THE UNIVERSITY OF ALBERTA

NOCTURNAL ACTIVITY PATTERNS AND HABITAT PREFERENCE OF SOME LEPIDOPTERA OF GEORGE LAKE, ALBERTA

by

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ABSTRACT

Nocturnal flight activity and habitat preference of common species of nocturnal Lepidoptera were examined at the George Lake Field Site (53°57'N - 114°06'W), a section of undisturbed aspen parkland ecotone about 10 miles west of Busby, Alberta.

Twenty-one species of moths were eventually chosen for study, representing 17,318 specimens, collected in 47 nights during June and July of 1970 and 1971. Six mercury vapor light traps were used to collect samples in a grid system transversing two habitats and their common transition zone. Seasonal occurrence is indicated. Nightly activity patterns and peaks are given for each species, and discussed. Major weather factors are analyzed against total moth flight activity and reasons speculated on, for correlations. Finally, an attempt is made to determine adult moth habitat specificity. Inferences are discussed i.e. that habitat specificity of adults corresponds well with habitat of larval food plants.

ACKNOWLEDGEMENTS

I wish to thank, first and foremost, my supervisor, Dr. W. G. Evans for his continual help and suggestions during the entire progress of this thesis. He was never "too busy" and was always willing to discuss problems, regardless of the mounds of other work on his desk. I would also like to thank the other faculty members of the Department of Entomology, particularly Drs. Ball and Heming for their advice as well as morale boosts.

I am greatly appreciative of the statistical help and "lines of attack" of Dr. Waltam who gave up whole afternoons to discuss appropriate statistical tests.

Furthermore, I cannot thank enough Mr. and Mrs. Edward Donald, neighbors near the George Lake Field Station, for their constant good humor. They were willing to help out at any time day or night whenever crises arose - whether real or imagined.

My indebtedness also extends to the Department of Entomology, University of Alberta, and the Boreal Institute for the funds to allow me to do the necessary fieldwork in 1970 and 1971.

In the field I had a number of assistants who helped me considerably, I wish to thank: M. Shaw, C. Hergert, D. Ball, and A. Schaaf. I am also grateful for the help, advice, and discussions of Fawn and Henri Goulet. It was not unusual for a problem-solving session to last into the wee hours, illuminated only by kerosene lantern. Finally, I would like to thank many of my fellow students in the Entomology Department for their concern and suggestions during the study; most notably M. A. C. Chance, D. Rosenberg, J. Ryan, and A. Thomas.

PROLOGUE

"What doest thou here,
Thou dusky courtier,
Within the pinky palace of the rose?
Here is no bed for thee,
No honeyed spicery,-
But for the golden bee,
And the gay wind, and me,
Its sweetness grows.
Rover, thou dost forget;-
Seek thou the passion-flower
Bloom of one twilight hour.
Haste, thou art late!
Its hidden savors wait.
For thee is spread
Its soft, purple coverlet;
Moth, art thou sped?
- Dim as a ghost he flies
Through the night mysteries."

- Moth Song -

E. M. H. Cortissoz

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INTRODUCTION

The George Lake Field Site provides one square mile of nearly undisturbed aspen parkland ecotone with its individual habitat components. Few projects have been initiated on the flight activity of nocturnal Lepidoptera in this ecotone, or at this latitude. I began a project at this site to learn more about the flight activity of the common moths of this ecotone in central Alberta.

Briefly, the study was designed to answer the following questions: Does each species have a unique, nocturnal flight pattern? Does the pattern remain constant from year to year? What is the general flight phenology of the common moth species at the George Lake Field Site? What influence has weather on flight activity of nocturnal Lepidoptera? Can any single weather factor be designated as the dominant influence? Do species, as adults, exhibit a habitat preference? Finally, if there is indication of habitat preference during flight activity, what might be the underlying cause.

Light traps for sampling purposes are ideal for a study of this nature and apparently have been employed albeit crudely to catch moths since at least the thirteenth century. Williams (1964) quotes from the ancient Arabic tome "Book of the Marvels of Nature and the Singularities of Created Things": "...that Khalif de Samarkande one night collected around the light (torch) a Macouc (drinking cup-ful) of moths and on dividing them he counted seventy-three different kinds." In spite of their long history of use, lights and light traps possess some inherent sampling problems since they "attract". Nevertheless, because light traps are convenient tools to use, they were chosen for sampling in this study.

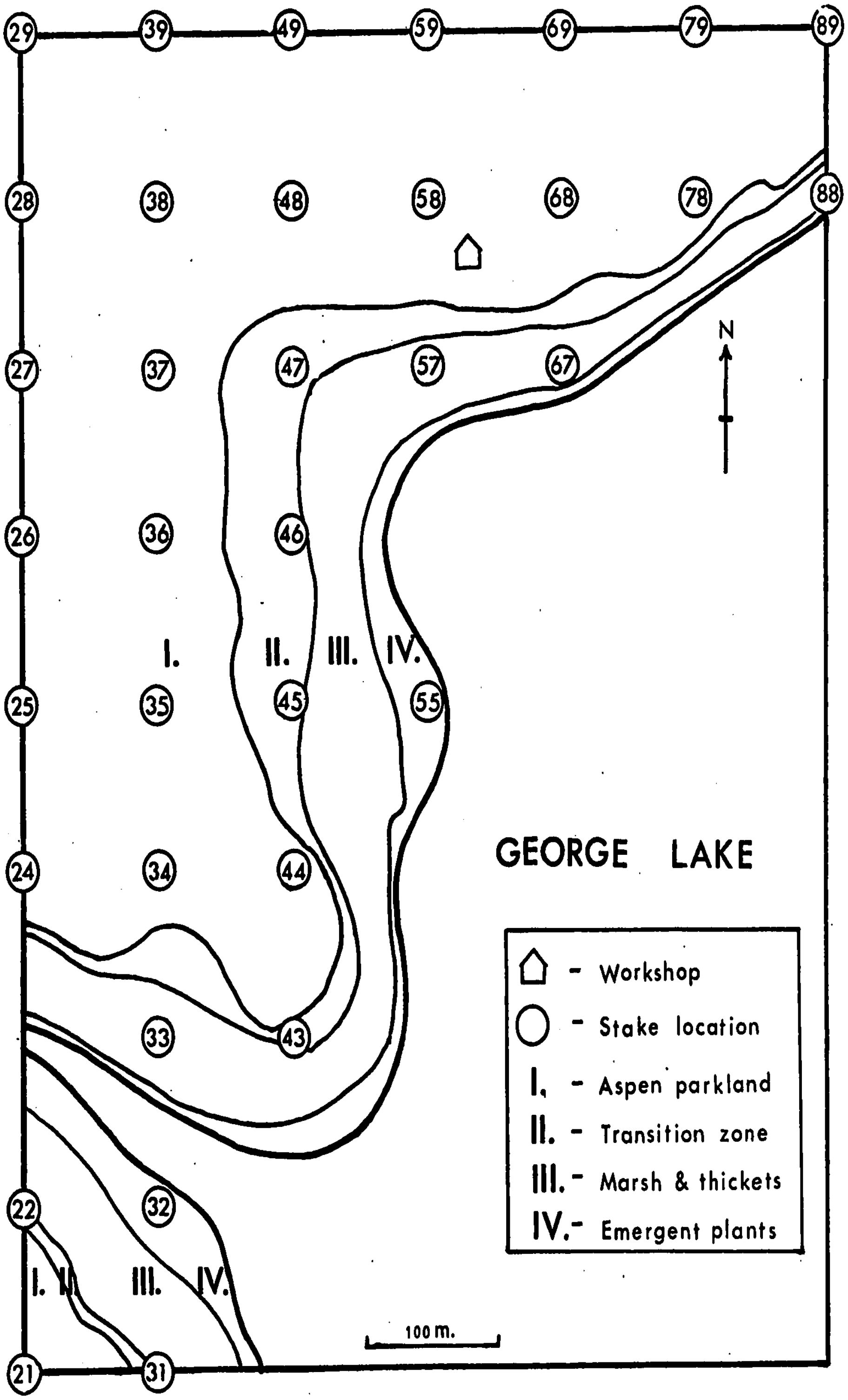
The most prolific researcher in the study of nocturnal insect flight activity is C. B. Williams. Many of the answers sought in this study have been provided for species that he worked with at Rothamstead Experimental Station, England. Battalions of other authors have researched most of the problems examined in this study; however, the question of habitat preference, or the distribution of species through various habitats has generally been disregarded. Hosny (1958) studied habitat specificity but did not replicate treatments nor propose any reasons why habitat preference during adult flight might be taking place. I hoped, in undertaking this project, that flight activity behaviour existing in moths of other geographical regions could be found in the common species of the aspen parkland ecotone. Furthermore, I also hoped to be able to demonstrate spatial (habitat) and temporal isolation in adult moth flight activity, and to propose possible reasons for it if it did exist.

METHODS AND EQUIPMENT

LOCATION - This study was undertaken during the summers of 1970 and 1971 at the George Lake Field Site (site description; Shorthouse, 1970). In a small region of the northwestern shore of George Lake, the gradual aging of the lake has produced three narrow bands of different habitats (Figure 1). Furthest inland from the lake shore is the aspen parkland (I) common to this region. Bordering the lake is exclusively emergent vegetation (IV), primarily *Typha latifolia* (L.). This habitat was not used in the study because of the basic problems of walking on a semi-floating habitat in darkness! The next band of distinct habitat is wet marsh and willow thicket (III), predominently *Salix spp.* and various species of Graminae. In Figure 1 another area (II) is indicated that is a transition zone between the aspen parkland and the wet marsh and willow thicket. In this transition zone are found sparse stands of grasses and a spotty shrub layer. The aspen parkland covers the largest proportion of the George Lake Field Site and is dominated by *Populus tremuloides* (Michx.).

Because these habitats and their transition zone were narrow and adjacent, it was thought that light traps could be effectively used to sample the moths of all these habitats within a relatively small area. Six light traps were used, two each in the transition zone, the aspen parkland, and the wet marsh and willow thicket. Each trap was in the center of a quadrat having 48 meters to a

FIGURE 1: NORTHWESTERN SHORE OF GEORGE LAKE INSIDE THE FIELD SITE, SHOWING THE HABITATS, TRANSITION ZONE, STAKE LOCATIONS AND WORKSHOP



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79
89
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67
N
26
36
46
I.
II.
III.
IV.
25
35
45
55
24
34
44
GEORGE LAKE
33
43
22
32
I.
II.
III.
IV.
21
31
100 m.
⌂ - Workshop
○ - Stake location
I. - Aspen parkland
II. - Transition zone
III. - Marsh & thickets
IV. - Emergent plants

side. This resulted in a three by two grid of quadrats which allowed two simultaneous samples to be taken in each of the three adjacent areas each night (Figure 2). According to Robinson (1961) and Harstack et al. (1968), the distance separating each light trap, 48 meters, is sufficient to make each quadrat distinct. Each light trap should thus have negligible or no influence in attracting a moth from any area outside the 24 meter radius. The light trap quadrats were lettered for easy reference - A and D were in the wet marsh and willow thicket; B and E in the transition zone; and C and F in the aspen parkland.

LIGHT TRAP EQUIPMENT - Each of the six light traps (Figure 3) was hand made and represents a hybrid between Robinsons' light trap (Robinson and Robinson, 1950) and the funnel and killing apparatus of the Pennsylvania light trap (Frost, 1957). The baffles were extended nine cm above the funnel since Frost (1958a, 1959) proposed that such a modification increased chance of capture by stopping and stunning the faster flying moths. Lepidoptera and other insects that fell into the funnels were collected and killed in a two quart jar containing approximately 30 ml of ethyl acetate. Canadian General Electric 100 watt mercury vapor bulbs were used with their appropriate ballasts. A 1250 watt Zeus gasoline generator, fitted with a large fuel tank was used to power the six light traps. The generator had to be stationed in the center of the grid, between quadrats B and E, so that the extension cords would be short enough to eliminate effective voltage drop. An eight foot vertical exhaust pipe and muffler were added to dissipate exhaust fumes and decrease

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FIGURE 2: DIAGRAM OF THE STUDY GRID, SHOWING HABITAT AND TRANSITION OUTLINES, WEATHER SHELTER, AND STAKE LOCATIONS

