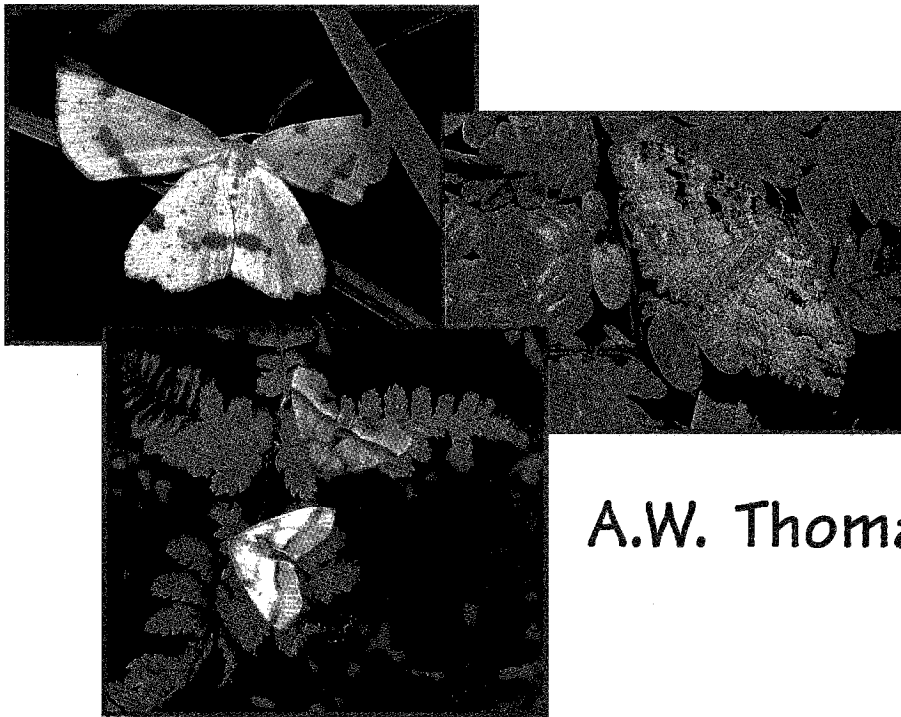# MOTH DIVERSITY IN A NORTHEASTERN

NORTH AMERICAN, RED SPRUCE FOREST

II. The Effect of Silvicultural Practices
on Geometrid Diversity
(Lepidoptera: Geometridae)

A.W. Thomas

Information Report M-X-213E

Canadian Forest Service - Atlantic Forestry Centre

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Summary

❖ There was a negative correlation between the amount of timber removed and the total number of individuals trapped in a plot.

❖ There was a negative correlation between the mean daily catch of individuals and the amount of timber removed.

❖ Species richness was greatest in the plot with 30% timber removed, followed by the uncut plot, then the strip cut, and least in the plot with 100% timber removed.

❖ There was a negative correlation between the mean daily catch of species and the amount of timber removed.

❖ Seasonal species accumulation curves showed the clearcut had a 5-day lag compared with the other plots.

❖ The number of species shared between the uncut plot and a prescription was negatively correlated with the amount of timber removed.

❖ Quantitative similarity indices ranked the plots in accordance with the amount of timber removed, *i.e.*, the more timber removed, the lower the similarity coefficient when compared with the uncut plot.

❖ Rank abundance plots were good fits to theoretical log series curves for all prescriptions, including the uncut plot.

❖ Species abundance plots took the form of truncated log normal distributions for the uncut, selection-cut, and strip-cut plots.

❖ Species abundance plots for the clearcut were typical of those of an impoverished site.

❖ McIntosh's diversity index, U, was the only diversity statistic that ranked the four plots in accordance with the severity of the prescription.

Résumé

❖ Entre le taux de bois prélevé et le nombre total d'individus capturés dans les pièges de la parcelle, la corrélation était négative.

❖ Entre le nombre journalier moyen d'individus capturés et le taux de bois prélevé, la corrélation était négative.

❖ La richesse spécifique était maximale dans la parcelle où 30 % du bois avait été prélevé, puis diminuait progressivement, de la parcelle non soumise à la coupe (parcelle témoin) à la parcelle coupée par bandes, puis à la parcelle soumise à la coupe à blanc.

❖ Entre le nombre journalier moyen d'espèces capturées et le taux de bois prélevé, la corrélation était négative.

❖ La comparaison des courbes de l'accumulation saisonnière des espèces a révélé un retard de cinq jours dans la parcelle soumise à la coupe à blanc par rapport aux autres parcelles.

❖ Entre le nombre d'espèces communes à la parcelle témoin et à une parcelle soumise à un traitement particulier (taux de bois prélevé), la corrélation était négative.

❖ Des indices de similitude quantitative ont permis de classer les parcelles selon le taux de bois prélevé, c'est-à-dire que plus ce taux était élevé, moins le coefficient de similitude était élevé par rapport à la parcelle témoin.

❖ Pour tous les traitements, y compris la parcelle témoin, les diagrammes rang-fréquence (DRF) correspondaient bien aux courbes des séries logarithmiques théoriques.

❖ Les diagrammes de l'abondance spécifique dans la parcelle témoin, la parcelle à coupe sélective et la parcelle coupée par bandes obéissaient à une distribution log normale tronquée.

❖ Les diagrammes de l'abondance spécifique dans la parcelle coupée à blanc étaient typiques d'une station appauvrie.

❖ L'indice de diversité de McIntosh (U) était la seule statistique de la diversité à avoir permis le classement en rang des quatre parcelles conformément à l'intensité du traitement.

Table of Contents

Preamble

This is the second report based on moth diversity in a red spruce forest that had undergone three silvicultural prescriptions immediately before sampling. The site contained undisturbed forest, selection-cut plots, strip-cut plots, and clearcut plots. The first report, a baseline study, contained an introduction to the project; detailed the sampling methodology; presented seasonal species accumulation curves, randomized species accumulation curves and richness estimates, rank abundance plots, diversity statistics, species abundance plots, and seasonal changes in diversity; and gave a list of species collected and their abundances (Thomas 2001). The data were summed across all plots and analyzed in three groupings: all species in 14 families of macromoths, geometrids, and noctuids.
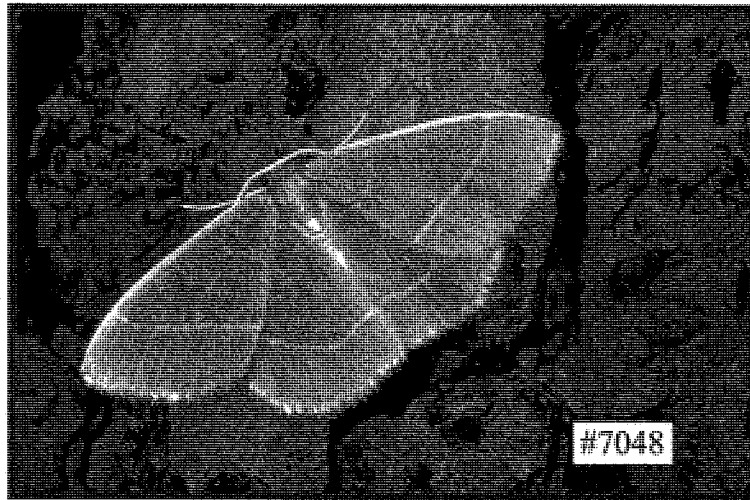
Introduction

The geometrid community was chosen for an in-depth analysis because earlier studies reported geometrids as good candidates to determine the effect of forestry practices on moth diversity because of their weak flight ability and high habitat fidelity (Holloway 1985, Usher and Keiller 1998, Intachat and Holloway 2000). Also, the baseline study (Thomas 2001) indicated that few geometrid species had been "missed' during the sampling period. This report examines the site on a plot-by-plot basis to determine the effect of the silvicultural prescriptions on insect diversity as exemplified by the community of the moth family Geometridae. The objective was to compare richness, abundances, diversity statistics, and complementarity of the geometrid fauna of the uncut plot with similar data from plots that had undergone the silvicultural prescriptions in order to determine the effect of such prescriptions on geometrid diversity.

