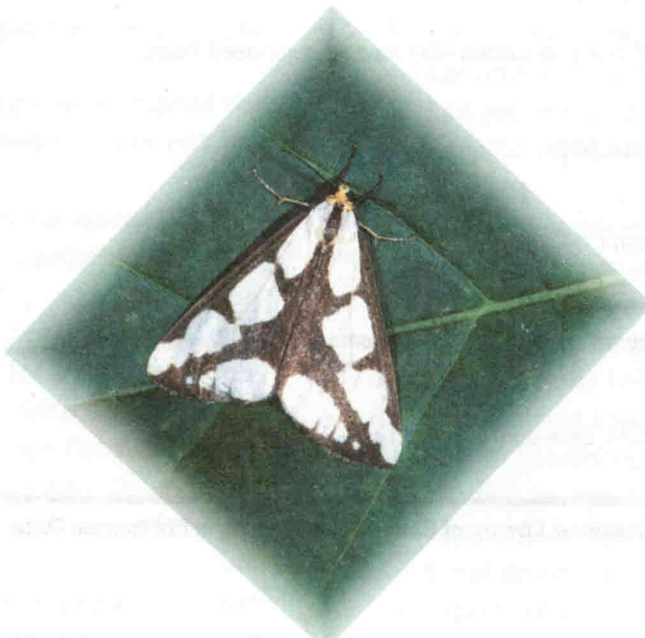
MOTH DIVERSITY IN A NORTHEASTERN, NORTH AMERICAN, RED SPRUCE FOREST

I. Baseline Study

by

A.W. Thomas



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SUMMARY

* Fourteen families were monitored for species richness and abundance
* The site was rich in species and individuals: 539 species, 31,634 individuals.
* Noctuidae and Geometridae together formed 81% of the species and 81% of the individuals
* There was a marked seasonality in the appearance of species
* Species richness estimators predicted 573-630 species
* Cumulative richness curves indicated that few species of geometrids had not been collected
* Coleman, rarefaction, curves indicated little heterogeneity in species composition between traps (plots)
* A rank abundance plot suggested a log normal distribution for the total catch
* Species abundance plots suggested log normal distribution for total catch and geometrids; noctuids were intermediate between log normal and log series distributions
* Diversity statistics showed more evenness and less dominance in the geometrid catch compared with the noctuid catch
* The *alpha* diversity index for the total catch was 92.3 but varied through the season

RÉSUMÉ

* Quatorze familles ont fait l'objet d'une analyse de l'abondance et de la richesse spécifique
* Le site est riche en espèces et en individus : on y a recensé 539 espèces et 31634 individus
* Ensemble, les Noctuidés et les Géométridés représentent 81 % des espèces et 81 % des individus
* L'apparition des espèces présente un caractère saisonnier prononcé
* Les estimateurs de la richesse spécifique prédisaient entre 573 et 630 espèces
* D'après les courbes de richesse cumulative, peu d'espèces de Géométridés n'ont pas été capturées
* Les courbes de raréfaction de Coleman indiquent une faible hétérogénéité de la composition taxinomique entre les pièges (parcelles)
* D'après la représentation graphique de l'abondance selon le rang, le nombre total de prises suit une distribution logarithmique normale
* Les représentations graphiques de l'abondance spécifique suggèrent une distribution logarithmique normale pour les prises totales et les Géométridés; pour les Noctuidés, la distribution se situe entre le modèle logarithmique normal et le modèle logarithmique sériel
* Les indices statistiques de diversité révèlent davantage d'uniformité et moins de dominance dans les prises de Géométridés que dans les prises de Noctuidés
* On a calculé un indice de diversité *alpha* de 92,3pour les prises totales, mais cette valeur a changé tout au long de la saison

GLOSSARY

Species richness — the number of species in a sample

Species composition — The names of species in a sample. Two samples could have the same species richness, *e.g.*, three species, but have totally different species composition (spA, spB, spC; vs. spD, spE, spF)

Abundance — the number of individuals

New species — species that have not been caught previously in a specific trap

Tourists — individuals not part of the specific forest community under study, they are transient between their specific habitats

TABLE OF CONTENTS

Aerial photograph of the study site in the Acadia Research Forest, New Brunswick, Canada; 46.02 N 66.38 W. Plot sizes are approximately 175 x 175 m, the undisturbed plot (100% timber retention) and selection-cut plot (30% timber removed) include a 25-m buffer strip adjacent to the roads.

PREAMBLE

This report is the first of three based on moth diversity in a red spruce forest that had undergone three silvicultural procedures immediately prior to sampling. The site contained undisturbed forest, selection-cut plots, strip-cut plots, and clearcut plots. This first report discusses moth diversity, in a broad sense, with the data summed across all plots. The second report will examine the site on a plot-by-plot basis to determine the effect of the specific silvicultural procedures on moth diversity. The third report will consider sampling protocol, especially the effects of sampling frequency (number of nights), intensity (number of traps), and duration (length of season) on the estimates of species richness.

INTRODUCTION

Night-flying Lepidoptera (moths) were selected as candidates for measuring the effect of several silvicultural prescriptions on animal diversity. Moths were chosen because of the relatively high numbers of species and individuals usually present in forest ecosystems, the ease of sampling the community with standardized procedures, *i.e.*, light traps, and my ability to identify all local individuals of 14 families to the species level. Most of the moth species have one generation per year, which is an advantage because they respond quickly to perturbations and to the recovery of the forest from such perturbations. In addition, the moths (in their larval stage) play a key role in the forest ecosystem by converting huge amounts of plant biomass to animal fats and proteins; and as larvae, pupae, and adults, are important as a food source for many of the forest vertebrates. As primary consumers, the larvae probably exploit all 31 food resources listed by Southwood *et al.* (1979) in their classification of architectural complexity of forests, *e.g.*, tree roots, wood, buds, needles, and leaves, as well as epiphytic lichens growing on the trees. This allows for the vertical partitioning of forests by insectivorous birds and a high species richness, seen especially in warblers, in the forest (MacArthur & MacArthur 1961).

One disadvantage of moths in a localized study is the possibility of 'tourists' (Wolda *et al.* 1994, Chey *et al.* 1997, Intachat & Holloway 2000). It is likely that such 'tourists' are dispersing between habitats and thus do not fly through the forest, but above the canopy (Thomas 1996). 'Tourists' are most likely to occur in the clearcut areas, as traps in these areas are far more visible than the traps in the relatively densely vegetated, undisturbed forest. Holloway (1985) conducted some research in tropical rain forests to determine which of the higher taxonomic groups in the Lepidoptera can be used to categorize undisturbed forest. He regarded members of the families Sphingidae and Noctuidae as poor discriminants for undisturbed forests because members of these families are strong flyers and are frequent 'tourists.' However, because many species in these families are characteristic of open habitats and secondary growth, their presence may be taken to indicate to some extent the degree of disturbance or degradation of rainforests. Species in the family Geometridae were considered as a suitable indicator group for rainforests (Holloway 1985, Scoble 1995, Intachat & Holloway 2000), as they are weak flyers and the number of species tends to increase with plant succession, reaching a peak in the climax vegetation type – woodland. As the noctuids and geometrids are the most dominant macro families in eastern North American (Landau & Prowell 1999a, 1999b; Summerville *et al.* 1999, Thomas *et al.* 1998, and other references in the discussion), the data will be analyzed in three taxonomic groupings, *viz.*, i) species in all 14 selected families (includes noctuids and geometrids), ii) noctuids, iii) geometrids.

A relatively recent paper by Colwell & Coddington (1994) has generated renewed interest in the methodology for estimating total species richness from sample data. The availability of a free statistical package, EstimateS (Colwell 2000), to analyze species-by-sample abundance matrices has enabled statistically challenged biologists to enter into this morass. EstimateS is a powerful tool for exploring sampling protocols, and will be used in the third report.

Excellent introductions to the measurement of diversity are to be found in Pielou (1975), Magurran (1988), Krebs (1989), and to a lesser extent in Southwood (1978). The basic idea of a diversity index is to summarize the data on the number of species and their proportional abundances into a

single numeric index (Hill 1973). This simplifies comparisons between sites and allows the researcher to determine if one site is more, or less, diverse than another. There is no single index suitable for all situations and the choice of an index depends upon which criteria the researcher wishes to emphasize. These criteria may include how well the index discriminates between sites or samples that are not unduly different, and whether the index is sensitive to sample size, to species richness, or to the evenness with which the individuals are apportioned among species.

The *alpha* statistic of Fisher *et al.* (1943) is often considered the "best" diversity index for many communities of species, including Lepidoptera (Southwood 1978, Taylor 1978, Wolda 1983, Barlow & Woiwod 1989, Robinson & Tuck 1993, Wolda *et al.* 1994, Chey *et al.* 1997), and was the only diversity measure, apart from species richness, used by Intachat & Holloway (2000). Magurran (1985) tested three species abundance models, log normal, log series, and broken stick, for goodness of fit to her light-trap data from forests in Northern Ireland. She found that the log normal model provided the best fit and thus used its value, λ, as the diversity index. Landau *et al.* (1999) studied moth diversity in Louisiana forests. They determined that the species distribution "roughly followed a log normal pattern" but did not did not give a diversity index based on this model. They reported the values of three indices, Fisher's *alpha*, Shannon-Wiener, and Simpson. However, the use of a single index, such as *alpha*, to describe a community's diversity has been criticized by Pielou (1975) because it confounds the two factors, species richness and the evenness with which the individuals are apportioned among the species. Thus, one disadvantage of *alpha* lies in its inability to discriminate between sites that have the same numbers of individuals and species. It is likely that such sites vary in the evenness of the frequencies of the constituent species. A site that has a greater evenness is usually considered more diverse than a site where a few species dominate, even though the *alpha* value may be higher in the site showing greater dominance. Indices that take into account both richness and the proportional abundances of species, such as those of Shannon and Simpson, are therefore useful in diversity studies. Hill (1973) has criticized the Simpson index as being a measure of "dominance concentration" as it is sensitive to the abundance of only the more plentiful species. However, when combined with species richness, the two values are suitable for characterizing the partition of abundance (Hill 1973). In a comparison between the diversity of moths in a conifer plantation and an adjacent relic oakwood in Northern Ireland, Magurran (1988) ranked the discriminatory abilities of ten indices. She found that the Margalef, McIntosh U, and species richness S measures gave the greatest degree of discrimination between the two forest types. In general, indices weighted towards species richness were more useful for detecting differences between sites than were the indices that emphasized the dominance/evenness components of diversity. The Berger-Parker Dominance index expresses the proportional importance of the most abundant species (the dominant species) and was considered by May (1975) as one of the most satisfactory diversity measures.

Whereas *alpha* diversity is the diversity of a moth community within a prescribed habitat and can be measured by the indices mentioned above, *beta* diversity or differentiation diversity is the degree of change in species between habitats (Magurran 1988). A simple way to measure *beta* diversity in the present context is to compare pairs of plots by the use of similarity coefficients. Such coefficients, or indices, can be qualitative (using only species data) or quantitative (using both species and their abundances). In both cases, index values can range from 0, no species in common, to 1, both sets of species identical (qualitative measures) or both species and abundances identical (quantitative measures). These *beta* diversity measurements will be used in the second report which will deal with the effect of silvicultural procedures on moth diversity.

As the abundances of insect species fluctuate enormously during a year in north temperate regions, the seasonal changes in species diversity are a useful adjunct to a single index for a community. Such seasonal changes in diversity of moth communities have been documented for the United Kingdom (Williams 1964, Taylor 1978). In a study of moth diversity in Fundy National Park, New Brunswick, Clay *et al.* (1998) graphed weekly and monthly diversities (*alpha* and Shannon indices) for each of 4 years from two sites. There were well marked, mid-summer peaks at each site for each year. Changes in richness and abundance throughout a year have been recorded for other North American moth communities (Profant 1990, Butler *et al.* 1999, Landau & Prowell 1999a, 1999b, Landau *et al.* 1999) but these authors did not calculate daily, weekly, or monthly diversity statistics. Seasonal changes are far less marked or even non-existent in tropical rainforests (Barlow & Woiwod, 1989, 1990). However, Robinson & Tuck (1993), working in Borneo, considered the phenomenon of an increase in a diversity index with progressive sampling worth investigating to determine after what period diversity stabilizes.

The specific objective of this first report was to describe the moth diversity for the overall site, in a broad sense, summed across all plots, *i.e.*, the data from all eight traps were pooled for each of three taxonomic groupings: all species, family Noctuidae, family Geometridae.

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 blocks 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) (aerial photograph, page 6). The silvicultural prescriptions had occurred during the 1998/1999 winter, immediately preceding the sampling period.

This study considered all ten families of moths in the Higher Ditrysia, the Macrolepidoptera (Scoble 1995), that occur in New Brunswick (Table 1) plus one family (Hepialidae) in the Exoporia and three families (Sesiidae, Cossidae, Limacodidae) in the Lower Ditrysia. Frequently, these 14 families are collectively called 'macro-moths' or 'macros' (Skinner 1984, Thomas 1996, Young 1997, Thomas *et al.* 1998).

Table 1. Total numbers of species and individuals trapped by family and summed across all plots

Family	Number of species	Number of individuals
Hepialidae	1	1
Sesiidae	2	82
Cossidae	2	6
Limacodidae	3	27
Drepanidae	6	492
Geometridae	169	11,815
Uraniidae	1	4
Lasiocampidae	4	344
Saturniidae	6	2,382
Sphingidae	11	408
Notodontidae	31	650
Arctiidae	27	1,381
Lymantriidae	5	135
Noctuidae	271	13,907
Totals	**539**	**31,634**

Eight light traps were operated from dusk to dawn for a total of 54 nights, *i.e.*, 432 collections (but see below), 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 an uncut plot; twc in a selection-cut plot, two in a strip-cut plot, and two in a clearcut plot. Individual traps in each plot were separated by distances ranging from 42 m to 100 m. One trap in the selection-cut plot became unplugged on the night of day 196/197 (15/16 July). On the previous night, this trap captured 151 individuals. The other trap in this plot captured 104 individuals on day 195/196 and 108 individuals on day 196/197, which suggests that approximately 150 individuals could be expected to have been captured in the unplugged trap on the night of 196/197. However, data analyses were performed on the 431 collections; no adjustment for missing data was made.