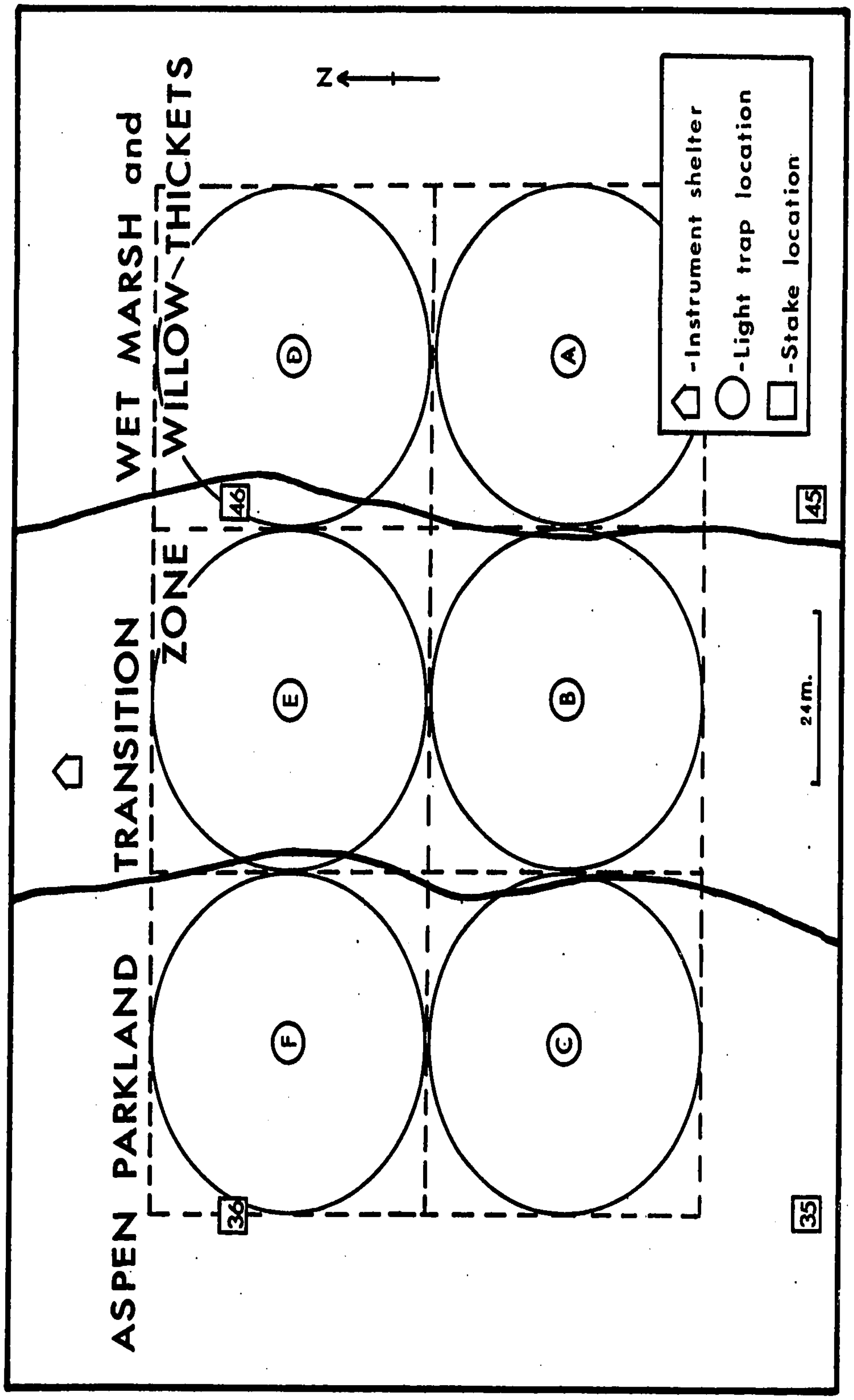
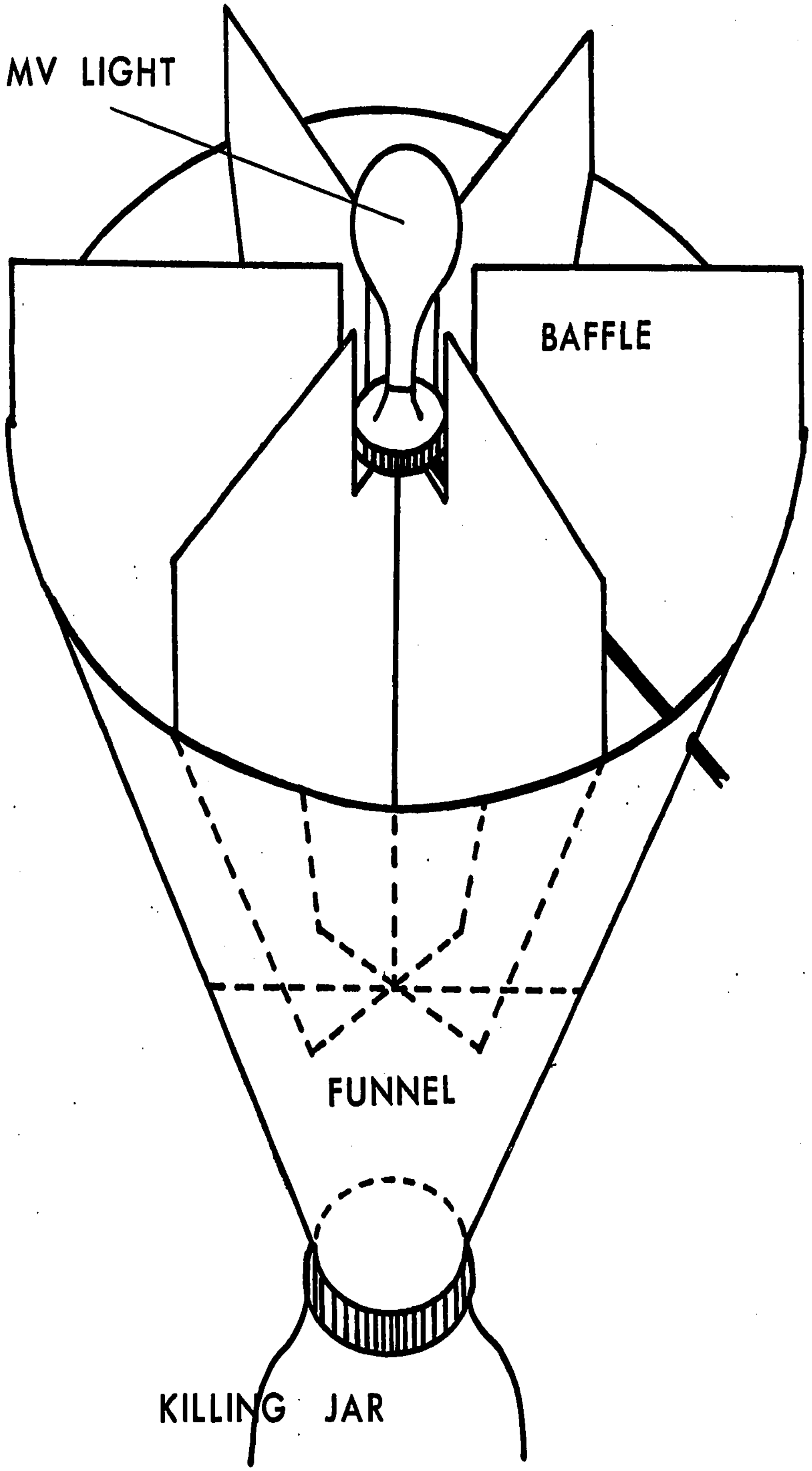

ASPEN PARKLAND
TRANSITION ZONE
WET MARSH and WILLOW-THICKETS
N
A
B
C
D
E
F
24m.
35
36
45
46
⌂ -Instrument shelter
○ -Light trap location
☐ -Stake location

FIGURE 3: DIAGRAM OF THE LIGHT TRAP (WITHOUT TRIPOD)


MV LIGHT
BAFFLE
FUNNEL
KILLING JAR

the noise level.

I built permanent wooden tripods, 1.5 m high, to hold each of the light traps stably in the center of their respective quadrats. The light traps could not be raised or lowered. Frost (1958b) and Taylor and Carter (1961) indicated that this height was within the general range of most flying nocturnal Lepidoptera.

LIGHT TRAP LIGHT MEASUREMENT - A photometer was used to take light intensity readings at an eight meter perimeter around each light trap. The photocell was fixed 10 cm behind a frame shielded with a sheet of honeycomb plastic and a sheet of frosted plastic. The sheets were used to integrate the light reaching the photocell through the foliage. Readings were taken at 50, 125, and 175 cm from the ground at approximately 18 degree arcs. Sixty readings were taken from each light trap quadrat.

LIGHT TRAPPING TIMES AND SEASON - Since one of the objectives of the study was to determine the time of greatest nocturnal flight activity, light trap "sub-samples" were also taken throughout the night. The period between sunset and sunrise was equally divided into four intervals. Because the length of time between sunset and sunrise is continually changing, time intervals within a night are equivalent but not those between nights (Appendix 1). Therefore, comparisons in activity made throughout the season do not reflect Mountain Standard Time, but rather quarterly night intervals based on actual sun time. Obviously, four time intervals per night will only give an approximation of actual activity patterns, but additional interval sampling was impractical. Killing jars were changed manually at the end of each interval, a process requiring six to eight minutes. A larger number of shorter sampling intervals would tend to increase the error factor due to this exchange time. Jars were changed in different sequences to eliminate biases for any one light trap quadrat. Changeover began three or four minutes before the determined end of the time interval and lasted three or four minutes afterwards.

In 1970, 25 nights were sampled from June 19 through July 16 and in 1971, 22 nights from June 9 through July 21 (Appendix 1).

METEOROLOGICAL DATA - Six weather parameters were recorded every night that the light traps were in operation. A wind-up drum hygro-thermograph was used for continuous recordings of temperature and relative humidity. This instrument was housed in an instrument weather shelter placed 10 m outside the grid system (Figure 2). All weather data was gathered from this location and therefore reflect quite accurately the weather measurements within the grid. Percentage of cloud cover was estimated at the start and end of each time interval. Wind velocity was recorded at these times with a vane anemometer, while rainfall was measured within the time interval with a rain gauge cylinder. I estimated the percentage of moon phase of the full moon using local calendars for the two seasons. Lack of time plus the short duration that this study was in progress prohibited a more complete record of daily and yearly weather measurements. The information collected is of use in analyzing insect activity (Williams, 1951).

VEGETATION DATA - Trees were considered such if their trunk diameters were one inch or greater at chest height. Basic descriptive techniques of dominance, frequency, and density were used. Each quadrat was split into four, square sub-quadrats of 24 m on a side. All trees were counted, measured, and identified in each sub-quadrat. In each sub-quadrat three random samples were picked for shrub measurements. Plants with woody stems were considered shrubs if their diameters were less than one inch in diameter. Thus, a quadrat contained 12 random samples with each sample encompassing 10 m^2. From these samples, I calculated shrub density and frequency. In addition, extrapolations for all tree and shrub measurements within the 24 m radius of each light trap were made to determine light trap influence within each quadrat. Unfortunately, lack of time and the partial inundation of the lake into the wet marsh and willow thicket did not permit similar measurements to be made with the herbaceous vegetation. Instead, I listed the species in each of the three areas that apparently constituted the greatest proportion of the herbaceous plant biomass.

TREATMENT OF LIGHT TRAP SAMPLES - Some manner of reducing the number of species of Lepidoptera to be considered in the light trap samples had to be devised. The samples do not represent population indices nor the total number of Lepidoptera species present, but indicate only the activity of the species that were attracted. Thus, I felt that imposing further restrictions on the samples would not make the samples more artificial. For example, males of *Sphinx luscitiosa* (Clem.) were seen in the area but were not caught

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in light traps, and are never known to come to light (Hodges, 1971). Therefore, I limited my working samples to members of the superfamilies Noctuoidea, Bombycoidea, Drepanoidea, Geometroidea, Sphingoidea, and the suborder Jugatae (McDunnough classification, 1938, 1939). This exclusion of other taxa decreased taxonomic problems that were apt to arise otherwise. Furthermore, species in some of the other superfamilies, collectively called Micro-Lepidoptera, became virtually indistinguishable from each other on rainy nights when the samples in the killing jars became a viscous mass of insects. In addition, I had to work only with those species that were collected in numbers, arbitrarily chosen at 100 or more, since for statistical purposes data on "rare" species would be useless. During the winter of 1970-1971, I identified all species that met these requirements, and discovered that I would be analyzing data of 22 species. Later, one, *Parastichtus discivaria* (Wlk.), was dropped because no specimens were collected in the 1971 summer season. These 21 species made up the bulk of the samples both in abundance and in relative weight in the two sampling seasons.

Females of many nocturnal moth species are infrequently or never attracted to light. Thus, with the exception of females of *Malacosoma disstria* Hbn., the data reflect the behavior of male specimens only. The large number of female *M. disstria* captured enabled me to treat their flight behavior separately from that of the males.

Williams (1937) proposed transforming data, such as that gathered by light trapping studies, into logarithmic values.

Because the logarithm of zero is an undefined value, he proposed the use of log (n+1) for any number n, including n equal to zero. Values are thereby increased, but the +1 becomes increasingly negligible in larger numbers. This allows the use of zero as a meaningful term. The major benefit of using logarithmic numbers rather than arithmetic numbers is that the greater weight is given to the consistency of the data and less to aberrancies or marked deviations. Nonetheless, because using log values skews a normal distribution curve assumed in this study, Williams' method of transformation could not be used in simple or partial correlations. Therefore, arithmetic values are used throughout except for the nightly moth catch in Figure 6, and seasonal moth catch in Figure 5.

RESULTS

LIGHT INFLUENCE - To sample adjacent habitats in an area small enough to be meaningful, it was necessary to decide at what distance a light trap ceased to attract moths. It was also necessary to eliminate, or at least quantify, the possible differences of light intensity, and hence the effectiveness of the light traps in different quadrats. This difference, if any, would be caused by obstacles preventing a sphere of illumination from the light source reaching a point where the intensity ceases to attract moths. In this study, vegetation was the only obstacle of differing influence, since truncation of the sphere by the ground was constant throughout.

Robinson (1961), using a mark, release, and recapture method, determined the effective light trapping radius for a 125 watt mercury vapor bulb. He concluded that the effective trapping radius for this bulb was 18.82 yards (17.2 m), although he did recapture the occasional specimen released from distances as great as 100 yeards away. Harstack et al. (1968) measured indirectly the trapping distance of a 15 watt fluorescent black light. Although their study was designed to answer a different problem, their data indicates that few *Heliothis zea* Boddie were influenced by light further than a 48 foot radius (14.6 m) from the source. Since the light traps used in this study were similar to Robinsons' except for the smaller watt bulbs in my traps (100 w), I spaced the traps in accordance with his results but allowed an extra margin of buffering, using a 24 m radius. The width of the transition zone actually prohibited a larger radius even if desired. Nevertheless, I assumed that a certain, but undefined proportion of the population of each species would be collected in light traps not necessarily in their "normal" habitat. Most likely reasons for this would be passive dispersal, caused by wind, or active dispersal - migration.