Materials and Methods

Study Site and Collection

The study was conducted in a red spruce forest at the Acadia Research Forest, Sunbury County, New Brunswick (46.02 N 66.38 W), that contained plots of approximately 3 ha ranging from mature, undisturbed forest (no timber removed), through selection cut (30% timber removed), and strip cut (50% timber removed), to clearcut (100% timber removed)—see aerial photograph, p. 6 (Thomas 2001). The silvicultural prescriptions had occurred during the winter of 1998/1999, immediately preceding the sampling period.

Eight light traps were operated from dusk to dawn, reasonably evenly spread over a period of 122 days beginning on 1/2 May and ending on 31 August/1 September, 1999. Each trap used a single 22-watt, black-light lamp as an attractant.

Traps were run from a single gasoline generator. The traps were operated in pairs in four plots: *i.e.*, two traps in each of an uncut, a selection-cut, a strip-cut, and a clearcut plot. Individual traps in each plot were separated by distances ranging from 42–100 m.

Statistical Analyses

In the baseline study, analyses were based on 11,815 geometrids from a total catch of 31,634 macros obtained from 54 nights, including an incomplete collection from the night of days 196/197 when only seven of the eight traps operated (Thomas 2001). As this current report compares catches between plots, all data from the night of 196/197 were discarded and the analyses were based on the 11,445 individual geometrids that were collected on the remaining 53 nights. Where practical, the data were analyzed on a per-trap basis as replicates give more credibility to any effect correlated with the silvicultural prescription. Some analyses were also performed on a plot basis, *i.e.*, data from the two traps in each of the four plots were summed before analysis.

Simple ways to detect an effect on a moth community are to determine whether there are differences in the numbers of individuals and species, and whether the seasonal species accumulation curves in the plots that underwent silvicultural prescriptions differed from those in the uncut plot. More complex ways to detect an effect involve measuring coefficients of similarities, plotting rank abundances and species abundances, and comparing these with ecological diversity models, and determining diversity statistics. The coefficient of similarity is an index of the extent to which two samples have either: i) species composition in common (qualitative measures) or ii) species and their abundances in common (quantitative measures). Values can range from 0, no similarity, to 1, complete similarity.

Four coefficients of similarity, Jaccard's qualitative, Sorensen's qualitative, Sorensen's quantitative, and Morisita-Horn's quantitative, were obtained from Estimate5 v6.0b program (Colwell 2000). Jaccard's qualitative similarity index is an incidence-based index of the ratio of the number of species shared between two samples divided by the total number of species in the two traps. Sorensen's qualitative similarity index uses identical variables to Jaccard's index but a different calculation. Because species diversity is usually considered to consist of two components, species richness (or the number of species) and evenness (or equitability) of species abundances, quantitative coefficients of similarity, *i.e.*, those that take into account the abundances of species, are regarded as being more meaningful than qualitative indices (Southwood 1978, Magurran 1988). Both the Sorensen abundance-based index and the Morisita-Horn index are quantitative indices and were used to compare the degree of similarity between samples, both within and between plots.

Estimates of true species richness were obtained from the log normal parametric model of relative abundance using the program LOGNORM (Krebs 1989, 1995). The accuracy of the estimates depended upon how well the sample data fit the model (Taylor 1978, Magurran 1988). The estimates were then used to determine the log normal diversity statistic, λ (Taylor 1978). Other diversity statistics were calculated using BIO-DAP (Thomas 2000), a software package based on the worked examples in Magurran (1988), and the programs DIVERS, LOGSERIE, and LOGNORM (Krebs 1989, 1995).

The ultimate goal of this study is to rank forestry practices according to their effect on diversity. This is a preliminary study and, in order to select statistics that can be used to evaluate the effects of forestry practices on local diversity, as many statistics as possible were calculated.
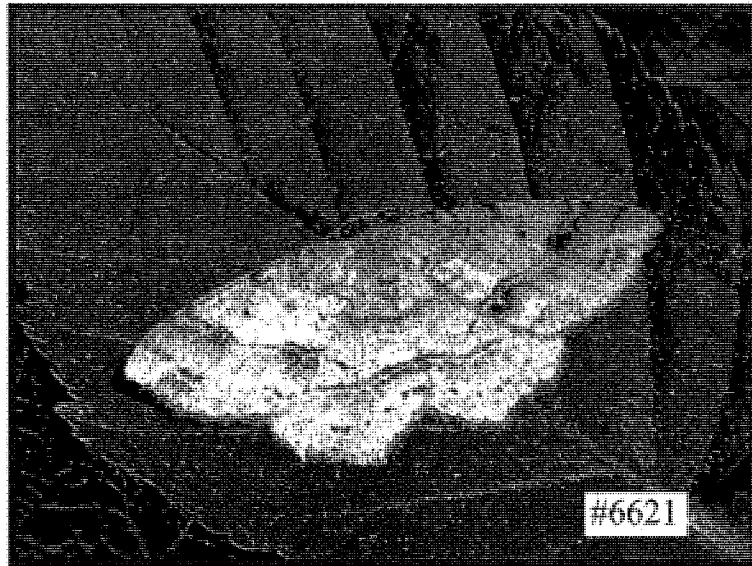
Table 1. Numbers of individuals and species of Geometridae per trap grouped by silvicultural prescription

Prescription (plot)	Trap*	Individuals	Species/ trap	Total species
Uncut (control)	UC-1	2198	118	142
	UC-2	2558	124	
Selection cut	SC-1	1497	126	147
	SC-2	2099	128	
Strip cut - residual	SCR-1	1254	99	128
- clear	SCC-1	1056	109	
Clearcut	CC-1	400	86	109
	CC-2	383	82	
Pooled data		11,445		169

* UC-1, UC-2, traps in Uncut plot (100% timber retention, plot undisturbed).
 SC-1, SC-2, traps in Selection-cut plot (30% timber removed).
 SCR-1, SCC-1, traps in Strip-cut plot (50% timber removed in alternate 14-m strips).
   SCR-1-residual strip (no timber removed).
   SCC-1-clearcut (100% timber removed).
 CC-1, CC-2, traps in Clearcut plot (100% timber removed).