For each evening of the night that the traps were to be operated, each trap was "charged" with about 15 mL of ethyl acetate as a killing agent. On the following morning, the traps were emptied and the individuals transported to the laboratory where they were identified to species and counted. When the catch was too great for sorting to be completed in one day, the remaining uncounted moths were stored in a freezer for later processing. Individuals were identified using the standard taxonomic literature as listed in Thomas (1996), plus the more recent literature (Lafontaine 1998, Handfield 1999).

Data Entry and Statistical Analyses

Raw data were entered into a .dat file in SAS (SAS Institute Inc. 1995) as single lines with single spaces separating each variable. Each line recorded the number of individuals of a single species captured in a single trap on a single day. The data set occupied 10,997 lines. Data sorting, tabulation, and simple analyses were performed using SAS programs written by the author. Data sets were outputted to GraphPad Prism (1995) spreadsheets where extraneous SAS-generated material was removed. The resulting matrices were then saved as .txt files, specifically formatted for professionally written statistical analysis programs. GraphPad Prism was used to draw the figures.

A 'seasonal species accumulation curve' was constructed for each taxonomic grouping (all species, noctuids, geometrids) by adding new species to the cumulative species list in the time-sequence of the catches. These curves, and the plots of daily catches of individuals and daily plots of species, were based on daily catches, *i.e.*, individual trap collections summed across all eight traps. For other analyses, the data were pooled into seasonal totals and designated as samples, *i.e.*, a sample contained all the species and all the individuals collected in one trap.

'Randomized species accumulation curves' and nine statistical estimators of true species richness for each taxonomic grouping were obtained from the EstimateS v6.0b program (Colwell 2000). For the total catch, the data were organized as a species-by-sample abundance matrix for "Format 1" input files. For the noctuids and geometrids, the data were organized as 'sample, species, abundance triplets' for "Format 4" input files. One hundred randomizations were used for the computations. There was no *a priori* reason for starting with the trap #1 sample and adding the trap #2 sample, *etc*. The nine true species richness models usually predict different richness and there is reason to expect that different models may prove to be more effective for different taxonomic groups or different environments (Colwell & Coddington 1994). At present, there appears to be no one best model for predicting true species richness by extrapolation from species accumulation curves and the current advice is to test all models as rigorously as possible for a wide variety of taxa and localities (Colwell & Coddington 1994).

An estimate of true species richness can also be obtained from parametric models of relative abundance. Of these models, the log normal predicts the total number of species; its accuracy depends upon how well the sample data fit the log normal model. The program LOGNORM (Krebs 1989) was used to estimate true species richness in each of the three groupings.

EstimateS was also used to compute a Coleman random placement curve, equivalent to a rarefaction curve, for each of the three groupings. Such a curve plots the expected richness for random subsamples of the matrix, and thereby permits an evaluation of sample heterogeneity (the patchiness of species between plots). If all the species were randomly dispersed between plots, the Coleman curve would coincide with the observed species accumulation curve. When the species are clumped (aggregated), the observed number is less than that predicted by the curve. The more the Coleman curve lies above the observed species accumulation curve, the more clumped are the species.

Several diversity statistics, Margalef, McIntosh diversity and evenness, Q, Shannon-Weiner diversity and evenness, Berger-Parker, McIntosh's evenness, and Simpson's, were obtained from BIO-DAP (Thomas 2000), a compilation of programs based on the worked examples detailed in Magurran (1988). Fisher's α of the log series, λ of the log normal distribution, data summation for the species abundance plots, and theoretical curves for the log series and log normal models, were calculated using the programs in Krebs (1989).

RESULTS

Family Representations and List of Species

The 14 families sampled are listed in Table 1 together with the numbers of species and numbers of individuals summed across all plots. Individuals in the families Noctuidae and Geometridae dominated with 44% and 37% of the catch, respectively. The Saturniidae with 2,382 individuals accounted for 7.5% of the catch. None of the other 11 families accounted for more than 5% of the catch. On a species basis, the noctuids dominated by having 50% of the total species; the geometrids had 31%; none of the other families had more than 6% of the total.

The species and their abundances are listed in the Appendix arranged according to current classification (Scoble 1995, Handfield 1999).

Seasonal Abundances

Individuals

The pattern of activity by individuals, for the entire fauna, showed an increase in numbers over the first 5 trapping nights (a period of 7 days) followed by low numbers that increased to reach a peak nightly activity on day 158/159 (7/8 June). Nightly activity then declined until the end of trapping on day 243/244 (31 August/1 September) (Fig. 1). The small peak during the first week was caused by the presence of overwintering noctuids augmenting the Spring-emerging species. Noctuid activity peaked on day 180 (29 June) (Fig. 2), 22 days later than peak geometrid activity (Fig. 3).

Species

The seasonal abundances of species for the entire fauna showed a steadily increasing curve resulting in a broad peak between days 158/159 and 185/186, *i.e.*, 7 June-4 July (Fig. 4). Species numbers/day then declined until day 203/204 (22/23 July) and then remained constant until the end of August. The noctuids showed an increase in the number of species until they reached a peak on day 180/181; numbers then declined and then rose again on day 214/215 (2/3 August) to about 30 species/day when the Fall-emerging species swelled the numbers (Fig. 5). The geometrids peaked around days 164 and 165 (13-14 June) and then steadily declined. Daily numbers of species were low, less than 20 species/day, after day 199/200 (18/19 July) (Fig. 6); which contrasts with the daily number of noctuid species during this period.

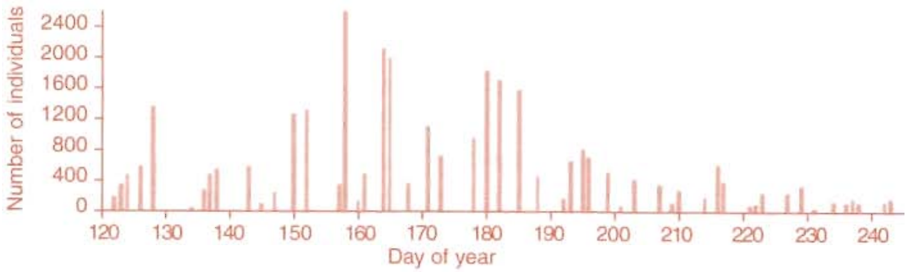

Figure 1. Daily catches of individuals of all species summed across all plots.

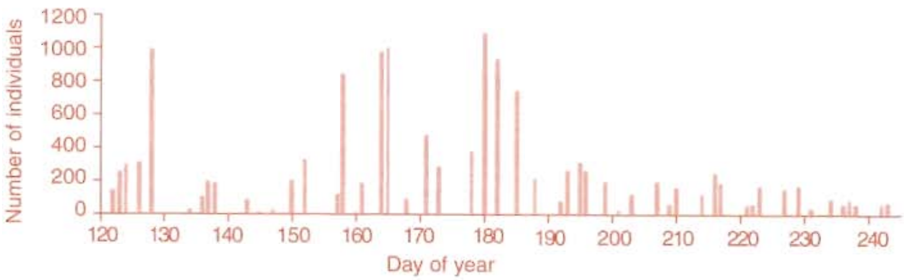

Figure 2. Daily catches of individuals of the family Noctuidae summed across all plots.

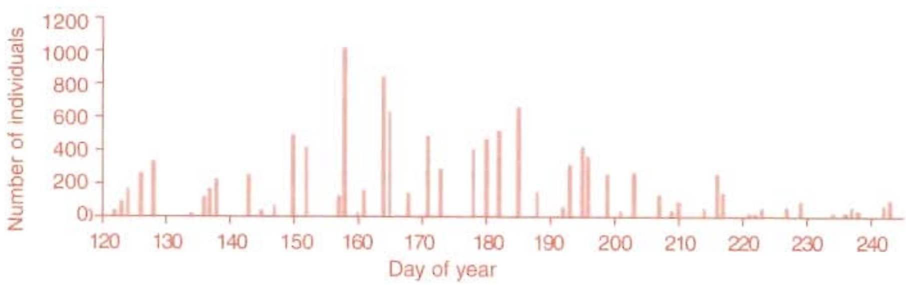

Figure 3. Daily catches of individuals of the family *Geometridae* summed across all plots.

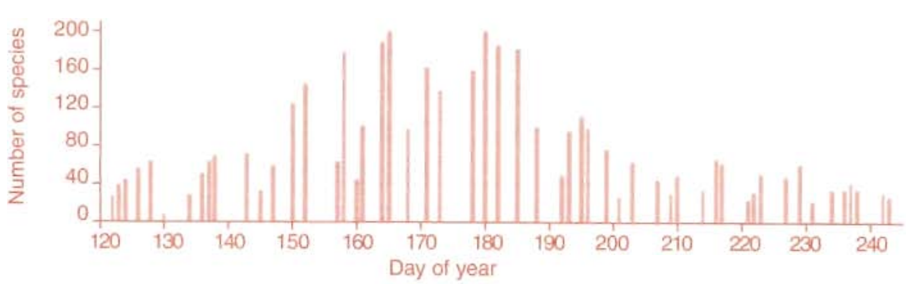

Figure 4. Daily catches of all species summed across all plots.

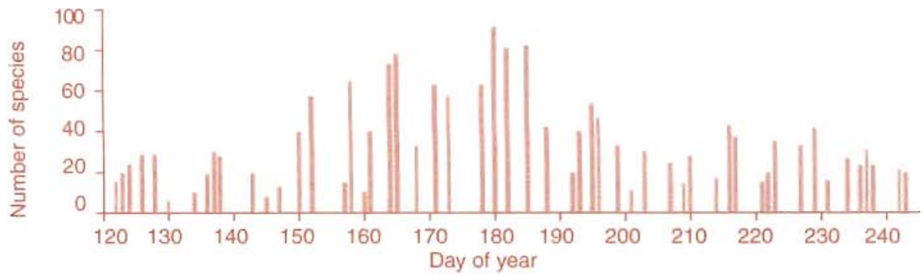

Figure 5. Daily catches of species of the family Noctuidae summed across all plots.

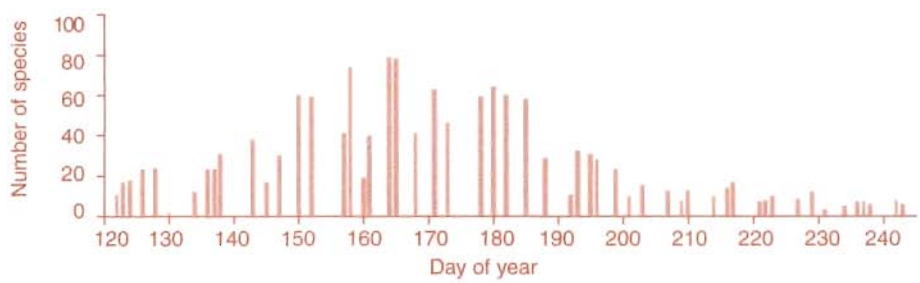

Figure 6. Daily catches of species of the family Geometridae summed across all plots.

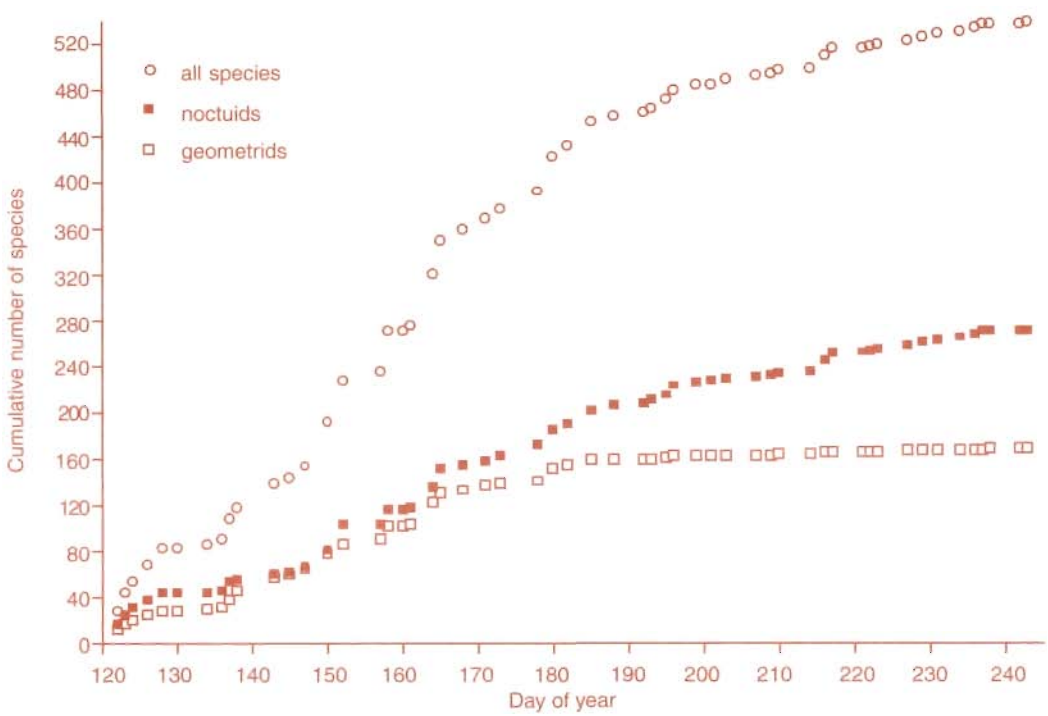

Figure 7. Seasonal cumulative number of species for three groupings: all species, noctuids, geometrids, summed across all plots.