I felt that it was important to study the possibility that light traps in different habitats might have differing light trapping influence due to obstacles or the physiognomy of surrounding vegetation. The mean light intensity described previously was obtained from each light trap *in situ*. With the use of an unpaired t-test, the two light traps in each habitat were compared. Since the intensity of illumination follows the inverse square law, $I = K/d^2$, the constant K can be derived. Without any light blockage by vegetation, the foot candle value at eight meters was 1.2 (I). Table 1 shows the results for each trap at eight meters. These results include the mean light intensity, K value, and the t-tests. In each habitat the difference in light intensity between quadrats was not significant. Fiducial limits for the mean light intensity is at the 5% level of probability, by solving for m in the expression: $\pm\, t = (\bar{x} - m)/S_{\bar{x}}$; where t is taken at this probability level.

Using the data in this manner unfortunately assumes a homogeneity of light trap influence which is false; however, this

TABLE 1: MEAN LIGHT INTENSITY, K VALUE AND T VALUE OF LIGHT TRAPS IN THREE HABITATS

Wet Marsh and Willow Thicket	Mean Light Intensity* and Fiducial Limits	K Value
Light trap A	.263 ± .074	16.83
Light trap D	.370 ± .090	23.68
Transition Zone		
Light trap B	.527 ± .080	33.73
Light trap E	.645 ± .096	41.28
Aspen Parkland		
Light trap C	.477 ± .082	30.53
Light trap F	.522 ± .096	33.41

*Mean of 60 readings at eight meters

	T Value	
Wet Marsh and Willow Thicket (A and D)	1.814	Not significant at 5%
Transition Zone (B and E)	1.903	Not significant at 5%
Aspen Parkland (C and F)	1.190	Not significant at 5%

T value at the 5% probability level = 1.980

is the only possible method for arriving at an answer. Table 2 shows the results of a simple correlation of the mean moths captured per night and per quadrat versus three general vegetation parameters. The K value is used for each quadrat. In this test, the mean moths captured is not significantly related to the light intensity. Evidently, the mean moths captured is more closely related to vegetation. My knowledge of the habitats studied permits speculation on the other significant correlations in the matrix in Table 2. The aspen parkland quadrats yielded the greatest number of species most likely because this habitat has the greatest plant diversity (Tables 5 - 11). This habitat has fewer trees than the wet marsh and willow thicket habitat, but more tree and shrub species. The tree species are of greater age and hence basal diameter. This may explain the other correlations except for shrub density versus the K value. It is logical to assume that the correlation between light intensity and shrub density would be negative but his is not the case. I believe that the stands of Graminae in the wet marsh and willow thicket were much denser than the shrub layer in the aspen parkland. Since herbaceous vegetation did not enter into this matrix, the positive correlation is misleading.

Results given indicate that there were no significant differences in light intensity between quadrats. If they do exist, they are masked by the overwhelming relationship of moths to plants. Therefore, no correction factors were used in the analyses of the samples.

TABLE 2: SIMPLE CORRELATION COEFFICIENTS OF MEAN MOTHS CAPTURED, SHRUB DENSITY, TREE DOMINANCE TREE DENSITY, AND K VALUE

	Mean Moths	Shrub Density	Tree Dominance	Tree Density	K Value
Mean Moths	1.000				
Shrub Density	+.858**	1.000			
Tree Dominance	+.781**	.938**	1.000		
Tree Density	-.515	-.842**	-.914**	1.000	
K Value	+.059	+.594*	.688**	-.900**	1.000

* 5% level of probability = ± .533

**1% level of probability = ± .684

SEASONAL FLIGHT PERIODS - During this study uncounted thousands of nocturnal Lepidoptera were light trapped. Of these, 17,318 specimens of 21 species were used for the final analyses. Table 3 lists the numbers and species tabulated from the two years. Except for *Malacosoma disstria*, only males were used.

Figure 4 illustrates the length of time that each species was captured in the two years (dates of 1970 are imposed above the dates of 1971). In some species, eg. *Apantesis virgo* L., the differences of seasonal flight periods between the two years is great - as much as 23 days. In some instances, species were undoubtedly flying earlier or later than the seasonal period in which this study was in progress. *Smerinthus cerisyi* Kby. was observed as early as late April in 1971 and *Campaea perlata* Gn. in mid September in 1970. I attempted to sample the season each year when these species were most likely to be collected in large numbers. Problems out of my jurisdiction - generator failure and late arrival of equipment - did not make this entirely possible.

NIGHTLY FLIGHT PERIODS - Nightly samples were collected for four equal time intervals from sunset to sunrise in the hopes of defining the peak intervals of nocturnal flight activity for the species considered and to see if any patterns were discernable. Better definition of species flight activity curves would have necessitated continuous monitoring of the six light traps - an impossible task. Four time intervals do indicate flight peaks (Figure 5) and the flight behavior was replicated for each species

TABLE 3: SPECIES AND NUMBERS OF SPECIMENS LIGHT TRAPPED DURING THE 1970 AND 1971 SEASONS*

Species	1970	1971	Total
Sphingidae			
Smerinthus cerisyi Kby.	157	191	348
Smerinthus jamaicensis Dru.	278	620	898
Arctiidae			
Eubaphe ferruginosa Wlk.	211	102	313
Apantesis virgo L.	113	25	138
Parasemia parthenos (Harr.)	244	85	329
Noctuidae			
Hypocaena inquinata Gn.	198	10	208
Notodontidae			
Pheosia rimosa Pack.	786	619	1405
Cerura scolopendrina Bdv.	133	303	436
Gluphisia septentrionalis Wlk.	178	244	422
Liparidae			
Olene vagans B. & McD.	429	461	890
Lasiocampidae			
Malacosoma disstria Hbn.	1903	1197	3100
Malacossoma disstria (females)	1551	2363	3914

*Males only except where indicated otherwise

TABLE 3: continued

Species	1970	1971	Total
Drepanidae			
Oreta rosea Wlk.	121	125	246
Geometridae			
Lygris xylina Hlst.	135	49	184
Hydrelia albifera Wlk.	518	371	889
Deilinia variolaria (Gn.)	109	98	207
Deilinia erythemaria (Gn.)	224	250	474
Dysmigia loricaria Evers.	300	30	330
Amphidasis cognataria Gn.	112	527	639
Euchlaena tigrinaria Gn.	314	179	493
Campaea perlata Gn.	468	299	767
Hepialidae			
Hepialus gracilis Grt.	501	214	715

FIGURE 4: DATES OF CAPTURE FOR THE TWENTY-ONE SPECIES OF NOCTURNAL LEPIDOPTERA, COMPARING THE 1970 (UPPER LINE) AND 1971 (LOWER LINE) SEASONS

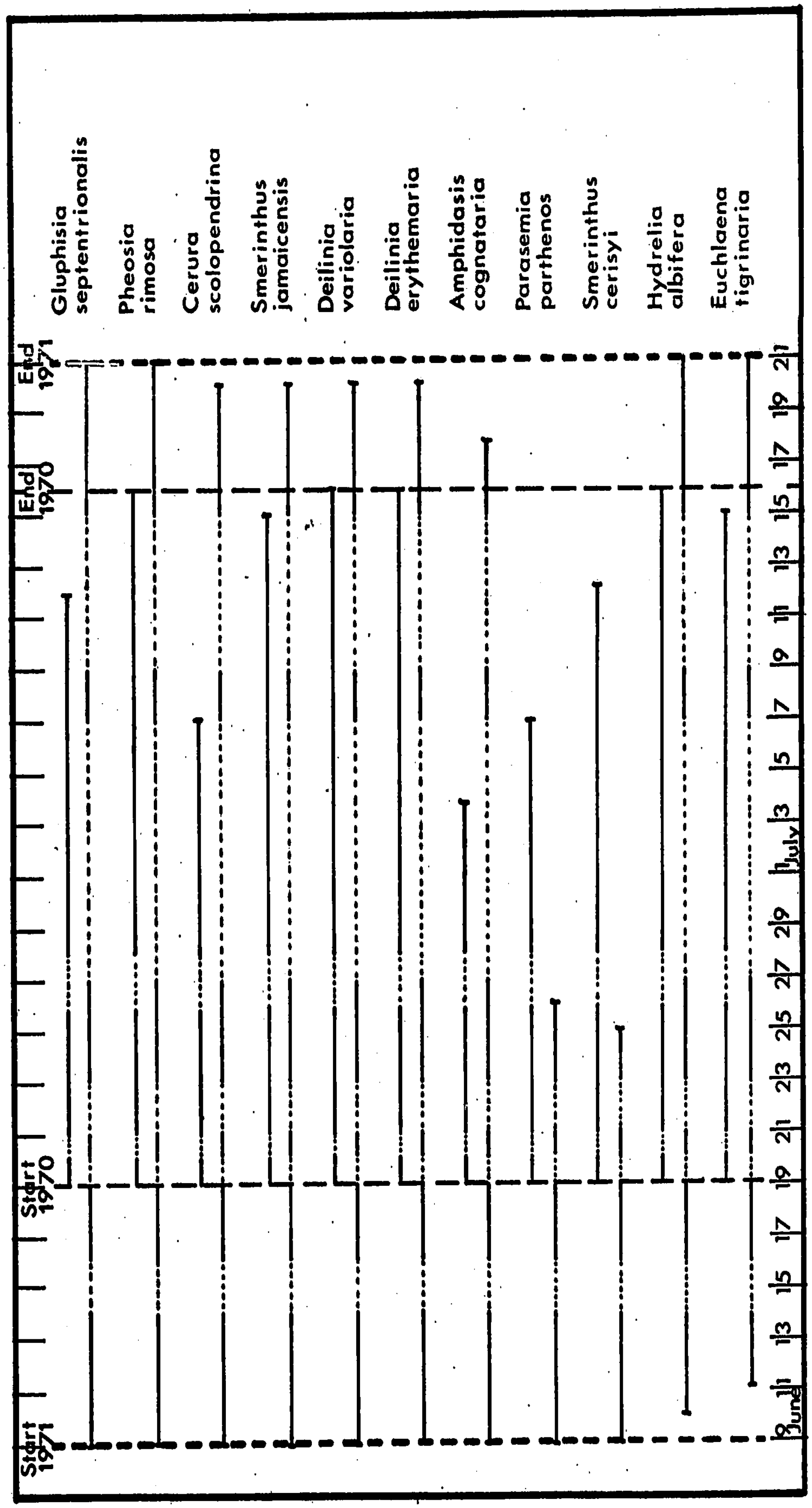
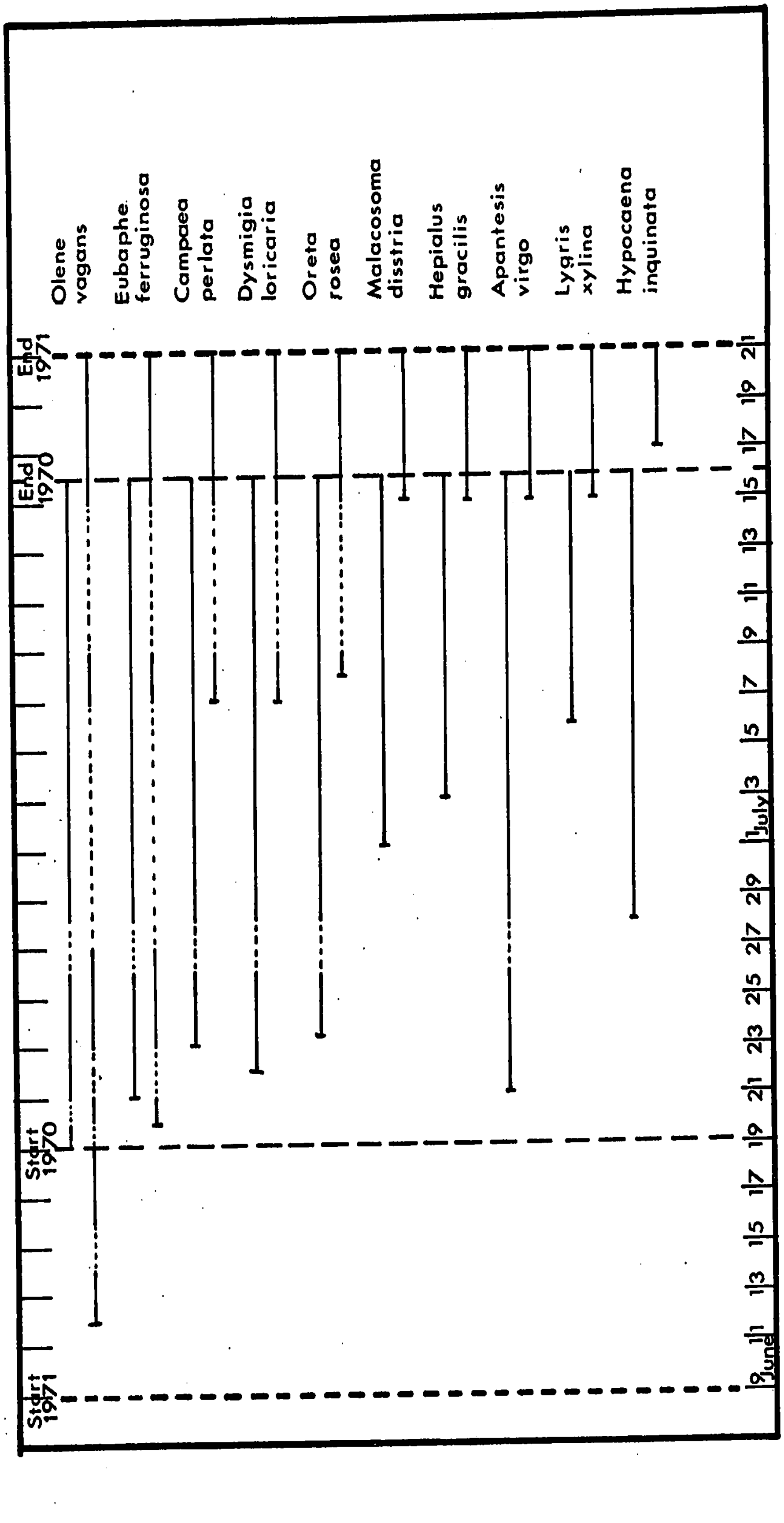