Results

Numbers of Individuals

Over the duration of the 53 sample nights, 11,445 individuals were collected in eight traps, of which 41.6% were trapped in the uncut plot, 31.4% in the selection cut, 19.2% in the strip cut, and only 6.8% in the clearcut (Table 1). The mean daily abundances of individuals were negatively correlated with the amount of timber removed. Thus, on average, 46.0% of the individuals trapped each day were in the uncut plot, 28.8% in the selection cut, 19.7% in the strip cut, and only 5.5% in the clearcut (Table 2). The proportional catch/ trap on a daily basis for the traps in the prescription plots are compared with the traps in the uncut plot in Figure 1. On most days, the proportional catches of individuals in the prescription plots were lower than the catches in the uncut plot. Thus, the lower abundances in the pre-

scription plots compared with the uncut plot were not time-restricted phenomena but were consistent throughout the sampling period.

Numbers of Species

Over the duration of the 53 sample nights, 169 species were collected with 84% of the species in the uncut plot, 87% in the selection cut, 75.7% in the strip cut and 65.5% in the clearcut (Table 1). On a daily basis, the mean proportional catches of species were negatively correlated with the amount of timber removed (Table 3). On average, the traps in the uncut plot contained 50% of the species captured/day, the selection cut 40%, the strip cut 32%, and the clearcut only 13%. The proportional catch/trap on a daily basis for the traps in the prescription plots are compared with the traps in the uncut plot in Figure 2. As with the
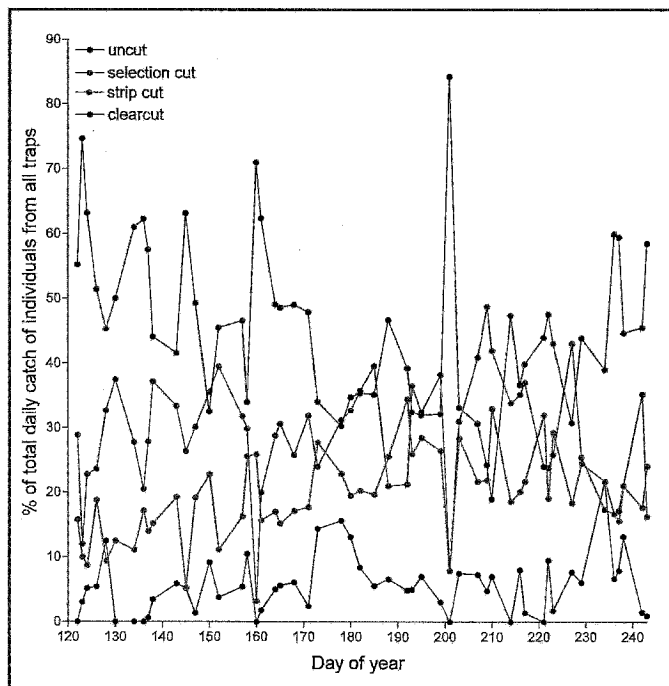
Figure 1. Daily proportional abundances of individual
geometrids in the plots.

Table 2. Mean daily abundances of individuals of geometrids by trap as percentages of the summed daily abundances from all eight traps

Plot	Uncut		Selection cut		Strip cut		Clearcut	
Trap*	UC-1	UC-2	SC-1	SC-2	SCR-1	SCC-1	CC-1	CC-2
mean	21.4	24.6	12.4	16.4	12.0	7.73	3.0	2.51
SE mean	1.14	1.19	0.72	0.85	0.70	0.61	0.36	0.38

* see Table 1 for trap coding

Table 3. Mean daily catches of geometrid species by trap as percentages of the total daily catches of species from all eight traps

Plot	Uncut		Selection cut		Strip cut		Clearcut	
Trap*	UC-1	UC-2	SC-1	SC-2	SCR-1	SCC-1	CC-1	CC-2
mean	47.1	54.0	36.9	42.0	35.9	28.6	14.0	11.7
SE mean	2.17	1.90	1.85	2.25	1.95	2.0	1.64	1.48

* see Table 1 for trap coding

numbers of individuals, on a daily basis fewer species were found in the prescription plots than in the uncut plot.

Seasonal Species Accumulation Curves

The seasonal species accumulation curves for the plots were identical at the beginning and end of the season. However, for the period when species accumulation was increasing most rapidly, day 138–180 (18 May–29 June), the clearcut showed about a 5-day lag behind that of the other plots (Fig. 3).

Differentiation Diversity

As the species richness in any single plot ranged between 64.5–87% of the total geometrid species recorded from the site ($S = 169$, Table 1), there were between-plot variations in species compositions. There were also variations in species compositions between traps within plots (Tables 1 and 4). This intra-plot variability was great-

est in the clearcut, with just 54% of the species common to both traps, *i.e.*, 59 common species out of a total 109 species (last cell, Table 4), and least in the selection cut (SC-1 vs. SC-2) and uncut (UC-1 vs. UC-2) with 73% and 70% of species in common, respectively. The two traps in the strip cut (SCR-1 vs. SCC-1) shared 63% of the 128 species captured in that plot (Table 4).

Qualitative Measures

Jaccard's qualitative similarity index separated the trap catches into three groupings. One group involved the six comparisons between the four traps in the uncut and selection cut, and gave indices ranging between 0.70 and 0.74 (first three columns, Table 5). A second grouping comprised the two traps in the clearcut. These traps shared the fewest species with each other, and with traps in the other plots, and had the lowest similarity indices when paired with other traps, 0.49–0.59 (last two columns, Table 5). The strip-cut traps formed a third grouping that shared more species with the traps in the uncut and selection

Figure 2. Daily proportional catches of geometrid species in the plots.
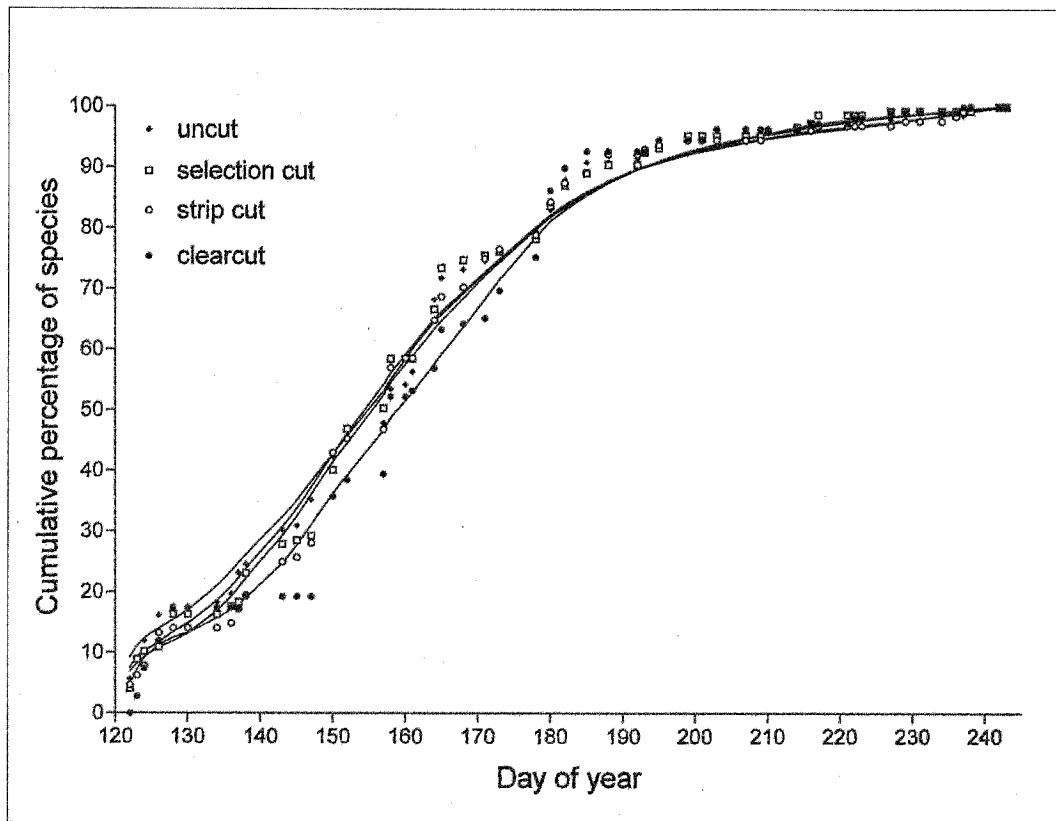
Figure 3. Seasonal species accumulation curves for geometrids from the four plots. Lines are coarsely fitted Lowess curves to show trends in the data. Note that the trends for the uncut, selection-cut, and strip-cut plots are almost identical but that the trend for the clearcut lags behind by about 5 days during the period of rapid increase in species appearance.

