hyblaenidae	others	<i>Hyblaea</i>	<i>constellata</i>	Guenee	free living	HYBL001
Hyblaenidae	others	<i>Hyblaea</i>	sp. near <i>puera</i>	Cramer 1777	free living	HYBL002
Hypertrophidae	others	unknown	sp.		semi concealed	HYPE001
Immidae	others	<i>Imma</i>	nr. not <i>campisigrama</i> & <i>crocozela</i>	Meyrick	semi concealed	IMMI001
Immidae	others	<i>Imma</i>	sp.		semi concealed	TORT158
Immidae	others	<i>Imma</i>	sp.		semi concealed	TORT159
Immidae	others	<i>Moca</i>	<i>congrualis</i>	(Walsingham)	free living	TORT071
Lacturidae	others	<i>Lactura</i>	sp. nr. <i>rhodographa</i>	Meyrick 1928	free living	LIMA030
Lacturidae	others	unknown	sp.		free living	LIMA029
Lecithoceridae	others	<i>Scythropiodes</i>	n. sp. near <i>perissa</i>	(Diakonoff)	semi concealed	XXXX090
Limacodidae	others	<i>Mambara</i>	<i>robigonosa</i> ?	Hering 1931	free living	GEOM084
Limacodidae	others	unknown	sp.		free living	LIMA025
Lycaenidae	butterflies	<i>Deudorix</i>	<i>epirus</i>		free living	LYCA018
Lycaenidae	butterflies	<i>Philiris</i>	<i>helena helena</i>	(Snellen)	free living	LYCA006
Lycaenidae	butterflies	<i>Philiris</i>	<i>moira</i>		free living	LYCA001
Lymantriidae	others	<i>Arctornis</i>	sp. nr. <i>intacta</i>	Walker	free living	LYMA007
Lymantriidae	others	<i>Artaxa</i>	sp.	Walker	free living	LYMA015
Lymantriidae	others	<i>Euproctis</i>	sp.		free living	LYMA003
Lymantriidae	others	<i>Nygmiiini</i>	sp. 2		free living	LYMA038
Lymantriidae	others	<i>Olene</i>	nr. <i>mendosa</i>	Huebner	free living	LYMA039
Lymantriidae	others	<i>Somena</i>	<i>alba</i>	(Bethune-Baker)	free living	LYMA060
Lymantriidae	others	<i>Teia</i>	nr. but not <i>dewara</i>	(Swinhoe) 1903	free living	LYMA001
Lymantriidae	others	unknown	sp.		free living	LYMA033
Lymantriidae	others	unknown	sp.		free living	LYMA045
Lymantriidae	others	unknown	sp.		free living	LYMA071
Noctuidae	Noctuidae	<i>Achaea</i>	<i>janata</i>	Linnaeus	free living	NOCT019
Noctuidae	Noctuidae	<i>Anomis</i> (s.l.)	sp.		free living	NOCT083
Noctuidae	Noctuidae	<i>Asota</i>	<i>carica</i>	(Fabricius)	free living	NOCT010
Noctuidae	Noctuidae	<i>Asota</i>	<i>heliconia</i>	(Linnaeus)	free living	NOCT002
Noctuidae	Noctuidae	<i>Asota</i>	<i>plana</i>	Walker	free living	NOCT009
Noctuidae	Noctuidae	<i>Asota</i>	<i>versicolor</i>	F	free living	NOCT004
Noctuidae	Noctuidae	<i>Avatha</i>	<i>pulcherima</i>	(Butler) 1892	free living	NOCT051
Noctuidae	Noctuidae	<i>Chasmina</i>	sp.		free living	NOCT080

<b>Moth Family</b>	<b>Moth Category</b>	<b>Moth Genus</b>	<b>Moth Species</b>	<b>Moth Author</b>	<b>Feeding Mode</b>	<b>Code</b>
Noctuidae	Noctuidae	<i>Chasmina</i>	<i>tibiopunctata</i>	Bethune-Baker	free living	LYMA062
Noctuidae	Noctuidae	<i>Chrysodeixis</i>	<i>dinawa</i>	(Bethune-Baker) 1906	free living	NOCT069
Noctuidae	Noctuidae	<i>Hipoepa</i>	<i>porphyrialis</i>	(Pagenstecher 1900)	free living	NOCT053
Noctuidae	Noctuidae	<i>Mecistoptera</i>	<i>franzwagneri</i>	Lodl	free living	GEOM024
Noctuidae	Noctuidae	<i>Mecistoptera</i>	n. sp.		free living	XXXX092
Noctuidae	Noctuidae	<i>Mocis</i>	<i>trifasciata</i>	(Stephens)	free living	NOCT079
Noctuidae	Noctuidae	<i>Ophyx</i>	<i>crinipes</i>	Felder	free living	NOCT099