Gluphisia septentrionalis
Pheosia rimosa
Cerura scolopendrina
Smerinthus jamaicensis
Deilinia variolaria
Deilinia erythemaria
Amphidasis cognataria
Parasemia parthenos
Smerinthus cerisyi
Hydrelia albifera
Euchlaena tigrinaria
Start 1971
Start 1970
End 1970
End 1971
9 June
11
13
15
17
19
21
23
25
27
29
1 July
3
5
7
9
11
13
15
17
19
21

FIGURE 4: continued


Olene vagans
Eubaphe ferruginosa
Campaea perlata
Dysmigia loricaria
Oreta rosea
Malacosoma disstria
Hepialus gracilis
Apantesis virgo
Lygris xylina
Hypocaena inquinata
Start 1971
Start 1970
End 1970
End 1971
9 June
11
13
15
17
19
21
23
25
27
29
1 July
3
5
7
9
11
13
15
17
19
21

from 1970 to 1971. Lewis and Taylor (1965), using one hour intervals throughout the entire day, found 22 different patterns or curves for 43 species of Lepidoptera. Williams (1935, 1939) used eight intervals from sunset to sunrise and found little variation in a given species flight pattern over his four year study. Significance tests were not calculated since in this study there were only two replicates. From the bar graphs in Figure 5, five different, general, nocturnal flight patterns are inferred. Pattern one is illustrated by *Malacosoma disstria* females where there is a high, generally equal activity level throughout the night, dropping off slightly before sunrise during the fourth interval. Further years of replications are needed to clarify the discrepancy of interval three in 1970. Another species with this pattern is *Euchlaena tigrinaria* Gn.. The second pattern type is demonstrated by *Pheosia rimosa* Pack., *Smerinthus jamaicensis* Dru., *Lygris xylina* Hlst., *Deilinia erythemaria* (Gn.), *Deilinia variolaria* (Gn.), and possibly *Dysmigia loricaria* Evers., Samples indicate that the activity steadily increased until peaking after true midnight (interval three). During the last time interval, a drastic reduction in activity is indicated. *Hepialus gracilis* Grt. is unique in its flight pattern. A truly bimodal pattern of activity is indicated although the activity during interval one is much greater than in the fourth interval. Obviously this is a true crepuscular species. Pattern four is the reverse of number two. In this case, the activity is fairly strong in interval one and

FIGURE 5: NIGHTLY FLIGHT PERIODS OF THE TWENTY-ONE SPECIES OF NOCTURNAL LEPIDOPTERA STUDIED, SHOWING THE LOG (n+1) OF THE MOTHS (ORDINATE) COLLECTED IN EACH TIME INTERVAL (ABSCISSA), THE YEAR, THE NUMBER OF DAYS COLLECTED, AND THE NUMBER OF SPECIMENS COLLECTED

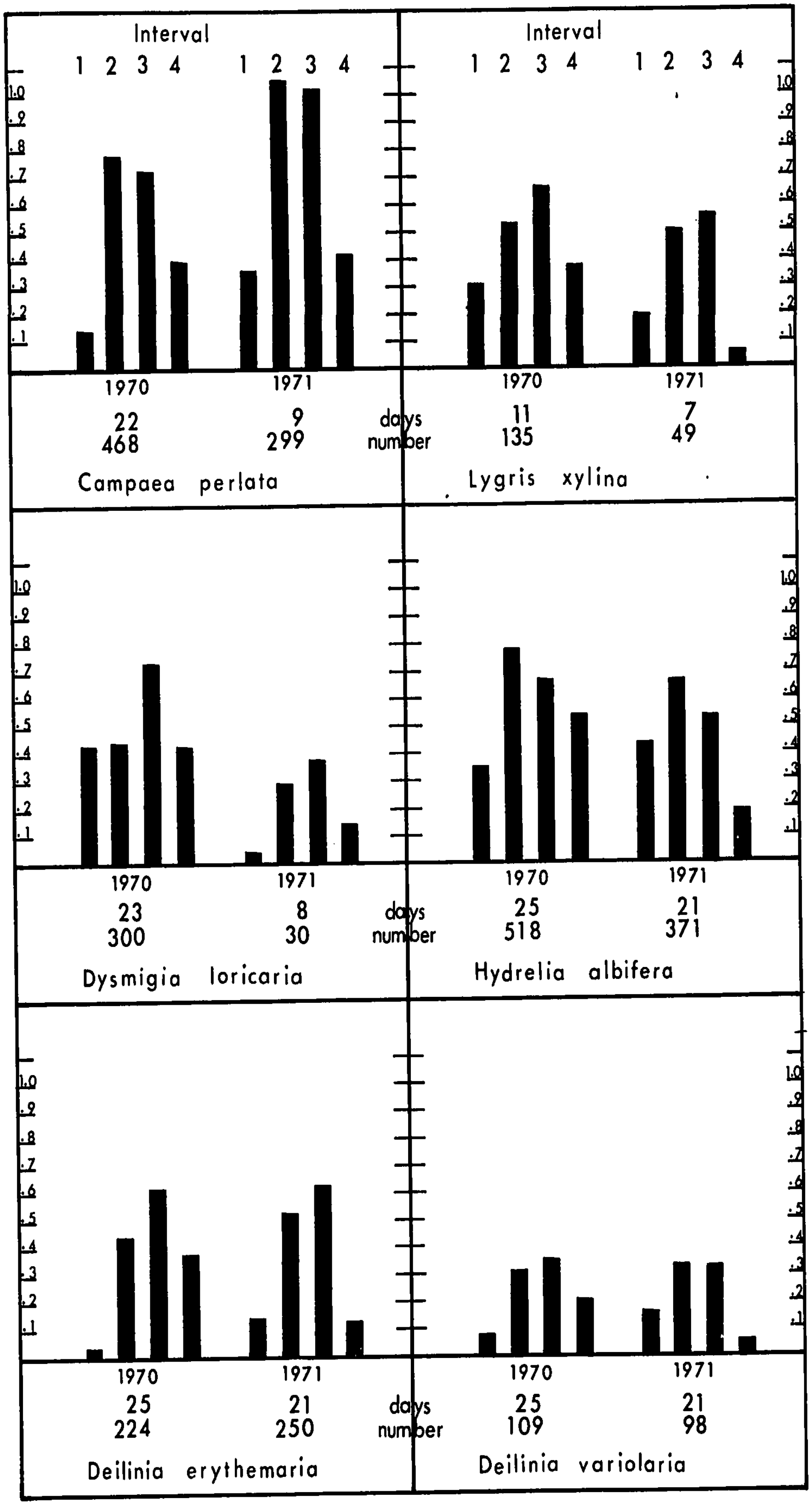

Interval
1 2 3 4 1 2 3 4
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
1970
1971
22
468
9
299
days
number
Campaea perlata
Interval
1 2 3 4 1 2 3 4
1970
1971
11
135
7
49
Lygris xylina
1970
1971
23
300
8
30
days
number
Dysmigia loricaria
1970
1971
25
518
21
371
Hydrelia albifera
1970
1971
25
224
21
250
days
number
Deilinia erythemaria
1970
1971
25
109
21
98
Deilinia variolaria

FIGURE 5: continued

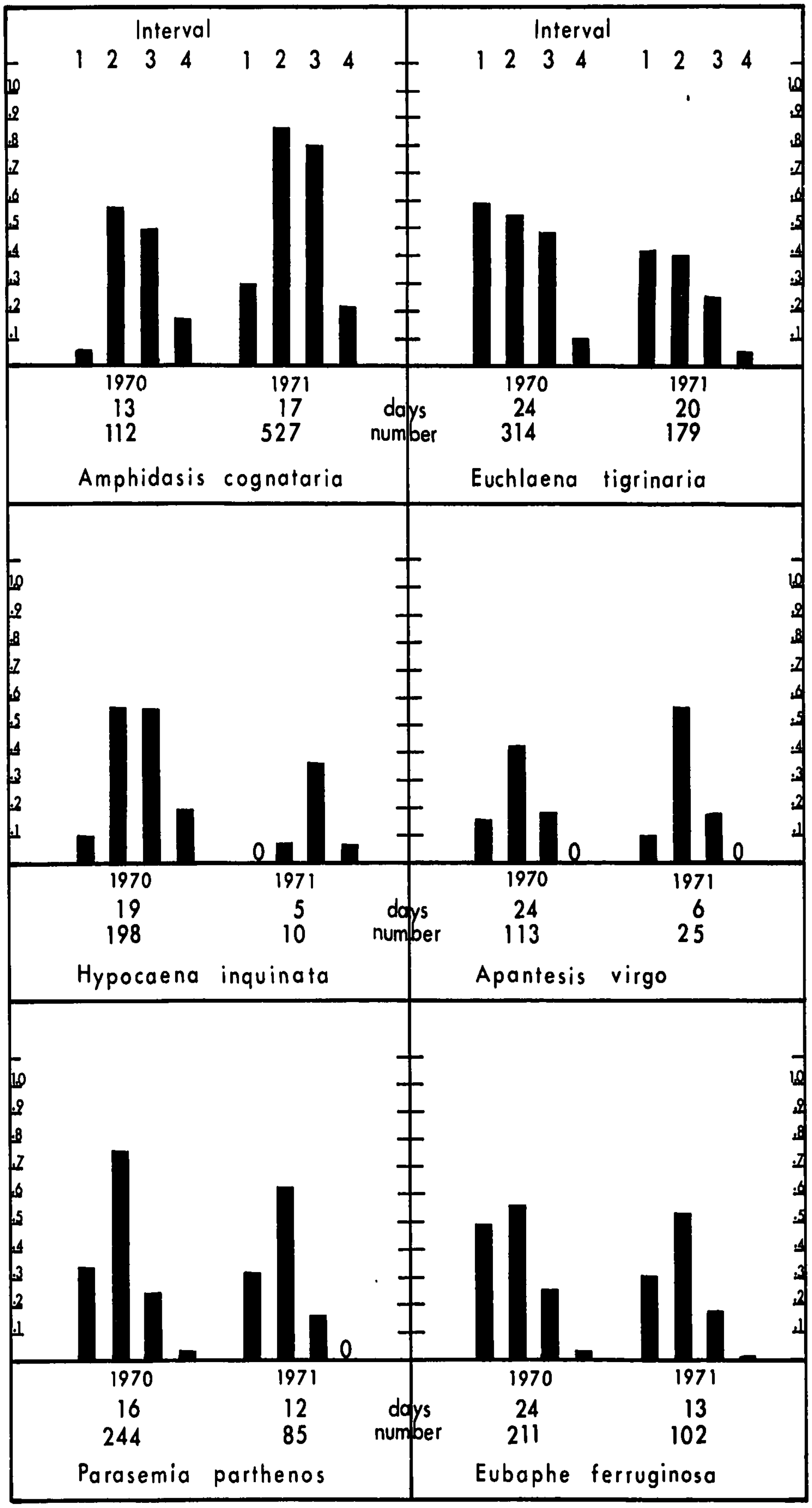

Interval
1 2 3 4 1 2 3 4
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
1970
1971
days
number
13
112
17
527
Amphidasis cognataria
24
314
20
179
Euchlaena tigrinaria
0
19
198
5
10
Hypocaena inquinata
24
113
6
25
Apantesis virgo
16
244
12
85
Parasemia parthenos
24
211
13
102
Eubaphe ferruginosa