cut, 83–96 species (Table 4), than with those in the clearcut, 65–67 species (Table 4). The similarity indices reflected this sharing, 0.62–0.68 with the uncut and selection cut (columns four and five, Table 5), and 0.50–0.59 with the clearcut (Table 5).

Sorensen's qualitative similarity values are higher than those produced by Jaccard's index but the grouping for traps is identical (Table 6).

Quantitative measures

The Morisita-Horn index ranked the catches in trap UC-2 as being less similar to its companion trap, UC-1, in the uncut plot than to the catches in the traps in the selective cut (Table 7). Otherwise, the rankings between this index and Sorensen's quantitative index (Table 8) were similar, except that the Morisita-Horn measure gave consistently higher coefficients than did the Sorensen index.

Table 4. Number of geometrid species per trap, and shared species/total species for between-trap comparisons

Trap*/species	Shared species/total species for between-trap comparisons						
	UC-2	SC-1	SC-2	SCR-1	SCC-1	CC-1	CC-2/82
UC-1/118	100/142	102/142	105/141	83/134	88/139	70/134	69/131
UC-2/124		104/146	106/146	88/135	94/139	72/138	68/138
SC-1/126			107/147	89/136	93/142	74/138	70/138
SC-2/128				92/135	96/141	72/142	70/140
SCR-1/99					80/128	67/118	67/114
SCC-1/109						65/130	67/124
CC-1/86							59/109

*see Table 1 for trap coding

Table 5. Jaccard's incidence-based similarity indices for between-trap comparisons of geometrid species

Trap*	UC-2	SC-1	SC-2	SCR-1	SCC-1	CC-1	CC-2
UC-1	.70	.72	.74	.62	.63	.52	.53
UC-2		.71	.73	.65	.68	.52	.49
SC-1			.73	.65	.65	.54	.51
SC-2				.68	.68	.51	.50
SCR-1					.63	.57	.59
SCC-1						.50	.54
CC-1							.54

* see Table 1 for trap coding

Table 6. Sorensen's incidence-based similarity indices for between-trap comparisons of geometrid species

Trap*	UC-2	SC-1	SC-2	SCR-1	SCC-1	CC-1	CC-2
UC-1	.83	.84	.85	.76	.78	.69	.69
UC-2		.83	.84	.79	.81	.69	.66
SC-1			.84	.79	.79	.70	.67
SC-2				.81	.81	.67	.67
SCR-1					.77	.72	.74
SCC-1						.67	.70
CC-1							.70

* see Table 1 for trap coding

Table 7. Morisita-Horn abundance-based similarity indices for between-trap comparisons of geometrid species

Trap*	UC-2	SC-1	SC-2	ST-R	ST-C	CC-1	CC-2
UC-1	.90	.83	.90	.76	.74	.72	.71
UC-2		.96	.96	.91	.91	.76	.73
SC-1			.96	.95	.96	.76	.73
SC-2				.90	.91	.76	.73
ST-R					.97	.69	.65
ST-C						.74	.72
CC-1							.90

* see Table 1 for trap coding

In a plot-by-plot comparison, both quantitative indices ranked similarity in accordance with amount of timber remaining (Table 9). The selection cut (70% timber remaining) was most similar to the uncut plot, and the clearcut the least similar. The strip cut (50% timber remaining) was most similar to the selection cut and least similar to the clearcut. The clearcut was most similar to the strip cut.

Rank Abundance

When the relative abundance of each species from the uncut plot was plotted over its sequence in a ranking of abundances, the resulting shallow curve was characteristic of a log series species abundance model and was a close fit to the theoretical log series curve for a community with identical richness ($S = 142$) and abundance ($N = 4,756$)(Fig. 4a). Similar curves and goodness-of-fit to the theoretical curves were obtained from the data from the three prescription plots (Fig. 4b, c, d)

Species Abundance

Several patterns of frequencies of individuals/species/trap are apparent in the data set (Appendix). In most of the *Macaria* spp. (#6273–

#6351), individuals were far more abundant in the forested plots than in the clearcut. This pattern was also seen in many other species, especially those where abundances exceeded 200 individuals, e.g., *Ectropis crepuscularia* (#6597), *Hypagyrtis piniata* (#6656), *Pero morrisonaria* (6755), *Petrophora subaequaria* (#6804), and *Cyclophora pendulinaria* (#6139). In contrast, only two species showed relatively high abundances in the clearcut, i.e., *Eufidonia convergaria* (#6637) and *Biston betularia cognataria* (#6640).

When species abundances were grouped into x2 geometric scale classes and used as the x-axis of a frequency plot, the resulting graphs from the uncut, selection-cut, and strip-cut plots took the form of truncated log normal distributions (Fig. 5a, b, c) that are almost identical to an annual sample from a stable ecosystem in Great Britain (Taylor 1978, Fig. 1.6b). Such distributions fit both the log series and log normal models equally well (Taylor 1978). In the clearcut, (Fig. 5d) the preponderance of singletons coupled with no species beyond the 64-127 class is suggestive of an impoverished site (Taylor 1978, Fig. 1.6c). Such a distribution is described equally well by both log series and log normal models.