Seasonal species accumulation curves

Together with the daily changes in species abundance there were changes in the species composition such that new species continued to be added on a daily basis throughout the season (Fig. 7). The major accumulation of new species occurred between days 145—188 (25 May—7 July) but new species were still being added when the study finished on day 243 (31 August/1 September).

The noctuids and geometrids showed significant differences in the pattern of appearance of new species throughout the season. In the noctuids, there was a greater surge of new species at the start of the trapping period (Fig. 7). After this surge, there was a comparable increase in both number of species and rate of increase in both families from day 143 (23 May) until day 164 (13 June). By day 164 only 50% of the noctuid species had been trapped, whereas 72% of the geometrids had been trapped. After day 164, the noctuids continued to accumulate new species at a rate similar to that of the earlier part of the season, and new species were still being added when the study finished. In contrast, few new species of geometrids were added after day 182 (1 July).

Randomized species accumulation curves and richness estimates

The means and standard deviation (SD), based on the number of species as a function of the number of samples for each of the taxonomic groupings, are shown in Figure 8. One sample represents the total catch from one trap. The means were calculated from 100 randomizations of sample accumulation order by the EstimateS program. The species accumulation curves gave low estimates of total species richness when less than five traps were used. Five traps gave from 84—87% of the total (predicted) richness, eight traps increased these values to 92%. A fitted two-parameter hyperbola (Michaelis-Menten equation), calculated by the GraphPad Prism program, is also shown on the figure. By extrapolation, this estimator predicted total species richness of 585 for the total catch, 297 for the noctuids, and 184 for the geometrids.

The maximum likelihood estimates for total species richness corresponding to successively larger subsets of the points in the species accumulation curve for the Michaelis-Menten Means estimator (MMMeans) reduced the bias seen in the species accumulation curve for low sample numbers (Fig. 8). After only two samples, this estimator gave richness values, for the total catch, noctuids, and geometrids, respectively, that were 94, 91, and 98% of the estimated total species richness. EstimateS was also used to obtain estimates of total species richness from eight other estimators (Table 2). The performances of all these species richness estimators will be examined in the third report.

Data points for Coleman, rarefaction, curves were within 1 SD of the observed (calculated) mean values for sample sizes greater than 1 for the total catch and the noctuids and were within 1 SD for all sample sizes for the geometrids (Fig. 8). These data indicate a low heterogeneity with regard to species composition between samples.

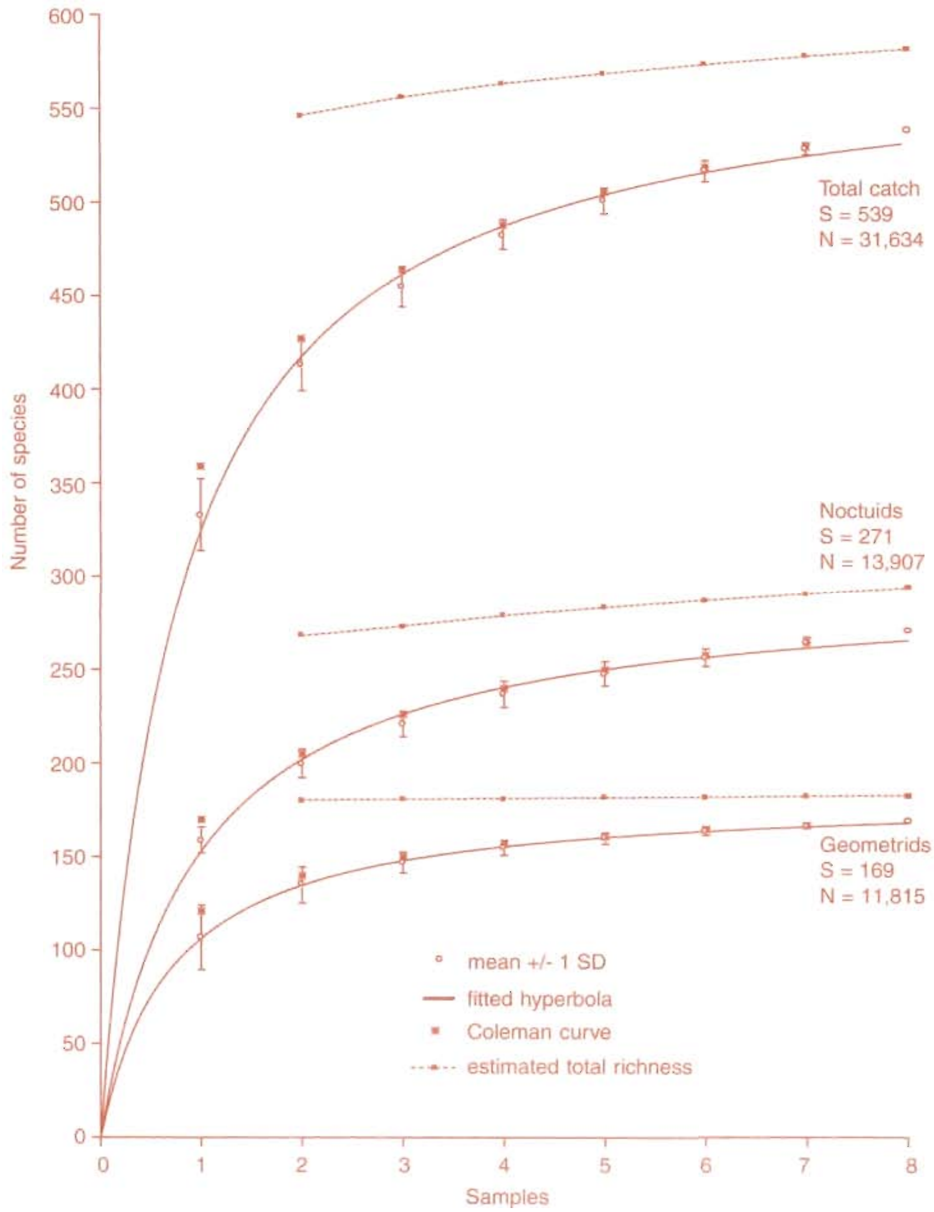

Figure 8. Species accumulation curves for three taxonomic groupings of moths. Each point on the lower of the three sets represents the mean of 100 randomizations of sample pooling order; error bars are the corresponding standard deviations. Each hyperbola was fitted using all eight sample means. Estimated total richness was from the Michaelis-Menten Means estimator and is based on successively larger numbers of samples from the data set. Coleman, rarefaction, data points estimate sample species richness from the pooled total species richness, based on all species actually discovered.

Table 2. Species richness estimator predictions and related variables for the total catch, noctuids, and geometrids summed across all plots

Variable	Total catch	Noctuids	Geometrids
Observed richness	539	271	169
ACE	579	302	176
ICE	577	300	176
Chao 1	585	312	173
Chao 2	590	315	179
Jackknife 1	608	317	185
Jackknife 2	630	337	189
Bootstrap	573	293	177
MMMean	582	294	183
MMRuns	583	294	185
log normal	576	301	176
Singletons	65	43	13
Doubletons	44	21	17
Uniques	79	52	18

Rank Abundance Plots and Species Diversity Indices

A rank abundance plot, of percentage relative abundance vs. species sequence, for the entire data set showed the shallow reverse S-shaped curve characteristic of a log normal distribution (Fig. 9). The equivalent plots for the total catch of noctuids and the total catch of geometrids are steeper and approach the straight lines, characteristic of the log series distribution (Fig. 9). The shallower the slope of the curve, the higher the diversity (Chey *et al.* 1997). The geometrids had fewer abundant and rare species than did the noctuids; *i.e.*, the geometrids, as a group, showed less dominance and more evenness when compared to the noctuids. Although greater evenness is often equated with higher diversity (Pielou 1975, Magurran 1988), the steepness of the rank abundance plot for the geometrids points to lower diversity than that of the noctuids. The indices that are biased towards species richness, α, λ, Margalef, McIntosh *U*, *Q*, Shannon diversity, reflect this in the higher values they assign to the noctuids (Table 3). The indices that are biased towards evenness, McIntosh evenness, Shannon evenness, and the reciprocal of those biased towards dominance, Berger-Parker, Simpson, all reflect the greater evenness of the geometrids over the noctuids (Table 3).

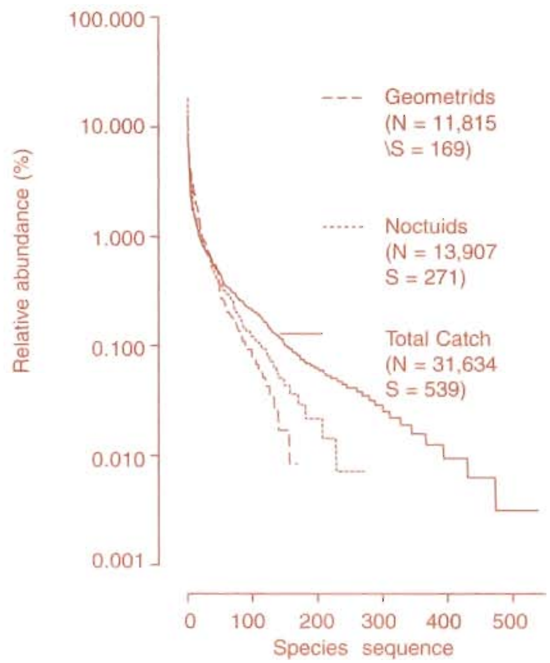

Figure 9. Rank abundance plots for three groupings, total catch, Noctuidae, Geometridae, summed across all plots.

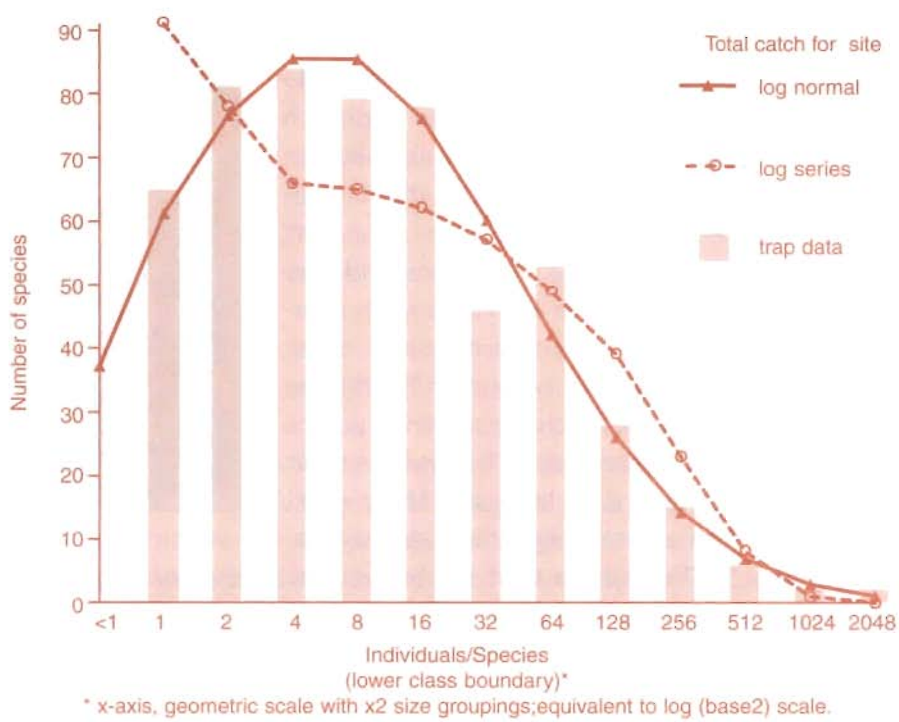

Figure 10. Species abundance plots for the total catch summed across all plots.

Table 3. Diversity statistics for the total catch, noctuids, geometrids, summed across all plots

Diversity statistic	Total catch	Noctuids	Geometrids
Species richness	539	271	169
Individuals	31,634	13,907	11,815
Log series index, α	92.3	47.7	27.9
Log normal index, λ	685	342	214
Margalef	51.9	28.3	17.92
McIntosh *U*	4572	3115	2310
Q	105.9	50.0	31.2
Shannon diversity	4.81	4.02	3.90
McIntosh evenness	0.894	0.826	0.871
Shannon evenness	0.77	0.72	0.76
Berger-Parker*	12.6	5.53	7.9
Simpson index*	47.9	19.9	26.2

** reciprocal*

Species Abundance Plots

Species abundance plots, with the individuals per species grouped into geometric scale units, are an excellent way to compare the observed trap data with the theoretical distributions of the log series and log normal models (Taylor 1978, Magurran 1988, Krebs 1989). They also confirm the patterns of dominance and evenness revealed by the various indices. The plot incorporating the total catch summed across all plots shows that the data are a good fit to the log normal distribution and approach the shape of a normal curve (Fig. 10). Likewise, for the geometrid trap data (Fig. 11). Neither distribution is a close fit to the log series distribution. The noctuid trap data fit both models to the same extent and also show high numbers of rare species, which is reflected in the slightly lower values for the evenness indices (Fig. 12).

