AN ANALYSIS OF WINDOW TRAP CATCHES OF DIPTERA OBTAINED IN THE SAINT-MAURICE RIVER WATERSHED, PROVINCE OF QUEBEC, CANADA.

by

François Millette

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McGill University

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François Millette

RESUME

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UNE ANALYSE DES CAPTURES DE DIPTERES A L'AIDE DE PIEGES-A-VITRE DANS LE BASSIN VERSANT DE LA RIVIERE SAINT-MAURICE, PROVINCE DE QUEBEC, CANADA

Cet ouvrage traite de l'écologie des diptères du versant supérieur de la Rivière Saint-Maurice au Québec. Les insectes furent collectionnés de juin à septembre 1970, au moyen de pièges-à-vitre.

L'étude porte sur une comparaison de trois habitats: une forêt de pin gris, un peuplement de feuillus et un autre d'épinettes noires. On captura 2,679 diptères dans les pins gris, 24,395 dans les feuillus et 8,946 parmi les épinettes noires.

Les pièges situés dans un endroit très ombragé étaient plus efficaces que les autres situés dans des lieux découverts ou plus dégagés. L'orientation des pièges n'eut aucune influence sur le nombre de mouches collectionnées.

Il y a une corrélation entre l'activité des diptères et la température dans la forêt de pin gris et une autre entre une famille prédatrice, les Dolichopodidae, et les Drosophilidae, Phoridae et Mycetophilidae, qui sont considérés comme les proies.

Les diptères primitifs préféraient les endroits frais et humides en accord avec les observations rapportées par Kennedy (1928) et Whittaker (1952).

On ne captura que les espèces Rhagio mystaceus (Macquart) et Chrysopilus quadratus (Say) de la famille des Rhagionidae. Cette dernière démontra une nette préférence pour le peuplement de feuillus, tandis que R. mystaceus avait un habitat varié.

ABSTRACT

M.Sc. François Millette Entomology

AN ANALYSIS OF WINDOW TRAP CATCHES OF DIPTERA OBTAINED IN THE SAINT-MAURICE RIVER WATERSHED, PROVINCE OF QUEBEC, CANADA

Window flight traps were used to study the ecology of Diptera from the upper Saint-Maurice River watershed in Québec. The insects were collected from June to September 1970.

The study compares the dipterous fauna of three habitats: a jack pine forest, a hardwood stand and one of black spruce. The jack pine plot yielded 2,679 Diptera, the hardwood, 24,395 and the black spruce, 8,946.

Traps located in deeply shaded areas caught significantly more insects than others in open and exposed sites. The direction faced by the trap did not influence the number of flies caught.

There is correlation between dipterous activity and temperature in the jack pine stand. There also exists a correlation between a predatory family, the Dolichopodidae and the following: Drosophilidae, Phoridae and Mycetophilidae which are considered as prey.

In agreement with the findings of Kennedy (1928) and Whittaker (1952) primitive insects were observed mostly in cool, humid habitats.

Only two species of the family Rhagionidae were captured: Rhagio mystaceus (Macquart) and Chrysopilus quadratus (Say). The latter preferred the hardwood stand while R. mystaceus occurred in various habitats.

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To Dawn,

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A. INTRODUCTION

The field work for the present study was conducted during the summer of 1970, from June through September. Samples were collected by means of window flight traps set up in three different forest types in the upper Saint-Maurice River watershed in Québec.

The type and model of window trap used was reported by Price (1971). Dr. Price, then a research officer with the Department of Forestry and Fisheries, extracted the parasitic Hymenoptera from the trap catches. The remainder of the trapped insects were passed to the present author who had the responsibility of mounting the traps in the field.

Diptera were selected for the present study for three reasons:-

1. They were constantly among the most numerous if not, the most numerous order of insects observed.
2. They fulfill all the requirements of true flying insects towards which the trapping technique was directed.
3. They vary considerably in their biology and life habits as both larvae and adults. The variation has interesting and important ecological implications, for example among flies, one finds predators, vegetarians, parasites, scavengers, nectar feeders, and blood feeders.

The purpose of this thesis is to analyse window flight trap data and investigate the ecology of selected Diptera, paying particular attention to habitat comparison. Three communities were considered: a 45 year old jack pine stand growing on a sandy plain; a birch and poplar dominant hardwood regeneration; and a dense stand of black spruce. Within each stand, the seasonal activity of the important dipterous families and the two rhagionid species observed: Rhagio mystaceus (Macquart) and Chrysopilus quadratus (Say) were investigated. Factors such as light, shade and trap direction, which might have influenced the catches, were also studied.

Other ecological factors examined were correlations between seasonal activity of the Diptera and seasonal temperature variation, trends in the evolutionary level of flies, their food habits and a possible predator - prey relationship.

B. LITERATURE REVIEW

1. Window Flight Traps

Window flight traps are not a new concept for insect sampling. Other methods, such as stationary nets, sticky traps and Malaise traps, were built with the same basic intention, that is, to sample flying insects without the bias due to attractants such as bait or light. These techniques allow population determinations, a check of seasonal activity, and comparison of habitats because they are easily kept standard for the duration of the sampling period or from one habitat to another.

Rice (1933) used a flight trap which was somewhat different from the more recent models. It consisted essentially of a vertical screen panel with a funnel attached on each side at the bottom. Each funnel had a small hole emptying into a collecting can. In this way most insects striking the screen and falling through the funnel would be trapped in the can. Almost 12,000 insect specimens were captured in two years with Coleoptera and Hymenoptera providing the greatest number of species trapped.

The total number of species caught each week was greatest in the spring and again in the early fall.

This trapping technique was reviewed by Chapman and Kinghorn (1955). These authors improved on the model used by Rice (op. cit.). Their trap consisted of a pane of glass (2 feet by 2 feet) set in a three-sided wooden frame from which a metal trough was hung. The trough was filled with fuel oil, or water with a wetting agent. Screened outlets prevented overflow due to rainwater. The insects were removed by pouring the trough content through a strainer. The traps were set up on various pole frameworks and stabilized by guy wires. They pointed out that wind influences trap efficiency and that light-bodied insects are not taken efficiently. For most insects, coloured barriers are less effective than the clear glass panes.

Regardless of site location, the traps take samples which allow satisfactory determinations of seasonal abundance, relationship of flight to weather conditions, and site distribution. According to the above writers, window traps are advantageous in that they are simple and economical, easily set up in a variety of locations, and can be left unattended for many days at a time.

Most of the literature from this point on refers to the trap model described above by Chapman and Kinghorn. Some of the recent models, however, have been altered to meet the particular needs of the researcher.

Juillet (1963) compared four sampling methods:- 1) Malaise, 2) glass-barrier, 3) rotary and 4) sticky traps. According to his data, the rotary is by far the most reliable and versatile for most insect groups, then the Malaise, glass-barrier and sticky traps in decreasing order of reliability but increasing order of versatility.

The versatility of the window flight was recognized by Martin (1965) who used them to see whether or not pruning a stand of red pine encouraged more flying insects to enter it. He placed window traps in adjacent pruned and unpruned stands for two weeks in June and July 1963. The results indicated greater activity in the pruned stand.

Southwood (1966) briefly mentions Chapman and Kinghorn's (op. cit.) model stating that flying Coleoptera and other insects that fall upon impact, can be collected with a window trap.

Merrill and Skelly (1968) dealt with a more specialized type of window flight trap which they used to sample flying insects above the forest canopy. The structure was of plywood and lumber supporting a 3 x 4 foot sheet of clear plexiglass 0.125 inches thick vertically over a steel pan 4 x 1.5 x 0.5 feet high. The pan contained 0.5 inches of water with a thin layer of mineral oil to retard evaporation. The main drawback of this apparatus is that, complete, it weighs over 100 pounds, necessitating a power winch and pulleys to lower and raise the trap.

A flight trap with a modified drain system was used by Franklin and Crossley (1970), they called it a self-maintaining window trap. It contained an automatic drain system consisting of an inverted U-shaped siphon positioned at one end of the trap with one arm inside and the other outside the trough. These alterations prevented overflow and loss of specimens. This modified version was found suitable for sampling most flying insects except Lepidoptera which are extensively damaged by the Kerosene preservative.

The flight traps used by Price (1971) were identical to those used in the present study. These are described in Materials and Methods. Price agreed with the previous authors, finding these traps very versatile, and also extremely productive for the effort required to operate them. Also, a great range in insect size and population size can be sampled.

2. Comparison or Utilization of Different Trapping and Sampling Techniques

The present research involved only one collecting method, the window flight trap. It is desirable, however, to compare findings, methods of analysis and results with other sampling techniques. One can better understand the advantages and shortcomings of a collecting method or device and the best methods of analysing the data collected. In this section, therefore, mention is made of techniques other than window flight traps of trapping and sampling flying insects, i.e. stationary nets, sticky traps, Malaise traps, suction traps, and also any other method such as hand-captures or emergence traps which have been used, either for comparison or to establish an index of efficiency.

Neilsen (1960) used stationary nets to selectively catch mosquitoes having directional flight and to study flight direction of the chironomid Glyptotendipes paripes (Edwards) while previously Lewis (1959) compared water, cylindrical sticky and suction traps with respect to catches of Thysanoptera. Lewis (op. cit.) tested black, green and white water traps and black sticky traps. These traps were used above a wheat field, the suction traps serving as a standard. The suction trap was more consistent at crop level while at higher levels, sticky traps gave more consistent catches.

Suction traps of various kinds and sizes, Vent Axia traps, Propellor traps and Aerofoil traps along with take-off cages were used by Calnaido, French and Taylor (1965) in their study of low altitude flight of Oscinella frit (L.), a chloropid fly. In this way the relative efficiency of each trap was determined.

Martin (1965) used pitfall traps and window flight traps in his study of soil-surface fauna. He realized that flying insects as adults, especially Diptera are not sampled in the best way with pitfall traps.

Coon and Pepper (1968) examined the usefulness of air traps to capture alate aphids. Six air traps were placed at different heights and supported by two television antennae standards anchored securely by guy wires. The aphids were captured in a "Baker's cap" bag at the top of the trap and from all inside surfaces at indeterminate times.

The study of a grassland insect community by Evans and Murdoch (1968) necessitated the use of different sampling procedures. Nylon gauze nets were used for insects in flight or on flowers (chiefly Odonata, Lepidoptera, Diptera, and Hymenoptera). Canvas sweep nets were employed to collect species in or on vegetation (chiefly Orthoptera, Hemiptera, Homoptera, and Coleoptera). A Malaise trap was an efficient sampler of fast fliers such as Tabanidae, Bombyliidae and the fragile Tipulidae, Culicidae, and Microlepidoptera. A large, cubical walk-in cage was carried about the field and set down at different sites for removal of insects (by sweeping and hand collection) from the enclosed vegetation. In this way the authors obtained a good cross-section of the insect fauna of a grassland community.

Thompson (1967) and Smith, Davies and Golini (1970) worked on tabanids and during their respective studies they employed different collecting methods.

The former author used three methods:-

1) swinging an insect net about a collector's head while he walked from one trap site to another, 2) removing flies from an automobile and 3) by collecting them from two types of traps modified from prototypes of the Manitoba horse fly trap.

Smith, Davies and Golini (op. cit.) used carbon dioxide-baited traps in different habitats. A sweep net was used to capture flies landing on and/or feeding from captive moose in a large forested pen. Flies attacking humans were collected by the same method. In addition, tabanids were trapped in cages set up near the cervid pens. The writers were thus able to investigate host preference, specificity and the biology of these biting flies.

Hamilton et. al. (1971) reduced the adult population of Popillia japonica (Newman) by mass trapping with baited traps. The traps were 100 to 160 feet apart and the bait generally used was anethole, geraniol, or phenethyl butyrate, each combined with eugenol at 9 parts lure to one part eugenol in either the green or the yellow traps. They discovered that 5,338 traps in 6,749 acres caught about 30 percent of the population and that one trap per acre would have caught about 40 percent.

Continuous Malaise trap collections revealed that Diptera comprised 44.7 percent of the catch, Plecoptera (20.8 percent), Hymenoptera (14.7 percent), Lepidoptera (7.2 percent), Hemiptera (7.1 percent), Coleoptera (2.4 percent) and other orders (3.1 percent) of the flying insects in a New York mixed forest (Mathews and Mathews, 1970).

Harris, Nakagawa and Urago (1971) experimented with different types of sticky traps to sample the Mediterranean fruit fly, Ceratitis capitata (Wiedemann). They observed that traps placed at windward sea level sites in Hawaii were equal to or superior to the standard 0.95-liter plastic trap in the five tests made with released fruit flies.

They also worked with the melon fly, Dacus cucurbitae. Cocquillett and discovered that three of the experimental traps with "cu-lure" as bait and "naled" as toxicant caught more flies than the standard but two were inferior to them. Trap efficiency was also tested with Dacus dorsalis Hendel, the oriental fruit fly. It was observed that these same two traps and a rectangular trap (baited with methyl eugenol and "naled" caught fewer flies than the standard while the others yielded as many as the standard.

An extensive survey of the arthropod fauna was carried out by Stebbings (1971) to study community transitions from tidal marsh to woodland. These animals were collected by sweep netting, butterfly netting, pitfall trapping and hand searching.

Price (1971), in his ecological study of ichneumonid parositoids, used two absolute methods: soil samples and emergence traps; and two relative estimate methods: window traps and cocoon planting.

The absolute results correlated well with the relative estimates. He concluded that the two methods for extensive sampling, flight traps and cocoon plants, gave good estimates of absolute abundance of parasitoids in the field.

This section demonstrates the manner in which the different sampling methods and devices achieved each study objective. Citing these researchers provided the present author with ideas of handling his own data and how their results compared with his. Also additional ways in which window flight traps can be used were discovered, such as placing traps at different vertical levels to compare occurrence of aerial insects at different heights, or window flight traps with bait used to reduce the population of a flying insect in an area.

3. Effects of Climatic Factors on Insect Occurrence and Behavior

Freeman (1938) and (1945) related much of his study of aerial insect fauna to the effects of climate. In his first investigation, he found generally that ideal conditions for insect occurrence were relative humidities below 59 percent, wind velocities below 9 miles per hour at ground surface and temperatures above 64°F, the last exerting the most control. In his second study, Freeman noted that population density (the total number of insects) and the number of species of insects captured increased with a rise in temperature over the range of 43 to 83°F. For individual groups and families, the temperature relationship was not clear, although, in general, Hymenoptera and Thysanoptera showed this relationship most clearly. The insects seemed to be most active between 70 to 85°F.

The density of flying insects generally showed a steady fall with increasing relative humidity from 37 to 73 percent. The highest humidity range (65 to 73 percent) was unfavourable for all groups. Precipitation either tended to prevent insect flight or washed them out of the air.

Aerial insect density generally tended to rise with wind velocities of 6 to 12 miles per hour and then fall steadily with an increase up to 35 miles per hour. The total number of species at all heights increased up to a wind speed of about 21 miles per hour and then dropped considerably with a further increase of wind velocity. Freeman states that insects tend to take cover from high winds and that this explains the very small population densities sampled at 35 miles per hour.

The maximum numbers of most groups occurred at temperatures greater than 64°F with this factor being the most important.

Parker (1949), who studied adult Culicoides Latreille species nearer to ground level noted that catch-size was very much affected by wind strength but that temperature and humidity had no apparent effect.

Tripp (1962) and Juillet (1964) worked on dipterous and hymenopterous parasites respectively. Spathimeigenia Townsend was observed by Tripp to prefer jackpine sawfly colonies situated in areas in direct sunlight and protected from wind. Juillet (op. cit.) concluded that, disregarding a few exceptions and the influence of wind, ichneumonids generally prefer a cool and humid habitat while braconids, in general, prefer a warm dry habitat. To arrive at this conclusion, he studied the effects of climatic factors on the flight activity of these two families. Four factors have a continuous influence on flight activity of ichneumonids and braconids: temperature, relative humidity, wind velocity, and light intensity. Precipitation, on the other hand, has a discontinuous or occasional influence. These factors, except precipitation, do not influence flight activity to the same degree. Precipitation, is not a reliable indication, as it is either favourable or unfavourable having no intermediate effects, and consequently, cannot be expressed quantitatively in relation to flight activity.

Maximum temperature during trapping hours was a significant indicator of flight activity, although more variable than the mean temperature. The minimum temperature during the night preceding the trapping day was not correlated to the catch.

Extremes of relative humidity, below 25 percent or above 90 percent, caused a drastic reduction in the catch of ichneumonids and braconids. Within these limits, an increase in humidity favoured flight activity of ichneumonids while it reduced that of braconids. Winds of low velocities stimulated flight activity and high velocity winds depressed it.

The influence of light intensity on flight activity is affected by the action of other weather elements, especially relative humidity. Low light intensity during trapping hours was always associated with high humidity (above 90 percent) and frequently with low temperatures and consequently low catches.

Calnaido, French and Taylor (1965) in their study of flight activity of <u>Oscinella frit</u> (L.) discovered, in contrast to the previous authors, that wind speed, maximum temperature and rainfall had no effect on the daily numbers of these insects flying.

An increase in wind or rain lowered the mean height of flight, and in the panicle generation only wind speed significantly affected the gradient of density while again lowering the mean height of flight. They noted that with respect to general aerial circulation, wind determines the distribution of insects.

According to Hamilton (1966), Hessian fly larval responses to simulated weather conditions indicated that the migratory stage of the larvae is extremely sensitive to adverse environmental situations. Low temperatures, low relative humidity, high rainfall and wind caused high mortality in newly hatched larvae. Freezing temperatures caused mortality in all the larval stages.

Yurkiewicz and Smith (1966) worked with adult sheep blowflies, investigating windbeat frequency in relation to the ambient temperature. Direct recordings of internal temperature indicated that there exists a relation between wingbeat frequency and ambient temperature.