Table 8. Sorensen's abundance-based similarity indices for between-trap comparisons of geometrid species

Trap*	UC-2	SC-1	SC-2	ST-R	ST-C	CC-1	CC-2
UC-1	.79	.66	.77	.61	.55	.26	.26
UC-2		.69	.80	.61	.54	.22	.22
SC-1			.77	.77	.74	.37	.36
SC-2				.67	.62	.28	.27
ST-R					.79	.39	.39
ST-C						.46	.47
CC-1							.72

* see Table 1 for trap coding

Table 9. Coefficients of similarity for between-plot catches, Sorensen's abundance-based index with Morisita-Horn index in parentheses

Plot	selection cut	strip cut	clearcut
uncut	.80 (.97)	.68 (.90)	.44 (.70)
selection cut		.76 (.93)	.53 (.74)
strip cut			.66 (.84)

Diversity Statistics

The log series statistic, α, was of similar magnitude for all plots and thus showed no discriminant power (Table 10). The log normal statistic, λ, was highest for the selection-cut plot but there was no correlation between the severity of prescription and the values of λ (Table 10). Similarly, the Q-statistic and Margalef index were marginally highest for the selection cut but showed no discriminant ability (Table 10). McIntosh's U proved to be have excellent discriminant abilities and ranked the prescription plots according to the degree of disturbance (Table 10). The three indices regarded by Magurran (1988) as having moderate discriminant abilities (Brillouin, Shannon, reciprocal of Simpson,) ranked the uncut, selection-cut, and strip-cut plots in the order of the amount of disturbance but failed to rank the clearcut correctly (Table 10). All of the above indices, except Simpson's, are strongly influenced by species richness (Magurran 1988). The uncut and selection-cut plots were the most similar with regard to species richness and number of individuals and the eight indices biased towards proportional abundances (Shannon, reciprocal of Simpson, reciprocal of Berger-Parker, McIntosh dominance, Brillouin evenness, McIntosh evenness, Shannon evenness, Simpson evenness) ranked the uncut plot as more diverse than the selection cut (Table 10). In contrast, the measures biased towards richness, α, λ, Q, Margalef, ranked the selection-cut plot as more diverse.

Table 10. Diversity statistics for geometrids, tabulated by plot

Plot	Uncut	Selection cut	Strip cut	Clear cut
Individuals	4756	3596	2310	783
Richness, S	142	147	128	109
Log series, $\alpha \pm$ SD	27.5 ± 2.31	30.8 ± 2.53	29.2 ± 2.58	34.4 ± 3.30
Log normal, λ	185	217	182	201
Q statistic	27.7	33.2	29.1	28.9
Margalef	16.7	17.8	16.4	16.2
McIntosh index, U	866	731	490	136
Brillouin diversity	5.53	5.44	5.30	5.42
Shannon diversity	5.61	5.55	5.44	5.72
Simpson diversity*	30.2	24.2	22.3	32.9
Berger-Parker index*	10.4	7.8	7.3	12.0
McIntosh dominance	.830	.810	.805	.856
Brillouin evenness	.785	.771	.778	.847
McIntosh evenness	.893	.868	.865	.913
Shannon evenness	.785	.771	.778	.845
Simpson evenness	.974	.965	.963	.979

* reciprocal

Discussion

As the total numbers of individuals in the plots together with the mean daily abundances per trap were negatively correlated with the severity of the prescription (Tables 1 and 2), there was a measurable effect of timber removal on the abundance aspect of diversity for the geometrids. Effects were not as consistent on species richness, the selection cut produced more species than the uncut plot but the effect of strip cutting and clearcutting was to lower richness. However, on a daily basis, the mean proportional catches of species per plot were negatively correlated with amount of timber removed (Table 3). Even though 65.5% of the species were eventually captured in the clearcut, the mean daily proportional catch of species (at 13%) indicates the ephemeral nature of their occurrences there. This, coupled with the 5-day lag in the appearances of 'new species' in the clearcut (Fig. 3) suggests that most

geometrids were 'tourists' from the adjacent wooded plots. I would have expected the seasonal species accumulation curve for the clearcut to be ahead of the curves for the vegetated plots because of the warmer soil temperature in the clearcut. The low intra-plot similarity of species in the clearcut traps is further suggestive of a transient community of moths. The relative low intra-plot similarity in the strip-cut traps is likely a reflection of the contrasting habitats in which the traps were located.

A plot of species frequencies on the logged abundance classes, a species abundance plot, shows the most promise for detecting a severe deleterious impact of a forestry prescription. When the first class, one individual per species, gives the highest frequency, as in the clearcut, this indicates an impoverished site.

Landau *et al.* (1999) gave values of 65% overlap of species for a pair of traps in one forested site and 75% overlap of species for a pair of traps in a second forested site in Louisiana. In the uncut plot in the present study, the incidence-based similarity indices for the two traps were 0.70 for Jaccard's index and 0.83 for Sorensen's. The abundance-based similarity indices were 0.79 for Sorensen's index and 0.90 for Morisita-Horn's. These within-plot similarity indices are similar to the higher value given by Landau *et al.* (1999) and give baseline values for detecting effects of the prescriptions on the geometrid community. Similarity indices below these values, for between-plot trap comparisons, indicate a measurable effect of the prescription on the geometrid community.

Based on shared species, Jaccard's (Table 5) and Sorensen's (Table 6) incidence-based indices showed that 30% timber removal by a selection cut had no effect on species composition when compared with an uncut plot. However, removal of 50% timber by a strip cut or 100% removal by a clearcut lowered the indices and thus had a negative effect on species composition relative to the uncut forest.

The abundance-based similarity indices give results similar to the incidence-based indices; Sorensen's giving extremely low values for the uncut/clearcut comparisons (Table 8).

Magurran (1988) ranked diversity statistics as having good, moderate, or poor ability to detect subtle differences between sites; she emphasized that to be really useful, a diversity statistic must have a high discriminant ability. Four of the six she ranked "good" (α, λ, Q, Margalef) showed no discriminant ability. Strip cutting and clearcutting negatively affected species richness, S, (also ranked as "good") and thus S showed high discriminant ability when these two prescrip-
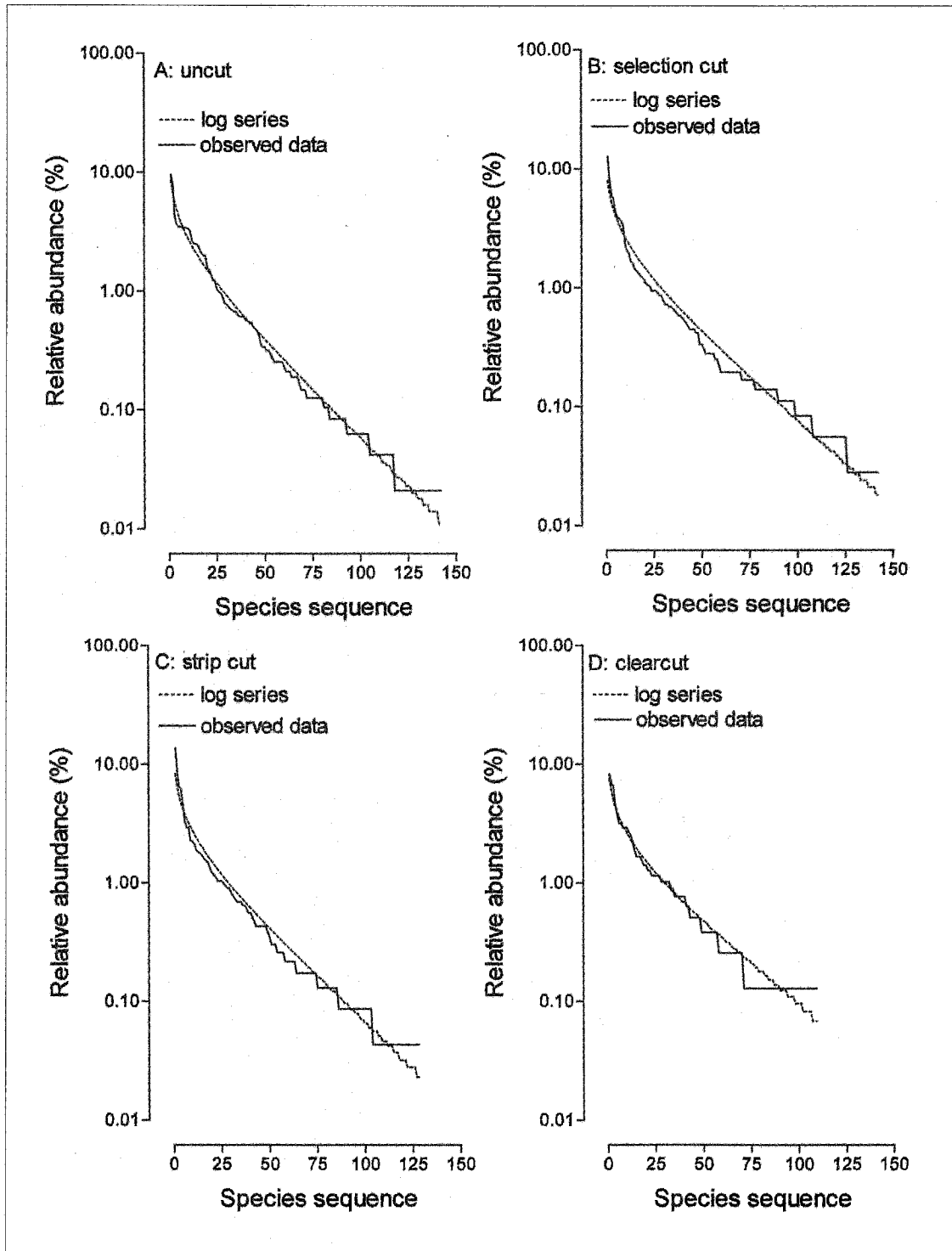