FIGURE 5: continued

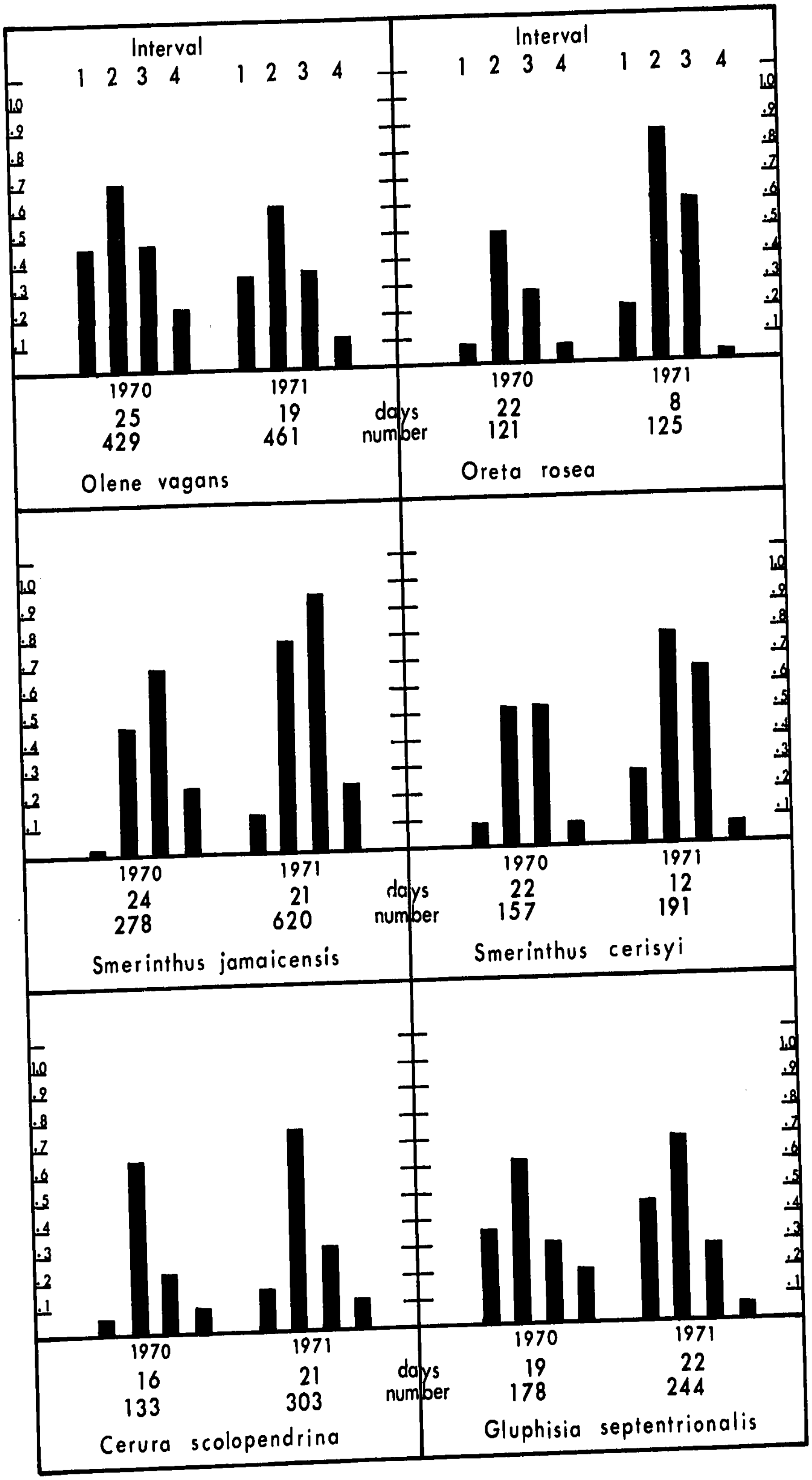
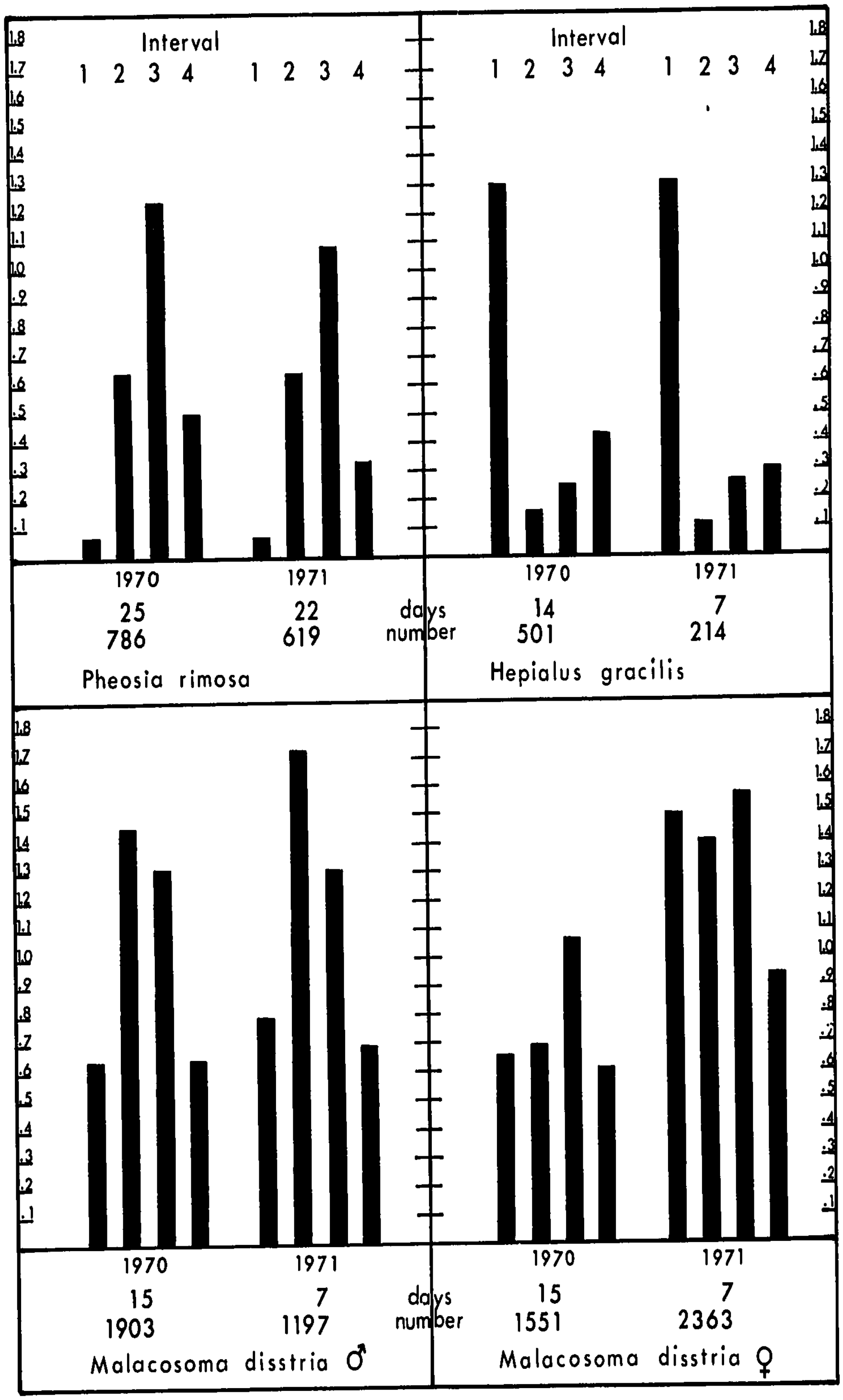

Interval
1 2 3 4 1 2 3 4
Interval
1 2 3 4 1 2 3 4
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
1970
25
429
1971
19
461
days
number
Olene vagans
1970
22
121
1971
8
125
Oreta rosea
1970
24
278
1971
21
620
days
number
Smerinthus jamaicensis
1970
22
157
1971
12
191
Smerinthus cerisyi
1970
16
133
1971
21
303
days
number
Cerura scolopendrina
1970
19
178
1971
22
244
Gluphisia septentrionalis

FIGURE 5: continued


Interval
1 2 3 4 1 2 3 4
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
1970
1971
25
786
22
619
days
number
Pheosia rimosa
Interval
1 2 3 4 1 2 3 4
1970
1971
14
501
7
214
Hepialus gracilis
1970
1971
15
1903
7
1197
days
number
Malacosoma disstria ♂
1970
1971
15
1551
7
2363
Malacosoma disstria ♀

peaks before true midnight in the second interval. Activity gradually diminishes during the next two intervals before sunrise. Species exemplifying this pattern are male *Malacosoma disstria, Olene vagans* B. & McD., *Oreta rosea* Wlk., *Apantesis virgo* L., *Eubaphe ferruginosa* Wlk., *Parasemia parthenos* (Harr.), *Smerinthus cerisyi, Cerura scolopendrina* Bdv., *Gluphisia septentrionalis* Wlk., and *Hydrelia albifera* Wlk.. The final pattern is indicated by *Amphidasis cognataria* Gn., *Campaea perlata*, and *Hypocaena inquinata* (Gn.). A high, nearly equal level of activity occurs before and after true midnight in intervals two and three with comparatively low levels just after sunset and before sunrise. Only ten specimens of *Hypocaena inquinata* were collected in 1971, therefore the data for this year is probably not reliable.

Photometric readings of moon and celestial light were taken at the start of the study but the photometer was too crude for light intensity measurements of this magnitude and the procedure had to be abandoned.

WEATHER EFFECTS ON MOTH FLIGHT ACTIVITY - The primary objectives of this study were not to record weather factors and correlate these with the number of moths captured; work in this field has been exhaustive. Nevertheless, some examination was needed since weather intimately effects moth activity.

Figure 6 plots the nightly average of six weather parameters and the log (n+1) moth catch for 47 collecting nights of 1970 and 1971. Particularly because of the discontinuity of sampling dates, no clear cut relationships can be observed from

FIGURE 6: THE LOG (n+1) MOTH CATCH AND NIGHTLY AVERAGE OF TEMPERATURE, ABSOLUTE HUMIDITY, PERCENTAGE OF MOON PHASE, PERCENTAGE OF CLOUD COVER, RAIN FALLEN, AND WIND VELOCITY DURING FORTY-SEVEN SAMPLING NIGHTS OF 1970 AND 1971

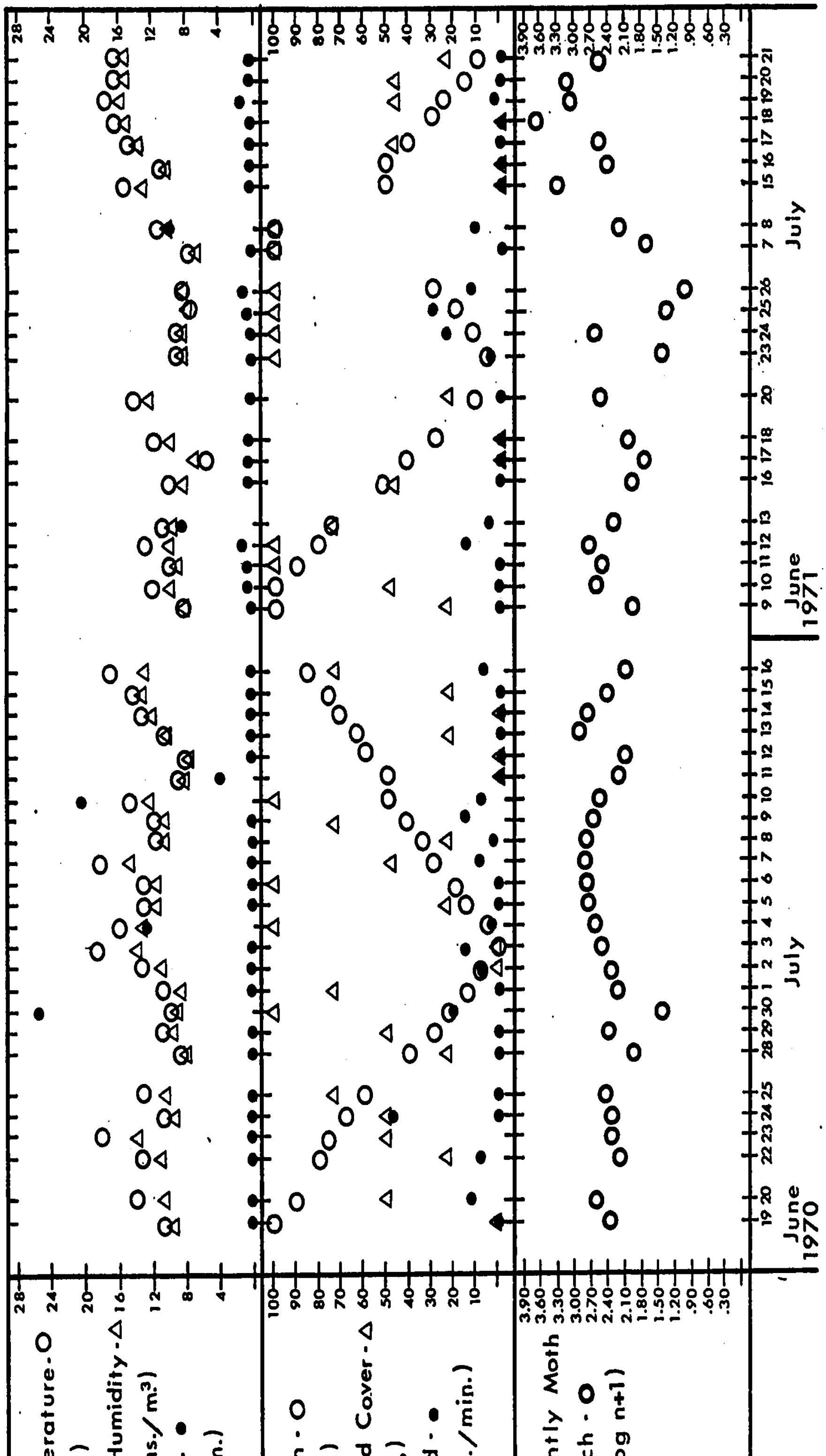

Temperature - O
(C°)
Abs. Humidity - △
(gms./m³)
Rain - ●
(mm.)
28
24
20
16
12
8
4
Moon - O
(%)
Cloud Cover - △
(%)
Wind - ●
(m./min.)
100
90
80
70
60
50
40
30
20
10
Nightly Moth
Catch - O
(log n+1)
3.90
3.60
3.30
3.00
2.70
2.40
2.10
1.80
1.50
1.20
.90
.60
.30
19 20 22 23 24 25 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
June
1970
July
9 10 11 12 13 16 17 18 20 23 24 25 26 7 8 15 16 17 18 19 20 21
June
1971
July

TABLE 4: PARTIAL CORRELATION COEFFICIENTS OF THE NIGHTLY MOTH CATCH (y) VS. SIX WEATHER PARAMETERS ($x_1 \ldots x_6$) FOR FORTY-SEVEN SAMPLING NIGHTS

	Moth Catch
Moon Phase	+ .014
Cloud Cover	- .125
Amount of Rain	- .031
Absolute Humidity	+ .209
Wind Velocity	- .177
Temperature	- .056

5% probability level = ± .285

1% probability level = ± .369

this graph. A partial correlation was computed between each weather parameter and the moth catch (arithmetic values) on Table 4 in order to more clearly ascertain dominating influences. On Table 4 there are no significant correlations between the moth catch and the weather variables. This is not entirely surprising since the 47 collecting nights represent discontinuous sampling each season, fluctuating populations of the 21 species of moths, and vastly different general weather conditions between 1970 and 1971.