The extent to which the actual speed of flight should vary with the temperature is not intuitively obvious, because there are many variables which are difficult to evaluate. That wingbeat frequency and flight speed have similar temperature co-efficients appeared fortuitious to these researchers.

Johnson (1968), studied the seasonal ecology of the dragonfly Oplonaeschna armata Hagen. He described definitive features of the habitat occurring in south western mountain streams of the United States. Adult emergence and flying season are related to annual and air temperature cycles. Emergence occurs over approximately 10 days in mid to late June. Adult maturation requires 12 to 20 days and total flight season lasts approximately one month.

Joyce and Hansens (1968) worked on greenhead flies (horseflies) and observed a high correlation between average daytime (8 a.m. to 8 p.m.) temperature and greenhead activity. Fly activity showed greater correlation with the daily maximum temperature, indicating that daily maximum temperatures had a greater influence than the average temperature. The daily minimum temperature showed no correlation with fly activity, indicating that minimum temperatures were not a factor in greenhead activity. Thus, the higher the daily maximum temperature, the more active the greenheads.

Significant correlation also existed between indices of cloud cover estimate and fly activity, while winds up to 11 miles per hour did not show any correlation with fly activity.

Malaise trap observations revealed that daily weather, particularly temperature and precipitation exercised a strong influence upon catch size, Mathews and Mathews (1970). The largest samples were obtained on hot, sunny days following rain.

4. Seasonal Occurrence

Freeman (1938) and (1945), who studied air borne insects, was interested in the different patterns of seasonal occurrence of the different families observed. In his first work he stated that the greatest number and variety of insects was caught in the nets during the months of June and September when insects are active in breeding and dispersal. Freeman furthered his work, and in his second publication he revealed that Diptera were very numerous in May owing to the capture of large numbers of Borboridae and Sciaridae at all heights (10, 177, and 277 feet), of Chloropidae at upper levels and of Chironomidae at ground level. During June many other families of Diptera were abundant, including Phoridae, Cecidomyiidae, Agromyzidae and Ephydridae. Population densities of Diptera were low during August but many groups appeared again in numbers at the beginning of September.

He concluded that the climate of the area generally determines the kinds of insects to be expected and the season and time of the year during which the insects are active. Certain groups tended to occur in large numbers during May and September, while others, during March and November. This can be ascribed mainly to the life histories of the various species. Thus, many insects emerged from hibernation (Cryptophagidae and Chrysomelidae) or reached an adult stage (many Diptera) during the spring and early summer. At this time insects are naturally active seeking food and mating.

The absence during July and August of many species taken during May and June, September and October would indicate that they are then in an immature or nondispersing stage. Towards the end of August the increase in population density and the numbers of species showed that a new generation was present and active in feeding, mating and seeking breeding places or winter quarters.

Seasonal occurrence of _Culicoides_ Latreille species was investigated by Parker (1949). He noted that different species had different peaks of occurrence; _Culicoides impunctatus_ Goetghebuer was active from June to August with a peak period in July; _Culicoides pallidicornis_ Kieffer was active from June to September with a peak period in July; _Culicoides heliophilus_ Edwards was about from June to July and saw a peak in activity in late July; while _Culicoides pulicaris_ L. and _Culicoides obsoletus_ Meigen showed no well defined peaks.

Evans and Murdoch (1968) examined the ecology of a grassland community in the Edwin S. George Reserve in south-eastern Michigan and observed that the number of insect species as adults was relatively small at the beginning (April) and the end (October), the peak in activity occurred in late July. The duration of adult occurrence in the field was shown to be related to the type of (adult) feeding habit: flower feeders tended to have short-lived populations, while insects feeding on leaves and stems persisted for longer periods. On the other hand, Mathews and Mathews (1970) who sampled a New York mixed forest by means of Malaise Traps observed the greatest catches in early June and the smallest catches in late July.

Thompson (1967) and Smith, Davies and Golini (1970) during their work on tabanids investigated their seasonal activity. Thompson's study was carried out in the Great Swamp National Wildlife Refuge in north-central New Jersey. He observed two distinct types of seasonal distributions: first, the abundant species which increased rapidly to peak numbers, then declined at varying rates but always more slowly than they increased and: second, the common species found throughout the season in small numbers. A few species did not conform to either of these types. Smith, Davies and Golini (op. cit.) who worked in Algonquin Provincial Park, Ontario, discovered that some tabanids were present from the first week of June until mid-September, the major biting period was late June until early August during which the largest number of species was present in the largest numbers. Seasonal distribution patterns for those species which were captured in sufficient numbers to permit analysis were generally unimodal and most variations in trap or host collections could be attributed to variations in weather.

The majority of the tipulids studied by Freeman (1968) had a single generation per year, although some were clearly bivoltine. In bivoltine species, the second generation of adults was generally more numerous than the first.

Turner et al. (1968) revealed that percentage natural emergence of the parasites Ravinia querula Walker and R. assidua Walker from the host puparia showed a definite seasonal trend. A higher percentage of the parasites emerged from the puparia in the middle of the summer than did in early or late in the season, irrespective of the total amount of parasitism.

Edgar's (1971) investigation of the wolf spider, Lycosa lugubris (Walckenaer), revealed that changes in the vegetation were closely associated with changes in the seasonal distribution of this animal. Changes in the state of the oak trees and the bracken in the habitat seemed particularly important because they in turn altered conditions of shade. The increase in the number of spiders in clearings in late May and early June coincides with the decrease in numbers to a low level in shaded wooded areas.

5. Habitat Preference

Freeman (1945) stated that the majority of insects depend directly upon growing plants for shelter, food and breeding places, and the constitution of any insect population will therefore depend to a great extent on the type of vegetation in the area under consideration.

Most insects taken during this study were inhabitants of grasslands (Cicadellidae and many Diptera). Mushroom - inhabiting insects, of which a number were taken, could have come from surrounding grassland, in which larger numbers of mushrooms grew. In addition, dung - inhabiting forms (Staphylinidae and many Diptera) could also find suitable breeding places in the fields.

The author concluded that local vegetation determined the general character of the aerial fauna which showed significant changes from month to month.

Juillet (1960) studied habitat preference in three families of hymenopterous parasites: Ichneumonidae, Braconidae, and Chalcidae. Ichneumonids tend to be relatively large insects capable of directed flight and are inclined to be most active where the vegetation is fairly dense. In such a situation, one expects a microclimate with a low or a more uniform temperature, high relative humidity, and low wind velocity. Braconids are mostly moderate sized insects capable of directed flight and tend to be most active where the vegetation is partly open and where there is a high temperature, low relative humidity and low wind velocity. Chalcids are small wasps readily carried by air currents and seem to be most active in the open or partly open vegetational growth where the temperature is at its maximum, the relative humidity at its minimum, and the wind velocity is variable (this last factor appeared to have no influence on the flight of this group).

Morgan (1964) studied microhabitat preferences of adult horn flies Haematobia irritans (L.). He observed that the flies preferred the dark areas of bicoloured cattle during the daylight hours and the black of the Holstein to the tan of the Guernsey.

Martin (1965) indicated that pitfall trap catches of Diptera reflected differences in species composition and density between the various stages of forest community development that are borne out by studies in other strata. The greatest dipterous activity occurred in the monoculture stage where the species were mainly representatives of Heliomyzidae, Mycetophilidae and other fungus feeding forms. Fewer flies were captured in the young forest stage, but the species complex was quite similar to that of the former stage. The two younger stages were represented by small numbers of flies, consisting mostly of metopiids, muscids, tachinids, and syrphids.

Ground cover appeared to be important; the loss of ground cover in 1963 was reflected by decreases of 48 to 55 percent from the previous year in pitfall captures in the 1960 and 1950 stands respectively. In older stands, where ground vegetation was not important to the soil surface fauna, the decrease was only 35 percent. With the use of flight traps the author revealed that there occurred greater insect activity in a pruned stand of red pine than in an unpruned stand.

The beetle fauna in grass tussocks was studied by Luff (1966) who discovered that most species were temporary inhabitants which occurred in small numbers. Similar numbers of individuals and species of beetles were found in tussocks of Dactylis glomerata (L.) and Deschampsia caespitosa (L.) but Deschampsia contained exclusive species associated with the marshy habitat in which it chiefly occurred, as well as some species which were common to Dactylis. The number of genera of beetles found in Dactylis tussocks was similar to that caught in pitfall traps between tussocks, but the commonest species in each were different.

The density of Coleoptera was higher in the tussocks than outside.

General specificity in habitat preference for individual families varies considerably. Freeman (1968) found that tipulids are generally very habitat-specific and more species were found in wet and/or woodland situations than in dry and/or non-woodland ones. Tabanids on the other hand were observed by Smith, Davies and Golini (1970) to be abundant and fairly uniformly distributed in all four habitat types studied except one which was unusually favourable. With a few exceptions, (habitat preferences of Tabanidae are far more rigid) there are great differences in the probability of encountering a given species in a given habitat. Tipulidae also have exceptions and Tipula scripta Meigen observed by Freeman (op. cit.) in his study, was found in dry woodlands in July, it may possess an undiscovered behavioral pattern to avoid water loss. Alternatively, it may be able to detect isolated sources of water such as rot holes in trees.

Mathews and Mathews (1970) and Bindlingmayer (1971) observed a great influence of individual sampling sites on the quantity and diversity of insects captured. The first authors worked with Malaise traps and one single trap out of a total of four was the most productive, obtaining 59 percent of the entire summer's collection. It also yielded the greatest number of taxa. These results were not unexpected, for this trap was in by far the most ecologically varied of the sampling stations. Bidlingmayer (op. cit.) stated that similar trap sites in close proximity to one another often differ appreciably in the size and composition of the catches due to physical objects and barriers.

Kitching (1971) investigated the ecological importance of water-filled tree hole habitats in a British woodland. He observed six insect species which passed their immature stages in tree-holes. Five species were Diptera and the sixth a beetle. All the larvae were saprophagous and are largely restricted to tree holes. The author concluded that water-filled tree holes and their fauna have many direct and indirect connections with other parts of the woodland ecosystem.

6. Community Structure

This topic involves a large measure of theory and theoretical work and entails, in part, investigation and discussion of these theories. Kennedy's (1928) investigation related the evolutionary level of insects to their geographic, seasonal, and diurnal distribution. Insects vary greatly in their speed of living or general metabolism. Plesiomorphic insects usually have a low rate of metabolism while apomorphic insects have a high metabolic rate. Series of insects, from slow moving with a low metabolism to fast moving with a high metabolism tend to be found in environments of parallel energy intensities. Slow insects which are primitive occur in environments of low energy intensity - cool, shady or even dark surroundings; while fast insects - usually apomorphic - occur in light, hot environments of high energy intensity such as the tropics, midsummer or mid-day.

Whittaker (1952), in his study of foliage insects investigated Kennedy's theories. Species were found to have distributions tapering along gradients through plant communities. The author noted a series of taxonomic trends, such as changes in relative numerical importance of advanced beetles and primitive flies; a trend in evolutionary level, with increasing representation of modern insect groups towards drier environments, a trend in food-habit composition of communities, with progressive changes in the ratio between fungivores and scavengers and herbivores of vascular plants and pollen feeders; a trend in community diversity; productivity of foliage insects was found to be correlated with the moisture gradient.

The results may also indicate something of the nature of order in natural communities, so to the moist, productive, ancient environment of the cone forest is matched the nematoceran-dominated, productive, primitive and moderately diverse foliage insect community.

Along the moisture gradient there is a trend in richness in species with diversity maximal in intermediate conditions and decreasing toward both extremes, even the favourable mesic site. Whittaker (op. cit.) noted that environments most favourable for high productivity are not the most favourable for high diversity and vice versa.

Hairston (1959) studied the organization of natural communities and discussed species abundance and community organization. He worked on the relative abundance of species of microarthropods in the soil of two similar communities on a long abandoned field. Examination showed a continuous inverse relationship between abundance and clumping of more than one hundred species studied. The organization of the community results from the outcome of interspecific competition for available resources, and is expressed both in relative abundance and spatial distribution of the constituent species.

Theoretical aspects of community structure were discussed by McNaughton and Wolf (1970) and Hurlbert (1971). The former authors expressed their belief that dominance, relative abundance of species in communities and species diversity of communities are interrelated in the conceptual framework of ecology. They felt that while diversity and relative abundance have been precisely explored, their relationships with the earlier idea of dominance have not been carefully developed. It is obvious that the abundance of species in a local area varies, and that diversities of communities are often distinct. What is not obvious is how these differences relate to the organization of communities.

Hurlbert (op. cit.) on the other hand states that species diversity per se does not exist. He believes that communities having a different composition are not intrinsically arrangeable in linear order on a diversity scale. He defined a few parameters with simpler and more direct biological interpretations than possessed by some commonly used diversity indices, but did not intend that these parameters be adopted simply as a new set of such indices. The fact that a particular index shows a correlation with other properties of the community or environment is not evidence that the index is either appropriate or useful.

Evans and Murdoch (1968) studied a grassland community and interesting data was obtained on taxonomic composition, trophic structure and seasonal occurrence.

They recognized thirty-one feeding classes, Diptera were represented in twenty-three of these. For most of the season, the ratio of the number of species with herbivorous larvae to the number of species whose larvae are carnivorous was found to be fairly stable, suggesting that feeding relationships impose a pattern on the community which overrides taxonomic composition.

Coulson, Crossley and Gist (1971) worked with beetles and compared two contrasting communities. The multispecies, multi-storied coppice canopy community contained more Coleoptera species (greater diversity) than did the monoculture of white pine. While no seasonal trend appeared in the white pine community, the coppice habitat showed seasonal trends in diversity, redundancy and evenness. The authors blame the lack of seasonal trend in the white pine community on restricted species composition and fewer individuals.

Stebbings (1971) sampled the fauna from the upper estuary of the River Fal in Britain, the study area ranging from bare mud through salt marsh and salt pasture to oak woodland, all of which are subject to tidal flooding.

To accomplish this, he measured the heights of the topographical features and also the stem base levels of all the plant species encountered. It was found that distinct changes occurred at certain levels. Thus the marsh was divided into three zones based on levels and faunal sampling was related to them.

He observed that the faunal species were not representative of marshlands of southern Britain and were not indicative of saline or brackish waters. The number of plant and animal species, however increased as the level increased.

7. Vertical Occurrence and Distribution of Insects

Rice (1933) installed his flight traps at different heights and observed that the number of species captured in a trap suspended 60 feet above ground was greater than in some traps placed near the ground, but less than in other lowly suspended traps.

Freeman (1938) and (1945) flew nets from masts of a beam wireless station from ground level up to 300 feet. In the former publication he reported an even distribution across the front although aggregations occurred in nets, especially at ground level, often owing to the close proximity of host plants upwind.

He also states that the presence of large numbers of insects in the air throughout the greater part of the year indicates the important part played by wind in their dispersal. In the 1945 publication the writer reveals that the population consists mainly of small, weak-flying insects of high buoyancy drifted involuntarily by the wind. Diptera were most numerous near the ground. Those species of insects confined to ground-level occurred less frequently than those taken at all heights. He classified the collected specimens into aerial and terrestrial forms according to their vertical distribution.

Lewis (1959) compared different coloured water traps, cylindrical sticky and suction traps in his study of Thysanoptera.

He installed these traps at different levels over a wheat field. Up to 48 feet, the aerial density of all species decreased with height, but the rapidity of the decrease differed between species.

Calnaido, French and Taylor (1965) who studied low altitude flight of Oscinella frit (L.) used a vertical series of suction traps and emergency cages. They observed that the aerial and ground populations are directly comparable except that the total aerial population extends well above 30 feet and is therefore understimated.

Increased rain, wind or take-off lowered the mean height of flight and together these factors accounted for 63 percent of the variance. In the panicle generation, the wind speed again lowered the mean height of flight.

Insect density generally diminishes with an increase in height. In general aerial circulation, wind determines the distribution of insects. Lower down there is a region, which has been called the boundary layer (Taylor 1960), in which the insect has control over its movements and from which it must break free to use the wind as a means of dispersal. Within this layer, the density gradient is not dependent on a turbulent convection of wind and the density may be independent of height in the absence of specific attractants.

Alate aphids were captured by Coon and Pepper (1968) in air traps arranged at six different heights (6 to 26 feet) above ground. The total number of aphids captured at the six heights tested was greatest at 6 feet above ground. The total catch dropped above 22 feet.

Greenhead flies were observed by Joyce and Hansens (1958) to occur in significantly greater numbers at a height of 1.5 to 3 feet above the marsh surface than at 3 to 5 feet.

C. MATERIALS AND METHODS

1. Field Methods

1.1 The Study Area and the Vegetation Survey

The topographical map, Plate 1 (scale 1:250,000) shows the study area and the exact location of the study plots.

The plots are situated near Lake Caousacouta which is in the western Saint-Maurice River watershed in Québec. Table 1 appearing on page 35 is adopted from Price (1970).

The vegetation survey was carried out towards the end of the sampling period. The height of each stratum of the vegetation - canopy dominant, subdominant, understorey, etc. about each trap site was estimated, vegetation diagrams were sketched and the plant species were determined according to the nomenclature of Frère Marie-Victorin (1964).

Other factors deemed important and noteworthy about each trap location were: the type of ground cover upon which the trap was resting, conditions of shade, moisture, temperature, general topography, the direction and the vegetation in the immediate vicinity of the trap.