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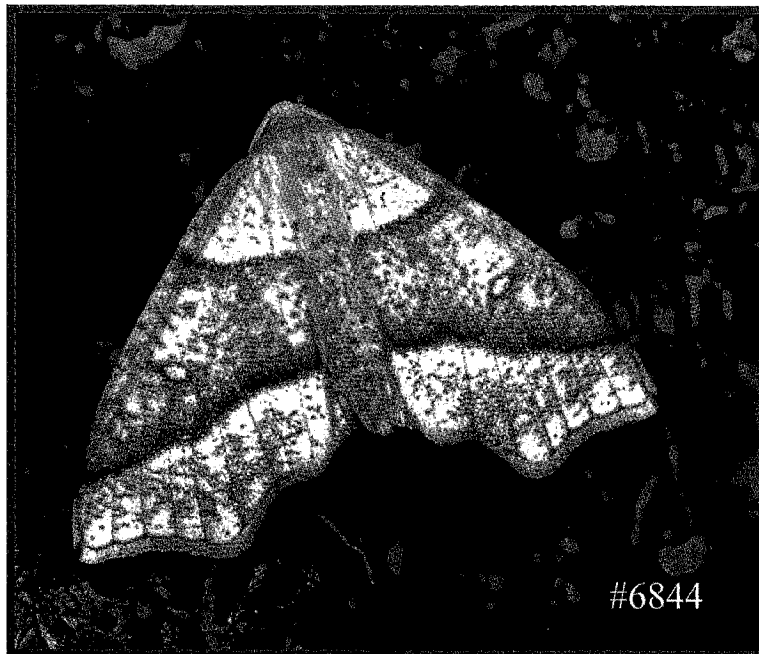
Figure 4. Rank abundance plots of geometrids in each of the four plots.
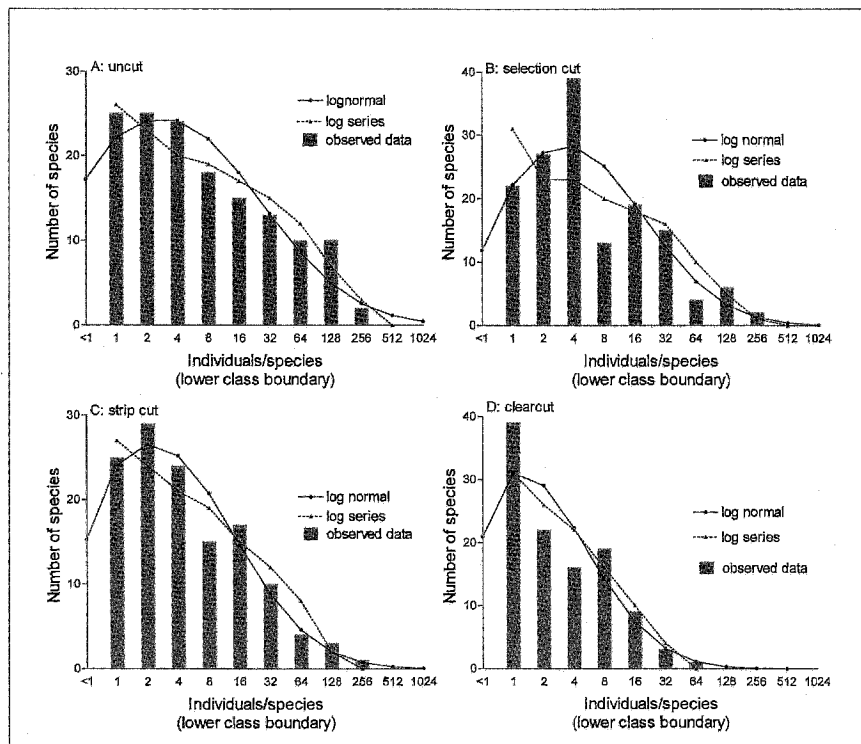
Figure 5. Frequencies of species abundance classes for geometrids in each of the four plots. Theoretical distributions from log series and log normal models compared with the observed data.

tions were compared with the uncut plot. McIntosh *U*, the sixth "good" index, showed a very high discriminant ability in that it ranked the prescriptions according to the degree of timber removal. A second set of diversity measures, biased towards the proportional abundances of species, have poor discriminant ability but are useful for comparing communities that have similar numbers of species and individuals (Magurran 1988). These include Simpson, Berger-Parker, Brillouin evenness, McIntosh evenness, McIntosh dominance, Shannon evenness, Simpson evenness. In such communities, those with a more even distribution of individuals amongst the species are regarded as more diverse. These eight indices rank the uncut plot as more diverse than the selection cut.

The relatively high values of α and λ for the clearcut mirror the high values seen in some impoverished sites in Great Britain. This phenomenon was interpreted by Taylor (1978) as occurring on impoverished sites where samples from the resident populations, at very low densities, were overweighted by single immigrant individuals (tourists) from many vagrant species bordering the impoverished sites. The resulting distribution then has a very high proportion of singletons and gives rise to unrealistic values, especially for the log normal.

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APPENDIX

Abundances of Geometrid Species in Traps

Catalogue numbers (Cat. #) and species names follow Hodges (1983), but nomenclature has been updated according to Handfield (1999).