VEGETATION MEASUREMENTS - Table 5 itemizes the predominent herbaceous plants, based solely on observation, of the two habitats and transition zone. Unlike the species of shrubs and trees, the transition zone has several unique herbaceous plants not found in the other two habitats of this study area. Frequency, density, and total density of the shrubs in the habitats are given on Tables 6 and 7. Productivity measurements were not used, hence importance values cannot be derived. Not withstanding this, these tables clearly show the distinction of the habitats. As to be expected, the transition zone has fewer shrub species than the aspen parkland, but five more than in the wet marsh and willow thicket. *Amelanchier alnifolia* (Nutt.) and *Prunus virginiana* (L.) occured only in the aspen parkland, but no species were restricted to the wet marsh and willow thicket. Table 7 shows the estimated number of plants for each quadrat in the trapping grid. Shrubs in the aspen parkland have up to 11 times greater density than in the wet marsh and willow thicket.

TABLE 5: PREDOMINENT HERBACEOUS VEGETATION

Wet Marsh and Willow Thicket Habitat:

Typha latifolia L.

Graminae spp.

Petasites palmatus Ait.

Caltha palustris L.

Heracleum lanatum Michx.

Transition Zone:

Urtica gracilis Ait.

Galeopsis tetrahit L.

Graminae spp.

Anemone canadensis L.

Aspen Parkland Habitat:

Fragaria sp.

Epilobium angustifolium L.

Aralia nudicaulis L.

Cornus canadensis L.

Viola spp.

TABLE 6: SHRUB FREQUENCY IN THE TWO HABITATS AND TRANSITION ZONE*

	Salix spp.	*Cornus stolonifera* Michx.	*Ribes spp.*	*Rubus sp.*	*Populus spp.*	*Viburnum edule* Raf.
Wet Marsh and Willow Thicket:						
A	16.7	8.3	16.7	-	-	-
D	-	33.3	41.7	8.3	-	-
Transition Zone:						
B	8.3	75.0	16.7	25.0	41.7	33.3
E	33.3	58.3	25.0	16.7	25.0	8.3
Aspen Parkland:						
C	-	66.7	8.3	50.0	50.0	91.7
F	16.7	75.0	50.0	33.3	50.0	66.7

	Rosa spp.	*Lonicera involucrata* Banks	*Symphoricarpos alba* Blake	*Amelanchier alnifolia* Nutt.	*Prunus virginiana* L.
Wet Marsh and Willow Thicket:					
A	-	-	-	-	-
D	-	-	-	-	-
Transition Zone:					
B	50.0	8.3	8.3	-	-
E	33.3	16.7	8.3	-	-
Aspen Parkland:					
C	91.7	16.7	50.0	16.7	8.3
F	83.3	33.3	25.0	41.7	16.7

*Percentage of occurrence in samples (10 square meters each)

TABLE 7: SHRUB DENSITY AND TOTAL DENSITY IN THE TWO HABITATS AND TRANSITION ZONE*

	Total Shrubs	*Salix spp.*	*Cornus stolonifera*	*Ribes spp.*	*Rubus sp.*	*Populus spp.*	*Viburnum edule*
Wet Marsh and Willow Thicket:							
A	191	0.42	0.08	0.33	-	-	-
D	498	-	1.00	1.08	0.08	-	-
Transition Zone:							
B	2882	0.17	4.83	0.67	1.92	0.42	1.42
E	2380	0.42	4.33	1.00	0.50	0.33	0.17
Aspen Parkland:							
C	5472	-	4.17	0.08	0.92	0.67	6.00
F	5933	0.25	9.00	1.92	0.42	0.83	4.75

	Rosa spp.	*Lonicera involucrata*	*Symphoricarpos alba*	*Amelanchier alnifolia*	*Prunus virginiana*
Wet Marsh and Willow Thicket:					
A	-	-	-	-	-
D	-	-	-	-	-
Transition Zone:					
B	2.42	0.58	0.08	-	-
E	2.08	1.00	0.50	-	-
Aspen Parkland:					
C	7.75	0.25	2.58	0.50	0.83
F	5.75	0.83	0.25	1.50	0.25

*Mean numbers of individuals per sample (10 square meters each)

Differences of physiognomy, which are striking upon first entering the study area, are perhaps best shown with vegetation measurements of the larger phanerophytes. Additional descriptive value could have been obtained with measurements of canopy height and coverage. The size of the trees are indicated on Table 8 which gives total basal area (square inches) per subquadrat - four to a quadrat. Although the wet marsh and willow thicket average about 800 to 900 square inches, this is made up entirely of *Salix spp. Populus tremuloides* (Michx.) and *Populus balsamifera* (L.) in the aspen parkland average a total basal area three times as great. Tables 9 and 10 also show the habitat distinctions of tree species with regard to frequency of occurrence and density of individuals. *Salix spp*. comprise a tree mono-culture in the wet marsh and willow thicket habitat with a comparatively high density and consistency of occurrence. Seven species of trees are found in the study area that included the aspen parkland. Many of these species, eg. *Picea glauca* (Moen.), are indicative of clumped distributions and Table 9 shows that they occur in low numbers. As with the shrub measurements, these tables show that the transition zone does exist. In the transition zone, *Picea glauca* and *Prunus virginiana* are entirely absent. Both *Populus spp*. are found in numbers and size in the transition zone not unlike that of the aspen parkland. In addition there is a greater number of individuals of *Salix spp*. in the transition zone than in the aspen parkland. Table 11 succinctly draws attention to these differences. Importance value

TABLE 8: TREE DOMINANCE IN THE TWO HABITATS AND THE TRANSITION ZONE*

		Salix sp.	*Populus tremuloides* Michx.	*Populus balsamifera* L.	*Betula papyrifera* Marsh.	*Alnus tenuifolia* Nutt.	*Picea glauca* Moen.	*Prunus virginiana* L.
Dominance:								
Wet Marsh and Willow Thicket:	A	824.2	-	-	-	-	-	-
	D	938.9	-	-	-	-	-	-
Transition Zone:	B	98.0	1663.8	514.4	30.4	1.6	-	-
	E	230.6	1767.7	53.8	10.5	3.6	-	-
Aspen Parkland:	C	2.8	1986.9	1288.9	-	-	-	12.4
	F	8.7	1623.5	863.2	15.9	25.6	106.4	6.1

*Average basal area (square inches) per subquadrat

TABLE 9: TREE FREQUENCY IN THE TWO HABITATS AND THE TRANSITION ZONE*

		Salix sp.	*Populus tremuloides*	*Populus balsamifera*	*Betula papyrifera*	*Alnus tenuifolia*	*Picea glauca*	*Prunus virginiana*
Frequency:								
Wet Marsh and Willow Thicket	A	100	–	–	–	–	–	–
	D	100	–	–	–	–	–	–
Transition Zone:	B	100	100	50	50	25	–	–
	E	100	100	25	25	25	–	–
Aspen Parkland:	C	50	100	100	–	–	–	100
	F	100	100	100	50	25	25	75

*Average percentage per subquadrat

TABLE 10: TREE DENSITY IN THE TWO HABITATS AND THE TRANSITION ZONE*

		Salix sp.	*Populus tremuloides*	*Populus balsamifera*	*Betula Papyrifera*	*Alnus tenuifolia*	*Picea glauca*	*Prunus virginiana*
Density:								
Wet Marsh and Willow Thicket:	A	453.8	-	-	-	-	-	-
	D	395.0	-	-	-	-	-	-
Transition Zone:	B	34.5	58.0	5.8	1.3	0.3	-	-
	E	51.0	53.0	0.3	0.3	0.5	-	-
Aspen Parkland:	C	0.8	67.8	15.5	-	-	-	7.5
	F	3.3	51.8	15.0	1.0	2.5	1.5	5.0

*Average number of individuals per subquadrat is the sum of the relative frequency, dominance, and density. Also included on Table 11 is the total basal area, and total number of trees for each quadrat.

I feel that these measurements show satisfactorily that there is a valid distinction between the two habitats and that the defined transition zone in the study area represents a vegetative region incorporating some characteristics of both the aspen parkland and the wet marsh and willow thicket.

HABITAT SPECIFICITY OF THE MOTH SPECIES STUDIED - In addition to other things, this study was designed to demonstrate the habitat preference of the recorded adult moths. The number of individuals of each species caught in each light trap for both years is given in Table 12. For each year, each light trap collection of a given species is ranked, 1 to 6, from lowest to highest. The sum of the two ranks, or ordinals, is given for the two light traps in each habitat. An easier comparison can thus be made of the consistancy of habitat selection of a species between the 1970 and 1971 sampling seasons. Using more conventional statistics for a day to day comparison of distribution to solve this problem of habitat specificity involves large variances. These variances which may be due to the activity of the adults, their emergence period, dispersal rate, or size and age of population, can yield unsatisfactory statistical results. I believe that to begin to answer this question of habitat specificity a method of masking these variances is desirable. With the method of summed ranks,

TABLE 11: IMPORTANCE VALUE*, TOTAL BASAL AREA, AND TOTAL NUMBER OF TREES IN THE TWO HABITATS AND TRANSITION ZONE

		Salix spp.	*Populus tremuloides*	*Populus balsamifera*	*Betula papyrifera*	*Alnus tenuifolia*	*Picea glauca*	*Prunus virginia*
IMPORTANCE VALUE:								
Wet Marsh and Willow Thicket	A	300.0	–	–	–	–	–	–
	D	300.0	–	–	–	–	–	–
Transition Zone	B	69.5	161.0	43.5	18.0	8.1	–	–
	E	96.5	172.4	12.0	9.9	9.8	–	–
Aspen Parkland	C	15.2	163.0	84.7	–	–	–	37.2
	F	25.5	147.1	72.5	12.4	9.4	11.2	22.3

		TOTAL BASAL AREA:	TOTAL TREES:
Wet Marsh and Willow Thicket	A	3297 in.^{2}	1815
	D	3756 in.^{2}	1580
Transition Zone	B	9233 in.^{2}	400
	E	8265 in.^{2}	421
Aspen Parkland	C	13,164 in.^{2}	366
	F	10,598 in.^{2}	320

*Sum of relative density +
relative dominance +
Relative frequency

TABLE 12: NUMBER OF INDIVIDUALS OF EACH SPECIES TRAPPED PER QUADRAT IN 1970 AND 1971 AND THEIR SUMMED RANKS* PER HABITAT

	Smerinthus cerisyi 1970	*Smerinthus cerisyi* 1971	*Smerinthus jamaicensis* 1970	*Smerinthus jamaicensis* 1971	*Eubaphe ferruginosa* 1970	*Eubaphe ferruginosa* 1971
Wet Marsh and Willow Thicket:						
A	9	15	83	121	20	11
	(3)	(3)	(11)	(10)	(3.5)	(3)
D	15	21	54	132	13	7
Transition Zone:						
B	25	22	30	52	20	14
	(7)	(7)	(3.5)	(6)	(6.5)	(7)
E	28	26	36	125	24	15
Aspen Parkland:						
C	44	41	36	87	58	28
	(11)	(11)	(6.5)	(5)	(11)	(11)
F	36	66	39	111	76	27

	Parasemia parthenos 1970	*Parasemia parthenos* 1971	*Apantesis virgo* 1970	*Apantesis virgo* 1971	*Hypocaena inquinata* 1970	*Hypocaena inquinata* 1971
Wet Marsh and Willow Thicket:						
A	23	14	19	5	93	4
	(4)	(5.5)	(9)	(10)	(11)	(11)
D	23	9	20	7	46	3
Transition Zone:						
B	23	11	9	2	20	1
	(6)	(8)	(7)	(6.5)	(7)	(7)
E	39	16	41	6	28	2
Aspen Parkland:						
C	56	9	10	2	4	0
	(11)	(7.5)	(5)	(4.5)	(3)	(3)
F	80	26	14	3	7	0