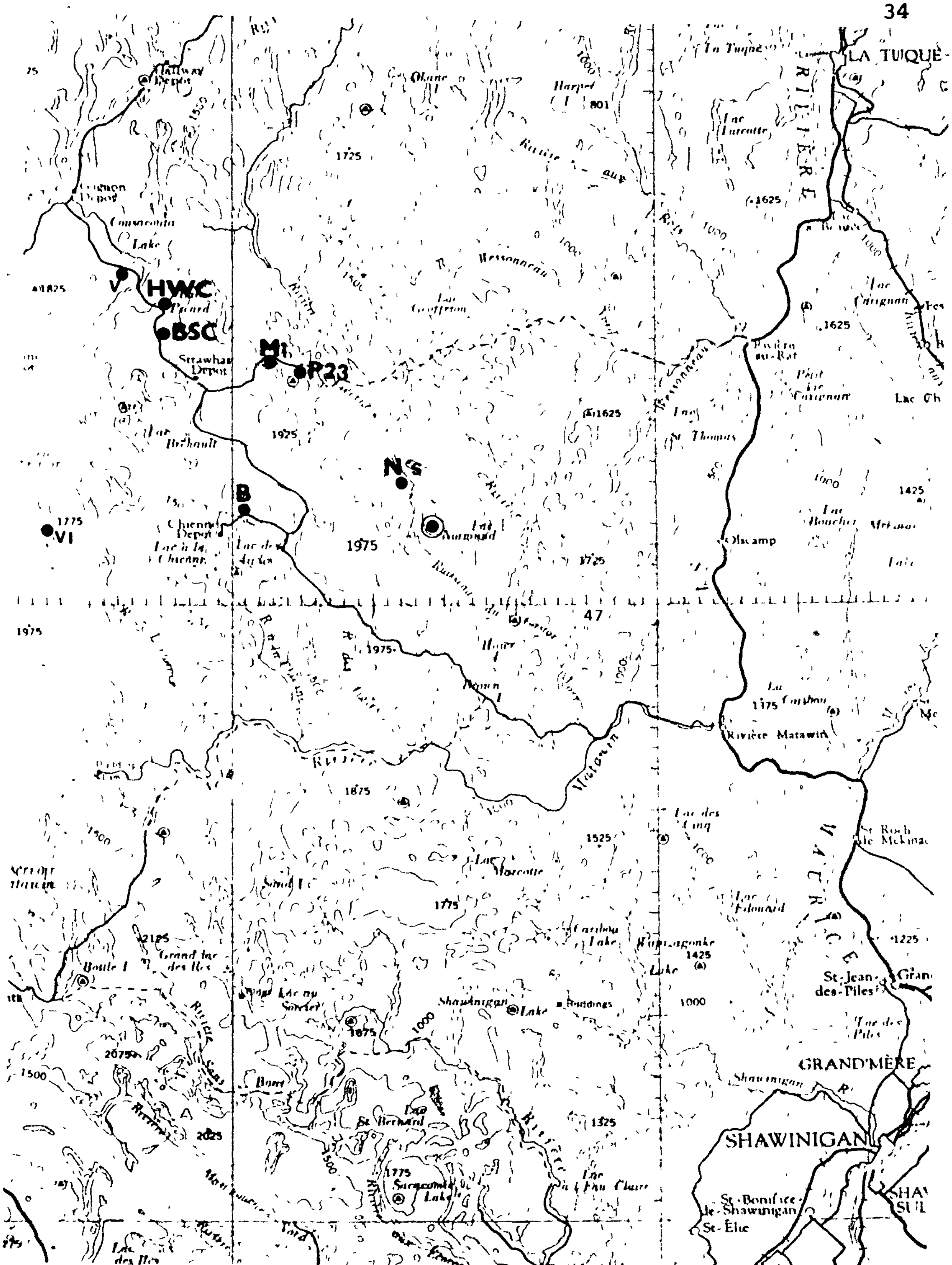


Plate 1. Topographical map (scale 1:250,000) of the general study area. The solid black dots are the field station study plots and the black dot with the concentric circle represents the Lac Normand Field Station.

Table 1. Location and description of each study plot

Plot	Nearest Lake	North Lat. Deg.	North Lat. Min.	West. Long. Deg.	West. Long. Min.	Dominant Tree Species	Other Factors
V	Caousa-couta	47	16	73	37	45 yr. Jack Pine	Sandy Plain
HWC	"	47	14	73	36	Birch & Poplar	Hardwood Regeneration
BSC	"	47	14	73	35	Black Spruce	Dense stand, dry site

These features are detailed in the legend of the vegetation diagram, Figures 1 and 2 and the observations for each plot are included in Tables 2 through 5. When all the trap site observations from a plot are combined, they demonstrate very well the vegetative characteristics and structure of that plot. The vegetation diagrams, Figure 2, are modified from Dansereau (1958) and they show clearly the different vegetative types that prevailed in each plot. One notes the density and diversity of the plant-life in plot HWC as compared to that of plot BSC and plot V which is the driest and most sparsely vegetated of the plots.

Table 2. Legend of the vegetation diagram and plot description

A.	Vegetation	
	i	Canopy dominants
	ii	Canopy subdominants
	iii	Understorey
	iv	Shrub layer
	v	Herb layer
	vi	Ground cover
B.	General site conditions at ground level	
	i	Height conditions - shaded, sunny or open above
	ii	Temperature conditions - hot or cool
	iii	Moisture conditions - very dry, dry, mesic, moist or wet
	iv	General topography - flat, undulating
	v	Slope - angle and direction
	vi	Other features - close to road, water, etc.
C.	Details of trap location	
	i	Direction faced by the trap
	ii	Vegetation immediately surrounding the trap

Figure 1. Legend of the symbols used in the vegetation diagram

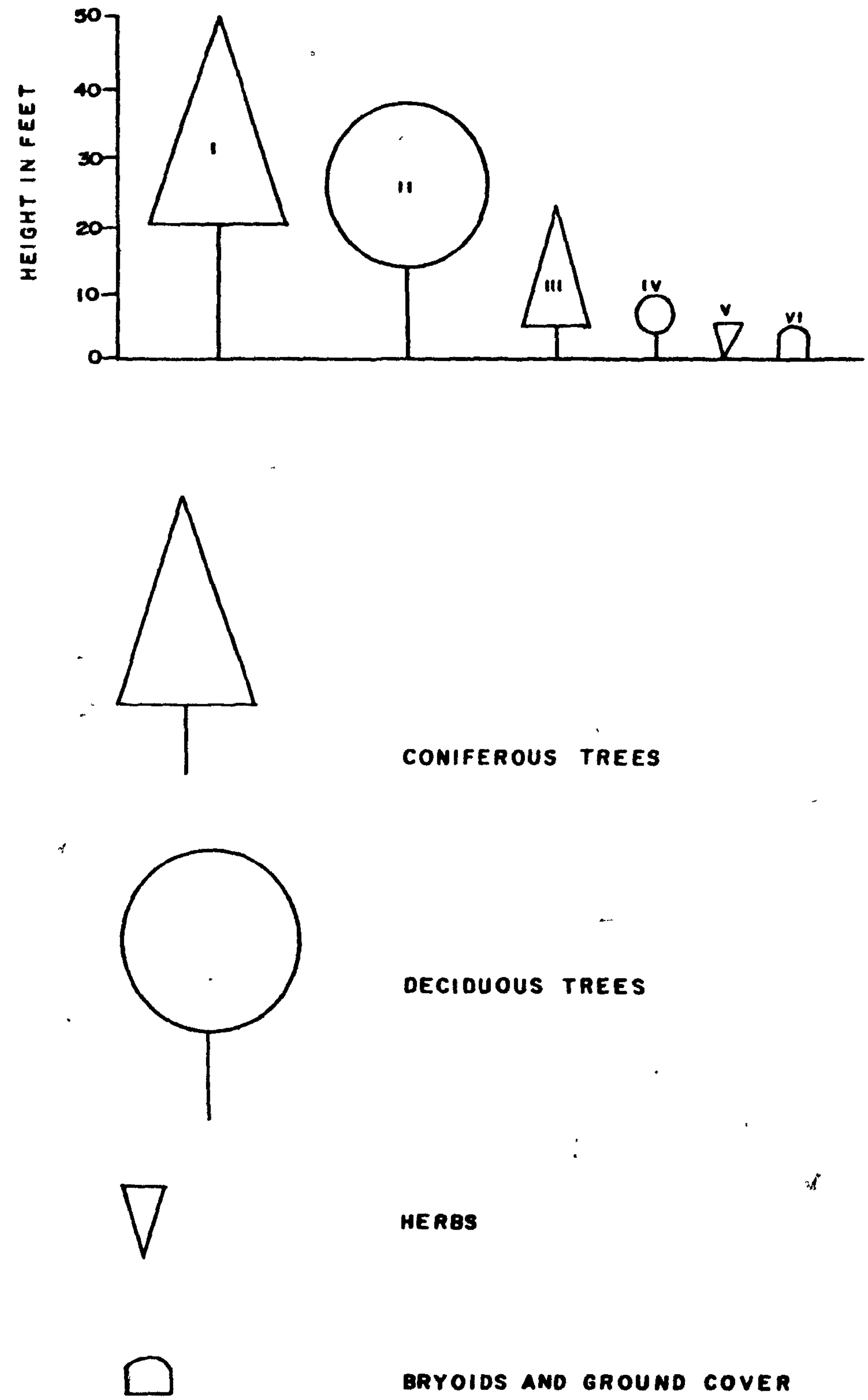


Figure 2. Vegetation diagrams of each trap site within the study plots

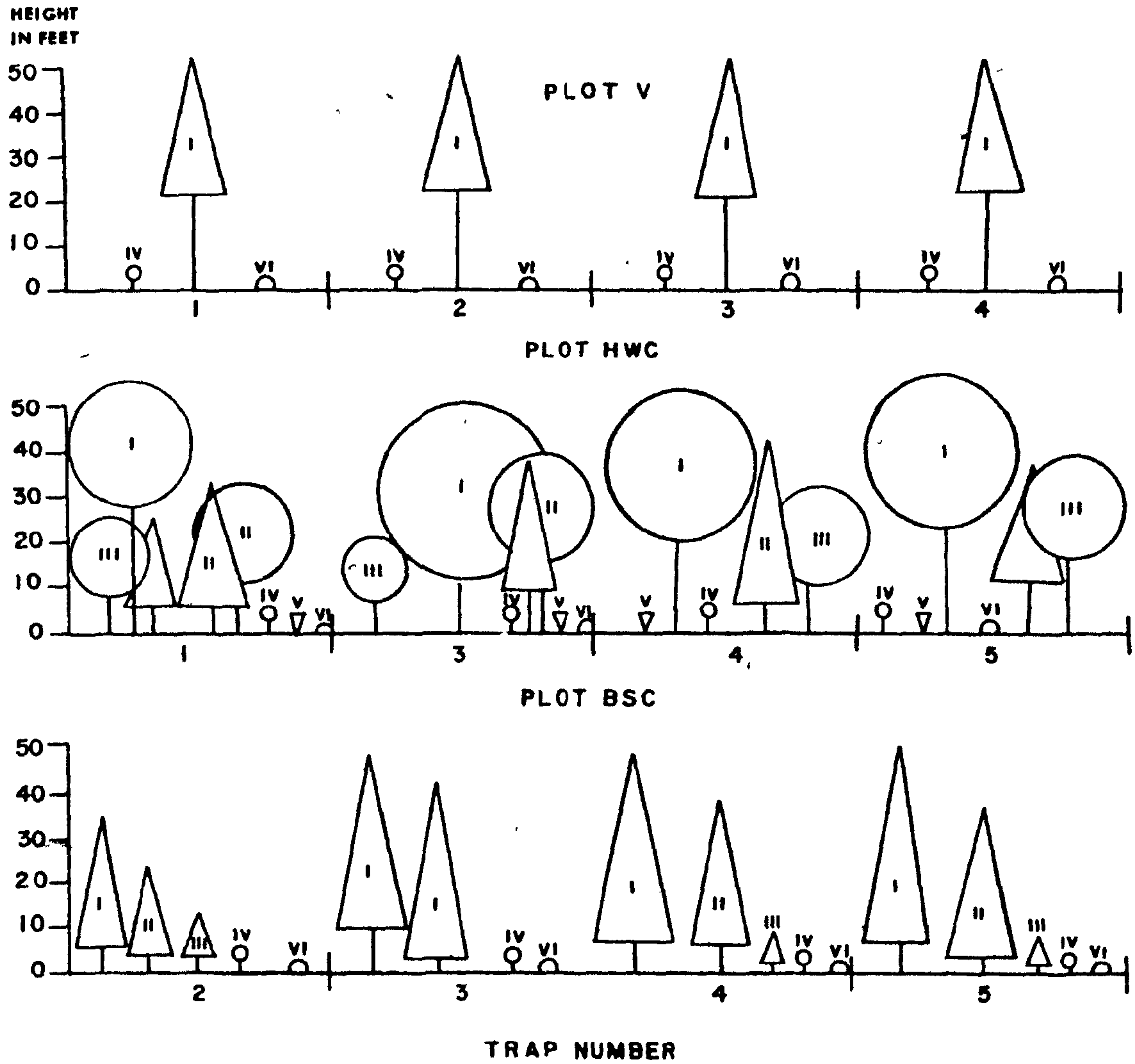


Table 3. List of plant species, general site conditions and details of trap location for plot V

	Trap 1	Trap 2	Trap 3	Trap 4
A				
i	*Pinus divaricata* (Ait.) Dumont	*Pinus divaricata*	*Pinus divaricata*	*Pinus divaricata*
ii	-	-	-	-
iii	-	-	-	-
iv	*Comptonia peregrina* (L.) Coulter (abundant), *Kalmia angustifolia* L. *Vaccinium angustifolium* Ait. (sparse and low shrubs)	*Kalmia angustifolia*, *Vaccinium myrtilloides* Michx., *Salix* L. (low but dense)	*Kalmia angustifolia*, *Vaccinium angustifolium*, *Vaccinium myrtilloides* (sparse and low)	*Kalmia angustifolia*, *Comptonia peregrina*, *Vaccinium angustifolium* (low out dense)
v	-	-	-	-
vi	*Cladonia* Hill, *Sphagnum* Dill	*Cladonia*	*Cladonia* and some *Sphagnum*	*Cladonia* and litter
B				
i	open and sunny	open and sunny	open and sunny	open and sunny
ii	hot	hot	hot	hot
iii	dry	dry	dry	dry
iv	flat	flat	flat	flat
v	0	0	0	0
vi	-	-	-	-
C				
i	east-west	east-west	northwest	northeast
ii	*Comptonia peregrina* within nine inches	vegetation within six inches but fairly open	sparse growth within six inches but generally clear	clear for two feet around the trap

Table 4. List of plant species, general site conditions and details of trap location for plot HWC,

	Trap 1	Trap 3	Trap 4	Trap 5
A				
i	Betula papyrifera Marsh.	Betula papyrifera (sparse)	Betula papyrifera	Betula papyrifera
ii	Abies balsamea (L.) Mill., Populus tremuloides Michx. (dense)	Acer spicatum, Acer rubrum L., Abies balsamea (dense)	Abies balsamea	-
iii	Acer spicatum Lam., Abies balsamea (dense)	Acer spicatum, Corylus cornuta Marsh. (dense)	Acer spicatum (very dense)	Abies balsamea, Acer spicatum and Acer rubrum
iv	Diervilla lonicera Mill. Pteridium aquilinum (L.) Kuhn., Viburnum cassinoides L., Vaccinium angustifolium Ait.	Pteridium aquilinum, Viburnum cassinoides, Corylus cornuta	Viburnum cassinoides, Acer spicatum (dense), Pteridium aquilinum	Acer spicatum, Corylus cornuta, Pteridium aquilinum, Diervilla lonicera, Viburnum cassinoides. Sorbus americana Marsh. All these plants are very dense
v	Aralia nudicaulis L., Aster macrophyllus L., Linnaea borealis L.	Aralia nudicaulis, Diervilla lonicera, Aster macrophyllus, Clintonia borealis (Ait.) Raf., Linnaea borealis, Cornus canadensis L. (dense)	Aralia nudicaulis, Trientalis borealis Raf., Clintonia borealis, Aster macrophyllus, Viola L.	Linnaea borealis, Aster macrophyllus, Clintonia borealis, Aralia nudicaulis
vi	-	Litter and sparse Polytrichum commune L.	-	Litter, Trientalis borealis, Cornus canadensis
B				
i	open, but one side is heavily shaded	shaded	very shaded	shaded
ii	cool	cool	cool	cool
iii	moist	moist	moist	moist
iv	slope	slope	slope	slight slope
v	10% slope; northwest	10% slope; northwest	10% slope; northwest	5% slope; northwest
vi	-	-	the trap is in a hollow on the slope	-
C				
i	east-west	northwest	northwest	northeast
ii	Pteridium aquilinum overhang the trap. There is Aralia nudicaulis 1 foot away	Aster macrophyllus and Diervilla lonicera within 6 feet touching, open on one side	the trap is completely overhung with vegetation. No plants are very close	overhung by Acer spicatum

Table 5. List of plant species, general site conditions and details of trap location for plot BSC

	Trap 2	Trap 3	Trap 4	Trap 5
A				
i	*Picea mariana* (Mill) BSP	*Larix laricina* (Du Roi) K.Koch *Abies balsamea* (surrounding and over the trap)	*Picea mariana*	*Picea mariana* (quite dense)
ii	*Picea mariana*	-	*Picea mariana* and *Abies balsamea*	*Picea mariana* (quite dense)
iii	*Picea mariana* and *Abies balsamea* (L.) Mill.	-	*Picea mariana*	*Picea mariana* (quite dense)
iv	*Ledum groenlandicum* Oeder., *Kalmia augustifolia* L., *Vaccinium augustifolium* Ait., *Vaccinium myrtilloides* Michx., *Salix* L., *Amelanchier* Medic. (dense), *Viburnum cassinoides* L.	*Kalmia augustifolia*, *Vaccinium myrtilloides*	*Kalmia augustifolia*, *Viburnum cassinoides*, *Ledum groenlandicum*, *Vaccinium augustifolium*	*Viburnum cassinoides*, *Amelanchier*, *Ledum groenlandicum*, *Vaccinium augustifolium*, thick *Vaccinium myrtilloides*
v	-	-	-	-
vi	*Pleurozium schreberi* (Brid.) Mitt., *Cladonia* Hill (dense)	*Dicranum* Hedw. and leaf litter	Dense *Pleurozium schreberi*	*Pleurozium schreberi*
B				
i	shaded	deep shade	open	shaded
ii	cool	cool	warm	cool
iii	moist	moist	moist	moist
iv	flat but tussocky	flat	flat	flat
v	0	0	0	-
vi	the trap is not in a hollow	-	the trap is situated in the middle of a tussock	the trap is situated on a tussock
C				
i	northwest	east-west	northeast	northeast
ii	there are willows and shadbush within one foot of the trap	there is very little vegetation close to the tray except the bases of the trees	there is *Kalmia augustifolia* within two feet	*Ledum groenlandicum* and *Kalmia augustifolia* touching the tray and six inches away

1.2 The Trapping Technique

Window flight traps were used, Plates 2 through 5. They consisted of a pane of glass a foot square, held vertically, with the base in a pan containing water and detergent as a wetting agent. The pan was placed on the ground, amid the litter and vegetation and wire clips held the glass upright. In this way, the habitat was altered very little, and insects were captured under natural conditions.