Cat. #	Genus	Specific epithet	Subspecies	UC-1	UC-2	SC-1	SC-2	ST-R	ST-C	CC-1	CC-2
6270	Protitame	virginalis		1	3	3	2	1	1	0	0
6273	Macaria	pustularia		148	308	205	255	172	145	32	21
6280	Macaria	andersoni		3	2	2	5	1	3	4	4
6286	Macaria	brunneata		20	23	16	17	4	6	5	2
6287	Macaria	anataria		2	1	0	5	2	2	0	0
6292	Macaria	exauspicata		0	0	1	0	0	0	0	0
6326	Macaria	aemulataria		8	22	8	16	7	4	0	0
6330	Macaria	ulsterata		8	1	1	16	3	4	1	0
6339	Macaria	transitaria		0	1	0	1	0	0	0	0
6340	Macaria	minorata		1	2	2	2	2	2	0	1
6341.1	Macaria	nsp. nr. bicolorata		0	0	1	0	0	0	0	0
6342	Macaria	bisignata		1	0	0	0	0	1	0	1
6343	Macaria	sexmaculata		40	79	72	66	116	84	6	6
6344	Macaria	signaria	dispuncta	3	11	6	14	13	14	2	0
6347	Macaria	pinistrobata		1	2	0	0	4	0	0	1
6348	Macaria	fissinotata		0	0	0	0	0	2	0	0
6349	Macaria	banksianae		0	1	0	1	0	0	0	0
6350	Macaria	submarmorata		46	118	96	108	74	70	8	15
6351	Macaria	oweni		71	90	43	77	45	23	7	6
6362	Digrammia	continuata		1	0	0	2	0	0	0	0
6396	Digrammia	neptaria	trifasciata	0	0	2	1	1	0	0	0
6428	Orthofidonia	tinctaria		5	4	0	9	0	3	0	0
6429	Orthofidonia	exornata		10	12	2	4	2	1	0	1
6430	Orthofidonia	flavivenata		20	7	2	3	0	0	0	0
6436	Ematurga	amitaria		0	0	0	1	0	0	0	0
6449	Glena	cribataria		4	0	1	2	0	0	0	0
6450	Glena	cognataria		0	0	0	0	0	0	1	0
6570	Aethalura	intertexta		9	20	20	14	9	7	3	3
6582	Iridopsis	vellivolata		4	2	1	3	2	0	0	0
6583	Iridopsis	ephyraria		0	3	1	3	3	1	1	0
6588	Iridopsis	larvaria		5	8	2	3	2	1	0	0
6590	Anavitrinella	pampinaria		9	7	12	13	12	9	1	0
6595	Cleora	projecta		2	0	1	0	0	0	0	0
6597	Ectropis	crepuscularia		70	50	29	21	31	6	2	7
6598	Protoboarmia	porcelaria	indicataria	14	21	5	11	18	18	5	2
6620	Melanolophia	canadaria		4	8	1	5	4	1	0	1

Cat. #	Genus	Specific epithet	Subspecies	UC-1	UC-2	SC-1	SC-2	Trap ST-R	ST-C	CC-1	CC-2
6621	Melanolophia	signataria		33	39	19	27	23	18	2	9
6637	Eufidonia	convergaria		3	1	7	4	0	4	10	3
6638	Eufidonia	notataria		2	0	0	1	4	6	0	3
6639	Eufidonia	discospilata		1	2	2	0	0	0	0	0
6640	Biston	betularia	cognataria	1	2	11	8	6	13	36	29
6651	Lycia	ursaria		5	2	3	1	2	2	1	2
6654	Hypagyrtis	unipunctata		16	17	13	15	6	3	0	0
6656	Hypagyrtis	piniata		55	62	19	29	37	16	3	1
6658	Phigalia	Titea		0	1	0	2	0	1	0	1
6667	Lomographa	vestaliata		11	12	8	8	7	3	4	6
6668	Lomographa	glomeraria		2	0	0	0	3	0	1	0
6677	Cabera	erythemaria		3	4	3	1	1	2	0	1
6678	Cabera	variolaria		2	0	1	1	0	0	0	0
6724	Euchlaena	serrata		0	0	0	0	1	0	2	1
6725	Euchlaena	muzaria		28	38	16	18	14	9	4	6
6728	Euchlaena	effecta		0	0	0	1	1	1	0	4
6729	Euchlaena	johnsonaria		2	2	8	10	8	5	2	0
6731	Euchlaena	madusaria		0	0	2	0	0	1	2	2
6734	Euchlaena	marginaria		16	16	18	26	17	9	9	6
6737	Euchlaena	tigrinaria		1	1	2	1	0	0	0	1
6739	Euchlaena	irraria		0	1	6	1	1	1	0	1
6740	Xanthotype	urticaria		0	2	3	4	2	3	2	0
6743	Xanthotype	sospeta		2	7	0	2	0	0	0	0
6755	Pero	morrisonaria		51	57	23	36	28	21	10	8
6763	Phaeoura	quernaria		1	4	0	2	0	3	2	0
6796	Campaea	perlata		48	47	14	24	7	2	0	1
6797	Ennomos	magnaria		1	0	2	3	4	8	0	0
6799	Epirranthis	substriataria		0	0	1	1	1	0	2	1
6804	Petrophora	subaequaria		74	81	60	83	37	31	13	12
6806	Tacparia	atropunctata		1	0	1	0	0	0	0	0
6807	Tacparia	detersata		87	81	62	91	30	46	20	32
6812	Homochlodes	fritillaria		19	19	4	6	11	6	6	3
6815	Gueneria	similaria		0	2	2	1	3	0	0	1
6817	Selenia	alciphearia		1	4	2	0	1	0	0	0
6818	Selenia	kentaria		0	1	1	0	0	1	0	0
6819	Metanema	inatomaria		0	8	3	4	1	4	0	0
6820	Metanema	determinata		2	2	1	1	0	2	1	0
6821	Metarranthis	warnerae		0	0	0	0	0	0	1	0
6822	Metarranthis	duaria		20	12	11	15	2	5	3	5
6825	Metarranthis	indeclinata		4	0	8	2	0	2	4	2