*In parentheses

TABLE 12: continued

	1970	1971	1970	1971	1970	1971
	Pheosia rimosa		*Cerura scolopendrina*		*Gluphisia septentrionalis*	
Wet Marsh and Willow Thicket:						
A	57	57	17	57	11	17
	(3)	(5)	(8)	(9)	(3)	(3)
D	85	45	22	56	5	12
Transition Zone:						
B	122	44	12	28	27	27
	(7)	(5)	(5)	(4)	(7)	(7)
E	80	82	18	39	22	41
Aspen Parkland:						
C	219	213	51	85	56	80
	(11)	(11)	(8)	(8)	(11)	(11)
F	223	178	13	38	57	67
	Olene vagans		*Hepialus gracilis*		*Oreta rosea*	
Wet Marsh and Willow Thicket:						
A	16	31	23	2	6	9
	(3)	(5.5)	(3)	(3)	(4.5)	(3.5)
D	22	38	15	3	23	0
Transition Zone:						
B	63	26	100	45	19	9
	(7)	(4.5)	(7)	(7)	(5.5)	(6.5)
E	56	38	61	18	23	14
Aspen Parkland:						
C	161	177	114	58	38	43
	(11)	(11)	(11)	(11)	(11)	(11)
F	111	151	188	88	28	50

TABLE 12: continued

	1970	1971	1970	1971	1970	1971
	Malacosoma disstria		*Malacosoma disstria*		*Campea perlata*	
Wet Marsh and Willow Thicket:						
A	162	156	211	445	66	35
	(3.5)	(6)	(7)	(8)	(9)	(4)
D	159	76	275	347	84	26
Transition Zone:						
B	262	114	253	297	65	48
	(6.5)	(4)	(5)	(3)	(4)	(6)
E	162	68	202	236	55	29
Aspen Parkland:						
C	735	424	369	632	62	69
	(11)	(11)	(8)	(10)	(8)	(11)
F	423	359	241	406	136	92

	Lygris zylina		*Hydrelia albifera*		*Dysmigia loricaria*	
Wet Marsh and Willow Thicket:						
A	9	7	13	23	21	1
	(3)	(5)	(3)	(3)	(3)	(4.5)
D	13	6	3	2	27	2
Transition Zone:						
B	19	5	89	43	59	1
	(7)	(5.5)	(7)	(7)	(7)	(5.5)
E	22	8	20	36	43	3
Aspen Parkland:						
C	32	8	203	155	72	17
	(11)	(10.5)	(11)	(11)	(11)	(11)
F	40	15	190	112	78	6

TABLE 12: continued

	1970	1971	1970	1971
	Euchlaena tigrinaria		*Amphidasis cognataria*	
Wet Marsh and Willow Thicket:				
A	38	15	15	87
	(3)	(3)	(7)	(7)
D	36	18	23	65
Transition Zone:				
B	44	22	3	27
	(7)	(8)	(3)	(3)
E	49	33	2	20
Aspen Parkland:				
C	76	29	25	178
	(11)	(10)	(11)	(11)
F	79	62	44	150
	Deilinia variolaria		*Deilinia erythemaria*	
Wet Marsh and Willow Thicket:				
A	17	11	13	12
	(4)	(4)	(3)	(3)
D	12	8	23	22
Transition Zone:				
B	20	9	37	36
	(6)	(7)	(7)	(7)
E	13	20	40	37
Aspen Parkland:				
C	24	19	41	75
	(11)	(10)	(11)	(11)
F	23	31	70	68

variances are masked and the relative importances of vegetational areas for a species are indexed.

Another facet that must be considered is that different stages of a species may require different habitats, one that contains food plants for the larvae, perhaps another for food for the adults. Furthermore, a species could be selecting a habitat on the basis of gross physiognomy and be polyphagous.

All the possible reasons for habitat specificity are not known; in addition, the particular reason for preference by any given species is even less understood. The only well known aspect of these species is their larval food plants. Because of this, I employed a simple correlation matrix that compared moth species to one or more shrub or tree species. Table 13 shows the results of this test. There is one fundamental problem that must be considered! There is no constant relationship quantifiable between a moth and its host plant. In most cases a homogeneous distribution does not exist. That is to say, for whatever the reason, a specimen of *Populus tremuloides* can support 5,000 larvae or it can support five - random contact, aggregation, and population size is the dominating force. Plant species significantly correlated to a moth may have, in actuality, no importance whatsoever to any stage in the moth's life cycle. As they stand in Table 13, the results are meaningless. Because of the size of the quadrats, clumping was an important factor. Results are, on face value, spurious, indicating plant species that were significantly

TABLE 13: SIMPLE CORRELATION COEFFICIENTS AND THE INTERPRETATION OF MOTH SPECIES VS. PLANT SPECIES

Smerinthus
cerisyi

.876** (*Populus*)

.876** (*Cornus*)

.897** (*Viburnum*)

.913** (*Rosa*)

.880** (*Amelanchier*)

Smerinthus
jamaicensis

.794* (*Salix*)

Eubaphe
ferruginosa

.807** (*Populus*)

.784* (*Cornus*)

.928** (*Viburnum*)

.910** (*Rosa*)

.910** (*Amelanchier*)

Parasemia
parthenos

.880** (*Alnus*)

.846* (*Cornus*)

.956** (*Amelanchier*)

Apantesis
virgo

(None)

Hypocaena
inquinata

.931** (*Salix*)

Pheosia
rimosa

.826* (*Populus*)

.881** (*Prunus*)

.986** (*Viburnum*)

.970** (*Rosa*)

.806* (*Amelanchier*)

Cerura
scolopendrina

.812* (*Salix*)

.862* (*Symphoricarpos*)

TABLE 13: continued

Gluphisia septentrionalis

.912** _(Populus)_
.842* _(Prunus)_
.755* _(Cornus)_
.955** _(Viburnum)_
.985** _(Amelanchier)_
.759* _(Rosa)_

Hepialus gracilis

.888** _(Populus)_
.778* _(Alnus)_
.943** _(Cornus)_
.833* _(Amelanchier)_
.832* _(Viburnum)_
.875** _(Rosa)_

Malacosoma disstria

.977** _(Prunus)_
.930** _(Viburnum)_
.879** _(Rosa)_
.857* _(Symphoricarpos)_

Olene vagans

.823* _(Populus)_
.932** _(Prunus)_
.985** _(Symphoricarpos)_
.981** _(Viburnum)_
.799* _(Rosa)_

Oreta rosea

.881** _(Prunus)_
.872* _(Viburnum)_
.942** _(Rosa)_
.845* _(Populus)_
.919** _(Symphoricarpos)_

Campaea perlata

.870* _(Alnus)_
.778* _(Cornus)_
.975** _(Amelanchier)_

TABLE 13: continued

Lygris xylina

.828* (*Populus*)
.815* (*Alnus*)
.904** (*Cornus*)
.927** (*Amelanchier*)

Hydrelia albifera

.875** (*Populus*)
.876** (*Prunus*)
.993** (*Viburnum*)
.981** (*Rosa*)

Dysmigia loricaria

.962** (*Populus*)
.780* (*Prunus*)
.816* (*Viburnum*)
.941** (*Cornus*)
.970** (*Rosa*)

Euchlaena tigrinaria

.836* (*Populus*)
.789* (*Alnus*)
.885** (*Cornus*)
.846* (*Viburnum*)
.865* (*Rosa*)
.914** *Amelanchier*

Amphidasis cognataria

.802* (*Salix*)
.843* (*Viburnum*)
.761* (*Amelanchier*)

Deilinia variolaria

.813* (*Populus*)
.777* (*Alnus*)
.847* (*Cornus*)
.911** (*Amelanchier*)
.841* (*Rosa*)

Deilinia erythemaria

.923** (*Populus*)
.909** (*Cornus*)
.878** (*Viburnum*)
.914** (*Rosa*)
.834* (*Amelanchier*)

* 5% level of probability (positive) = .754

**1% level of probability (positive) = .874

correlated - but not necessarily significant to the moth. Nonetheless, the listed plants are indicative of one or more of the habitat preferences of the moths. By examining the data in this manner, no deductions need be drawn about with which species of plants the moth is associated. This is particularly beneficial since some moths may be associated with an herbaceous plant that did not enter into this analysis. The probability then is that the habitat inferred is also the habitat of the herbaceous plant. The inferences of habitat preference are that *Hypocaena inquinata* and *Smerinthus jamaicensis* are associated with the wet marsh and willow thicket; *Apantesis virgo*, *Cerura scolopendrina*, and *Amphidasis cognataria* show no preference; and are associated with all habitats. All other species are associated with the aspen parkland. Comparing these results with the ordinals on Table 12 shows correspondence throughout.

Larval foodplants for the 21 moth species taken from McGugan (1958), Prentice (1962, 1963, 1965), Jones (1951), and Forbes (1948, 1954, 1960) are given on Table 14. Listed are only those plant species occuring in the George Lake study grid. As previously mentioned, "reasons" for habitat specificity can be numerous; however, larval foodplants are known and are possibly the most important factor. I compared these plant species with the results of the study of habitat specificity. With species that are larval feeders of plants of both habitats, eg. *Salix* and *Populus*, I hoped that the plant preference in this study area might be inferred, although safer speculation can be given for

TABLE 14: RECORDED LARVAL FOOD PLANTS OF THE TWENTY-ONE MOTH SPECIES AT GEORGE LAKE FIELD SITE

Smerinthus cerisyi	*Smerinthus jamaicensis*	*Eubaphe ferruginosa*	*Parasemia parthenos*
Populus	*Salix*	"low plants"	*Salix*
Salix	*Populus*		*Alnus*
	Betula		*Betula*
	Prunus		

Apantesis virgo	*Hypocaena inquinata*	*Pheosia rimosa*	*Cerura scolopendrina*
"low plants"	"wet grasses"	*Populus*	*Salix*
		Salix	*Betula*
			Populus

Gluphisia septentrionalis	*Olene vagans*	*Hepialus gracilis*	*Oreta rosea*
Populus	*Populus*	*Picea*	*Viburnum*
Betula	*Salix*	*Populus*	
	Betula	"ferns"	
	Picea		
	Rosa		

TABLE 14: continued

Malacosoma disstria	*Campaea perlata*	*Lygris xylina*	*Hydrelia albifera*
Populus	*Populus*	*Salix*	*Cornus*
Salix	*Salix*	*Betula*	*Betula*
Betula	*Betula*	*Amelanchier*	
Prunus	*Picea*	*Symphoricarpos*	
Amelanchier	*Alnus*	*Populus*	
Cornus	*Amelanchier*		
Rosa			
Picea			

Dysmigia loricaria	*Euchlaena tigrinaria*	*Deilinia variolaria*	*Deilinia erythemaria*
Populus	*Populus*	*Salix*	*Salix*
Salix	*Betula*	*Populus*	*Populus*
Picea		*Prunus*	
Betula		*Picea*	

Amphidasis cognataria
Salix
Betula
Populus
Cornus
Alnus
Prunus
Rosa
Amelanchier
Ribes
Rubus
Picea

species with larval foodplants in one habitat only. Referring to Table 13, one can see that there is a close correspondence with these species. *Hypocaena inquinata*, *Hepialus gracilis*, *Oreta rosea*, *Gluphisia septentrionalis*, *Hydrelia albifera*, and *Euchlaena tigrinaria* were collected in greatest numbers in one habitat (Table 12); correlated with the same habitat (Table 13); and have known foodplants in the same habitat (Table 14). Although inferences were drawn throughout the whole process, by necessity, the agreement is striking. I feel that speculation is possible for the remaining species which are known to be polyphagous on plant species found in both habitats; for example, *Pheosia rimosa* is known to feed on *Salix* but the results on Tables 12 and 13 indicate that at least in the study area there is a high association with the aspen parkland - hence *Populus*.

DISCUSSION

SEASONAL FLIGHT PERIODS - Phenology of moth flight as shown by light trapping in a study of this duration is only minimally useful. Differences between the seasonal flight periods of a species, I believe, are not artifacts but reflect, to some extent, the differences in weather conditions between the two years. This is most likely a reflection of day-degree accumulation requirements needed for cessation of diapause. Shelford (1927) demonstrated this with the codling moth, *Cydia pomonella* (L.). Dates of the first and last capture (seasonal flight period) for any given species are not necessarily indicative for the region but can be considered accurate even within the small study area of 3.1 acres. In some species, older adults are less likely to be caught in light traps. Geier (1960) showed that *C. pomonella* was caught most frequently during its "maiden" flight. If discrepancies do exist between the flight periods inferred by my data and the actual, it is possibly due to a similar change in behavior.

The seasonal period of flight can be more accurately estimated and predicted only with years of continuous data. Williams (1939), after four years of continuous light trapping, was able to work out the mean first and last dates of flight for a number of species light trapped at Rothamstead Experimental Station. He noted that there was less variance of expected dates during the warmest months and more in spring and autumn. It might be expected that the variability of central Alberta weather would increase the variance of the mean first and last date so that even four years of tabulation would not suffice.

NIGHTLY FLIGHT PERIODS - Activity periods that are not merely "nocturnal" or "diurnal" is not a new discovery. Naturalists for years have noted the time that a species was active and may be collected. Many periodic environmental phenomena may cue an insect to initiate activity; however, in Trichoptera (and probably in the Lepidoptera), Corbet and Tjonneland (1955) proposed that light intensity was the key mechanism for the onset and cessation of flight activity. I was involved with quantifying these flight periods for the 21 moth species of George Lake and was not able to examine the mechanism of cueing.

Corbet and Tjonneland (1955) also raised the question whether flight peaks are artifacts arising from changes in the trap light relative to incident light throughout the evening, possibly effecting the light trapping influence or attraction. Nimmo (1966) discussed this at length and decided that this must be considered a negligible effect. Since all the species studied had distinct and repeatable flight patterns peaking at different intervals, any masking of light trap influence occurring must not cover up the basic peaks in flight activity.