Noctuidae	Noctuidae	<i>Parilyrgis</i>	<i>intacta</i>	(Hampson)	free living	PYRA010
Noctuidae	Noctuidae	<i>Piratisca</i>	<i>minax</i>	Meyrick 1902	free living	GEOM067
Noctuidae	Noctuidae	<i>Rusicada</i>	<i>nigritarsus</i> <i>xanthochroa</i>	(Butler)	free living	NOCT077
Noctuidae	Noctuidae	<i>Savara</i>	<i>pallidapex</i>	Holloway 2005	free living	NOCT081
Noctuidae	Noctuidae	<i>Spodoptera</i>	<i>litura</i>		free living	NOCT067
Noctuidae	Noctuidae	<i>Targalla</i>	<i>palliatrix</i>	(Guenee) 1852	free living	NOCT064
Noctuidae	Noctuidae	unknown	sp.		free living	GEOM154
Noctuidae	Noctuidae	unknown	sp.		free living	GEOM157
Noctuidae	Noctuidae	unknown	sp.		free living	GEOM158
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT071
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT078
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT084
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT085
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT087
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT096
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT101
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT108
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT122
Noctuidae	Noctuidae	unknown	sp.		free living	NOCT123
Noctuidae	Noctuidae	unknown	sp.		free living	NOTO005
Noctuidae	Noctuidae	unknown	sp.		free living	THYR011
Noctuidae	Noctuidae	unknown	sp.		free living	TORT201
Nolidae	others	<i>Barasa</i>	<i>cymatistis</i>	Meyrick 1889	free living	NOCT065
Nolidae	others	<i>Beara</i>	<i>falcata</i>	Barlow	free living	LIMA024
Nolidae	others	<i>Chora</i>	<i>huntei</i>	Warren	free living	PSYC007
Nolidae	others	<i>Earias</i>	<i>uniplaga</i>	Bethune-Baker	free living	LYMA059
Nolidae	others	<i>Giaura</i>	<i>leucophaea</i>	Hampson	free living	GEOM132
Nolidae	others	<i>Lophothripa</i>	<i>vitea</i>	Swinhoe	free living	TORT137
Nolidae	others	unknown	sp.		free living	TORT151
Notodontidae	others	<i>Chadisra</i>	<i>striata</i>	Rothschild	free living	NOTO004
Nymphalidae	butterflies	<i>Cyrestis</i>	<i>acilia</i>	Godart	free living	NYMP002
Nymphalidae	butterflies	<i>Euploea</i>	<i>leucosticos</i>	Gmelin	free living	NYMP001
Nymphalidae	butterflies	<i>Mycalesis</i>	<i>duponchelii</i>		free living	NYMP013
Nymphalidae	butterflies	<i>Taenaris</i>	sp. probably <i>myops</i>	C&R Felder, 1860	free living	NYMP012
Oecophoridae	others	<i>Stathmopoda</i>	sp. nr. <i>masinissa</i>	Meyrick	semi concealed	XXXX108
Oecophoridae	others	<i>Stathmopoda</i>	sp.		semi concealed	XXXX118
Oecophoridae	others	unknown	sp.		semi concealed	TORT150
Peleopodidae	others	<i>Acria</i>	<i>sciogramma</i>	Meyrick 1915	semi concealed	TORT120
Psychidae	others	unknown	sp.		free living	PSYC022
Pyalidae	Pyraloidea	<i>Agrotera</i>	<i>coelatalis</i>	Walker	semi concealed	PYRA018
Pyalidae	Pyraloidea	<i>Macna</i>	n. sp. nr. <i>atrifufalis</i>	Hampson	semi concealed	TORT149
Pyalidae	Pyraloidea	<i>Macna</i>	<i>oppositalis</i>	(Walker)	semi concealed	TORT146
Pyalidae	Pyraloidea	<i>Macna</i>	sp.		semi concealed	TORT152
Pyalidae	Pyraloidea	<i>Orthaga</i>	<i>melanoperalis</i>	Hampson	semi concealed	PYRA002
