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Comparative Study of the Photopositive Coleoptera of the Embarras River Floodplain and Upland Ridge

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Comparative Study of the Photopositive Coleoptera of the Embarras River Floodplain and Upland Ridge

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BY

Ann Decker

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DEPARTMENT HEAD

The undersigned, appointed by the Head of the Department of Zoology,

have examined a thesis entitled

Comparative Study of the Photopositive Coleoptera of

the Embarras River Floodplain and Upland Ridge

Presented by

Ann Decker

a candidate for the degree of Master of Science

and hereby certify that in their opinion it is acceptable.

Table of Contents

List of Tables and Figures

Table

Figure

Introduction and Historical Background

The moth hovering around the flame has fascinated man for centuries. The poets were first to write of this but early records by scientists are few. At first the development of the light trap was slow. The earliest accounts are of entomologists merely capturing insects as they were attracted to the flame. Rev. C. S. Bird (1835), cited by Frost (1952), published such an account. He described the insects that came to his lamp during various periods of the night and identified Lepidoptera, Ichneumonidae, and Tipulidae.

Capturing insects by hand near light was quite ineffective for many escaped. Entomologists learned to erect a white sheet to allow for easier capture of the insects. Finally, in order to utilize the insects' positive phototropism most fully, traps were developed (Williams, 1939). Lallemant (1874), cited by Frost (1952), was among the first to describe an actual light trap. It consisted of a lantern in a pan of oil. From 1860 to 1880 there was great development of light traps in North America. According to Frost (1952) they were then designed chiefly to control the cotton moth.

Considerable evolution has taken place in the development of both traps and of the radiation used with these traps. Candles and kerosene with their thin yellow flames were the earliest. These were followed by acetylene with its white light, incandescent light, mercury-vapor lights, and finally fluorescent electric lamps (Stanley and Dominick, 1957).

I. Functions of Light Trapping and Light Trap Collections

The earliest light traps functioned merely as a means to capture insects for waiting entomologists. Today their functions have become much more specialized. Light trapping and light trap collections have five basic functions: general surveys, specialized surveys (for detection, quarantine, and vector studies), insect control, behavioral studies, and studies for development and improvement of light traps.

The General Survey:

This is the broadest category and can be further broken down into eight subcategories. The first and one of the most basic uses of light trapping is as a means to build museum collections and provide specimens for faunal studies. Bogush (1936) described light trapping in Central Asia, realizing that this is a very effective means of gaining rapid knowledge of an unknown area. Under somewhat similar circumstances, Gaskin (1970) found the light trap of utmost value in collecting the basically unrevised lepidopterous fauna of Palmerstone North, New Zealand.

This function of light trapping is also of significance in Great Britain and the United States. One of the pioneers of light trapping, C. B. Williams (1939, 1940), published an analysis of the factors influencing capture of light trapped insects at Rothamsted Experimental Station in England. French (1951) carried out similar work on the Lepidoptera in the same vicinity. In the United States much of this type of research has been carried out by S. W. Frost who has done a great deal of this work at the Archbold Biological Station in Highland County, Florida. Frost (1962, 1963, 1964) has done general surveys and also (1967) published on specific groups of insects. A list of the Culicoides of New Orleans was compiled mainly from light trapped specimens by Khalaf (1967a). Two other authors, Chapin and Callahan (1967), also working in Louisiana, compiled a list of the Noctuidae collected by light trapping in the vicinity of Baton Rouge. In conjunction with this type of research, Frost (1964) states that there is a basic need for a detailed catalog of species known to be attracted to light.

The second function of the general survey is as a means to obtain specimens for purely taxonomic work. This function was suggested as early as the 1930's (Williams, 1939). Some studies are purely taxonomic in nature. Khamala (1971) did a taxonomic study on some East African Culicoides which were obtained by light trap. Gaskin (1970) found that his light trap study of some New Zealand Lepidoptera provided an excellent source for material to be used in revisions of this fauna.

Other light trap studies, although not necessarily designed for taxonomic work, do provide material for such studies. M. W. Service (1971), while light trapping in Nigeria, discovered a new species of

Anopheles. K. T. Khalaf (1967b) was studying the seasonal fluctuations of Culicoides in Southern Louisiana. By examining specimens of two "species" with identical seasonal activity, he decided that they were probably conspecific.

The third type of general survey, although not used to any great degree, does have potential. This is light trapping for determination of geographical and ecological distribution. Bogush (1936) found that if a species was collected primarily in a particular area, it could often be associated with the plants growing there. Khamala (1971) correlated certain East African Culicoides with different vegetational and ecological zones.