Seasonal Changes in Diversity

Moths were sampled for 18 weeks, week 1 being 2-8 May and week 18 being 29 August—4 September. The *alpha* values for the total catch show peak values around weeks 7—10 (13 June—10 July) and a minor increase during week 16 (15—21 August) (Fig 13). The maximum weekly value of 60.3 was much lower than the value of 92.3 obtained from the overall index. For geometrids, the *alpha* diversity index increased rapidly to peak at week 7, 13—19 June, decreased rapidly until week 12, 18—24 July, and then decreased at a slower steady rate until the end of the sampling period, when it reached a low value of 2.0 (Fig. 13). The maximum weekly *alpha* value of 23.5 was lower than the value for the total geometrid sample of 27.9. For noctuids, maximum weekly values, 24.3, occurred on weeks 9 and 10 (27 June—10 July) (Fig. 13). Again there was a rapid increase in *alpha* values before the peak and a steep decline after the peak until week 13 (25—31 August) and then a further increase in values that reflected the appearance of the Fall-emerging species. The maximum weekly value was significantly lower than the overall value of 47.7 for the total noctuid sample.

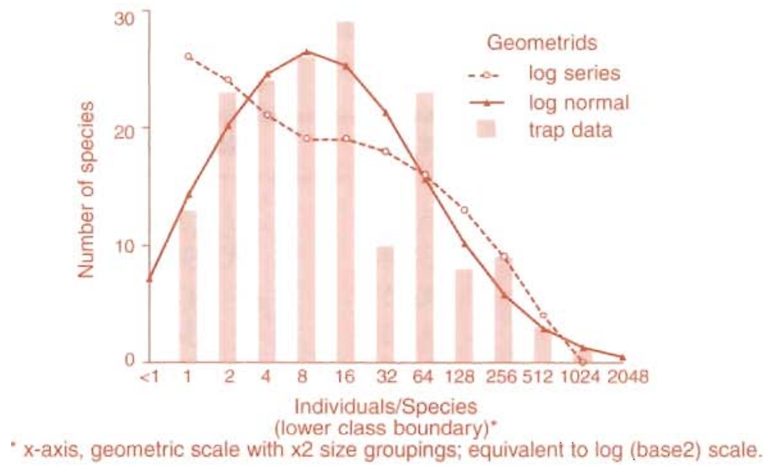

Figure 11. Species abundance plots for the family *Geometridae* summed across all plots.

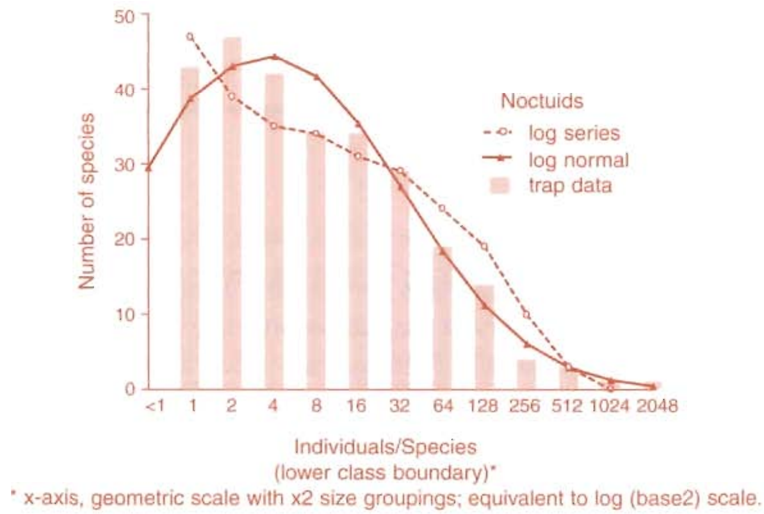

Figure 12. Species abundance plots for the family Noctuidae summed across all plots.

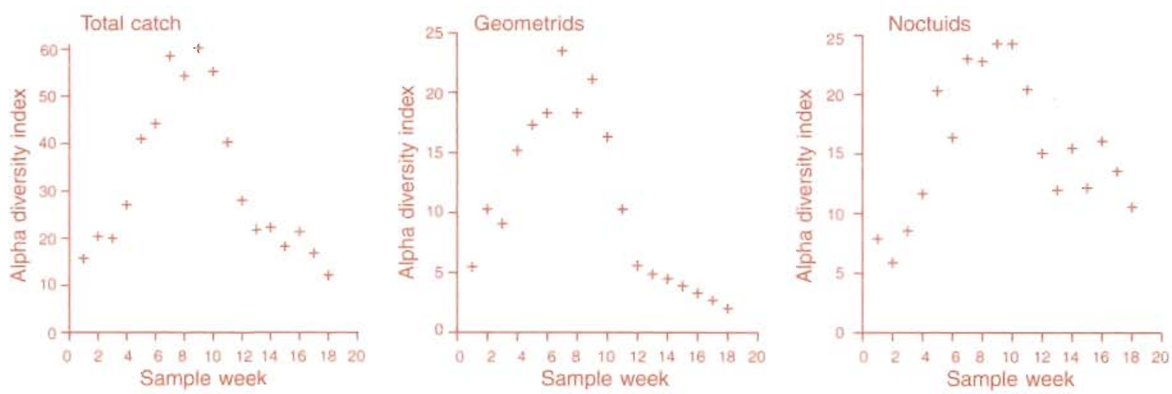

Figure 13. Weekly *alpha* diversity indices for three groups of macro's summed across all plots for the weeks 2–8 May (week 1) through to 29–31 August (week 18).

DISCUSSION

Biologists often seek answers to two fundamental questions: what is the true species richness for the taxonomic group in the study site, and what extra sampling effort is required to bring the survey to some specified level of completeness? Clench (1979) appears to be the first to apply the technique of extrapolating a species accumulation curve to estimate richness of a local butterfly fauna. He used the Michaelis-Menten model equation. This model, and four others, were also used by Landau *et al.* (1999) to estimate species richness in their study of macrolepidoptera in two Louisiana forests. One objective of the present study was to obtain a complete list of species present in the red spruce forest site, and especially for the two families that constituted the major components of the macromoth fauna. For the **geometrids**, this goal came as close to being achieved as was possible in a 1-year study. The plot of daily catches of species (Fig. 6) shows that very few species were captured after day 199 (18 July). The seasonal species accumulation curve (Fig. 7) shows that few of these species were 'new'. In fact, the curve became asymptotic by early July and remained essentially unchanged until the end of August. This indicates that no further species were likely to be collected after the end of August when the sampling stopped. The randomized species accumulation curve was still increasing after eight samples but only slightly (Fig. 8). These data were a good fit to the theoretical Michaelis-Menten rectangular hyperbola. The performance curve of the Michaelis-Menten Mean was asymptotic for samples 4—8 with values between 181.6—183.0. These analyses suggest that the sampling effort for the geometrids was efficient in that 169 species of a possible 183 species were collected. This estimate is in good agreement with the log normal model prediction of 176 species (Table 2), seven of which are hidden below the "veil line" (Fig.11). The other eight species richness estimators gave values for total species of 173—189 (Table 2). It is worth noting that this value of approximately 180 species applies only to the study period (*i.e.*, end of August) and that there are a few species of local geometrids that emerge in September, October, and even November.

The species list for the **noctuids** is obviously incomplete. The plot of the daily catch of species (Fig. 5) shows about 20 species/day were collected during the last week of the study. The seasonal accumulation curve (Fig. 7) shows that many of these were "new" and that the curve had not reached an asymptote. The randomized species accumulation curve was also increasing after eight samples (Fig. 8), and the weekly *alpha* values were still relatively high during the last few weeks of sampling (Fig. 13). The nine species richness estimators gave values for total species richness of 293—337, and the log normal predicted 301 species (Table 2). Several species were "missed" during the collection period and the indicators point to the emergence of several species after the end of August. Analysis of noctuid community structure may be difficult because of the propensity for tourist species whose appearance in traps is often sporadic and ephemeral. However, such vagrants affect data analysis only for impoverished sites having low resident populations (Taylor 1978). Nevertheless, the possible effect of such species on diversity has led researchers to ignore species that had <5 individuals/year (Wolda *et al.* 1994) or singletons (Usher & Keiller 1998). In the current study, ignoring species with <5 individuals would remove 100 species of noctuids and 43 species of geometrids; ignoring singletons would remove 43 noctuid and 13 geometrid species (Table 2). The method may have some merit. The 100 noctuids represent 37% and the 43 noctuids 15.9% of the noctuid richness, whereas the 43 geometrids represent just 25% and the 13 geometrids

7.7% of geometrid richness. Perhaps this higher proportion of noctuids does indicate the presence of several tourist species. The approach taken by Intachat & Holloway (2000) was to restrict their study to moths of the superfamily *Geometroidea*, a group that has low mobility and high habitat fidelity.

There is much literature containing data on moth communities in North America but the primary topic is not diversity. However, basic diversity data are frequently contained within them in the form of species richness, species abundances, and the seasonal distribution of both species and individuals. Other papers deal specifically with diversity, some contain diversity statistics and all contain species richness data. An early North American study, from six localities in Kansas and Nebraska, was analyzed by Williams (1945). Although the total number of individuals was high (396 420) richness was low (285 species). The α diversity index was very low at each of these sites, ranging from 7.95 to 26.58. This attempt by a British scientist to promote the use of diversity indices and proportional species abundances by American lepidopterists went unheeded for 49 years (Thomas & Thomas 1994).

Butler & Kondo (1991) summarized most of the studies that had used light traps to evaluate the macromoth communities in North America. These early studies were concerned with species richness at single sites often over several years. When compared with the present study (539 species in 14 families), these and more recent studies recorded fewer species. Thus Dirks (1937) recorded 344 species from Orono, Maine; Frost (1964) recorded 330 species from the Archbold Biological Station in Florida; and Moulding & Madenjian (1979) recorded 410 species in a New Jersey oak forest. Long-term studies of moth diversity at four sites in Ohio resulted in species numbers ranging from 374 to 426 (Rings *et al.* 1987, Rings & Metzler 1988, 1989, 1990). In their baseline study at Cooper's Rock State Forest, West Virginia, Butler & Kondo (1991) recorded 400 species of macros in 13 families over a 3-year period. The noctuids dominated with 220 species (55% of the species) followed by the geometrids with 102 species (25.5% of the species). These proportions are comparable with the present study, 50% noctuids, 31% geometrids.

In a long-term study of the moths of the Douglas Lake region at the northern tip of the Lower Peninsula of Michigan, Voss (1969) recorded 73 species in the families Saturniidae, Sphingidae, and Arctiidae, 311 species of noctuids (Voss 1981), 55 species in the families Drepanidae, Lasiocampidae, Notodontidae, and Lymantriidae (Voss 1983) and 165 species of geometrids (Voss 1991). This region is richer than the New Brunswick location.

Profant (1990) studied the Lepidoptera of a central Florida pine scrub community. He recorded 591 species of moths, but the second and third largest families were microlepidoptera (pyralids and tortricids) that are usually not considered in North American moth diversity studies. When these two families are excluded, there were 415 species remaining. The Noctuidae were the most species-rich family but had only 172 species. The Geometridae were equally depauparate with 68 species. Species richness peaked in March with a minor peak in October. During the summer, richness was extremely low with only 32 species being collected in July.

In a 9-year study of Lepidoptera at Black Sturgeon Lake in northwestern Ontario, Sanders (1991) recorded 481 moth species; the noctuids with 237 species formed 49% of the species, but the geometrids with 97 species accounted for only 20%.

Grimble & Beckwith (1992) recorded moth species from four sites in two National Forests in the Blue Mountains of Oregon. Only 383 species of moths were trapped, of which 55% were noctuids and 24% geometrids.

A study of macros in West Virginia's Fernow Experimental Forest in the Allegheny Mountains by Butler *et al.* (1995) resulted in 376 species over a 5-year period. A further study from the same area recorded 343 species and 36,160 individuals (Butler *et al.* 1999). I calculated an *alpha* diversity index of 52.5 from these data, which is significantly less than the *alpha* index of 92.3 recorded in the present study (539 species, 31,634 individuals). These two sets of data illustrate the concept of one fauna being richer than another as defined by Williams (1945): "By richer fauna we mean more species for the same number of individuals." The proportional catches of noctuids and geometrids in the West Virginia forest were 50% and 29% for species and 19% and 60% for individuals, respectively. Proportionally at the species level, the fauna of this forest was almost identical to that of the New Brunswick forest (50% noctuids, 31% geometrids). However, the proportional abundances differed significantly between the two locations, 44% noctuids and 37% geometrids in New Brunswick. In the Fernow Experimental Forest, individuals showed a broad peak of seasonal abundances from the middle of May to the middle of July, with daily peaks of around 500 individuals/trap/night. This contrasts with the New Brunswick site where the seasonal abundances of individuals peaked around 7 June with an average of 300 individuals/trap/night.

Chaundy (1999) recorded 241 species of macros in a mixed jack pine/deciduous forest in the Sudbury region of Ontario; 52% of the species were noctuids, 26% geometrids.

A 1-year moth diversity study at two sites in a mixed mesophytic forest in Louisiana yielded 362 species from 21 families (Landau *et al.* 1999). The study compared a long-term, 8-month study with an intensive, 2-month study, in the same forests. It's worth noting that the Louisiana data are based on 21 families, including the species-rich superfamily Pyraloidea, as opposed to 14 families, not including this superfamily, in the New Brunswick study. The authors give three diversity statistics for each study, and I compare those from the long-term study with similar data from the New Brunswick forest (in parentheses). Long-term study: α = 87.0 (92.3), Shannon = 4.93 (4.81), Simpson = 78.5 (47.9). The similarity of the *alpha* values points to a similar relationship between numbers of individuals and numbers of species in the Louisiana and New Brunswick forests, even though the latter study produced ten times the number of individuals than the former (31,634 vs. 3,154) and 1.7 times as many species (539 vs. 314). The similarity between the Shannon indices is due to the similarity of the proportional abundances of the species in each data set. Magurran (1988) makes reference to Margalef (1972) and states that "the Shannon diversity index is usually found to fall between 1.5 and 3.5 and rarely surpasses 4.5." Both the Louisiana data and the New Brunswick data gave values greater than 4.5. Such high values are obtained from an underlying log normal distribution only when richness is large (*ca.* 1,000 species), or when the distribution is approaching that of the broken stick model. As species richness does not approach high numbers, especially in the Louisiana study, the high Shannon index values are probably due to the species abundances being more even than would have been the case if the distributions closely followed the log normal distribution. Landau *et al.* (1999) showed a rank abundance plot for their long-term collection and concluded that the species distribution roughly followed a log normal pattern. The value for the Simpson index is significantly greater for the Louisiana forest than for the New Brunswick forest. This is because the Simpson index is sensitive to species abundances and increases with richness as evenness increases. Evenness, therefore, was much greater in the Louisiana sample than in the New Brunswick sample and, in this sense, the Louisiana forest has a richer fauna. The seasonal distribution of both individuals and species in the Louisiana forest resembled the New Brunswick data, in that peaks occurred in June, rather than resembling the bi-modal distribution seen in Florida moths (Profant 1990).