Cat. #	Genus	Specific epithet	Subspecies	Trap							
				UC-1	UC-2	SC-1	SC-2	ST-R	ST-C	CC-1	CC-2
6826.1	Metarranthis	mestusata		4	8	3	2	1	0	0	1
6832	Metarranthis	obfirmaria		0	0	2	6	1	2	1	1
6834	Cepphis	decoloraria		0	1	0	0	0	0	1	0
6835	Cepphis	armataria		0	1	1	0	0	0	0	0
6836	Plagodis	pulveraria	occiduaria	12	3	2	5	5	1	0	0
6837	Probole	alienaria		9	18	12	19	7	11	3	2
6840	Plagodis	serinaria		28	22	14	23	7	9	4	2
6842	Plagodis	phlogosaria	phlogosaria	45	29	4	8	7	3	1	1
6844	Plagodis	alcoolaria		1	0	1	2	0	0	0	0
6863	Caripeta	divisata		22	25	11	15	23	16	3	6
6864	Caripeta	piniata		2	2	0	2	0	1	0	1
6867	Caripeta	angustiorata		0	1	1	0	0	1	0	1
6884	Besma	endropiaria		2	8	3	1	1	1	1	0
6888	Lambdina	fiscellaria		68	60	17	35	34	18	16	9
6906	Nepytia	canosaria		20	17	2	8	12	10	0	0
6912	Sicya	macularia		1	0	2	1	0	2	0	0
6941	Eusarca	confusaria		0	0	0	0	0	0	0	1
6963	Tetracis	crocallata	aspilatata	1	2	2	0	0	1	1	0
6964	Tetracis	cachexiata		27	19	12	27	10	6	5	1
6965	Eugonobapta	nivosaria		0	3	0	2	1	0	0	0
6966	Eutrapela	clemataria		5	11	1	6	2	0	1	0
6982	Prochoerodes	lineola		12	14	20	14	9	5	5	3
6987	Antepione	thisoaria		7	3	4	6	3	2	3	2
7009	Nematocampa	resistaria		3	8	3	2	3	3	0	0
7048	Nemoria	mimosaria		5	4	0	2	2	0	0	0
7058	Synchlora	aerata	albolineata	2	0	2	5	0	0	0	0
7071	Chlorochlamys	chloroleucaria		0	0	0	1	0	0	0	0
7084	Hethemia	pistasciaria		0	0	0	0	0	0	1	1
7125	Idaea	rotundopennata		2	4	14	8	1	0	2	0
7126	Idaea	dimidiata		5	2	2	2	0	0	3	0
7139	Cyclophora	pendulinaria		200	167	91	193	62	41	15	8
7159	Scopula	limboundata		91	73	39	93	26	18	15	14
7164	Scopula	junctaria		8	4	3	9	4	11	2	7
7165	Scopula	quadrilineata		1	0	0	0	0	0	1	0
7169	Scopula	inductata		1	1	1	0	0	0	1	1
7182	Dysstroma	citrata		3	3	3	3	4	0	1	0
7188	Dysstroma	walkerata		13	13	8	13	6	4	1	1
7201	Eulithis	testata		0	1	0	0	0	1	0	0
7206	Eulithis	explanata		87	116	77	138	83	68	17	20
7208	Eulithis	serrataria		0	2	2	3	1	1	0	0

Cat. #	Genus	Specific epithet	Subspecies	UC-1	UC-2	SC-1	SC-2	Trap ST-R	ST-C	CC-1	CC-2
7213	*Ecliptopera*	*silaceata*	*albolineata*	2	0	0	2	1	2	0	1
7229	*Hydriomena*	*perfracta*		0	0	0	0	0	2	0	0
7235	*Hydriomena*	*divisaria*	*Frigidata*	8	9	13	18	13	11	9	4
7263	*Hydriomena*	*renunciata*		24	33	11	12	16	8	3	1
7254	*Hydriomena*	*ruberata*		0	0	0	2	0	0	0	0
7285	*Triphosa*	*haesitata*	*affirmaria*	0	1	0	1	0	0	1	0
7291	*Rheumaptera*	*undulata*	*bluff*	0	0	0	0	0	2	0	0
7293	*Rheumaptera*	*hastata*	*gothicata*	1	5	1	8	0	0	1	0
7307	*Mesoleuca*	*ruficillata*		0	0	0	0	0	0	1	0
7312	*Spargania*	*magnoliata*		0	0	2	1	0	0	1	0
7313	*Spargania*	*luctuata*	*obductata*	0	0	1	0	0	0	0	0
7316	*Perizoma*	*basaliata*		12	12	8	7	12	16	1	2
7320	*Perizoma*	*alchemillata*		2	1	0	0	0	0	2	1
7329	*Anticlea*	*vasiliata*		17	17	10	6	6	4	4	5
7330	*Anticlea*	*multiferata*		3	3	3	7	2	1	1	0
7368	*Xanthorhoe*	*labradorensis*		0	1	1	1	0	1	0	0
7370	*Xanthorhoe*	*abrasaria*	*congregata*	24	35	6	15	7	5	5	3
7371	*Xanthorhoe*	*iduata*		1	2	2	2	0	2	0	0
7388	*Xanthorhoe*	*ferrugata*		0	0	0	1	2	0	1	0
7390	*Xanthorhoe*	*lacustrata*		0	2	1	0	0	0	0	0
7399	*Euphyia*	*intermediata*		0	1	0	0	0	0	0	0
7414	*Orthonama*	*obstipata*		0	0	0	0	0	0	0	1
7419	*Hydrelia*	*lucata*		0	2	0	0	0	0	0	0
7420	*Hydrelia*	*condensata*		0	1	0	0	0	1	0	0
7422	*Hydrelia*	*inornata*		1	0	0	1	0	0	0	0
7428	*Venusia*	*comptaria*		114	61	29	46	16	15	3	5
7440	*Eubaphe*	*mendica*		2	4	5	0	1	2	1	5
7449	*Eupithecia*	*palpata*		31	64	21	21	10	14	6	5
7459	*Eupithecia*	*columbiata*		10	10	1	4	2	0	0	1
7474	*Eupithecia*	*miserulata*		0	0	2	4	0	1	0	0
7476	*Eupithecia*	*misturata*		6	23	16	9	5	8	1	3
7487	*Eupithecia*	*subfuscata*		59	104	26	45	12	22	10	11
7489	*Eupithecia*	*lariciata*		2	2	2	4	2	2	0	2
7491	*Eupithecia*	*fletcherata*		1	0	1	0	0	0	0	0
7492	*Eupithecia*	*casloata*		0	1	1	0	1	0	0	0
7520	*Eupithecia*	*satyrata*	*dodata*	9	3	3	3	0	5	0	0
7523	*Eupithecia*	*strattonata*		0	0	3	0	1	0	2	1
7524	*Eupithecia*	*cimicifugata*		0	0	0	0	0	1	0	0
7526	*Eupithecia*	*russeliata*		97	70	30	55	19	23	8	15
7528	*Eupithecia*	*assimilata*		0	1	0	0	0	0	0	0

Cat. #	Genus	Specific epithet	Subspecies	UC-1	UC-2	SC-1	SC-2	ST-R	ST-C	CC-1	CC-2
7529	Eupithecia	absinthiata		2	1	4	3	0	1	0	0
7531	Eupithecia	indistincta		1	0	1	2	0	0	0	1
7538	Eupithecia	gelidata		0	0	1	0	0	1	0	0
7540	Eupithecia	perfusca		2	1	3	4	0	2	0	0
7543	Eupithecia	annulata		3	3	1	1	0	1	0	0
7574	Eupithecia	albicapitata		17	12	10	5	1	5	2	0
7575	Eupithecia	mutata		3	1	3	3	0	5	3	3
7594	Eupithecia	anticaria		5	7	4	1	1	3	0	3
7625	Pasiphila	rectangulata		2	4	2	3	2	6	1	3
7635	Acasis	viridata		4	2	0	4	0	1	0	0
7637	Cladara	limitaria		39	61	29	31	12	9	9	11
7639	Cladara	atroliturata		5	10	6	1	7	0	1	1
7640	Lobophora	nivigerata		0	10	4	3	2	2	1	0

The column header "Trap" spans UC-1 through CC-2.