Starting on June 11, 1970, when the traps were first placed in the field, the traps were emptied at weekly intervals. Each pan was emptied into a piece of very fine dacron screening which was placed with the contents into a labelled jar containing 70 percent ethanol. At this time the water in the pan was replaced, the wetting agent added, and the pane of glass was washed. Approximately 100 grams of salt was added to the trap as a preservative. In this manner the data was collected weekly until August 19, 1970. The date used on the labels of the vials was the date on which the trap was set up and ready for the coming week's sample (Table 6).

Plate 2. Window flight trap

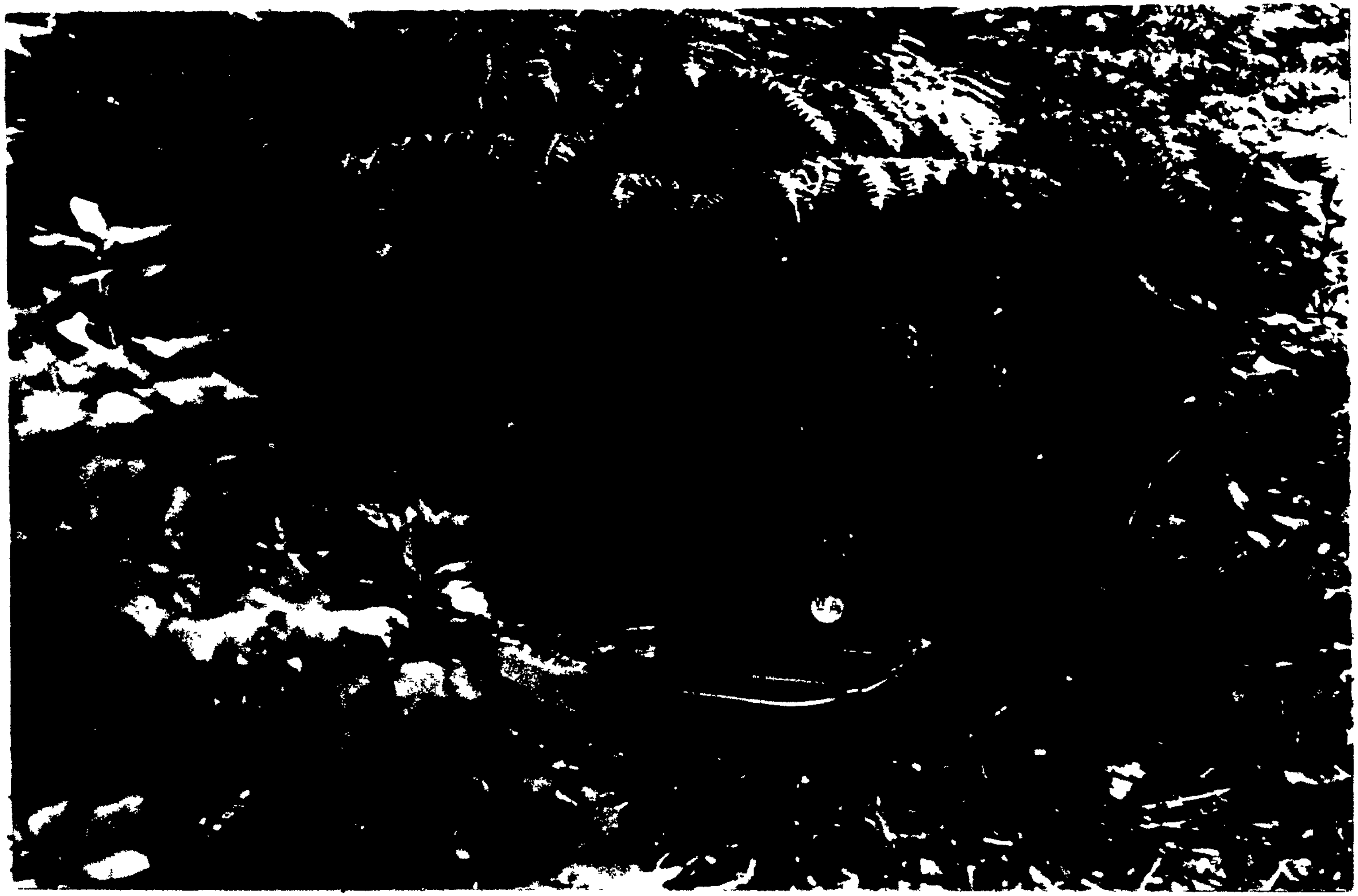


Plate 3. Flight trap in a situation typical of plot HWC

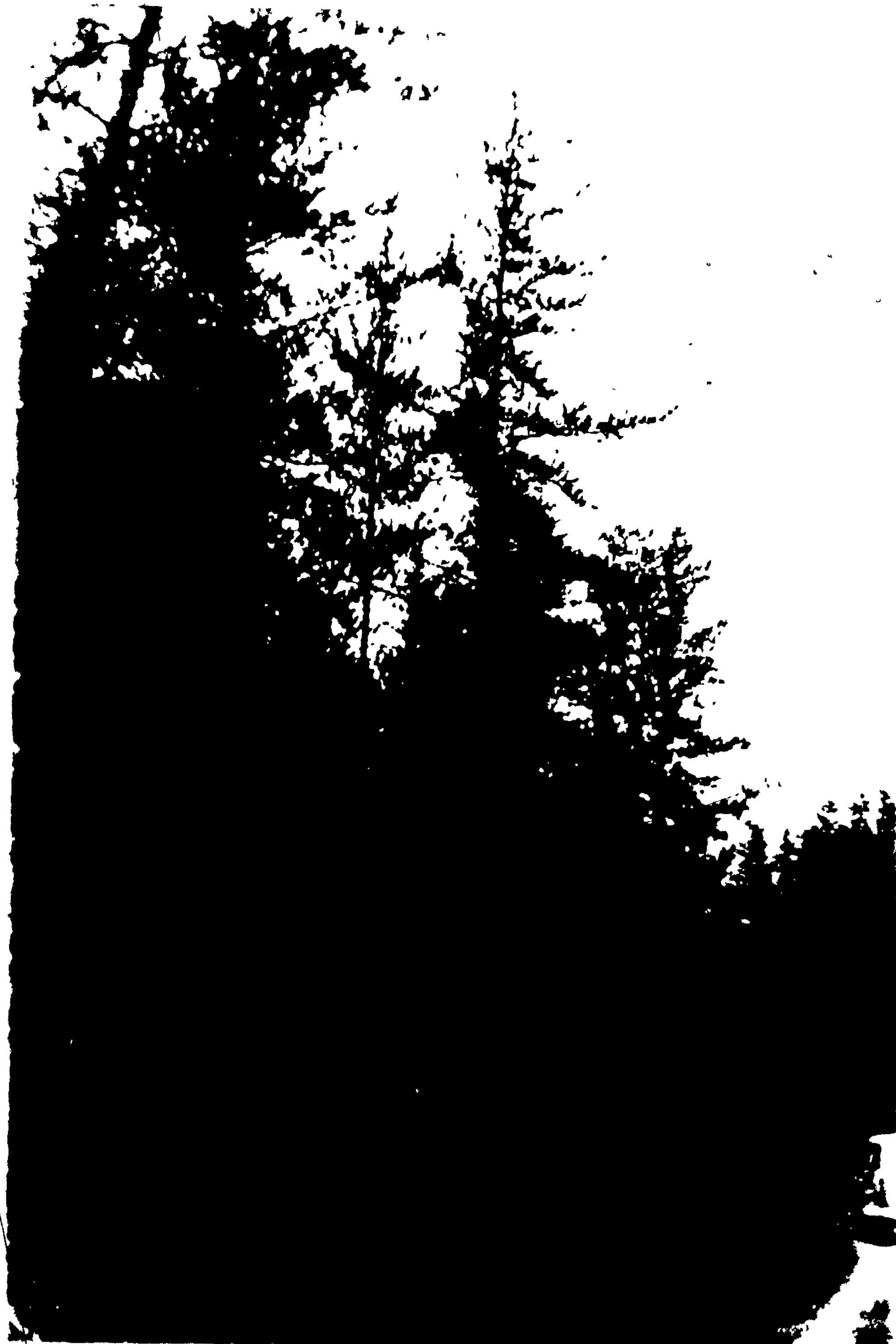


Plate 4. Plot V

Plate 5. Window flight trap in an open site typical of plot V

Table 6. Explanation of the term "Week Number" and corresponding dates of each week during the summer of 1970

Sampling during Summer 1970		
Trap set up on:	Sample gathered on:	Week Number
June 11	June 17	1
June 17	June 24	2
June 24	July 1	3
July 1	July 8	4
July 8	July 14	5
July 14	July 21	6
July 21	July 29	7
July 29	August 5	8
August 5	August 12	9
August 12	August 19	10
August 19	August 26	11

At the beginning of the field season, trap sites were selected where the pan of each trap would remain horizontal in order to prevent overflow of the water. Care was taken to have each window trap become an integral part of the immediate habitat with the minimum of disturbance. These criteria determined how the traps were placed and the direction they faced, but in the final analysis the directions faced by the traps in each plot compared very well.

Traps were placed so that they sampled each plot as thoroughly as possible, for example, in plots HWC and BSC where different conditions of shade, vegetation density and types existed, the five traps of each plot were placed in each situation. On the other hand, in the uniform jack pine stand of plot V where all conditions are very similar, this was less important and therefore the ten traps were mounted in a straight line, approximately 10 meters apart.

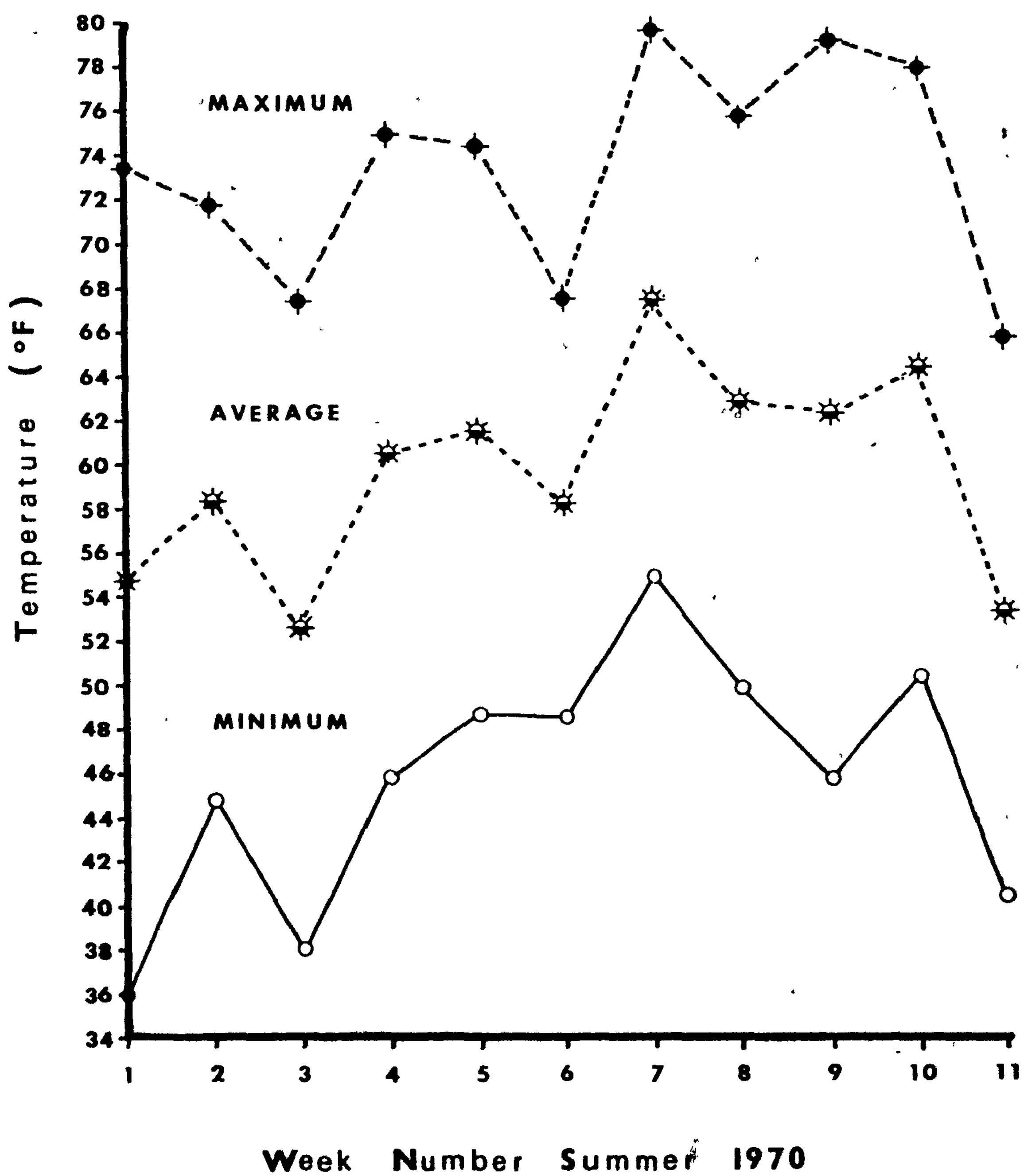
1.3 Weather Data and Meteorological Observations

The study plots are close to one another, Plate 1. A Stevenson's Shelter with its thermohygrograph situated in the center of plot V also served for the other plots. Thus the microclimates of plots HWC and BSC were not recorded. The weekly average, mean maximum and minimum temperatures were computed from the daily thermohygrograph data of plot V. These values were plotted to show the weekly temperature trend, Figure 3.

Results obtained from the randomized complete block design analysis and Duncan's new multiple-range test performed on plot V allowed calculation of correlation coefficients between the average number of flies caught each week and the mean maximum and minimum and average temperatures. The corresponding student's "t" values were obtained for each of these correlation coefficients.

The study on the Rhagionidae entailed computation of day-degree temperature summations above the threshold of 42^{O}F. (Maxwell and Parsons 1969). The mean daily temperature was calculated from the daily minimums and maximums. The following are the sources from which this temperature data was extracted during 1970:

Figure 3. Weekly average temperatures throughout the summer



a) temperature summation during April until May 24th inclusive, temperature data from the weather station at the Mattawin Dam (Barrage Mattawin), the Monthly Record of Meteorological Observations in Canada, April and May 1970, was used;

b) from May 25th until June 3rd inclusive, temperature accumulation was computed from the Stevenson's Screen at the Lac Normand Field Station;

c) from June 4th until the second week of sampling when Rhagio mystaceus reached a peak in activity, temperature data from the Stevenson's shelter in plot V was used.

This method is subject to error (Andrewartha and Birch, 1954). It was found that the use of hours degrees is much more exact than the concept of day-degrees because on occasions when the minimum daily temperature is lower than the threshold it is unrealistic and inaccurate to use the mean temperature for the full day to estimate the amount of development. For the purposes of this work, however, in which part of the temperature data comes from a weather station 70 miles away (Barrage Mattawin) and part from the Lac Normand Field Station, 40 miles away from plot V and the remaining data from plot V, the approximation thus obtained is sufficient and the most feasible.

Table 7. List of weather stations and dates from which the temperature summation (day-degrees) was computed

Date	Origin	(Day-degrees F. above 42°F) Temperature Accumulation
April	Barrage Mattawin	22
May 1-24	Barrage Mattawin	108
May 25-June 3	Lac Normand Station	118.5
June 4-24	Caousacouta Plot	298.0
total		546.5

2. Laboratory Techniques

In the laboratory, the specimens were transferred from the jars to labelled vials containing 70 percent ethanol. Before identification, the Diptera specimens were placed in ethyl acetate for approximately 24 hours. They were then spread on a glass petri dish and allowed to dry. Keys from Borror and De Long (1964) were used to identify to the family level, then keys from Curran (1965) were used for identification to the genus. Specimens were also pinned and compared with specimens in the Lyman Museum at Macdonald College to obtain the generic and in some cases the species name.