Pyalidae	Pyraloidea	<i>Orthaga</i>	sp. nr. <i>percnodes</i>		semi concealed	NOCT020
Pyalidae	Pyraloidea	<i>Orthospila</i>	sp. B		semi concealed	PYRA021

Moth Family	Moth Category	Moth Genus	Moth Species	Moth Author	Feeding Mode	Code
Pyralidae	Pyraloidea	<i>Pagyda</i>	<i>salvalis</i>	Walker 1859	semi concealed	PYRA024
Pyralidae	Pyraloidea	<i>Pycnarmon</i>	<i>glaucias</i>	(Meyrick)	semi concealed	PYRA019
Pyralidae	Pyraloidea	<i>Pycnarmon</i>	<i>praeruptalis</i>	(Lederer) 1863	free living	PYRA027
Pyralidae	Pyraloidea	<i>Unadophanes</i>	<i>trissomita</i>	(Turner)	semi concealed	XXXX021
Sphingidae	others	<i>Macroglossum</i>	<i>inspida papuanum</i>	Rothschild & Jordan	free living	SPHI009
Sphingidae	others	<i>Macroglossum</i>	<i>melas pullius</i>	Rothschild & Jordan	free living	SPHI004
Thyrididae	others	<i>Addaea</i>	<i>pusilla</i>	(Butler)	semi concealed	TORT062
Thyrididae	others	<i>Addaea</i>	sp. near <i>probolopsis</i>	Meyrick	semi concealed	CRAM083
Thyrididae	others	<i>Aglaopus</i>	<i>ignefissa</i>	(Warren) 1908	semi concealed	THYR006
Thyrididae	others	<i>Homodes</i>	<i>iomolybda</i>	Meyrick 1889	free living	THYR009
Thyrididae	others	<i>Mellea</i>	sp.		semi concealed	THYR012
Thyrididae	others	<i>Mellea</i>	<i>nitida</i>	(Pagenstecher)	semi concealed	TORT083
Thyrididae	others	<i>Mellea</i>	<i>ordinaria</i>	(Warren)	semi concealed	THYR001
Thyrididae	others	<i>Mellea</i>	<i>ramifera</i>	(Warren)	semi concealed	TORT075
Thyrididae	others	<i>Mellea</i>	sp. near but not <i>ramifera</i> and <i>nitida</i>		semi concealed	THYR016
Thyrididae	others	<i>Pharambora</i>	<i>splendida</i>	(Butler)	semi concealed	THYR003
Thyrididae	others	<i>Rhodoneura</i>	<i>aurata</i>	(Butler)	semi concealed	THYR005
Thyrididae	others	<i>Striglina</i>	<i>asinina</i>	Warren 1899	semi concealed	NOCT048
Thyrididae	others	<i>Striglina</i>	<i>cinnamomea</i>	(Rothschild)	semi concealed	THYR010
Thyrididae	others	unknown	sp.		free living	THYR020
Thyrididae	others	unknown	sp.		semi concealed	THYR023
Thyrididae	others	unknown	sp.		semi concealed	THYR025
Tortricidae	Tortricidae	<i>Adoxophyes</i>	<i>fasciculana</i>	(Walker) 1866	semi concealed	TORT034
Tortricidae	Tortricidae	<i>Adoxophyes</i>	sp.		semi concealed	TORT131
Tortricidae	Tortricidae	<i>Adoxophyes</i>	sp. 11		semi concealed	TORT094
Tortricidae	Tortricidae	<i>Adoxophyes</i>	sp. 6A		semi concealed	TORT066
Tortricidae	Tortricidae	<i>Adoxophyes</i>	sp.2 <i>nebrodes</i> , female	Diakonoff	semi concealed	TORT022
Tortricidae	Tortricidae	<i>Adoxophyes</i>	<i>templana</i> complex		semi concealed	TORT008
Tortricidae	Tortricidae	<i>Adoxophyes</i>	<i>thoracica</i>	Diakonoff	semi concealed	TORT044
Tortricidae	Tortricidae	<i>Adoxophyes</i>	<i>tripselia</i>	(Lower) 1908	semi concealed	TORT037
Tortricidae	Tortricidae	<i>Ancylophyes</i>	sp.		semi concealed	XXXX114
Tortricidae	Tortricidae	<i>Archigraptis</i>	<i>chrysodema</i>	(Diakonoff) 1952	semi concealed	TORT196
Tortricidae	Tortricidae	<i>Dudua</i>	n. sp. nr. <i>aprobola</i>	(Meyrick) 1886	semi concealed	TORT143
Tortricidae	Tortricidae	gen. nov. nr. <i>Loboschiza</i>	sp. nov.		semi concealed	TORT172
Tortricidae	Tortricidae	<i>Heleanna</i>	sp. 1		semi concealed	TORT065