All species, except *Hepialus gracilis*, exhibited a single peak of activity, although this may have lasted for more than one interval. Because of the length of the designated time interval, bimodal flight activity may have been masked if it was not in general synchrony with these intervals. Interestingly enough, other workers in this field, such as Hutchins (1940) and Graham et al. (1964) discovered unique flight activity patterns for the species that they studied yet published figures of the temporal activity of lumped taxa (eg. Microlepidoptera or Noctuidae) thereby cancelling out these species' patterns! The largest compilation of temporal flight periods has been for Lepidoptera of England, published by Williams (1935, 1939) and Lewis and Taylor (1965). Both studies found that species of Lepidoptera within a higher taxon often had widely differing activity peaks and that it was difficult, if not useless, to generalize for any groups. Hitchen et al. (1969) and Nimmo (1966) stressed the uniqueness of a species' temporal activity pattern and suggested reasons. Hitchen et al. (1969) hypothesised that unique species activity periods evolved to insure reproductive isolation from congeneric species. Their results - and mine - show that some specimens of any species are active at other times than during peak activity. Probably species contamination (hybrids) cannot therefore be prevented by this mechanism alone; thus the evolution of species specific activity patterns may not have arisen only for this purpose. Banerjee (1967), working with six species of sympatric *Crambus* moths, found that all had the greatest activity from 1:00 A.M. to 4:00 A.M. with peaks considerably overlapping. Since *Crambus* moth females also are attracted to light, Banerjee was able to compare sexual distinction in temporal flight activity. In every species, females exhibited a different peak than that of males. In this study, there were two congeneric groups - *Smerinthus* and *Deilinia*. In the species of these genera peak activity was the same or greatly overlapping. *Malacosoma disstria*, the only species of my study which both sexes were light trapped, may show disparity in flight activity, as found in *Crambus* sexes although my results (Figure 5) were not strictly homologous for the two seasons of 1970 and 1971.

WEATHER EFFECTS ON MOTH FLIGHT ACTIVITY - The effects of weather on the behavior of insects has been examined from nearly every conceivable angle. Williams (1936, 1940, 1951, 1961) found significant relationships to each of the weather parameters I recorded as well as to barometric pressure. He was aided by having data accumulated continuously over nearly 2,900 nights with some 1,400,000 specimens. Since his study was in operation continuously for two sets of four year periods, he had the benefit of correlation of moths to weather in periods of weeks and months previous to the date of sampling - as well as during. Therefore, his study included, in theory, the weather conditions effecting the entire life cycle; hence populations of adults could even be speculated about in relative magnitude. In this study, emulation of Williams' work was impossible and was not felt necessary to answer questions of other aspects. On the other hand, a study of this type has never, to my knowledge, been carried out in the central Alberta area and I hoped to be able to contrast results. Weather factors also required measurement to enable differences in seasonal and total nightly activity to be explained.

Although wind was not correlated to number of moths captured in my study, Harling (1968), besides Williams, found a significant negative correlation with higher velocities resulting in lower catches to a point of minimization. Hollingsworth et al. (1961) demonstrated the effects of wind shielding on moth flight activity. In my study the wind velocity measurements were taken at a level below canopy layer. Perhaps the vegetation acted as a wind shield and prevented wind velocity from influencing flight activity. The maximum reading in my study, 20 meters per minute, is merely 1.2 miles per hour! It is interesting to note that Williams (1936) from his data at Rothamstead, England found a correlation between flight activity and moon phase. If this is true, it is unlikely that the moths of George Lake behave much differently. A possible reason for not finding a significant correlation in this study is that the majority of nights had an entire or partial cloud cover. This may have obscured the moon, hence incident light, sufficiently to negate this possible correlation. On the other hand, Hardwick (1972) found no correlation with this parameter in 274 sampling nights in his study that covered areas in western North America. Hardwick discusses this and concludes that in this region of the world lunar periodicity has no influence on moth activity. This is in accord with my study. Instead he found significant correlation of flight activity to temperature and feels this is the dominating influence. Taylor (1963) suggested that this relationship is only valid above the flight activity threshold temperature - a temperature that is unique for each species. Tree canopy may be a partial cause in finding no correlation with rainfall by reducing intensity.

As Williams (1940) indicated, all weather factors are to some extent inter-related; yet, to isolate each of the factors and analyze them individually is difficult. One parameter may have a positive influence on moth activity but, perhaps normally, the parameter is associated with another of adverse influence. Finally, one never can be certain that one is considering all the aspects of weather that are of an influential force.

SEASONAL WEATHER EFFECTS ON MOTH FLIGHT ACTIVITY - Although Figure 6 does not readily show the differences, there were some marked distinctions in weather between 1970 and 1971. Rainy days throughout June and July in 1970 averaged about one in five. In 1971, thunder storms were so common and severe during the sampling period that often a given night had to have the sampling cancelled. Along with these continuous storms, there was an average nightly temperature of 10.5°C in 1971. When this rainy period ended in early July, temperatures soared. June and July were fairly uniform in 1970 and the average temperature during the sampling period was 12.8°C. The generally inclement weather of 1971 had several effects on moth activity and, apparently, on actual population densities of some species. Most drastically, the almost continual rain of 1971 caused the lake level to rise two feet and inundate the wet marsh and willow thicket and part of the transition zone. This probably had the effect of drowning moth species in this habitat that pupate on or near the ground. *Parastichtus discivaria* collected exclusively in the wet marsh and willow thicket were found in large numbers (381 total) in 1970. No specimens were collected in 1971. Another plausible explanation is that this species was undergoing rapid population flux. This is possible but undoubtedly not the case. Another species, *Hypocaena inquinata*, also is a ground dweller and also was collected *primarily* in this habitat in 1970. There were 198 specimens light trapped in 1970 but only 10 in 1971.

Finally, the low average temperature of June and July in 1971 probably effected the day degree accumulation requirements necessary for emergence from diapause or completion of the larval stadia of the moths. After temperatures sharply increased beginning July 16 (July 16 to 21 averaged 16.8°C) enormous samples were taken.

VEGETATION MEASUREMENTS - The two habitats and the transition zone that I studied comprise sequential components of a hydrach succession (Oosting, 1956). The oldest is the aspen parkland. The aspen parkland ecotone is not a stable, self-perpetuating community but is continually changing, depending on fires, drought, and agriculture (Bird, 1961). The George Lake Field Site, however, has been safe from fire and agriculture for a long time and, being near the margin of aspen parkland occurrence, receives sufficient rainfall for any two years. Because of this, the stands of aspen are older than the norm and a few other tree species are also found within the ecotone at George Lake. Animals associated with the two major biotic components of the aspen parkland - grassland and aspen forest - by necessity must retreat from and invade into their respective habitats as the range of these components fluctuates (Bird, 1961). Undoubtedly, moth species follow this same pattern. A reasonable speculation is that moth species associated with this ecotone are more inclined to have strong dispersal tendencies.

HABITAT SPECIFICITY - Reasons for habitat specificity of a given moth species might include the suitability of the habitat for oviposition, mating, and larval and/or adult food source (the last possibility nonexistent for species with atrophied mouth-parts, eg. *Smerinthus jamaicensis*). In addition to these probable "reasons", an unknown percentage of the population is assumed to be actively or passively dispersing; or performing simple random movements, leaving the habitat of the early stages briefly before returning. Nevertheless, a percentage of the imaginal population is sure to remain in the habitat of the immature stages. Ford (1955) demonstrated that *Panaxia dominula* (L.) remains in a limited area throughout its entire life cycle. Furthermore, a female emitting a sex pheromone could be doing so in a marginal region of the species' preferred habitat. In this instance, males flying around the emitting female might occur - and be trapped - in quadrats of uncharacteristic habitats. Therefore, when light trapping moths, which constitute mobile populations, it is very unlikely to find absolute habitat specificity.

In this study, I have no basis for judging the percentage of a given moth population that is in its preferred habitat. To attempt to clarify the question of habitat specificity, it was necessary to make a foundation assumption: I suspect that, barring phenomenal migration, the greatest number of individuals of a given species light trapped during flight activity will be in the prefered habitat. Hosny (1958) was forced to make this same assumption - although not clearly stated - when he published his environmental preference charts of certain moth species in England.

Very little quantitative work has been done on the habitat preference of moth species, undoubtedly because of the magnitude of problems that are incurred as I have listed. Cook (1930) showed that different species of moths were consistently collected in a light trap from the third floor of a city building than from an agricultural experiment station. He noted that species collected in the building light trap could not have possibly emerged in the adjacent vicinity. Most likely this trap in his experiment was sampling the relative activity of some moth species in active dispersal. Frost (1958b), Williams (1939), and Taylor and Carter (1961) compared light trap samples from light traps of different heights (in the same habitat) and found differing amounts of specimens and even species. Taylor and Carter found that the height of greatest activity may change during the night and, if exceptional, may effect flight period data. These studies infer that habitat specificity is three dimensional and that samples in all dimensions are needed for more accurate analysis. A study with greater intensity botanical examination in two adjacent, distinct, habitats - using light traps in replicate as well as at varying heights - may possibly more rigorously answer questions about habitat specificity as indicated by the flight activity of moths.

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APPENDIX 1: DATES AND DURATION OF LIGHT TRAP SAMPLES AT GEORGE LAKE FIELD SITE

Night	Sunset	Sunrise	Time Period
19-20/vi/70	21:07	4:04	6 hr. 57 min.
21-22/vi/70	21:07	4:04	6 hr. 57 min.
22-23/vi/70	21:08	4:05	6 hr. 57 min.
23-24/vi/70	21:08	4:05	6 hr. 57 min.
24-25/vi/70	21:08	4:05	6 hr. 57 min.
25-26/vi/70	21:08	4:06	6 hr. 58 min.
28-29/vi/70	21:07	4:07	7 hr. 00 min.
29-30/vi/70	21:07	4:08	7 hr. 01 min.
30/vi-1/vii/70	21:07	4:09	7 hr. 02 min.
1-2/vii/70	21:06	4:10	7 hr. 04 min.
2-3/vii/70	21:06	4:10	7 hr. 04 min.
3-4/vii/70	21:06	4:11	7 hr. 05 min.
4-5/vii/70	21:05	4:12	7 hr. 07 min.
5-6/vii/70	21:04	4:13	7 hr. 09 min.
6-7/vii/70	21:04	4:14	7 hr. 10 min.
7-8/vii/70	21:03	4:15	7 hr. 12 min.
8-9/vii/70	21:02	4:16	7 hr. 14 min.
9-10/vii/70	21:02	4:17	7 hr. 15 min.
10-11/vii/70	21:01	4:18	7 hr. 17 min.
11-12/vii/70	21:00	4:20	7 hr. 20 min.
12-13/vii/70	20:59	4:21	7 hr. 22 min.

APPENDIX 1: continued

Night	Sunset	Sunrise	Time Period
13-14/vii/70	20:58	4:22	7 hr. 24 min.
14-15/vii/70	20:57	4:23	7 hr. 26 min.
15-16/vii/70	20:56	4:25	7 hr. 29 min.
16-17/vii/70	20:55	4:26	7 hr. 31 min.
9-10/vi/71	21:01	4:05	7 hr. 04 min.
10-11/vi/71	21:02	4:05	7 hr. 03 min.
11-12/vi/71	21:03	4:05	7 hr. 02 min.
12-13/vi/71	21:03	4:04	7 hr. 01 min.
13-14/vi/71	21:04	4:04	7 hr. 00 min.
16-17/vi/71	21:06	4:04	6 hr. 58 min.
17-18/vi/71	21:06	4:04	6 hr. 58 min.
18-19/vi/71	21:07	4:04	6 hr. 57 min.
20-21/vi/71	21:07	4:04	6 hr. 57 min.
23-24/vi/71	21:08	4:05	6 hr. 57 min.
24-25/vi/71	21:08	4:05	6 hr. 57 min.
25-26/vi/71	21:08	4:06	6 hr. 58 min.
26-27/vi/71	21:08	4:06	6 hr. 58 min.
7-8/vii/71	21:03	4:15	7 hr. 12 min.
8-9/vii/71	21:02	4:16	7 hr. 14 min.
15-16/vii/71	20:56	4:25	7 hr. 29 min.
16-17/vii/71	20:55	4:26	7 hr. 31 min.
17-18/vii/71	20:53	4:27	7 hr. 34 min.
18-19/vii/71	20:52	4:29	7 hr. 37 min.

APPENDIX 1: continued

Night	Sunset	Sunrise	Time Period
19-20/vii/71	20:51	4:30	7 hr. 39 min.
20-21/vii/71	20:50	4:32	7 hr. 42 min.
21-22/vii/71	20:48	4:33	7 hr. 45 min.

AUTOBIOGRAPHICAL SKETCH

I was born in Milwaukee, Wisconsin, U.S.A. on February 8, 1947. From an early age I became interested in insects as well as all outdoor wildlife - such that can be found in an urban area, backyard, rock garden. My parents encouraged this predilection and at 11 years old they drove me to the monthly meetings of the Milwaukee Lepidoptera Society.

After graduating from West Milwaukee High School in 1965, I entered the University of Wisconsin in Madison, Wisconsin. After searching about fruitlessly for an interesting, satisfying major subject, a friend - now my wife - suggested that I pursue my love of the outdoors in school. I did this, and, losing my disenchantment, I majored in the Biological Aspects of Conservation which included several courses in entomology. In my fourth year I wrote a senior "thesis" on a survey of nocturnal Lepidoptera of the university's arboretum. During this project I became intrigued with apparent Lepidoptera behavioral patterns that I was observing. I entered the University of Alberta in the fall of 1969 under the supervision of Dr. W. G. Evans. With his encouragement, I decided to research my master's thesis on testing the existence of these possible behavior patterns in species of nocturnal Lepidoptera.