Four traps were chosen for analysis from each plot to reduce the work load involved in handling and identifying so many specimens. This was done keeping the trap directions in mind so that orientations were similar in each plot and valid comparisons were thus made possible between the plots. In order to conform to the plot nomenclature as established by Price (pers. comm) and the Lac Normand Field Station research staff, the trap numbers were not changed so that the following traps were chosen for the present study:-

traps 1, 2, 3, 4 from plot V

traps 1, 3, 4, 5 from plot HWC

traps 2, 3, 4, 5 from plot BSC

D. RESULTS

1. Comparison between the Three Plots

1.1 Seasonal Catch of Diptera (see Figure 4)

This section compares the total number of flies caught in each plot which represents a different habitat type, during the summer of 1970. This exercise is very important because much of the following analyses and discussion are based upon the assumption that different community types will differ in their insect fauna - numbers and species composition.

The graph shown in Figure 4 best depicts the magnitude of the differences existing in the seasonal catches of the three plots. The total catch of Diptera for the summer of 1970 is 36,020. Spaces along the horizontal axis were reserved for each plot, while the y-axis demarks the number of flies captured during the sampling period of 1970.

1.2 Seasonal Activity

1.2.1 Diagrams of Individual Trap Catches for Each Week through the Season

A vertical logarithmic scale of the histo-grams, (Figure 5) shows clearly individual trap efficiency for each plot through the sampling season. Each column represents one trap and each individual diagram includes the four traps of that plot arranged in ascending numerical order.

Figure 4. Plot Comparison of Total Number of Diptera during Summer of 1970

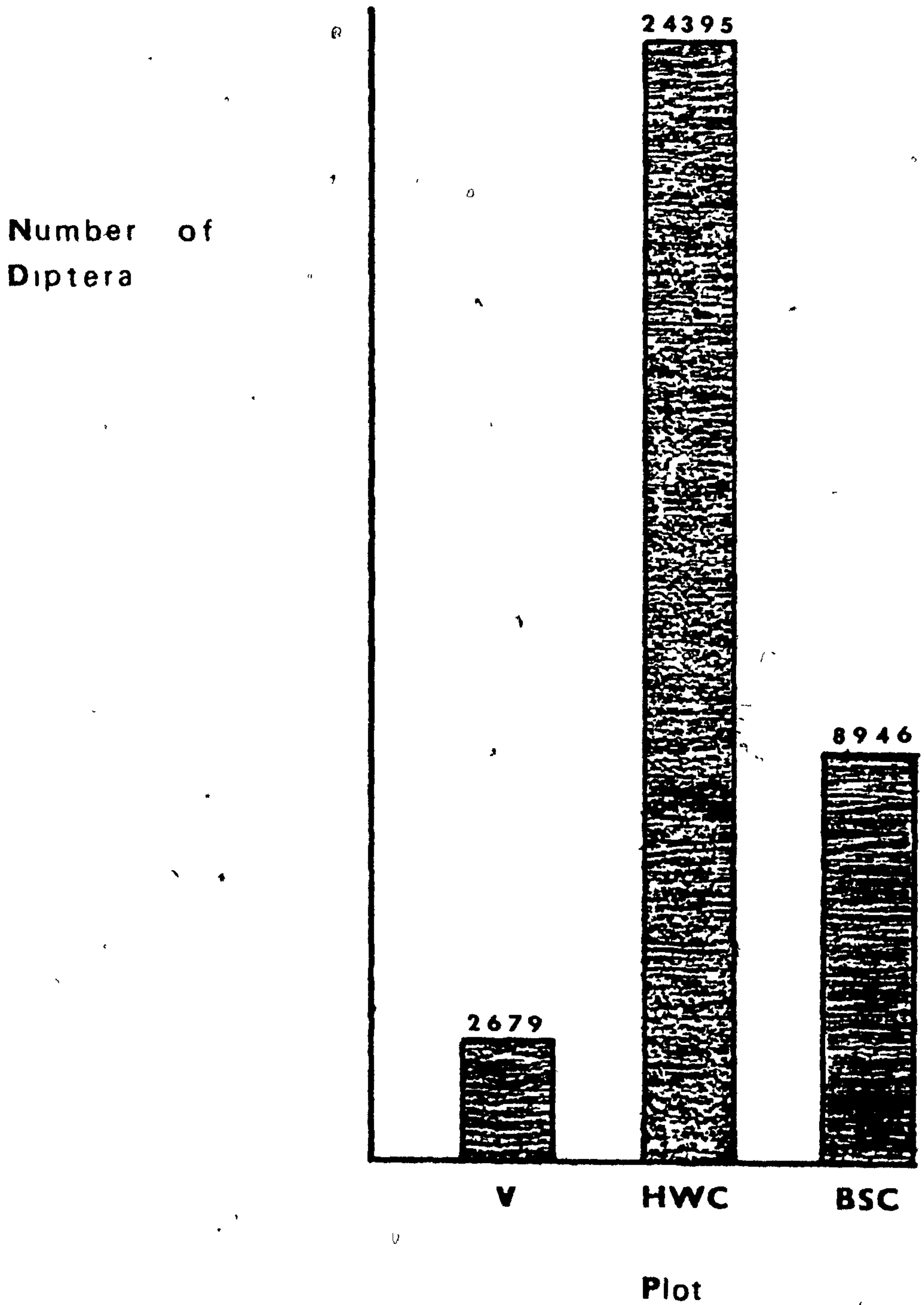
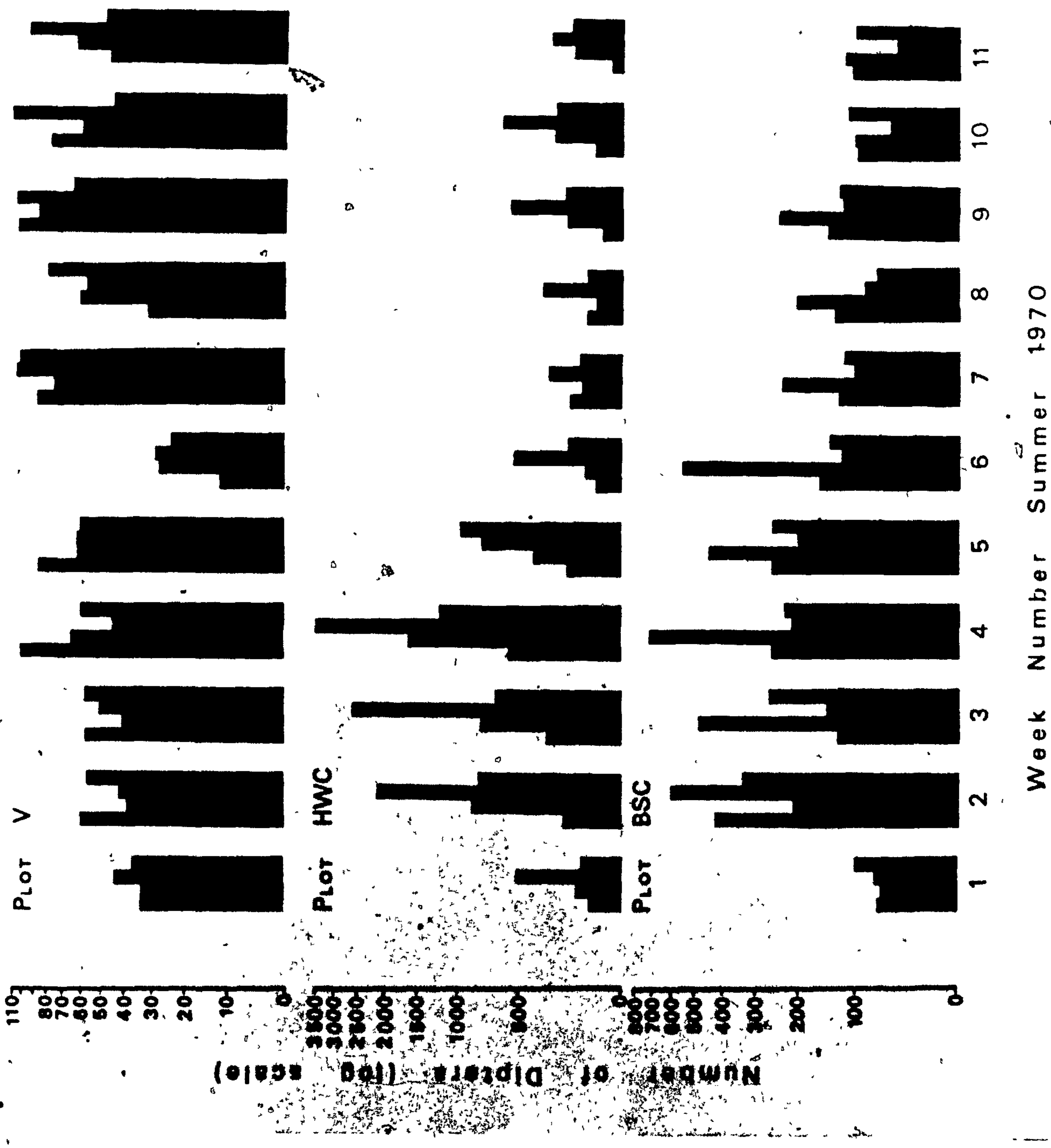


Figure 5. Histograms of semi logarithmic scale representing the trap catches for each week's sampling during 1970



Logarithmic scales were used for the vertical axis to make the figures more manageable and easier to represent on the same page. The numbers along the vertical axis represent the number of flies captured.

Spaces were reserved along the horizontal axis for each of the eleven weeks of data collection. The diagrams enable easy comparison of the figures and show definite trends of weekly plot and individual trap captures.

1.2.2 Comparison of Weekly Meteorological Observations with Weekly Dipterous Activity in Plot V

A comparison of Figures 3 and 7 shows clearly the dependence of dipterous activity in plot V on temperature, the patterns of all three; mean maximum, average and mean minimum temperatures bear a strong resemblance to the pattern of seasonal activity of all the Diptera of plot V. There is a dip of the temperature values at the third and sixth weeks, a peak at the seventh and the mean maximum temperature also reaches a peak at the ninth week, Figure 3.

Results obtained from the randomized complete block design analysis and Duncan's new multiple-range test (Steel and Torrie, 1960), performed on plot V allowed calculation of correlation coefficients between the average number of flies caught each week and the mean maximum and minimum and average temperatures. The corresponding student's "t" values were obtained for each of these correlation coefficients.

1.3 Investigation of Trends in the Evolutionary Level

The plots in Table 9 from left to right are arranged along a decreasing moisture gradient, i.e. plot HWC is the most humid and plot V, the driest. Plot BSC qualifies between but it is much closer to plot HWC.

The ratios were computed by dividing the percentage composition of each plot by the lowest percentage of that suborder or group observed between the three plots.

Figure 6 is a diagrammatic representation of Table 9. The plots were arranged along the same decreasing moisture gradient. It expresses in a visually vivid fashion the trends of the evolutionary level from the mesic plots towards a drier environment.

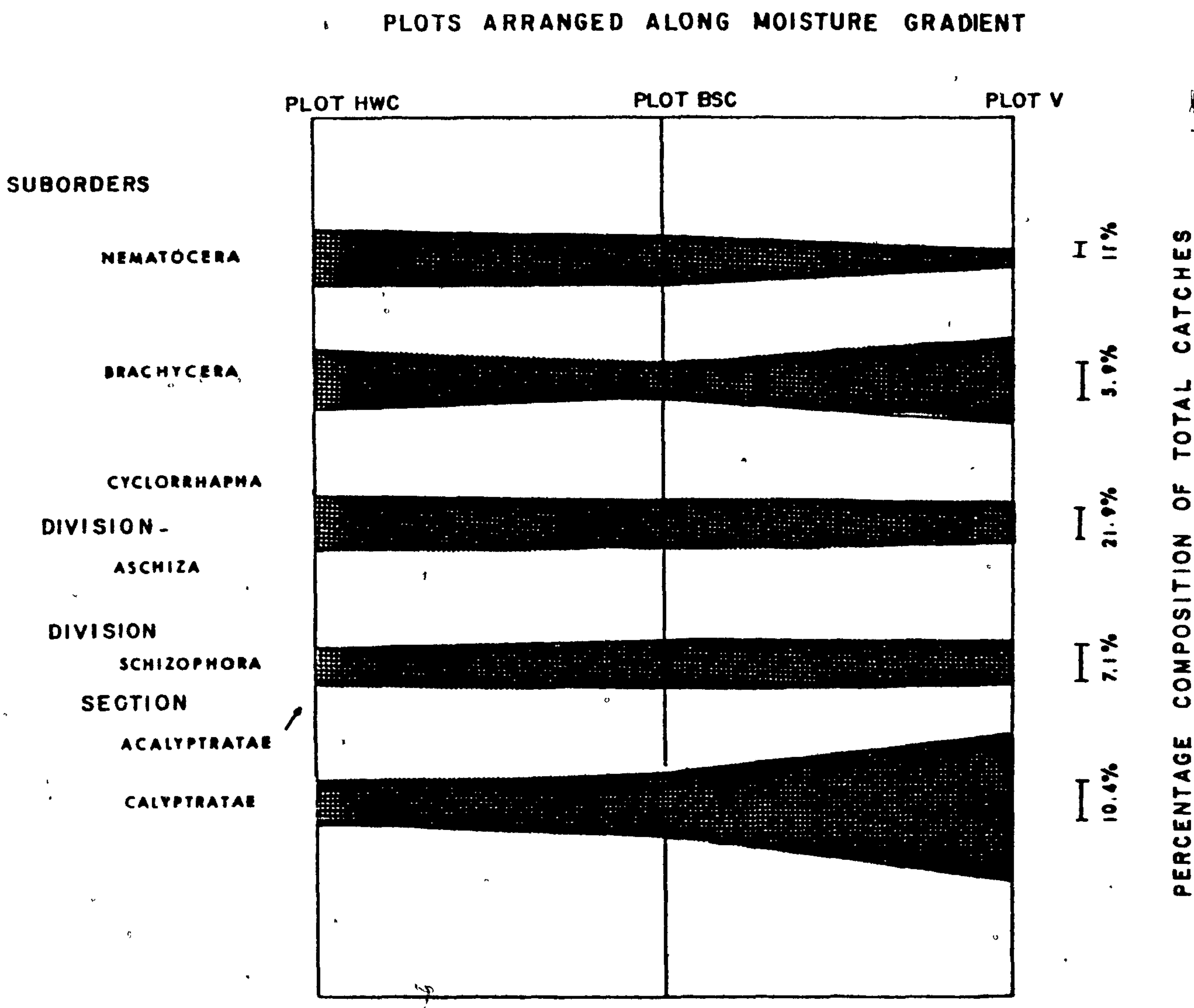
Table 8. Correlation coefficients and corresponding student's "t" values between the flies caught each week and the corresponding temperature values

	Correlation Coefficients	Student's "t" values
Mean maximum temperature	0.6903	8.5811**
Average temperature	0.6331	7.3620**
Mean minimum temperature	0.4564	4.6150**

Table 9. Ratios computed from the percentage composition of each group of the total catch of Diptera

Suborder or group	Ratios and Percentage of the Total Catch					
	HWC		BSC		V	
Nematocera	3.9	42.4%	3.7	40.5%	1.0	11.0%
Brachycera	1.5	8.7%	1.0	5.9%	2.3	13.7%
Aschiza	1.4	31.4%	1.2	26.4%	1.0	21.9%
Cyclorrhapha						
Schizophora-Acalyptrate	1.0	7.1%	1.2	8.8%	1.2	8.8%
Calyptrate	1.0	10.4%	1.8	18.5%	4.3	44.3%

Figure 6. Diagrammatic representation of Table 9 showing the composition of the various dipterous groups in the 3 plots



1.4 Investigations of Food Habit Composition among the Diptera of each Community

For this purpose families of Diptera whose food habits are well known were chosen. Families of flies such as Muscidae which have a very wide range of food habits were not used in this study.

The classification of the food groups is slightly modified from Whittaker (1952)

1) fungivores and compost feeders, 2) scavengers, 3) predators, 4) vegetarians, 5) pollen feeders and 6) parasites.

The criterion of food habit was chosen from the most important or best known feeding stage of the insect. Empididae, for example, which are well known for their predaceous habits as adults and are known as scavengers in the larval form are considered as both, and they are included in the ratios of both these trophic levels. Ephydrids have been considered as vegetarians for this study. Vegetarians include leaf miners and gall flies, in general, those insects feeding on living plants, excluding fungi.

2. Comparisons Within Each Plot

2.1 Comparison of Different Trap Directions

For each plot, in order to test for this criterion, traps were chosen which had similar conditions of shade or lack of cover and similar surrounding vegetation so that they differed only in the direction they faced.

The four traps of plot V fulfilled the above conditions. The only difference among them was their orientation. With each trap considered as a treatment and sampling weeks as blocks, a randomized complete-block design analysis was carried out. A Duncan's new multiple-range test was also performed.

In plot V, trap-direction did not influence the capture of Diptera significantly. The reason for carrying out this analysis was also to emphasize statistically, and it does, the fact that fluctuations of weekly catches are highly significant. Duncan's new multiple-range test similarly revealed no significant difference between trap directions.

In plot HWC, traps 3 and 5 were chosen for this purpose. An analysis of variance was performed and these were homogeneous. A T-test showed that we do not reject the null hypothesis at any statistical level so that here too, trap direction was not an important factor influencing the total captures of these traps.

From plot BSC, trap 2 was compared to trap 5. The variances were found to be homogeneous. Similarly, trap direction had no effect on the total catches of these traps.

2.2 Comparison of Different Conditions of Traps in the Open, Shade and Deep Shade

Since it has been shown by the previous analysis that trap direction did not have any influence on total trap captures it was decided to investigate different conditions of light and shade. Also in analyzing these criteria the factor of trap-orientation can be ignored.

It has been shown by the randomized complete-block design analysis of plot V that weekly catches for each trap differ highly significantly. Therefore, one glance at the weekly fluctuations of plots HWC and BSC (Figure 7) shows that these are highly significant.

This means that plots HWC and BSC qualify for a Duncan's new multiple-range test. Table 10.