The above studies indicate that the red spruce forest in the Acadia Research Forest, New Brunswick has one of the highest moth diversities, in terms of species richness, for any single site in North America. Intuitively, this must be false. It is probably simply a reflection of the lack of studies in more species-rich North American sites. A similar study in a red spruce forest in Fundy National Park, New Brunswick, yielded 522 species of macros (Thomas *et al.* 1998), whereas the total macros for Fundy National Park and its immediate area total 634 species, which is even greater than the 604 species recorded for the Lower Peninsula of Michigan.

REFERENCES

Barlow, H.S., and Woiwod, I.P. 1989. Moth diversity of a tropical forest in Peninsular Malaysia. J. Tropical Ecology. 5: 37-50.

Barlow, H.S., and Woiwod, I.P. 1990. Seasonality and diversity of macrolepidoptera in two lowland sites in the Dumoga-Bone National Park, Sulawesi Utara. *In* W.J. Knight and J.D. Holloway (*Eds.*) Insects and the rain forests of South East Asia (Wallacea). The Royal Entomological Society of London, London, U.K. pp. 167-172

Butler, L., and Kondo, V. 1991. Macrolepidopterous moths collected by blacklight trap at Cooper's Rock State Forest, West Viginia: a baseline study. Agricultural and Forestry Experiment Station, West Virginia University, Bulletin 705, 25 p.

Butler, L., Kondo, V., and Chrislip, G. 1995. Canopy arthropods at Fernow Experimental Forest in West Virginia's Allegheny mountain section. I. Macrolepidopterous moths collected by blacklight trap during dimilin impact study. Agricultural and Forestry Experiment Station, West Virginia University, Bulletin 712, 17 p.

Butler, L., Kondo, V., Barrows, E.M., and Townsend, E.C. 1999. Effects of weather conditions and trap types on sampling for richness and abundance of forest macrolepidoptera. Environ. Entomol. 28: 795-811.

Chaundy, R.F.C. 1999. Moth diversity in young jack pine-deciduous forests after disturbance by wildfire or clear-cutting. M.Sc. thesis, University of Toronto, Ontario. 96 p.

Chey, V.K., Holloway, J.D., and Speight, M.R. 1997. Diversity of moths in forest plantations and natural forests in Sabah. Bull. Entomol. Res. 87: 371-385.

Clay, D., Thomas, A.W., and Edsall, J. 1998. Biodiversity of moths of Fundy National Park. 3. Biodiversity measures in natural habitats. Research Notes of Fundy National Park No.FUN/98-05. ii + 19 p. (Unpublished.)

Clench, H.K. 1979. How to make regional lists of butterflies: some thoughts. J. Lepid. Soc. 33: 216-231

Colwell, R.K. 2000. EstimateS: Statistical estimation of species richness and shared species from samples. Version 6.0b1. User's guide and application published at: http://viceroy.eeb.uconn.edu/estimates 24 p.

Colwell, R.K., and Coddington, J.A. 1994. Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society (Series B) 345: 101-118.

*Dirks, C.O. 1937. Biological studies of Maine moths by light trap methods. Maine Agric. Expt. Stn. Bull. 389.

Fisher, R.A., Corbet, A.S., and Williams, C.B. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. J. Animal Ecology. 12: 42-58.

Frost, S.W. 1964. Insects taken in light traps at the Archbold Biological Station, Highlands County, Florida. Fla. Entomol. 47: 129-161.

GraphPad Prism 2.0 1995. User's guide. GraphPad Software, Inc. San Diego, California. 385 pp. http://www.graphpad.com

Grimble, D.G., and Beckwith, R.C. 1992. A survey of the Lepidoptera fauna from the Blue Mountains of eastern Oregon. J. Res. Lepid. 31: 83-102.

Handfield, L. 1999. *Le guide des papillons du Québec. Version scientifique.* Brouquet inc., Québec. 982 p. + 123 plates.

Hill, M.O. 1973. Diversity and evenness: a unifying notation and its consequences. Ecology 54: 427-432

Hodges, R.W. (*Ed.*) 1983. Check list of the Lepidoptera of America north of Mexico. E.W. Classey Ltd., and The Wedge Entomological Research Foundation. xxiv + 284 p.

Holloway, J.D. 1985. Moths as indicator organisms for categorizing rain-forest and monitoring changes and regeneration processes. *In* A.C. Chadwick and S.L. Sutton (*Eds.*). Tropical Rain Forests. The Leeds Symposium, special publication, Leeds. Philosophical and Literary Society, pp. 235-242

Intachat, J., and Holloway, J.D. 2000. Is there stratification in diversity or preferred flight height of geometroid moths in Malaysian lowland tropical forest? Biodiversity and Conservation 9: 1417-1439.

Krebs, C. J. 1989. Ecological methodology. HarperCollins*Publishers*, New York. 654 p.

Lafontaine, J.D. 1998 The moths of America north of Mexico. Noctuoidea: Noctuidae (part): Noctuinae (part — Noctuini). The Wedge Entomological Research Foundation, Washington. 348 p. + 44 pl.

Landau, D., and Prowell, D. 1999*a*. A partial checklist of moths from longleaf pine savannas in Louisiana (Insecta: Lepidoptera). Trans. Am. Entomol. Soc. 125: 127-138.

Landau, D., and Prowell, D. 1999*b*. A partial checklist of moths from mixed mesophytic hardwood forests in Louisiana (Insecta: Lepidoptera). Trans. Am. Entomol. Soc. 125: 139-150.

Landau, D., Prowell, D., and Carlton, C.E. 1999. Intensive versus long-term sampling to assess lepidopteran diversity in a southern mixed mesophytic forest. Ann. Entomol. Soc. Amer. 92: 435-441.

Margalef, R. 1972. Homage to Evelyn Hutchinson, or why is there an upper limit to diversity. Trans Connect. Acad. Arts Sci. 44: 211-235. (Original not seen.)

MacArthur, R.H. and MacArthur, J.W. 1961. On bird species diversity. Ecology 42: 594-598.

Magurran, A.E. 1985. The diversity of macrolepidoptera in two contrasting woodland habitats at Banagher, Northern Ireland. Proc. Royal Irish Academy. 85B: 121-132.

Magurran, A.E. 1988. Ecological diversity and its measurement. Princeton University Press, New Jersey. 179 p.

May, R.M. 1975. Patterns of species abundance and diversity. *In* M.L. Cody and J.M. Diamond (*Eds.*). Patterns of Species Abundance and Diversity. Harvard University Press, MA. pp. 81-120.

*Moulding, J.D., and Madenjian, J.J. 1979. Macrolepidopteran moths light-trapped in a New Jersey oak forest (Lepidoptera). Proc. Entomol. Soc. Wash. 81: 135-144.

Pielou, E.C. 1975. Ecological Diversity. John Wiley & Sons, New York. 165 p.

Profant, D. 1990. The Lepidoptera of a central Florida sand pine scrub community. J. Res. Lepid. 28: 37-74.

*Rings, R.W., Rittles, R.M., Hawes, R.W., and Metzler, E.H. 1987. A nine-year study of the Lepidoptera of the Wilderness Center, Stark County, Ohio. Ohio J. Sci. 87: 55-61.

*Rings, R.W., and Metzler, E.H. 1988. Preliminary annotated checklist of the Lepidoptera of Atwood Lake Park, Ohio. Ohio J. Sci. 88: 59-168.

*Rings, R.W., and Metzler, E.H. 1989. A preliminary checklist of the Lepidoptera of Mohican State Forest and Mohican State Park, Ashland County, Ohio. Ohio J. Sci. 89: 78-88.

*Rings, R.W., and Metzler, E.H. 1990. The Lepidoptera of Fowler Woods State Nature Preserve, Richland County, Ohio. The Great Lakes Entomol. 23: 43-56.

Robinson, G.S., and Tuck, K.R. 1993. Diversity and faunistics of small moths (microlepidoptera) in Bornean rainforest. Ecol. Entomol. 18: 385-393.

Sanders, C.J. 1991. List of the Lepidoptera of Black Sturgeon Lake, northwestern Ontario, and dates of adult occurrence. The Great Lakes Entomol. 24: 51-62.

SAS Institute Inc. 1995. The Little SAS Book: A Primer. Cary, NC. http://www.sas.com

Scoble, M.J. 1995. The Lepidoptera: form, function and diversity. The Natural History Museum, London, and Oxford University Press. 404 p.

Skinner, B. 1984. Colour identification guide to moths of the British Isles. Viking, Middlesex. 267 p.

Southwood, T.R.E. 1978. Ecological Methods with Particular Reference to the Study of Insect Populations. Chapman and Hall, London. 524 p.

Southwood, T.R.E., Brown, V.K., and Reader, P.M. 1979. The relationship of plant and insect diversities in succession. Biol. J. Linn. Soc. 12: 327-348.

Summerville, K.S., Jaquot, J.J., and Stander, R.F. 1999. A preliminary checklist of the moths of Butler County, Ohio. Ohio J. Sc. 99: 66-76.

Taylor, L.R. 1978. Bates, Williams, Hutchinson – a variety of diversities. *In* L.A. Mound and N. Warloff (*Eds.*). Diversity of Insect Faunas: 9th Symposium of the Royal Entomological Society. Blackwell, Oxford. pp. 1-18.

Thomas, A.W. 1996. Light-trap catches of moths within and above the canopy of a northeastern forest. J. Lepid. Soc. 50(1): 21-45

Thomas, A.W., and Thomas, G.M. 1994. Sampling strategies for estimating moth species diversity using a light trap in a northeastern softwood forest. J. Lepid. Soc. 48: 85-105.

Thomas, A.W., Edsall, J., and Clay, D. 1998. Biodiversity survey of moths of Fundy National Park: I: A checklist of the macromoths of Fundy National Park, and its greater ecosystem. Pks. Can. — Tech. Repts. in Eco. Sci. v + 33 p.

Thomas, G.M. 2000. BIO-DAP. A biodiversity analysis package. Downloadable from: http://nhsbig.inhs.uiuc.edu/www/populations.html

Usher, M.B., and Keiller, S.W.J. 1998. The macrolepidoptera of farm woodlands: determinants of diversity and community structure. Biodiversity and Conservation 7: 725-748.

Voss, E.G. 1969. Moths of the Douglas Lake region (Emmet and Cheboygan Counties), Michigan: I. Sphingidae-Ctenuchidae (Lepidoptera). The Michigan Entomol. 2: 48-54.

Voss, E.G. 1981. Moths of the Douglas Lake region (Emmet and Cheboygan Counties), Michigan: II. Noctuidae (Lepidoptera). The Great Lakes Entomol. 14: 87-101.

Voss, E.G. 1983. Moths of the Douglas Lake region (Emmet and Cheboygan Counties), Michigan: III. Thyatiridae, Drepanidae, Lasiocampidae, Notodontidae, Lymantriidae (Lepidoptera). The Great Lakes Entomol. 16: 131-137.

Voss, E.G. 1991. Moths of the Douglas Lake region (Emmet and Cheboygan Counties), Michigan: IV. Geometridae (Lepidoptera). The Great Lakes Entomol. 24: 187-201.

Williams, C.B. 1945. Recent light trap catches of Lepidoptera in U.S.A. analysed in relation to the logarithmic series and the index of diversity. Ann. Entomol. Soc. Amer. 38: 357-364.

Williams, C.B. 1964. Patterns in the balance of nature. Academic Press, London. 324 p.

Wolda, H. 1983. Diversity, diversity indices and tropical cockroaches. Oecologia (Berlin). 58: 290-298.

Wolda, H., Marek, J., Spitzer, K., and Novak, I. 1994. Diversity and variability of Lepidoptera populations in urban Brno, Czech Republic. Eur. J. Entomol. 91: 213-226.

Young, M. 1997. The natural history of moths. T & A D Poyser Ltd., London. 271 p.

* *original papers not seen, references from Butler and Kondo, 1991.*

APPENDIX

List of species and their abundances. Catalogue numbers (Cat. #) and species names follow Hodges (1983) but nomenclature has been updated according to Scoble (1995) and Handfield (1999).