Tortricidae	Tortricidae	<i>Holocola</i>	n. sp.		semi concealed	TORT170
Tortricidae	Tortricidae	<i>Homona</i>	<i>aestivana</i>	(Walker) 1866	semi concealed	TORT085
Tortricidae	Tortricidae	<i>Homona</i>	<i>mermerodes</i>	Meyrick 1910	semi concealed	TORT040
Tortricidae	Tortricidae	<i>Homona</i>	<i>phanaea</i>	Meyrick	semi concealed	TORT051
Tortricidae	Tortricidae	<i>Homona</i>	<i>salaconis</i> group	(Meyrick) 1912	semi concealed	TORT086
Tortricidae	Tortricidae	<i>Homona</i>	<i>trachyptera</i>	Diakonoff	semi concealed	TORT067
Tortricidae	Tortricidae	<i>Isotenes</i>	sp. nr. but not <i>miserana</i>	(Walker)	semi concealed	TORT061
Tortricidae	Tortricidae	<i>Macrothyma</i>	<i>sanguinolenta</i>	(Diakonoff) 1941	semi concealed	TORT098
Tortricidae	Tortricidae	<i>Nycteola</i>	<i>indicatana</i>	(Walker)	free living	TORT145
Tortricidae	Tortricidae	<i>Ophiorrhabda</i>	<i>deceptor</i>	Diakonoff	semi concealed	TORT142
Tortricidae	Tortricidae	<i>Sorolopha</i>	<i>cyclotoma</i>	Lower	free living	TORT183
Tortricidae	Tortricidae	<i>Sorolopha</i>	sp.		semi concealed	TORT147
Tortricidae	Tortricidae	<i>Sorolopha</i>	sp. 8		semi concealed	TORT117
Tortricidae	Tortricidae	<i>Sorolopha</i>	sp. probably <i>caryochlora</i>	Diakonoff	semi concealed	TORT184
Tortricidae	Tortricidae	<i>Statherotis</i>	<i>leucapsis</i>	(Meyrick) 1902	semi concealed	TORT129

<b>Moth Family</b>	<b>Moth Category</b>	<b>Moth Genus</b>	<b>Moth Species</b>	<b>Moth Author</b>	<b>Feeding Mode</b>	<b>Code</b>
Tortricidae	Tortricidae	unknown	sp.		semi concealed	TORT130
Tortricidae	Tortricidae	unknown	sp.		semi concealed	TORT144
Tortricidae	Tortricidae	unknown	sp.		semi concealed	TORT155
Tortricidae	Tortricidae	unknown	sp.		semi concealed	TORT160
Tortricidae	Tortricidae	unknown	sp.		semi concealed	TORT185
Tortricidae	Tortricidae	unknown	sp.		free living	TORT197
Tortricidae	Tortricidae	unknown	sp.		semi concealed	TORT203
Tortricidae	Tortricidae	unknown	sp.		semi concealed	TORT204
Tortricidae	Tortricidae	unknown	sp.		semi concealed	TORT207
Tortricidae	Tortricidae	unknown	sp.		semi concealed	TORT209
Tortricidae	Tortricidae	<i>Xenothictis</i>	n. sp.		semi concealed	TORT039
XXXX	others	unknown	sp.		semi concealed	XXXX115
XXXX	others	unknown	sp.		semi concealed	XXXX130
XXXX	others	unknown	sp.		semi concealed	XXXX131
XXXX	others	unknown	sp.		free living	XXXX132
XXXX	others	unknown	sp.		free living	XXXX133
XXXX	others	unknown	sp.		semi concealed	XXXX139
XXXX	others	unknown	sp.		semi concealed	XXXX150

**APPENDIX C. Overview of number of Lepidoptera species reared from each family and number of species for which parasitoids were recorded.**

<b>Family</b>	<b>Species</b>	<b>Parasitised Species</b>
Geometridae	43	8
Tortricidae	39	14
Crambidae	37	20
Noctuidae	37	9
Thyrididae	16	6
Choreutidae	13	8
Pyralidae	11	7
Lymantriidae	10	5
Gelechiidae	9	5
Arctiidae	8	2
Nolidae	7	4
unknown	7	1
Elachistidae	5	1
Immidae	4	2
Nymphalidae	4	2
Hesperiidae	3	1
Hyblaenidae	3	2
Lycaenidae	3	2
Oecophoridae	3	
Lacturidae	2	2
Limacodidae	2	1
Sphingidae	2	1
Gracillariidae	1	1
Hypertrophidae	1	
Lecithoceridae	1	1
Notodontidae	1	
Peleopodidae	1	
Psychidae	1	
<b>Grand Total</b>	<b>274</b>	<b>105</b>