Traps underscored by the same line show no significant difference among them. Traps 4 and 3 from plots HWC and BSC respectively which are in deep shade, lie apart, not underscored by any line. These two traps are significantly different from the others in their respective plots.

Figure 7. Weekly occurrence of the total Diptera sampled and of Phoridae and Mycetophilidae considered together

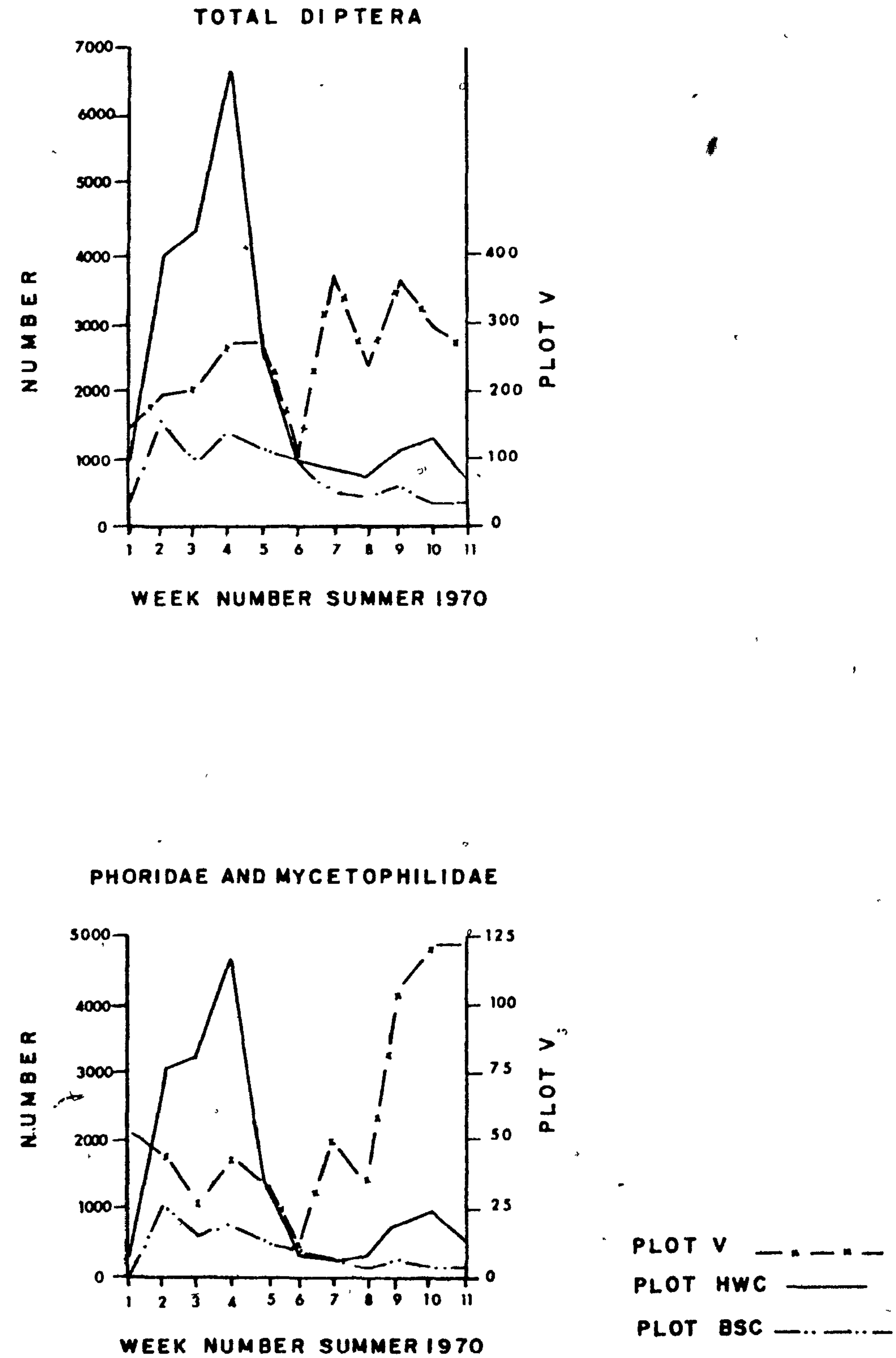


Table 10. Results of Duncan's new multiple-range test comparing the mean weekly catch of each trap

	Plot V				Plot HWC				Plot BSC			
Trap Number	2	4	1	3	1	3	5	4	4	5	2	3
Mean Catch per week	55.6	57.4	63.3	67.4	194.1	455	462.4	1106.3	161.6	168.3	177.3	306.1
Total Catch	2,679				24,395				8,946			

The numbers not underscored by a line are significantly different from others in the same plot.

3. Seasonal Activity of the Observed Families of Diptera

Each plot, over the summer, differed in the total number of families of Diptera observed; to test whether this was significant or not, a Chi-Square analysis was performed.

No significance was observed, the data are generally considered as agreeing with the expectation, that is each plot will yield the same number of dipterous families. The differences between observation and expectation might well be due to chance alone (Crow, 1966).

The families represented by the seasonal activity diagrams (Figures 8, 9 and 10), comprised 84.9 percent of all the flies caught that summer. The activity patterns of the flies demonstrated possible relationships between families and also, the number of peaks of activity and the period of the summer during which they occurred, revealed valuable evolutionary trends.

4. Relationships Between Families of Diptera

A definite resemblance in activity patterns was noted between the following families: Dolichopodidae, Drosophilidae, Mycetophilidae and Phoridae. A predator-prey relationship was suspected with the dolichopodids as predator and the other families as prey. Plot HWC was chosen for an analysis of this possibility because of the great abundance of individuals of these families in this plot.

Coefficients of correlation, r, were calculated and their corresponding student's "t" values obtained.

Figure 8. Weekly occurrence of families of Diptera

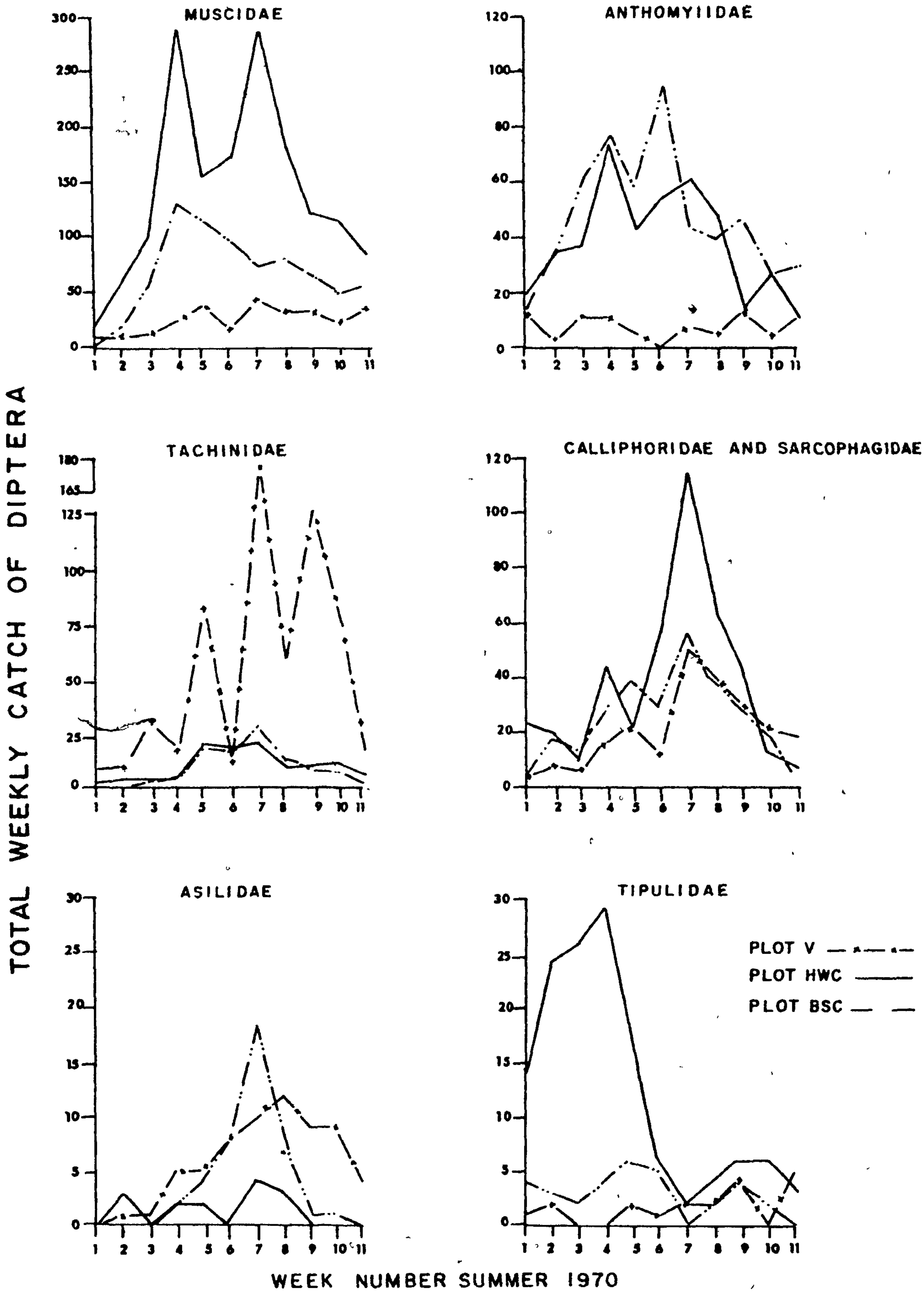


Figure 9. Weekly occurrence of families of Diptera

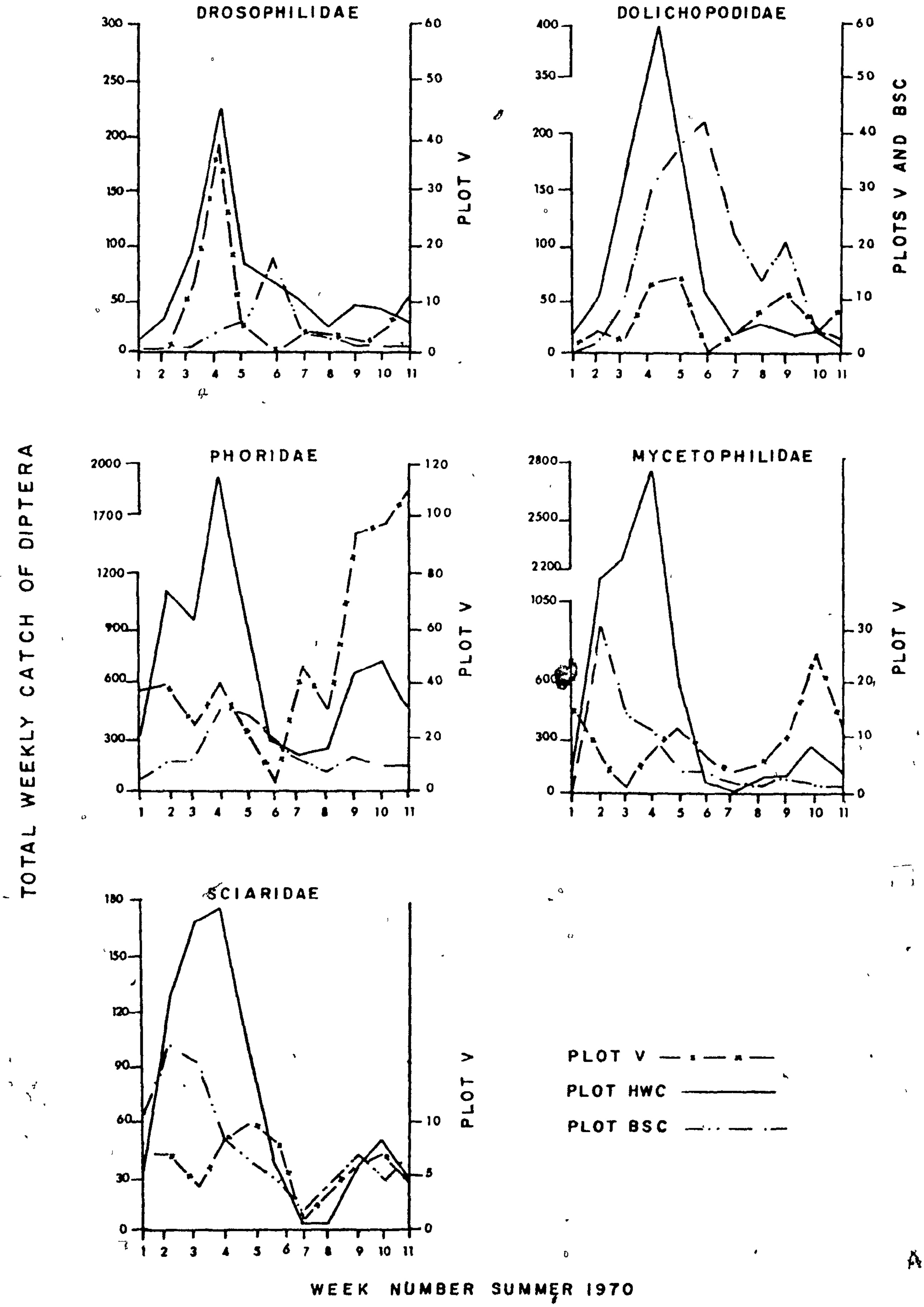
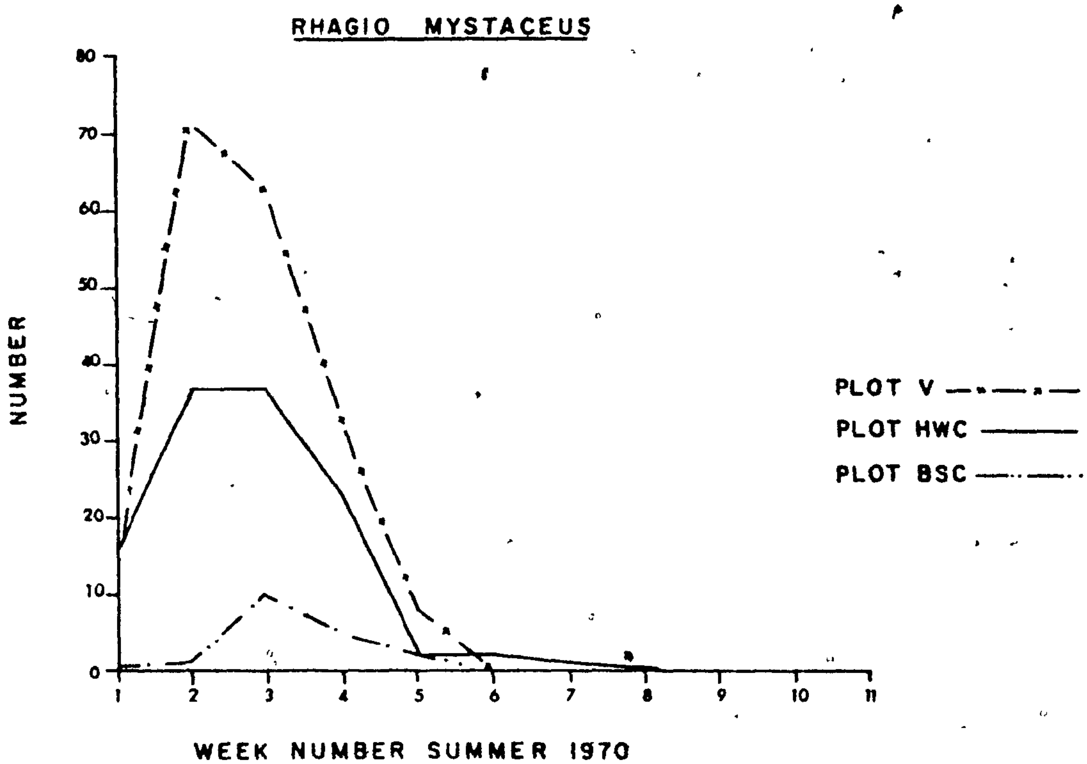
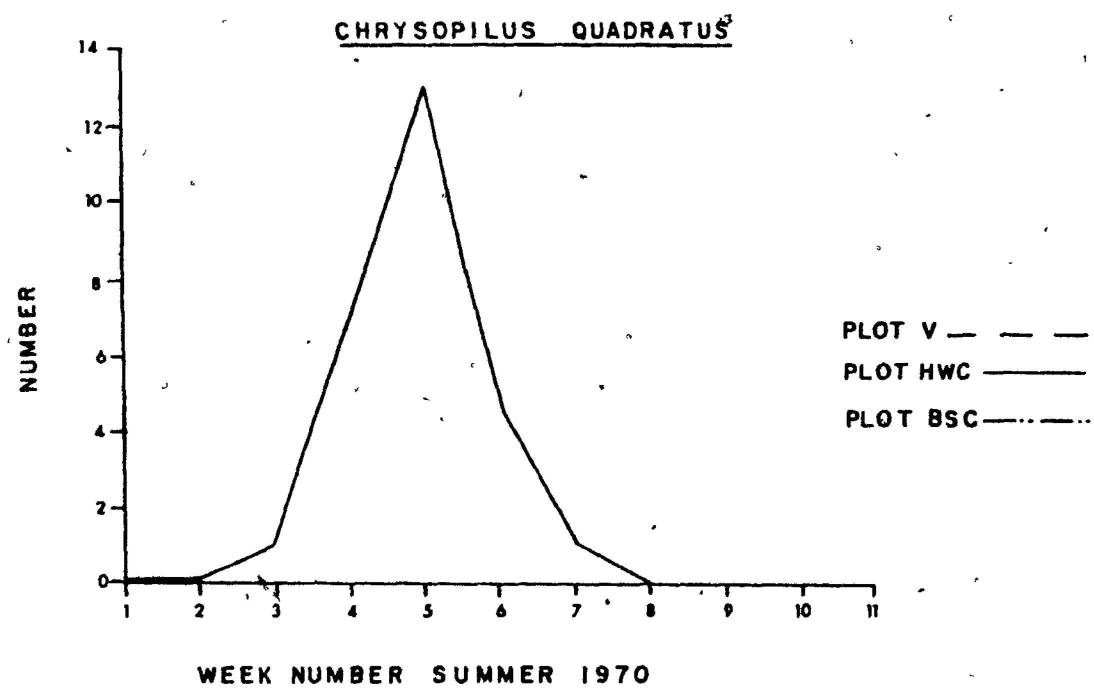


Figure 10. Weekly occurrence of _Rhagio mystaceus_ and _Chrysopilus quadratus_





5. Study of the Rhagionidae

The rhagionid family was studied in greater detail and in the study area is composed of two species: Rhagio mystaceus (Macquart) and Chrysopilus quadratus (Say). Factors such as species abundance in the plots and individual trap site variation within a plot were investigated. Seasonal activity patterns of each species and the use of day-degrees accumulation above a threshold of 42°F for R. mystaceus (total of 546.5 day-degrees until its peak of activity) Table 7 were used in discussing habitat preference of these insects and their place on the evolution scale.