Cat. #	Genus	Specific epithet	Subspecies	Author, year	Total catch
Family: Hepialidae					
31	***Korscheltellus***	***gracilis***		(Grote, 1864)	1
Family: Sesiidae					
2554	***Synanthedon***	***acerni***		(Clemens, 1860)	81
2555	***Synanthedon***	***fatifera***		Hodges, 1962	1
Family: Cossidae					
2675	***Acossus***	***centerensis***		(Lintner, 1877)	3
2693	***Prionoxystus***	***robinae***		(Peck, 1818)	3
Family: Limacodidae					
4652	***Tortricidia***	***testacea***		Packard, 1864	16
4659	***Packardia***	***geminata***		(Packard, 1864)	4
4665	***Lithacodes***	***fasciola***		(Herrich-Schäffer, 1854)	7
Family: Drepanidae					
6235	***Habrosyne***	***scripta***		(Gosse, 1840)	13
6237	***Pseudothyatira***	***cymatophoroides***		(Guenée, 1852)	5
6240	***Euthyatira***	***pudens***		(Guenée, 1852)	2
6251	***Drepana***	***arcuata***		Walker, 1855	238
6252	***Drepana***	***bilineata***		(Packard, 1864)	157
6255	***Oreta***	***rosea***		(Walker, 1855)	77
Family: Geometridae					
6270	***Protitame***	***virginalis***		(Hulst, 1900)	11
6273	***Macaria***	***pustularia***		(Guenée, 1857)	1502
6280	***Macaria***	***andersoni***		(Swett, 1916)	24
6286	***Macaria***	***brunneata***		(Thunberg, 1784)	93
6287	***Macaria***	***anataria***		(Swett, 1913)	13
6292	***Macaria***	***exauspicata***		(Walker, 1861)	1
6326	***Macaria***	***aemulataria***		(Walker, 1861)	65
6330	***Macaria***	***ulsterata***		(Pearsall, 1913)	34
6339	***Macaria***	***transitaria***		(Walker, 1861)	2
6340	***Macaria***	***minorata***		(Packard, 1873)	12
6341.1	***Macaria***	***nsp. nr. bicolorata***			1
6342	***Macaria***	***bisignata***		(Walker, 1866)	3
6343	***Macaria***	***sexmaculata***		(Packard, 1867)	479
6344	***Macaria***	***signaria***	***dispuncta***	(Walker, 1860)	63
6347	***Macaria***	***pinistrobata***		(Ferguson, 1972)	8
6348	***Macaria***	***fissinotata***		(Walker, 1863)	2
6349	***Macaria***	***banksianae***		(Walker, 1863)	2
6350	***Macaria***	***submarmorata***		(Walker, 1861)	548
6351	***Macaria***	***oweni***		(Swett, 1907)	362
6362	***Digrammia***	***continuata***		(Walker, 1862)	3
6396	***Digrammia***	***neptaria***	***trifasciata***	(Packard, 1874)	4
6428	***Orthofidonia***	***tinctaria***		(Walker, 1860)	21
6429	***Orthofidonia***	***exornata***		(Walker, 1862)	32

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6430	***Orthofidonia***	***flavivenata***		(Hulst, 1898)	32
6436	***Ematurga***	***amitaria***		(Guenée, 1857)	1
6449	***Glena***	***cribataria***		(Guenne, 1857)	7
6450	***Glena***	***cognataria***		(Hübner, 1831)	1
6570	***Aethalura***	***intertexta***		(Walker, 1860)	85
6582	***Iridopsis***	***vellivolata***		(Hulst, 1881)	12
6583	***Iridopsis***	***ephyraria***		(Walker, 1860)	13
6588	***Iridopsis***	***larvaria***		(Guenée, 1857)	21
6590	***Anavitrinella***	***pampinaria***		(Guenée, 1857)	64
6595	***Cleora***	***projecta***		(Walker, 1860)	3
6597	***Ectropis***	***crepuscularia***		(Denis & Schiffermüller, 1775)	216
6598	***Protoboarmia***	***porcelaria***	***indicataria***	(Walker, 1860)	102
6620	***Melanolophia***	***canadaria***		(Guenée. 1857)	24
6621	***Melanolophia***	***signataria***		(Walker, 1860)	170
6637	***Eufidonia***	***convergaria***		(Walker, 1860)	32
6638	***Eufidonia***	***notataria***		(Walker, 1860)	16
6639	***Eufidonia***	***discospilata***		(Walker, 1862)	5
6640	***Biston***	***betularia***	***cognataria***	(Guenée, 1857)	111
6651	***Lycia***	***ursaria***		(Walker, 1860)	18
6654	***Hypagyrtis***	***unipunctata***		(Haworth, 1809)	70
6656	***Hypagyrtis***	***piniata***		(Packard, 1870)	226
6658	***Phigalia***	***titea***		(Cramer, 1782)	5
6667	***Lomographa***	***vestaliata***		(Guenée, 1857)	59
6668	***Lomographa***	***glomeraria***		(Grote, 1881)	6
6677	***Cabera***	***erythemaria***		Guenée, 1857	16
6678	***Cabera***	***variolaria***		Guenée, 1857	4
6724	***Euchlaena***	***serrata***		(Drury, 1773)	5
6725	***Euchlaena***	***muzaria***		(Walker, 1860)	133
6728	***Euchlaena***	***effecta***		(Walker, 1860)	7
6729	***Euchlaena***	***johnsonaria***		(Fitch, 1869)	37
6731	***Euchlaena***	***madusaria***		(Walker. 1860)	7
6734	***Euchlaena***	***marginaria***		(Minot, 1869)	117
6737	***Euchlaena***	***tigrinaria***		(Guenée, 1857)	6
6739	***Euchlaena***	***irraria***		(Barnes & McDunnough, 1917)	11
6740	***Xanthotype***	***urticaria***		Swett, 1918	16
6743	***Xanthotype***	***sospeta***		(Drury, 1773)	11
6755	***Pero***	***morrisonaria***		(Henry Edwards, 1881)	234
6763	***Phaeoura***	***quernaria***		(J.E. Smith, 1797)	12
6796	***Campaea***	***perlata***		(Guenée, 1857)	151
6797	***Ennomos***	***magnaria***		Guenée, 1857	12
6799	***Epirranthis***	***substriataria***		(Hulst, 1896)	6
6804	***Petrophora***	***subaequaria***		(Walker, 1860)	391
6806	***Tacparia***	***atropunctata***		(Packard, 1874)	2
6807	***Tacparia***	***detersata***		(Guenée, 1857)	449
6812	***Homochlodes***	***fritillaria***		(Guenée, 1857)	74
6815	***Gueneria***	***similaria***		(Walker, 1860)	9
6817	***Selenia***	***alciphearia***		Walker, 1860	8
6818	***Selenia***	***kentaria***		(Grote & Robinson, 1867)	3
6819	***Metanema***	***inatomaria***		Guenée, 1857	21
6820	***Metanema***	***determinata***		Walker, 1866	9
6821	***Metarranthis***	***warnerae***		(Harvey, 1874)	1
6822	***Metarranthis***	***duaria***		(Guenée, 1857)	73

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6825	***Metarranthis***	***indeclinata***		(Walker, 1861)	22
6826.1	***Metarranthis***	***mestusata***		(Walker, 1860)	19
6832	***Metarranthis***	***obfirmaria***		(Hübner, 1823)	13
6834	***Cepphis***	***decoloraria***		(Hulst, 1886)	2
6835	***Cepphis***	***armataria***		(Herrich-Schäffer, 1855)	2
6836	***Plagodis***	***pulveraria***	***occiduaria***	(Walker, 1861)	28
6837	***Probole***	***alienaria***		Herrich-Schäffer, 1855	81
6840	***Plagodis***	***serinaria***		Herrich-Schäffer, 1855	109
6842	***Plagodis***	***phlogosaria***	***phlogosaria***	(Guenée, 1857)	98
6844	***Plagodis***	***alcoolaria***		(Guenée, 1857)	4
6863	***Caripeta***	***divisata***		Walker, 1863	126
6864	***Caripeta***	***piniata***		(Packard, 1870)	8
6867	***Caripeta***	***angustiorata***		Walker, 1863	5
6884	***Besma***	***endropiaria***		(Grote & Robinson, 1867)	17
6888	***Lambdina***	***fiscellaria***		(Guenée, 1857)	257
6906	***Nepytia***	***canosaria***		(Walker. 1863)	69
6912	***Sicya***	***macularia***		(Harris, 1850)	9
6941	***Eusarca***	***confusaria***		Hübner, 1813	1
6963	***Tetracis***	***crocallata***	***aspilatata***	Guenée, 1857	7
6964	***Tetracis***	***cachexiata***		Guenée, 1857	107
6965	***Eugonobapta***	***nivosaria***		(Guenée, 1857)	6
6966	***Eutrapela***	***clemataria***		(J.E. Smith, 1797)	26
6982	***Prochoerodes***	***lineola***		(Goeze, 1781)	82
6987	***Antepione***	***thisoaria***		(Guenée, 1857)	30
7009	***Nematocampa***	***resistaria***		(Herrich-Schäffer, 1855)	24
7048	***Nemoria***	***mimosaria***		(Guenée, 1857)	13
7058	***Synchlora***	***aerata***	***albolineata***	Packard, 1873	9
7071	***Chlorochlamys***	***chloroleucaria***		(Guenée, 1857)	1
7084	***Hethemia***	***pistasciaria***		(Guenée, 1857)	2
7125	***Idaea***	***rotundopennata***		(Packard, 1876)	31
7126	***Idaea***	***dimidiata***		(Hufnagel, 1767)	14
7139	***Cyclophora***	***pendulinaria***		(Guenée, 1857)	790
7159	***Scopula***	***limboundata***		(Haworth, 1809)	371
7164	***Scopula***	***junctaria***		(Walker, 1861)	48
7165	***Scopula***	***quadrilineata***		(Packard, 1876)	2
7169	***Scopula***	***inductata***		(Guenée, 1857)	5
7182	***Dysstroma***	***citrata***		(Linnaeus, 1761)	17
7188	***Dysstroma***	***walkerata***		(Pearson, 1909)	59
7201	***Eulithis***	***testata***		(Linnaeus, 1761)	2
7206	***Eulithis***	***explanata***		(Walker, 1862)	672
7208	***Eulithis***	***serrataria***		(Barnes & McDunnough, 1917)	11
7213	***Ecliptopera***	***silaceata***	***albolineata***	(Packard, 1873)	8
7229	***Hydriomena***	***perfracta***		Swett, 1910	2
7235	***Hydriomena***	***divisaria***	***frigidata***	(Walker, 1863)	85
7263	***Hydriomena***	***renunciata***		(Walker, 1862)	110
7254	***Hydriomena***	***ruberata***		(Freyer, 1831)	2
7285	***Triphosa***	***haesitata***	***affirmaria***	(Walker, 1860)	3
7291	***Rheumaptera***	***undulata***	***bluff***	(Bryk, 1921)	2
7293	***Rheumaptera***	***hastata***	***gothicata***	(Guenée, 1857)	16
7307	***Mesoleuca***	***ruficillata***		(Guenée, 1857)	1
7312	***Spargania***	***magnoliata***		Guenée, 1857	4
7313	***Spargania***	***luctuata***	***obductata***	(Möschler, 1860)	1

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7316	*Perizoma*	*basaliata*		(Walker, 1862)	75
7320	*Perizoma*	*alchemillata*		(Linnaeus, 1758)	6
7329	*Anticlea*	*vasiliata*		Guenée, 1857	69
7330	*Anticlea*	*multiferata*		(Walker, 1863)	20
7368	*Xanthorhoe*	*labradorensis*		(Packard, 1867)	4
7370	*Xanthorhoe*	*abrasaria*	*congregata*	(Walker, 1862)	100
7371	*Xanthorhoe*	*iduata*		(Guenée, 1857)	9
7388	*Xanthorhoe*	*ferrugata*		(Clemens, 1759)	4
7390	*Xanthorhoe*	*lacustrata*		(Guenée, 1857)	4
7399	*Euphyia*	*intermediata*		(Guenée, 1857)	1
7414	*Orthonama*	*obstipata*		(Fabricius, 1794)	1
7419	*Hydrelia*	*lucata*		(Guenée, 1857)	2
7420	*Hydrelia*	*condensata*		(Walker, 1862)	2
7422	*Hydrelia*	*inornata*		(Hulst, 1896)	2
7428	*Venusia*	*comptaria*		(Walker, 1860)	289
7440	*Eubaphe*	*mendica*		(Walker, 1854)	21
7449	*Eupithecia*	*palpata*		Packard, 1873	172
7459	*Eupithecia*	*columbiata*		(Dyar, 1904)	28
7474	*Eupithecia*	*miserulata*		Grote, 1863	7
7476	*Eupithecia*	*misturata*		(Hulst, 1896)	72
7487	*Eupithecia*	*subfuscata*		(Haworth, 1809)	289
7489	*Eupithecia*	*lariciata*		(Freyer, 1841)	16
7491	*Eupithecia*	*fletcherata*		Taylor, 1907	2
7492	*Eupithecia*	*casloata*		Dyar, 1904	3
7520	*Eupithecia*	*satyrata*	*dodata*	(Taylor, 1906)	23
7523	*Eupithecia*	*strattonata*		Packard, 1873	7
7524	*Eupithecia*	*cimicifugata*		Pearsall, 1908	1
7526	*Eupithecia*	*russeliata*		Swett, 1908	318
7528	*Eupithecia*	*assimilata*		Doubleday, 1856	1
7529	*Eupithecia*	*absinthiata*		Clemens, 1759	11
7531	*Eupithecia*	*indistincta*		Taylor, 1910	5
7538	*Eupithecia*	*gelidata*		Möschler, 1860	2
7540	*Eupithecia*	*perfusca*		(Hulst, 1898)	12
7543	*Eupithecia*	*annulata*		(Hulst, 1896)	9
7574	*Eupithecia*	*albicapitata*		Packard, 1876	52
7575	*Eupithecia*	*mutata*		Pearsall, 1908	22
7594	*Eupithecia*	*anticaria*		Walker, 1863	24
7625	*Pasiphila*	*rectangulata*		(Linnaeus, 1758)	23
7635	*Acasis*	*viridata*		(Packard, 1873)	11
7637	*Cladara*	*limitaria*		(Walker, 1860)	201
7639	*Cladara*	*atroliturata*		(Walker, 1863)	31
7640	*Lobophora*	*nivigerata*		Walker, 1862	22
Family: Uraniidae					
7650	*Callizzia*	*amorata*		Packard, 1876	4
Family: Lasiocampidae					
7673	*Tolype*	*laricis*		(Fitch, 1856)	263
7687	*Phyllodesma*	*americana*		(Harris, 1841)	13
7698	*Malacosoma*	*disstria*		Hübner, 1820	30
7701	*Malacosoma*	*americanum*		(Fabricius, 1793)	38
Family: Saturniidae					
7715	*Dryocampa*	*rubicunda*		(Fabricius, 1793)	2318
7723	*Anisota*	*virginiensis*		(Drury, 1773)	8

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7757	*Antheraea*	*polyphemus*		(Cramer, 1776)	30
7758	*Actias*	*luna*		(Linnaeus, 1758)	7
7767	*Hyalophora*	*cecropia*		(Linnaeus, 1758)	13
7768	*Hyalophora*	*columbia*		(S.I. Smith, 1865)	6
Family: Sphingidae					
7784	*Dolba*	*hyloeus*		(Drury, 1773)	4
7787	*Ceratomia*	*undulosa*		(Walker, 1856)	6
7809	*Sphinx*	*kalmiae*		J.E. Smith, 1797	3
7810	*Sphinx*	*gordius*		Cramer, 1780	184
7817	*Lapara*	*bombycoides*		Walker, 1856	26
7821	*Smerinthus*	*jamaicensis*		(Drury, 1773)	21
7822	*Smerinthus*	*cerisyi*		Kirby, 1837	10
7824	*Paonias*	*excaecatus*		(J.E. Smith, 1797)	112
7825	*Paonias*	*myops*		(J.E. Smith, 1797)	1
7828	*Pachysphinx*	*modesta*		(Harris, 1839)	2
7886	*Darapsa*	*pholus*		(Cramer, 1776)	39
Family: Notodontidae					
7895	*Clostera*	*albosigma*		Fitch, 1856	19
7898	*Clostera*	*strigosa*		(Grote, 1882)	8
7901	*Clostera*	*apicalis*		(Walker, 1855)	40
7902	*Datana*	*ministra*		(Drury, 1773)	2
7915	*Nadata*	*gibbosa*		(J.E. Smith, 1797)	72
7919	*Peridea*	*basitriens*		(Walker, 1855)	4
7921	*Peridea*	*ferruginea*		(Packard, 1864)	155
7922	*Pheosia*	*rimosa*		Packard,1864	11
7924	*Odontosia*	*elegans*		(Strecker, 1885)	1
7926	*Notodonta*	*scitipennis*		Walker, 1862	9
7928	*Notodonta*	*simplaria*		Graef, 1881	4
7931	*Gluphisia*	*septentrionis*		Walker, 1855	61
7933	*Gluphisia*	*avimacula*		Hudson, 1891	22
7934	*Gluphisia*	*lintneri*		(Grote, 1877)	10
7937	*Furcula*	*cinerea*		(Walker, 1865)	3
7939	*Furcula*	*occidentalis*		(Lintner, 1878)	5
7940	*Furcula*	*scolopendrina*		(Boisduval, 1869)	1
7941	*Furcula*	*modesta*		(Hudson, 1891)	2
7951	*Symmerista*	*albifrons*		(J.E. Smith, 1797)	2
7952	*Symmerista*	*canicosta*		Franclemont, 1946	15
7990	*Heterocampa*	*umbrata*		Walker, 1855	34
7994	*Heterocampa*	*guttivitta*		(Walker, 1855)	18
7995	*Heterocampa*	*biundata*		Walker, 1855	31
7998	*Lochmaeus*	*manteo*		Doubleday, 1841	4
8005	*Schizura*	*ipomoeae*		Doubleday, 1841	5
8006	*Schizura*	*badia*		(Packard, 1864)	12
8007	*Schizura*	*unicornis*		(J.E. Smith, 1797)	11
8010	*Schizura*	*concinna*		(J.E. Smith, 1797)	1
8011	*Schizura*	*leptinoides*		(Grote, 1864)	6
8012	*Oligocentria*	*semirufescens*		(Walker, 1865)	16
8017	*Oligocentria*	*lignicolor*		(Walker, 1855)	66
Family: Arctiidae					
8043	*Eilema*	*bicolor*		(Grote, 1864)	81
8045.1	*Crambidia*	*pallida*		Packard, 1864	13
8090	*Hypoprepia*	*fucosa*	*tricolor*	(Fitch, 1857)	82

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8098	*Clemensia*	*albata*		Packard, 1864	4
8111	*Haploa*	*lecontei*		(Guérin-Meneville, 1832)	7
8112	*Haploa*	*confusa*		(Lyman, 1887)	27
8114	*Holomelina*	*laeta*	*treatii*	(Grote, 1865)	214
8123	*Holomelina*	*ferruginosa*		(Walker, 1854)	42
8129	*Pyrrharctia*	*isabella*		(J.E. Smith, 1797)	13
8133	*Spilosoma*	*latipennis*		Stretch, 1872	3
8134	*Spilosoma*	*congrua*		Walker, 1855	86
8136	*Spilosoma*	*dubia*		(Walker, 1855)	19
8137	*Spilosoma*	*virginica*		(Fabricius, 1798)	61
8140	*Hyphantria*	*cunea*		(Drury, 1773)	65
8156	*Phragmatobia*	*fuliginosa*	*rubricosa*	(Harris, 1841)	22
8158	*Phragmatobia*	*assimilans*		Walker, 1855	300
8162	*Platarctia*	*parthenos*		(Harris, 1850)	65
8175	*Grammia*	*virguncula*		(W. Kirby, 1837)	14
8186	*Grammia*	*williamsii*		(Dodge, 1871)	2
8196	*Grammia*	*parthenice*		(W. Kirby, 1837)	14
8197	*Grammia*	*virgo*		(Linnaeus, 1758)	10
8198	*Grammia*	*doris*		(Boisduval, 1869)	1
8203	*Halysidota*	*tessellaris*		(J.E. Smith, 1797)	1
8214	*Lophocampa*	*maculata*		Harris, 1841	208
8230	*Cycnia*	*tenera*		Hübner, 1818	1
8231	*Cycnia*	*oregonensis*		(Stretch, 1873)	4
8262	*Ctenucha*	*virginica*		(Esper, 1794)	22
Family: Lymantriidae					
8293	*Dasychira*	*dorsipennata*		(Barnes & McDunnough, 1919)	8
8294	*Dasychira*	*vagans*		(Barnes & McDunnough, 1913)	14
8304	*Dasychira*	*plagiata*		(Walker, 1865)	89
8316	*Orgyia*	*leucostigma*	*plagiata*	(Walker, 1855)	20
8319	*Leucoma*	*salicis*		(Linnaeus, 1758)	4
Family: Noctuidae					
8322	*Idia*	*americalis*		(Guenée, 1854)	169
8323	*Idia*	*aemula*		Hübner, 1813	1
8323.1	*Idia*	*concisa*		authors, not Walker, 1860	47
8326	*Idia*	*rotundalis*		(Walker, 1866)	554
8335	*Idia*	*lubricalis*		(Geyer, 1832)	2
8338	*Phalaenophana*	*pyramusalis*		(Walker, 1859)	40
8341	*Zanclognatha*	*theralis*		(Walker, 1859)	35
8341.1	*Zanclognatha*	*deceptricalis*		Zeller, 1873	99
8349	*Zanclognatha*	*protumnusalis*		(Walker, 1859)	419
8351	*Zanclognatha*	*cruralis*		(Guenée, 1854)	17
8352	*Zanclognatha*	*jacchusalis*		(Walker, 1859)	52
8353	*Zanclognatha*	*ochreipennis*		(Grote, 1872)	3
8356	*Chytolita*	*petrealis*		Grote, 1880	37
8357	*Macrochilo*	*absorptalis*		Walker, 1859	1
8362	*Phalaenostola*	*metonalis*		(Walker, 1859)	42
8364	*Phalaenostola*	*larentioides*		Grote, 1873	2
8365	*Phalaenostola*	*hanhami*		(Small, 1899)	3
8370	*Bleptina*	*caradrinalis*		Guenéee, 1854	205
8384.1	*Renia*	*flavipunctalis*		(Geyer, 1832)	6
8387	*Renia*	*sobrialis*		(Walker, 1859)	99
8397	*Palthis*	*angulalis*		(Hübner,1796)	26

Cat. #	Genus	Specific epithet	Subspecies	Author, year	Total catch
8404	***Rivula***	***propinqualis***		Guenée, 1854	10
8442	***Hypena***	***baltimoralis***		(Guenée, 1854)	7
8452	***Hypena***	***edictalis***		(Walker, 1859)	1
8461	***Hypena***	***humuli***		Harris, 1841	1
8479	***Spargaloma***	***sexpunctata***		Grote, 1873	6
8490	***Pangrapta***	***decoralis***		Hübner, 1818	70
8536	***Calyptra***	***canadensis***		(Bethune, 1865)	1
8555	***Scoliopteryx***	***libatrix***		(Linnaeus, 1758)	4
8636	***Drasteria***	***adumbrata***	***alleni***	(Grote, 1877)	13
8694	***Zale***	***aeruginosa***		(Guenée, 1852)	105
8697	***Zale***	***minerea***		(Guenée, 1852)	56
8703	***Zale***	***duplicata***		(Bethune, 1865)	17
8704	***Zale***	***helata***		(Smith, 1908)	4
8713	***Zale***	***lunifera***		(Hübner,1818)	2
8706	***Zale***	***unilineata***		(Grote, 1876)	4
8717	***Zale***	***horrida***		Hübner, 1818	8
8727	***Parallelia***	***bistriaris***		Hübner, 1818	10
8738	***Caenurgia***	***crassiuscula***		(Haworth, 1809)	7
8833	***Catocala***	***concumbens***		Walker, 1858	2
8846	***Catocala***	***sordida***		Grote, 1877	61
8857	***Catocala***	***ultronia***		(Hübner, 1823)	3
8865	***Catocala***	***praeclara***		Grote & Robinson, 1866	3
8867	***Catocala***	***blandula***		Hulst, 1884	1
8896	***Diachrysia***	***aereoides***		(Grote, 1864)	4
8897	***Diachrysia***	***balluca***		Geyer, 1832	1
8904	***Chrysanympha***	***formosa***		(Grote, 1865)	30
8905	***Eosphoropteryx***	***thyatyroides***		(Guenée, 1852)	1
8908	***Autographa***	***precationis***		(Guenée, 1852)	1
8912	***Autographa***	***mappa***		(Grote & Robinson, 1868)	4
8916	***Autographa***	***flagellum***		(Walker, 1858)	1
8923	***Autographa***	***ampla***		(Walker, 1858)	3
8925	***Syngrapha***	***altera***		(Ottolengui, 1902)	9
8926	***Syngrapha***	***octoscripta***		(Grote, 1874)	4
8927	***Syngrapha***	***epigaea***		(Grote, 1875)	5
8929	***Syngrapha***	***viridisigma***		(Grote, 1874)	6
8939	***Syngrapha***	***alias***		(Ottolengui, 1902)	10
8940	***Syngrapha***	***abstrusa***		Eichlin & Cunningham, 1978	10
8941	***Syngrapha***	***cryptica***		Eichlin & Cunningham, 1978	5
8942	***Syngrapha***	***rectangula***		(W. Kirby, 1837)	19
8950	***Plusia***	***putnami***		Grote, 1873	7
8953	***Plusia***	***venusta***		Walker, 1865	1
8955	***Marathyssa***	***inficita***		(Walker, 1865)	1
8969	***Baileya***	***doubledayi***		(Guenée, 1852)	5
8970	***Baileya***	***ophthalmica***		(Guenée, 1852)	5
9037	***Hyperstrotia***	***pervertens***		(Barnes & McDunnough, 1918)	6
9046	***Deltote***	***bellicula***		Hübner, 1818	82
9047	***Lithacodia***	***muscosula***		(Guenée, 1852)	38
9048	***Lithacodia***	***albidula***		(Guenée, 1852)	62
9049	***Maliattha***	***synochitis***		(Grote & Robinson, 1868)	20
9050	***Maliattha***	***concinnimacula***		(Guenée, 1852)	7
9053	***Pseudeustrotia***	***carneola***		(Guenée, 1852)	48
9057	***Homophoberia***	***apicosa***		(Haworth, 1809)	1