An analysis of variance was performed between plots V and HWC and found to be Heterogeneous. Therefore a modified T-test according to Cochran and Cox (1957) was applied and no significant difference was observed between the T-values.

In Duncan's new multiple-range test performed on plot V (Table 13), traps underscored by the same line are not significantly different.

Table 11. Correlation coefficients and corresponding student's "t" values between Dolichopodidae and the following families: Drosophilidae, Phoridae and Mycetophilidae

	Correlation Coefficient	Student's "t" values
Dolichopodidae and Drosophilidae	0.9721	12.4362 **
" and Phoridae	0.8637	5.1421 **
" and Mycetophilidae	0.7944	3.9243 **

Table 12. Occurrence of rhagionid species in the 3 plots

	Plot V				Plot HWC				Plot BSC			
Trap	1	2	3	4	1	3	4	5	2	3	4	5
Rhagio mystaceus	47	50	25	68	28	37	25	27	7	4	5	2
Chrysopilus quadratus	-	1	-	-	9	9	5	4	2	-	-	-
Trap Totals	47	51	25	68	37	46	30	31	9	4	5	2
Plot Totals	191				144				20			

Table 13. Duncan's new multiple-range test within plot V for catches of Rhagio mystaceus

Trap number	V3	V1	V2	V4
Weekly average catch of *R. Mystaceus*	2.27	4.27	4.55	6.18

The numbers not underscored by a line are significantly different from others in the same plot.

E. DISCUSSION AND CONCLUSIONS

Window flight traps caused a minimum amount of disturbance to the habitat and proved to be very efficient and versatile - capturing insects of all sizes. The traps yielded a considerable amount of material (36,020 Diptera alone) and for the purpose of the present investigation, the specimens were identified to the family level.

The assumptions and discussions that follow will bear in mind that identification to the family level only limits conclusions, and that the families are composed of an unknown number of species. Therefore, unless otherwise stated, differences in the number of flies observed (either from one plot or trap to the other) will not reflect different populations of one or a few species but that of individuals in that family.

The use of only one trapping technique did not allow a determination of efficiency for the window traps in the habitats sampled. This makes it more difficult to determine whether weekly fluctuations in the catches were due to population changes or to changes in activity. The outline of many of the activity patterns is evident, however, and makes interpretation easier. Also, according to Price (1971), who used this trapping method to sample ichneumons parasitic on the jack pine sawfly, Neodiprion swainei Middleton in this very same jackpine stand at Lake Caousacouta, it was found that results thus obtained correlated well with absolute estimates for parasitoid populations obtained from emergence traps and soil samples. He felt that the window flight trap was very useful because it sampled parasitoids of both sexes and covered a good range of population densities.

Plot V yielded the lowest number of Diptera, Figure 4. Conditions in this plot are very different from those prevalent in plot HWC, Figure 2 and Tables 3 through 5. There is only a canopy dominant layer and the plot is open to sunlight; there is little plant species diversity and very little undergrowth. As a result it is a hot and very dry stand, more directly influenced by temperature fluctuations and wind. The soil in this plot is sand and ground cover is sparse. The importance of ground cover with respect to the ability of the habitat to support dipterous population was indicated by Martin (1965). He discovered that loss of ground cover in 1963 was reflected in decreases of 48 and 55 percent from the previous year in pitfall captures in the 1960 and 1950 stands respectively. In older stands, where ground vegetation was not important to the soil-surface fauna, the decrease was only 35 percent. Calnaido, French and Taylor (1965) on the other hand observed that for *Oscinella frit*, aerial and ground populations are directly comparable except that the total aerial population extends well above 30 feet and is therefore understimated.

These factors result in a poorer habitat in plot V for Diptera, adults and larvae. Many fly larvae prefer a humid or watery medium (Oldroyd, 1966) and almost all thrive in a more or less humid environment. The larvae of fungus gnats, Mycetophilidae for example prefer the damper, cooler and more shaded environment of plot HWC and as a result are captured there in much greater numbers as adults than in plot V.

Traps in plot HWC caught the most Diptera because, presumably, it is also the most diverse habitat. There is a great diversity in the plant species composing the different canopy strata; dense undergrowth provided the right conditions of moisture and shade. These factors resulted in a higher population and increased activity of Diptera, reflected by the trap catches. The understory of shrubs and small trees shielded plot HWC from air currents.

The number of flies captured in plot BSC lies between that of plot V and plot HWC. Conditions in plot BSC were also between those of the other two plots. While there are more canopy layers than in plot V and more plant species, the undergrowth is more sparse than that of plot HWC and there are fewer plant species than in plot HWC. The conifers occur in clumps which shield from the wind to a lesser extent than the understories of plot HWC. More shade and humidity is provided in plot BSC than in plot V.

Ground cover surrounding these traps was dense moss, trap 3, however, was surrounded more by leaf litter.

Quality of the habitat is extremely important in supporting populations of Diptera and/or promoting their activity. It would seem that the greater the variety of plant species and the more canopy strata present in a habitat, the greater the population and/or the greater the activity of Diptera. These factors alone, however, may not be more important than others such as optimal conditions of humidity, shade and shelter which result from the vegetation of plot HWC.

Martin (1965) compared various stages of community development in red pine plantations. He states that the greatest dipterous activity occurred in the monoculture stage and that fewer flies were captured in the young forest stage, but the species complex was quite similar to that of the former stage.

From Figure 5, one observes that plot V has no recognizable pattern among the four trap catches from week to week. The weekly fluctuations observed can be accounted for by fluctuations in weather conditions and by phenology of the different species that composed the families sampled.

All trap locations are very similar in this plot and the results obtained agree with the expectation that no one trap should consistently catch more or fewer insects than the other traps in the same plot.

Plot HWC offers a completely different picture from that of plot V. The shapes of the histograms of plot HWC remain almost constant. Only at the fifth week is there a noticeable change among trap catches. This can be explained by the greater capture at this time of Phoridae, Mycetophilidae, Sciaridae and Anthomyiidae by trap 5. Distribution at week 6 resembles week 1, while weeks 7 and 8 are similar.

Trap location in this plot was very important in catching flies. Some locations were more productive than others. This explains why one trap, trap 4, caught consistently more Diptera than the others. It was situated in deep shade and possibly these conditions were preferred by flies or they could not see the glass barrier as readily as in the open and therefore were more easily caught. The surroundings of traps 3 and 5 resembled one another. Their location was not as favourable so they consistenly caught fewer flies than trap 4. Trap 1, situated in the open, consistently caught the fewest Diptera of any of the traps examined in this plot.

Histograms of plot BSC bear some characteristics of plot V and of plot HWC. Consistency exists in that trap 3 caught more flies than the other traps during most of the summer. This dominance in the trap catches is not as clear cut as that of trap 4 in plot HWC. Therefore in plot BSC the most productive location was that of trap 3. The other traps vary considerably from week to week although trap 4 seems to consistently catch the fewest insect

Trap locations in plot V are the most homogeneous with respect to catches of Diptera, plot BSC is not as homogenous in this manner and trap catches for plot HWC are the least homogeneous. All three plots are affected by the same basic factors such as weather conditions and insect phenology. The additional factors such as vegetation species composition and canopy layers are simplest in plot V and are the same for all the traps in this plot. There is an increase in the complexity of these environmental factors in plots BSC and HWC and they vary from one trap to the other inside each of these plots.

From Figure 7, three peaks of acitivty are clearly visible in plot V. The dip at the sixth week is probably due to a decrease in the weekly mean maximum and average temperatures. The over-all aspect of the activity chart shows that it coincides quite well with the weekly temperature fluctuations. The peaks at weeks 7 and 9 can be explained partly by emergence and increased activity of parasitic tachinids, Figure 8, and also by an increased mean maximum temperature, Figure 3.

There is one huge peak of activity in plot HWC at the fourth week after a sharp increase from week 1. The shape of this graph is due mainly to species of two extremely numerous families: Mycetophilidae and Phoridae which emerged at the beginning of the season and saw peaks in activity at the fourth week and also at the tenth week, Figure 7.

The pattern of the activity chart for plot BSC is also explained by seasonal activity of mycetophilids and phorids.

Plots HWC and BSC differ completely from plot V. Plot V has different peaks, troughs at different weeks and fluctuates less abruptly than either of the other stands. The reason for this is that in plot V numbers of Mycetophilidae were negligible. Emergence and activity of tachinids were important in forming the peaks, especially at the seventh and ninth weeks.

There is a similarity in the activity patterns of the three plots, from the seventh week to the end. This may be due to the overriding influence of temperature over the phenomenon of life cycle and biology of the different species.

The importance of temperature fluctuations upon weekly catches of flies in plot V was examined more closely by means of correlations and their corresponding student's "t" values.

In each case the difference between t-calculated and t-tabulated is highly significant. Therefore there is high correlation between weekly activity and weekly mean maximum, minimum and average temperatures. It can be concluded that in plot V, temperature appears to be an important factor which regulates activity of Diptera.

There is variation among the coefficients of correlation. The highest correlation coefficient, 0.6903, was obtained with the weekly mean maximum temperature, the second highest was that obtained with the average temperature; r = 0.6331. Correlation of dipterous activity was lowest with the weekly mean minimum temperature; r = 0.4564. These differences among the temperature correlation coefficients are not unexpected. One expects flies to be more active in flight when the temperature is higher than when it is cooler (Lewis and Taylor, 1967). The present data suggest that the flies were more active while the temperature was near its maximum, especially species of calyptrate flies and asilids which were more active during the warmer weeks of the sampling season, Figure 8.

The data do not allow exact determination of a threshold temperature except that catches were much smaller at weeks 3 and 6 when the mean maximum temperature went down to 67°F (comparison of Figures 3 and 7).

The Diptera-activity graph of plots HWC and BSC demonstrates that weekly sampling of Diptera in these plots was not nearly as dependent on temperature as that in plot V. In plots HWC and BSC the effect of the phenology of Mycetophilidae and Phoridae overrode the influence of temperature on the catches. The jack pine community of plot V is simple and temperature fluctuations are much more likely to affect insect activity. There is only one canopy layer in plot V while the other plots have two or three; Figure 2 and Tables 3 through 5. There is virtually no undergrowth in plot V as it is mostly sand with sparse lichen growth and lowbush and Canada blueberry, Vaccinium angustifolium Ait. and V. myrtilloides Michx. respectively. This resulted in plot V being much more exposed to sunlight or cloud-cover and wind. This probably resulted in greater temperature fluctuations than in plots BSC and HWC where thicker vegetation provided more protection from wind and greater shade and humidity which were a moderating influence.

Also in plot V the greatest proportion of the dipterous fauna was composed of thermophilous calyptrate muscoids and certain heat-preferring brachycerans such as robber-flies, while in plots HWC and BSC the largest percentages were made up of shade and moisture-loving nematoceran families and phorids (Table 9 and Figure 6). These more primitive insects thrived in the different micro-climatic conditions prevalent in plots HWC and BSC.

Kennedy (1928) suggested the distribution of insects in space, season and day in correlation with the intensity of insect metabolism on one hand and energy intensity of the environment on the other. He states that primitive insects usually have a low rate of metabolism and very evolved insects have a high rate. These insects tend to seek out an environment with a parallel energy intensity and choose to be active at the time of day or during the part of the growing season that best fulfills this requirement; i.e. primitive types occur in habitats with low energy intensity - areas that are cool, shaded or even dark while more evolved insects prefer hot environments of high energy intensity such as the tropics, mid-summer or mid-day.

Whittaker (1952) undertook a study which agreed very closely with the findings of Kennedy. Whittaker stated that species are rarely present in one community and absent in adjacent ones; they occur with the populations along various gradients through apparent communities. This was found to be true in the present study at the family level and for the rhagionid species, Chrysopilus quadratus (Say) and Rhagio mystaceus (Macquart) and also the muscid genus Hypodermodes Knab.

In the present study the trends along the moisture gradient are considered similarly to those of Whittaker (1952). The moisture gradient will be studied from the dampest to the driest site, i.e. from plot HWC, BSC to V.

The results agree very well with the findings by Whittaker and the work by Kennedy (1928). The cool mesic plots HWC and BSC (Table 9 and Figure 6) produced a much greater proportion of primitive nematocerans. Plot V yielded more brachycerans, (Such as robber flies) some of which thrive in hot, dry environments. The more modern forms become of lesser importance in the most humid plot, HWC, while BSC is intermediate and in plot V calyptrate muscoids attain the highest proportion.

Referring to Figures 8, 9, 10, one notes that activity of primitive flies in general (Tipulidae, Phoridae, Mycetophilidae, Sciaridae, Dolichopodidae and Rhagionidae) is restricted to the beginning of the season with sometimes a much smaller peak at the end. In this way, their life cycle is synchronized with the cooler part of the growing season.

Therefore, the results indicate an evolutionary trend with more modern Diptera towards the drier habitat and active during the hottest part of the summer. The moist section of the scale is distinguished by a greater proportion of primitive flies which are active during the cooler weeks of the summer. These results support the Kennedy trend which implies that modern insects can cope with the dessicating conditions of a hot, dry environment.

The data also agree with Kennedy (1928) who stated that primitive insect orders, such as Mayflies and Stoneflies, have, as a rule, but one generation a year, while higher insect orders, such as flies, bees, wasps and butterflies, frequently have short life cycles and several generations a year. It was observed, Figures 8, 9, 10, that the more primitive Diptera have fewer peaks in activity than the calyptrate flies.

With respect to these trends, plot BSC appears to be intermediate but closer to plot HWC.

The trend in food habit composition of the three sites revealed a change in ratio between fungivores and compost feeders, more important in the moister plots HWC and BSC to a greater proportion of predators and especially the highly evolved parasitic habit in the dry habitat of plot V. These results show that fungal food is more available in mesic sites. The results concerning the distribution of predators and parasites are in contrast with Whittaker's (op. cit.) observations. While he notes no consistency with respect to either group, I observed a trend of increasing representation of both groups towards the drier plot V, especially parasites which are much more numerous in plot V. Similarly, composition of scavengers did not agree with Whittaker's data. The main reason for these differences lies in the fact that in plot V the parasites were modern tachinids and the scavengers were calliphorids and sarcophagids. Not many nematoceran scagengers and primitive parasites formed part of the dipterous fauna in plots HWC and BSC. In agreement with Whittaker (1952) it was found that pollen-feeders, though present only in a small percentage, were more important towards the drier environment.

The correlation existing between richness in plant species and the amount of vegetation and fly-abundance has already been discussed.

The data are considered to agree very well with the theory and results of the aforementioned authors. It can be concluded, based on Whittaker (1952) that the moist, productive site of plot HWC is dominated by a primitive nematoceran dipterous fauna. At the other extreme, plot V, the dry, hot and least productive site was dominated by highly evolved calyptrate muscoids and higher brachycerans.

In plot HWC, the factor responsible for one trap such as trap 4 catching a great many more flies than any other is deep shade. In deep shade flies may not see the trap as well and are therefore more readily caught. Chapman and Kinghorn (1955) support this and state that in their model window trap, reflection and supporting structures present visual obstruction. It is possible, they continued, that in the forest or brush-covered areas, where there are other obstacles to flight, the traps are more efficient.

The increase in the numbers caught in deep shade is due to a significantly higher catch of shade-loving species in this location. The preference can be either that of the larva or the adult.

Trap 3 of plot BSC which caught a significantly greater number of flies than the other traps in this plot is also situated in a deeply shaded area.

Results from Edgar (1971) agree with these findings, he showed that sticky traps in a shaded area caught more large Diptera than sticky traps placed in a clearing.

Therefore, it can be concluded that the factor of trap location, whether in the open, shade or deep shade completely dominates trap-direction as a factor affecting the catches of flies. This was found to be true for all the plots. In plot V where all the traps were exposed to the same degree, no difference between the traps was observed.

Mathews and Mathews (1970) observed that the quantity and diversity of the insects collected was greatly influenced by trap placement. Their most ecologically varied sampling station was the most productive and yielded the greatest number of taxa. Joyce and Hansens (1968), for their part, concluded that green head flies disperse randomly with respect to both compass directions (trap locations) and prevailing wind directions.

Rice (1933) stated that trap locations had no consistent effect on the number of species captured. This was found to be true in the present study at the family level. No significant difference was observed between the number of families caught in the different plots. Also no difference in the numbers of *Rhagio mystaceus* between the trap sites of plot V was observed.

Rice (op. cit.) also observed that the directions faced by the traps did not consistently influence the number of specimens collected. This observation agrees very well with the results obtained in the present research.