Cat. #	Genus	Specific epithet	Subspecies	Author, year	Total catch
9059	***Capis***	***curvata***		Grote, 1882	316
9065	***Leuconycta***	***diphteroides***		(Guenée, 1852)	5
9066	***Leuconycta***	***lepidula***		(Grote, 1874)	14
9177	***Panthea***	***acronyctoides***		(Walker, 1861)	222
9183	***Panthea***	***pallescens***		McDunnough, 1937	6
9189	***Charadra***	***deridens***		(Guenée, 1852)	14
9193	***Raphia***	***frater***		Grote, 1864	52
9200	***Acronicta***	***americana***		(Harris, 1841)	58
9203	***Acronicta***	***dactylina***		Grote, 1874	114
9205	***Acronicta***	***lepusculina***		Guenée, 1852	3
9206	***Acronicta***	***vulpina***		(Grote, 1883)	11
9207	***Acronicta***	***innotata***		Guenée, 1852	15
9211	***Acronicta***	***tritona***		(Hübner, 1818)	15
9212	***Acronicta***	***grisea***		Walker, 1856	214
9221	***Acronicta***	***funeralis***		Grote & Robinson, 1866	28
9226	***Acronicta***	***superans***		Guenée, 1852	2
9227	***Acronicta***	***laetifica***		J.B. Smith, 1897	2
9229	***Acronicta***	***hasta***		Guenée, 1852	4
9237	***Acronicta***	***interrupta***		Guenée, 1852	1
9238	***Acronicta***	***lobeliae***		Guenée, 1852	1
9241	***Acronicta***	***fragilis***		(Guenée, 1852)	28
9249	***Acronicta***	***increta***		Morrison, 1874	116
9251	***Acronicta***	***retardata***		(Walker, 1861)	206
9257	***Acronicta***	***impleta***		Walker, 1856	2
9258	***Acronicta***	***sperata***		Grote, 1873	1
9259	***Acronicta***	***noctivaga***		Grote, 1864	64
9261	***Acronicta***	***impressa***		Walker, 1856	143
9264	***Acronicta***	***longa***		Guenée, 1852	3
9272	***Acronicta***	***oblinita***		(J.E. Smith, 1797)	16
9281	***Agriopodes***	***fallax***		(Herrich-Schäffer, 1854)	140
9286	***Harrisimemna***	***trisignata***		(Walker, 1856)	10
9326	***Apamea***	***verbascoides***		(Guenée, 1852)	1
9331	***Apamea***	***cristata***		(Grote, 1878)	1
9341	***Apamea***	***vultuosa***		(Grote, 1875)	1
9348	***Apamea***	***amputatrix***		(Guenée, 1852)	7
9360	***Apamea***	***impulsa***		(Guenée, 1852)	3
9362.1	***Apamea***	***unanimis***		(Hübner, 1813)	1
9364.1	***Apamea***	***ophiogramma***		(Esper, 1794)	1
9367	***Apamea***	***dubitans***		(Walker, 1856)	1
9382	***Apamea***	***devastator***		(Brace, 1819)	2
9393	***Luperina***	***stipata***		(Morrison, 1875)	4
9415	***Oligia***	***bridghami***		(Grote & Robinson, 1866)	2
9416	***Oligia***	***minuscula***		(Morrison, 1874)	16
9420	***Oligia***	***illocata***		(Walker, 1857)	15
9427	***Meropleon***	***diversicolor***		(Morrison, 1874)	3
9431	***Parastichtis***	***discivaria***		(Walker, 1856)	1
9434	***Spartiniphaga***	***includens***		(Walker, 1858)	3
9436	***Spartiniphaga***	***panatela***		(J.B. Smith, 1904)	17
9437	***Chortodes***	***inquinata***		(Guenée, 1852)	6
9454	***Amphipoea***	***velata***		(Walker, 1856)	2
9457	***Amphipoea***	***americana***		(Speyer, 1875)	5
9480	***Papaipema***	***pterisii***		Bird, 1907	11

Cat. #	Genus	Specific epithet	Subspecies	Author, year	Total catch
9503	***Papaipema***	***rigida***		(Grote, 1877)	1
9545	***Euplexia***	***benesimilis***		McDunnough, 1922	12
9546	***Phlogophora***	***iris***		Guenée, 1852	41
9547	***Phlogophora***	***periculosa***		Guenée, 1852	41
9548	***Conservula***	***anodonta***		(Guenée, 1852)	1
9550	***Enargia***	***infumata***		(Grote, 1874)	2
9555	***Ipimorpha***	***pleonectusa***		Grote, 1873	3
9556	***Chytonix***	***palliatricula***		(Guenée, 1852)	37
9578	***Hyppa***	***xylinoides***		(Guenée, 1852)	3
9578.1	***Hyppa***	***ancocisconensis***		(Morrison, 1875)	13
9582	***Nedra***	***ramosula***		(Guenée, 1852)	9
9631	***Callopistria***	***mollissima***		(Guenée, 1852)	20
9633	***Callopistria***	***cordata***		(Ljungh, 1825)	259
9638	***Amphipyra***	***pyramidoides***		Guenée, 1852	6
9639	***Amphipyra***	***tragopogonis***		(Clemens, 1759)	1
9647	***Proxenus***	***miranda***		(Grote, 1873)	39
9653	***Caradrina***	***morpheus***		(Hufnagel, 1766)	2
9657	***Platyperigea***	***multifera***		(Walker, 1857)	37
9663	***Balsa***	***tristigella***		(Walker, 1866)	3
9664	***Balsa***	***labecula***		(Grote, 1880)	6
9678	***Elaphria***	***versicolor***		(Grote, 1875)	54
9681	***Elaphria***	***festivoides***		(Guenée, 1852)	2515
9818	***Amolita***	***fessa***		Grote, 1874	3
9874	***Xylena***	***curvimacula***		(Morrison, 1874)	28
9875	***Xylena***	***thoracica***		(Putnam-Cramer, 1886)	19
9876	***Xylena***	***cineritia***		(Grote, 1875)	3
9881	***Homoglaea***	***hircina***		Morrison, 1876	5
9884	***Litholomia***	***napaea***		(Morrison, 1874)	13
9887	***Lithophane***	***bethunei***		(Grote & Robinson, 1868)	1
9888	***Lithophane***	***innominata***		(J.B. Smith, 1893)	2
9889	***Lithophane***	***petulca***		Grote,1874	20
9891	***Lithophane***	***amanda***		(J.B. Smith, 1900)	1
9892	***Lithophane***	***disposita***		Morrison, 1874	1
9899.1	***Lithophane***	***thujae***		Webster & Thomas, 1999	4
9902	***Lithophane***	***baileyi***		Grote, 1877	5
9909	***Lithophane***	***tepida***		Grote, 1874	19
9915	***Lithophane***	***grotei***		Riley, 1882	1
9917	***Lithophane***	***fagina***		Morrison, 1874	44
9922	***Lithophane***	***pexata***		Grote, 1874	19
9935	***Eupsilia***	***tristigmata***		(Grote, 1877)	2
9943	***Metaxaglaea***	***inulta***		(Grote, 1874)	16
9952	***Eucirroedia***	***pampina***		(Guenée, 1852)	17
9980	***Xylotype***	***acadia***		Barnes & Benjamin, 1922	3
9989	***Sutyna***	***privata***		(Walker, 1857)	11
10005	***Feralia***	***jocosa***		(Guenée, 1852)	96
10007	***Feralia***	***major***		J. B. Smith, 1890	3
10008	***Feralia***	***comstocki***		(Grote, 1874)	160
10021	***Copivaleria***	***grotei***		(Morrison, 1874)	1
10055	***Apharetra***	***dentata***		(Grote, 1875)	194
10065	***Homohadena***	***infixa***	***dinalda***	J. B. Smith, 1908	1
10198	***Cucullia***	***postera***		Guenée, 1852	1
10265	***Sideridis***	***rosea***		(Harvey, 1874)	6

Cat. #	Genus	Specific epithet	Subspecies	Author, year	Total catch
10268	***Sideridis***	***maryx***		(Guenée, 1852)	41
10272	***Mamestra***	***curialis***		(J. B. Smith, 1888)	2
10275	***Polia***	***nimbosa***		(Guenée, 1852)	14
10276	***Polia***	***imbrifera***		(Guenée, 1852)	96
10280	***Polia***	***purpurissata***		(Grote, 1864)	53
10288	***Polia***	***detracta***		(Walker, 1857)	251
10292	***Melanchra***	***adjuncta***		(Guenée, 1852)	31
10294	***Melanchra***	***pulverulenta***		(J. B. Smith, 1888)	4
10295	***Melanchra***	***assimilis***		(Morrison, 1874)	19
10296	***Lacanobia***	***nevadae***		(Grote, 1876)	1
10297	***Lacanobia***	***atlantica***		(Grote, 1874)	13
10298	***Lacanobia***	***radix***		(Walker, 1857)	1
10299	***Lacanobia***	***subjuncta***		(Grote & Robinson, 1868)	3
10300	***Spiramater***	***grandis***		(Guenée, 1852)	77
10301	***Spiramater***	***lutra***		(Guenée, 1852)	88
10303	***Trichordestra***	***tacoma***		(Strecker, 1900)	7
10304	***Trichordestra***	***legitima***		(Grote, 1864)	5
10307	***Trichordestra***	***lilacina***		(Harvey, 1874)	2
10311	***Papestra***	***biren***		(Goeze, 1781)	56
10312	***Papestra***	***cristifera***		(Walker, 1858)	1
10370	***Lacinipolia***	***lustralis***		(Grote, 1875)	44
10372	***Lacinipolia***	***anguina***		(Grote, 1881)	7
10397	***Lacinipolia***	***renigera***		(Stephens, 1829)	9
10405	***Lacinipolia***	***lorea***		(Guenée, 1852)	26
10406	***Lacinipolia***	***olivacea***		(Morrison, 1874)	70
10431	***Faronta***	***diffusa***		(Walker, 1856)	1
10436	***Aletia***	***oxygala***		(Grote, 1881)	2
10438	***Pseudaletia***	***unipuncta***		(Haworth, 1809)	9
10440	***Leucania***	***linita***		Guenée, 1852	1
10446	***Leucania***	***multilinea***		Walker, 1856	21
10447	***Leucania***	***commoides***		Guenée, 1852	3
10449	***Leucania***	***insueta***		Guenée, 1852	3
10459	***Leucania***	***inermis***		(Forbes, 1936)	5
10487	***Orthosia***	***rubescens***		(Walker, 1865)	7
10490	***Orthosia***	***revicta***		(Morrison, 1876)	1035
10495	***Orthosia***	***hibisci***		(Guenée, 1852)	7
10501	***Crocigrapha***	***normani***		(Grote, 1874)	146
10513	***Egira***	***dolosa***		(Grote, 1880)	30
10517	***Egira***	***alternans***		(Walker, 1857)	44
10520	***Morrisonia***	***evicta***		(Grote, 1873)	554
10521	***Morrisonia***	***confusa***		(Hübner, 1831)	15
10291	***Morrisonia***	***latex***		(Guenée, 1852)	15
10524	***Nephelodes***	***minians***		Guenée, 1852	52
10563	***Protorthodes***	***oviduca***		(Guenée, 1852)	3
10585	***Orthodes***	***crenulata***		(Butler, 18900	13
10587	***Orthodes***	***cynica***		Guenée, 1852	466
10644	***Trichosilia***	***mollis***		Walker, 1857	5
10651	***Agrotis***	***venerabilis***		Walker, 1857	10
10659	***Agrotis***	***volubilis***		Harvey, 1874	24
10663	***Agrotis***	***ipsilon***		(Hufnagel, 1766)	5
10676	***Feltia***	***herilis***		(Grote, 1873)	1

Cat. #	Genus	Specific epithet	Subspecies	Author, year	Total catch
10680	***Trichosilia***	***geniculata***		Grote & Robinson, 1868	22
10702	***Euxoa***	***divergens***		(Walker, 1857)	8
10705	***Euxoa***	***messoria***		(Harris, 1841)	2
10738	***Euxoa***	***mimallonis***		(Grote, 1873)	2
10755	***Euxoa***	***declarata***		(Walker, 1865)	2
10756	***Euxoa***	***campestris***		(Grote, 1875)	9
10780	***Euxoa***	***comosa***	***ontario***	(J. B. Smith, 1900)	3
10801	***Euxoa***	***ochrogaster***		(Guenée, 1852)	1
10865	***Euxoa***	***perpolita***		(Morrison, 1876)	15
10891	***Ochropleura***	***implecta***		Lafontaine, 1998	27
10902	***Euagrotis***	***forbesi***		Franclemont, 1952	3
10915	***Peridroma***	***saucia***		(Hübner, 1808)	1
10917	***Diarsia***	***rubifera***		(Grote, 1875)	109
10919	***Diarsia***	***jucunda***		(Walker, 1857)	122
10922	***Diarsia***	***rosaria***	***freemani***	Hardwick, 1950	3
10925.1	***Noctua***	***pronuba***		(Linnaeus, 1758)	12
10929	***Eurois***	***occulta***		(Linnaeus, 1758)	19
10930	***Eurois***	***astricta***		Morrison, 1874	107
10942	***Xestia***	***c-nigrum****		(Linnaeus, 1758)	24
10943	***Xestia***	***normaniana***		(Grote, 1874)	644
10944	***Xestia***	***smithii***		(Snellen, 1896)	154
10947	***Xestia***	***oblata***		(Morrison, 1875)	2
10951	***Xestia***	***tenuicula***		(Morrison, 1874)	18
10962	***Xestia***	***perquiritata***		(Morrison, 1874)	42
10967.1	***Xestia***	***praevia***		Lafontaine, 1998	1
10968	***Xestia***	***badicollis***		(Grote, 1873)	45
10970	***Xestia***	***youngii***		(J. B. Smith, 1902)	67
10988	***Coenophila***	***opacifrons***		(Grote, 1878)	51
10993	***Hemipachnobia***	***monochromatea***		(Morrison, 1874)	3
10994	***Cerastis***	***tenebrifera***		(Walker, 1865)	1
10996	***Cerastis***	***salicarum***		(Walker, 1857)	165
10997	***Cerastis***	***fishii***		(Grote, 1878)	3
10999	***Aplectoides***	***condita***		(Guenée, 1852)	69
11000	***Anaplectoides***	***prasina***		(Denis & Schiffermüller, 1775)	13
11001	***Anaplectoides***	***pressus***		(Grote, 1874)	26
11004	***Protolampra***	***rufipectus***		(Morrison, 1875)	13
11008	***Eueretagrotis***	***perattenta***		(Grote, 1876)	17
11009	***Eueretagrotis***	***attenta***		(Grote, 1874)	152
11010	***Lycophotia***	***phyllophora***		(Grote, 1874)	96
11012	***Cryptocala***	***acadiensis***		(Bethune, 1870)	20
11029	***Abagrotis***	***alternata***		(Grote, 1864)	5
11043	***Abagrotis***	***cupida***		(Grote, 1865)	4
11044	***Abagrotis***	***brunneipennis***		(Grote, 1875)	23

* Includes *Xestia c-nigrum* and *Xestia dolosa* Franclemont, 1980. Both species identified by female genitalic dissection; males inseparable.