Considering the distribution of Muscidae between plots, plots HWC caught the greatest number of individuals in this family. Plot BSC was next, followed by plot V. In plot V, its percentage of the dipterous fauna is greatest, followed by BSC then HWC.

The two high peaks in plot HWC suggest an emergence and/or an increase in activity of flies of this family, Figure 8. In plot V where fewer muscids were collected, the peaks are similar to the above but the activity here seems to follow the temperature fluctuations more closely.

The activity pattern of flies from plot BSC is completely different from either of the above. Many factors, for example different micro-climate conditions can be responsible for this.

The Calliphoridae and Sarcophagidae have been grouped together because they are very similar in habits and appearance. They are considered as a single family, the Metopiidae, by some authors. (Borror and DeLong, 1964).

They are scavengers as larvae and the adults fly around looking for carrion on which to deposit their eggs and larvae. Plot HWC caught the most in total numbers while plots V and BSC had a similar catch.

The activity pattern in the three plots is quite similar. In all the plots there are two peaks of activity. The greatest captures were made at the seventh week, probably because this was the warmest week of the sampling season.

Members of the family Tachinidae are all parasitic on other insects and are worth considering in relation to the jack pine sawfly, Neodiprion swainei Middleton. Plot V contained a high population of jack pine sawfly which served as host to ichneumonid parasitoids. Price (1971) stated that the host species required by hymenopterous parasitoids was clearly concentrated in plot V. Some tachinid species also attack sawfly larvae, this may explain why a much greater number of them thrive in plot V than in either of the other two plots where the sawfly population is not nearly as concentrated or numerous.

Tripp (1962) observed that numbers of the tachinid, Spathimeigenia spinigera Townsend were not affected by the presence of ichneumonids even though they parasitized the same host, Neodiprion swainei. Parasitism by S. spinigera mostly occurs after ichneumonids deposit their eggs. Tripp states also that adult tachinids seem to favor certain host colonies over others in the same general area. There is indication that one is more likely to encounter adult parasites around colonies exposed to direct sunlight and protected from wind.

The present status of the taxonomy of this family is very confusing and time did not allow complete identification of the specimens, although a few specimens of the genus Cnephaliodes (Brauer and Bergenstramm) were determined.

Four peaks of seasonal activity (Figure 8) can be recognized in plot V. In the other plots, activity is similar but there are only two small peaks.

Plot V was the best habitat for these flies, with lots of direct sunlight, sparse vegetation and a high host density. Of these factors host density is probably the most important. The numbers caught in plots HWC and BSC were very close.

The peak of activity at the seventh week coincides with the general emergence period of sawfly larvae from the egg and an increase in the maximum weekly temperature. The next peak at the ninth week is probably due to increased temperature. Tripp (1960) observed that S. spinigera can attack any larval stage or the prepupae.

Members of the Tachinidae family may provide a biological control of sawflies in plot V. In addition to the above mentioned tachinid which parasitizes N. swainei, Tripp (op. cit.) stated also that Diplostichus bamatus (A. and W.) has been recorded from this host in the past. A more intensive ecological study of the relationship between Tachinids and the sawfly population is certainly desirable.

The Anthomyiidae and Scopeumatidae have been grouped together because they are considered to be part of the same family - Anthomyiidae (Borror and DeLong, 1964).

Plot BSC appears to have the most suitable habitat for these flies, followed closely by plot HWC, then plot V. Many of their larvae feed on plants and this might in part explain why there are so many more in plots HWC and BSC where the plant diversity is much greater.

The trend of seasonal activity is similar in plots HWC and BSC. In HWC activity follows the temperature pattern quite well, while in BSC some peaks appear a week sooner. This might be due to microclimatic conditions but these have not been measured.

Plot V provided too few specimens of this family to allow a worthwhile interpretation.

From the point of view of percentage of the seasonal catch, the Asilidae are not very important, especially in plots HWC and BSC. However, the presence of these efficient predators in greater numbers in plot V than in the others is interesting. This may indicate not only better conditions for these flies, but also the presence of a greater number of prey insects. The results agree well with Hull (1962) who affirmed that most adult robberfly species prefer open, dry, and sandy areas. These species are habitat selective: In some asilids, individual populations in a habitat may be very restricted (Hull, op. cit.) and they may be a considerable distance apart. This explains why they are not caught in large numbers.

Plot V yielded the only two specimens of *Bombomima posticata* (Enderlein) sampled that summer. Most species have certain resting or observation sites and greatly preferred ones (Hull, op. cit.) which may be a limiting factor in the number found in an area.

The remaining species observed were smaller in size than *Bombomima posticata* and included species of *Laphria* (Meigen) *Cryptopogon* (Loew) and *Machimus notatus* (Loew). Their prey is varied, including moths, bees, wasps and other flies.

Another aspect of plot V which makes it more suitable for robberflies is the kind of soil. The soil of plot V is sand with sparse ground cover. Most Asilidae scatter their eggs on the ground and cover them up with soil or sand (Oldroyd, 1966). In the other plots, the ground is mostly covered with moss, lichens or leaf litter.

These flies obviously prefer hot temperature conditions for their activity. Hull (1962) states that asilids become active several hours after dawn but mostly they are active from 10 AM to 2 PM and react strongly to hot bright sunshine. Similarly, from a seasonal point of view, it was observed in the present study that their activity was concentrated more towards the hottest part of the summer.

Tipulidae made up only a very small proportion of the catches in their respective plots. Crane-flies prefer cool, damp areas with plenty of vegetation (Oldroyd, 1966). Oldroyd mentioned that the life histories of craneflies depend mostly on the requirements of their larvae and therefore adults occur where conditions best suit their larvae. Plot HWC caught by far the largest number of crane-flies and this is not unexpected. Moist soil conditions are present here and this certainly accounts for the greater number of these insects sampled in this area. Plot BSC provided more than plot V because it is a more humid habitat and has more vegetation than plot V.

Members of the Tipulidae restricted their activity to the early part of the summer when temperatures were cooler. Figure 8 shows that there was only one generation in 1970;, also, species diversity is restricted, the main genus being <u>Tipula</u>. Examples of this genus were specimens <u>Tipula trivittata</u> Linnaeus; there were also a few captures of <u>Pedicea albivitta</u> (Latreille).

The Sciaridae exhibit a definite habitat preference. The two damp plots caught the most with plot HWC being first. These minute flies prefer moist, shady places (Oldroyd, op. cit.) and their larvae feed on fungi and decaying plant material. The next best habitat is plot BSC which is well ahead of plot V in terms of number of Sciaridae captured. Plot V is too hot and dry an environment for these flies.

Acitivity trends in plots HWC and BSC are quite similar. The peak occurs earlier in plot BSC possibly due to a difference in microclimate which resulted in a quicker temperature accumulation and earlier emergence of these species.

Phorid species demonstrated a marked habitat preference. They definitely prefer a humid, shaded area where there is an abundance of decaying vegetation; this is supported by comparison of the catches between plots.

The peaks are probably due to a series of generations of these flies or emergence of different species.

The activity pattern is similar in plot BSC but less emphasized because of the fewer number of these flies sampled.

Plot V has a different activity pattern in that there is a sizeable increase in numbers from the ninth week until the end of the season.

Mycetophilidae (fungus gnats) exhibit very clearly their preferred habitat. In plot HWC where all their requirements -

shade, moisture, fungi and decaying vegetation - exist, they are extremely numerous (Figure 9). Plot BSC was not nearly as good a habitat for mycetophilids although it was much better for these insects than plot V.

In plots HWC and BSC, fungus gnats make up about a third and a fourth of the total captures respectively, while in plot V they were scarce.

It is obvious that there is a large emergence in plots HWC and BSC at the beginning of the season. Not too much can be said about activity in plot V because not enough of them were caught there.

The greatest number of drosophilids were caught in plot HWC, plot BSC was a distant second, then plot V. Fruit flies live on decaying vegetation and fruit and the larvae of some species also attack fungi (Borror and DeLong, 1964). This explains their habitat preference.

In each of the three plots, the shape of the curve is very similar. This suggests that the same species are common to all plots and that species diversity is limited. The later peak in plot BSC might be due to a different microclimate.

The Dolichopodidae, which are predators, show a very marked preference for plot HWC; plot BSC is a distant second, while plot V has the smallest number of these individuals. The larvae require a fairly humid habitat (Curran, 1965). The adults prefer areas in the vicinity of water and shaded streams. Many species are extremely local in habitat, occurring only where conditions are perfectly suitable. The present data support this very clearly.

The data from specimens collected in plot HWC suggest that only one generation occurs, and plot BSC appears to have one major emergence of adults. The dip at the eight week might well be due to the decrease in temperature during that week. The main increase in the activity of these species in this plot occurs later than in plots HWC and V, possibly because of different microclimatic factors. Plot V did not yield a large sample but the number of Dolichopodidae caught at the sixth week decreased when the mean weekly temperatures dropped.

In plot HWC, the dolichopodids have a very similar activity pattern to those of mycetophilids, sciarids, phorids and fruit flies. This might be due in part to a predator-prey relationship. Plot HWC was chosen for an analysis of this possibility because of the great abundance of individuals in these families in this plot.

a) Comparison of Dolichopodidae and Drosophilidae

The number of individuals of each of these families and their proportion among the three plots is very similar. There is also a similarity in the percentage of each family of the total catch among the plots.

A comparison of activity patterns (Figure 9) shows a remarkable similarity. The correlation coefficient is extremely high and the difference between t-calculated and t-tabulated is very highly significant. Therefore, there is excellent correlation in the activity patterns of these families. It is possible that the activity of each of these families correlates with a common environmental factor such as temperature accumulation which affects their activity in a similar way.

b) Comparison of Dolichopodidae and Phoridae

Percentages of Dolichopodidae and Phoridae from one plot to the other do not vary too much. The correlation coefficient is very high and the difference between t-calculated and t-tabulated is highly significant. Therefore, there is high correlation in the activity trends of these families.

c) Comparison of Dolichopodidae and Mycetophilidae

The correlation coefficient is high and the difference between t-calculated and t-tabulated is highly significant. Therefore, there is good correlation between these two families.

The correlation between the predator and the fungivores and vegetation-feeders is very good. The correlation is closest between dolichopodids and fruit flies followed by the correlation between dolichopodids and phorids and the relationship between the predator and mycetophilids. An interesting relationship exists between these flies but a more complete study is necessary to examine the possibility of a predator-prey relationship.

Fabricius (1775) first proposed the genus Rhagio but later (1805) changed it to Leptis in order to avoid confusion with the beetle genus Rhagium, Fabricius (1775).

Leonard (1930) revised the Rhagionidae which had been formerly termed the Leptidae. He observed that adults are usually found in meadows or in open woods, frequently in the vicinity of a stream. They rest upon leaves of low shrubs or, head downward, upon stems or tree trunks. Some species are found on the foliage of weeds and in low grass.

The larvae are undoubtedly to a great extent predaceous and live in a variety of situations. Some species pass their larval stages in the soil, in decaying wood, or in passages of wood-boring beetles.

The following year (1931) Leonard commented on his revision of the family Rhagionidae.

Hardy and McGuire (1947) described the genus Ptiolina which was not well known and was poorly represented in collections.

Most of the known nearctic species are from Canada, Alaska and the Northern United States. Except for records of Ptiolina fasciata (Loew) in Colorado, the genus has not been recorded from the western States. Hardy and McGuire (op. cit.) described two new species of Ptiolina from New-York and one from Alaska. Notes and descriptions of the known nearctic species are also given.

Sailer (1951) observed the biting snipe fly, Symphoromyia atripes (Bigot) in Alaska. The flies appeared to prefer open areas between clumps of vegetation. They acted much like certain horse flies of the family Tabanidae, but were slower and more easily caught. Under favourable conditions they were more aggressive than the horseflies encountered in Alaska during 1948. The bites are painful, usually draw blood and result in some swelling.

A contribution to the biology of Vermileo degeeri (Macquart) was made by Le Faucheux (1961) who examined more particularly the larval stages of this insect.

Chillcott (1961) concentrated his work on the genus Bolbomyia (Loew). These rhagionids are extremely small members of this family. In the spring, males usually occur on leaves of shrubbery, while females are frequently collected from flowers.

James (1964) studied the taxonomy of the Rhagio dimidiatus group in western North America and discovered that it consists of four species, all but one polytypic. Traditional taxonomic procedure has not been successfully applied to this complex, since component taxa are variable and poorly defined. Consequently, a quantitative approach is used.

Chillcott (1965) described three new species of the genus Rhagio (Fabricius), stating that this genus is a difficult group with relatively minor characters differentiating the species.

The author introduced, in the taxonomy of this groups, such characters as the distribution of thoracic hairs and bristles. In this description, where possible, familiar terminology is retained, but for greater precision some morphological terms have been employed.

In his general description of the family, Curran (1965) mentions that they are small to medium sized and nearly bare or pilose flies. Snipe flies are predaceous in both the adult and larval stages.

Rhagio mystaceus (Macquart) seems to favor the environment of plots V and HWC over that of BSC, while Chrysopilus quadratus (Say) prefers the humid site of plot HWC. The family as a whole was not well represented in plot BSC.

Rhagionids are found in woods (Curran, op. cit.) near humid places. They are not very fast fliers and can be found on foliage, tree trunks or posts and long grass. *Rhagio mystaceus* appears to be quite adaptable and does not exhibit any clear habitat preference. In plot V, Duncan's new multiple-range test revealed no significant difference between the trap catches for *R. mystaceus.* In plot HWC, trap catches for this species varied even less than those of plot V (Table 12). Therefore, trap location within the plots was not an important factor influencing the capture of adult *R. mystaceus*.

Chrysopilus quadratus demonstrates a clear affinity for the mesic site of plot HWC. This species seems to be more habitat specific than *R. mystaceus.* Oldroyd (1966) states that *Chrysopilus* species prefer damp vegetation of the dense, shady type growing along the edges of woods and margins of streams.

The small catches of these two species in plot BSC might be due to limiting factors such as insufficient landing perches for *R. mystaceus* and vegetation which is not dense or humid enough for *C. quadratus*. Possibly too, ground cover and soil conditions may not be ideal for the larvae of these species in plot BSC. Larvae of *Rhagio* and *Chrysopilus* occur in damp soil, rotting wood and leaf mould (Oldroyd, 1966).

Rhagionids are an interesting family of flies because according to Oldroyd (op. cit.), they are at the base of the evolutionary tree of the Brachycera. Some species have more evolved habits, others are more primitive. Some species suck blood, others are predators and still others are flower feeders. Larvae of the sub-family Vermileoninae lead a very terrestrial way of life while other rhagionids have larvae well adapted to aquatic life.

Rhagio mystaceus reaches a peak in activity at the second week through the third week in all the plots (at the third week in plot BSC). The shape of the activity graphs of plots V and HWC are similar. In plot V, R. mystaceus were not observed after the fifth week while in plot HWC none were collected after the seventh week of sampling.

Because snipe flies were already around when the collecting started the day-degrees summation was continued until the peak in activity of R. mystaceus at the second week.

The total temperature accumulation until June 24, 1970 inclusive when the activity of this species reached a peak in plot V was 546.5 day-degrees above 42°F.

The peak emergence occurs the following week in plot BSC, probably due to different microclimatic factors, but these were not measured.

Chrysopilus quadratus reached a peak in activity at week 5 in plot HWC which is much later than the peak reached by R. mystaceus in the same plot. C. quadratus probably requires a greater temperature summation in order to attain its peak of activity.

These two species suggest a certain primitiveness as defined by Kennedy (1928); primitive flies restricting their activity to the cooler portions of the growing season and having only one peak of activity. The rhagionids in this study exhibit only one peak in activity and it occurs at the beginning of the season for R. mystaceus and that of C. quadratus is still in the first half of the sampling season.

The study aims at comparing and contrasting different habitat types with respect to flora and insect fauna. The trapping technique and procedure of data collection were very well suited to this type of research. Regular collections were possible and the number and variety of insects was enormous, 36,020 Diptera alone.

Because of the large amount of work involved in handling and identifying the great number of insects, and given that the identification of some insect groups to the species level is confused, the work load was reduced by identifying flies to the family level only.

The greatest drawback lies in the fact that explanation and conclusions are limited, because families are composed of a number of species which are lumped together. Therefore, it is impossible to determine whether one or many species result in a peak of activity. It is also difficult to determine the part played by emergence of new generations in the shapes of the activity patterns and the time of the season during which the individual species were most numerous in the field.

This is the reason for discussing first the more general aspects of the work, such as the differences in total catch from one plot to the other; seasonal activity of all the Diptera from a plot compared to that of the two other plots; and investigations of trends in the evolutionary level of the flies. From this point, the study concentrates more on intraplot and trap location differences, e.g., trap direction, density of vegetation around the trap which resulted in different conditions of shade, humidity, etc. More specifically, the following sections investigated and discussed different activity patterns, occurrences and such of the important families of Diptera.

Realizing the difficulties and limitations imposed by considering only dipterous families in this study, it was decided to investigate one family, the Rhagionidae, in detail. The main reason for this being that little or no work of this kind has been attempted on this family or the two species observed: Rhagio mystaceus and Chrysopilus quadratus.

This type of investigation could have been performed on each family of Diptera collected, the only limiting factor being the time expended in mounting, identifying and counting the insects.

In a project such as this one where only one trapping technique was used which yielded so many specimens, one must know the shortcomings and difficulties of one's methods in order to use the data and interpret them to advantage. It is felt that in spite of these limitations, very significant findings in comparison of communities, trap site differences, trap direction comparisons, evolutionary trends, relationships between activity and temperature, correlations between the activity patterns of certain families, examination of these different activity patterns, the study of the Rhagionidae, and more, resulted in an interesting and informative study.

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