The fourth type of general survey, used in conjunction with light trapping, is the survey to determine seasonal activity. Light trapping is considered to be an accurate method of determining seasonal activity. Benedek and Jaszai (1971) felt that it was accurate enough to be used as the standard in a test of the "museum method" for studying seasonal activity of insects.

Many of the insects used as subjects for such studies are economically important. Bradley and McNeel (1935) were early workers in the field of determining seasonal abundance of Mansonia and Anopheles. Hammon, Reeves, and Izumi (1942a) used light traps in the Yakima Valley, Washington, to study the seasonal activity of various mosquito species in an attempt to discover the vectors for encephalitis. K. T. Khalaf (1967b, 1967c) used light traps to study the seasonal fluctuation of inland and coastal Culicoides of Southern Louisiana.

Several economically important species have been studied by means of light trap in order to determine seasonal activity. Madsen and Sanborn (1962) studied the seasonal activity of the naval orangeworm, peach twigborer, codling moth, and other fruit pests. Merkel and Fatzinger (1971) studied the seasonal flight activity of five pine-infesting Lepidoptera for use in control schedules. As late as 1972, studies of the seasonal activity of click beetles in the Everglades have been undertaken (Genung, 1972).

General seasonal studies have been carried out by several entomologists. Bogush (1936) recognized the times of activity of some species of Central Asia. Hassanein (1970) made an attempt to determine seasonal activity for many of the species captured by light trap in Egypt during his study. A seasonal study of insects found near a cocoa area in West Africa was undertaken by Gibbs and Leston (1970).

Studies of seasonal activity of some particular groups of insects have been carried out by light trap. Poole (1970) worked on temporal variation in woodland caddisflies of Central Illinois. Frost (1967), who has done much general seasonal work, has published on the seasonal activity of mayflies at the Archbold Biological Station.

A type of general survey, closely related to the survey to determine seasonal activity, is the survey to study reproductive cycles and their progress. Bogush (1936) suggested that with light traps it might be possible to estimate or forecast a serious infestation of insects before it occurs. This same method has been used with various economically important insects. Barnes, Wargo, and Baldwin (1965) successfully studied codling moth reproductive cycles with the light trap. This method allowed treatment of the pest at the correct time and was useful in determining what protection was needed against a second generation. Blacklight insect traps have also proved successful in detecting threatening infestations of cabbage loopers and bollworms (Falcon et al., 1967). Hanna (1970) found the light trap useful for determining the number of generations per year of several insects not previously studied in certain parts of Egypt.

Studies to determine nocturnal activity are the sixth type of general survey by light trap. Williams (1935) devised a light trap which collected insects in eight different periods during the night. He utilized this trap in a study of nocturnal activity of certain Lepidoptera. Bradley and McNeel (1935) researched the activity of Anopheles and Mansonia during the night hours, making hourly collections. Similar work by Pinchin and Anderson (1936) was carried out on Tipulinae. Frost (1963) made general collections of insects during twelve nightly periods. He also did a specific study of nocturnal activity of mayflies in the area. During this study, insects were collected in four periods during the night (Frost, 1967).

The seventh type of general survey by light trap is the survey to determine relative population levels. Bradley and McNeel (1935) were among the early workers in this field with a study on the relative abundance of mosquito species. They felt that light trapping could provide a valuable index of the relative abundance of mosquito species, suggesting that all-night collections provide more accurate measurement than do short collections. Locke (1971) reports that in Orleans Parish, Louisiana, twenty-five light traps are operated continuously in order to determine the number, species, and location of adult mosquitoes for use in the control of these insects.

Another important study of this general type is determination of population levels of certain crop pests. Several entomologists during the 1950's studied the relative population levels of bollworms. Glick, Hollingsworth, and Eitel (1956) found the number of bollworms collected in blacklight traps corresponded closely with the infestation in the field. In another study, a definite correlation was found between the number of bollworms trapped and the number of eggs in the field, according to Pfrimmer (1957).

Several authors have attempted to set up mathematical methods to calculate the theoretical catch level of insects taken by light trap. Williams (1937, 1940) proposed a mathematical means of calculating the catch level of insects. It took in consideration the activity of the population at a particular time and the size of the population available. Another method of this type was proposed by King and Hind (1960).

Whether light trapping provides figures accurate enough to determine relative population levels is still under debate. Gaskin (1970) feels that there are serious drawbacks to the accuracy of this type of study.

The last type of general survey is the detection survey by light trap at Ports of Entry. This, according to Hartsock, Deay, and Barrett (1966) is a method commonly used to monitor insect populations at locations where foreign species might be introduced.

Specialized Surveys for Detection, Quarantine, and Vector Studies

Hammon et al. (1942a) reported on a field survey of the Yakima Valley, Washington as part of a study of epidemic encephalitis. By use of modified New Jersey Light Traps, Hammon et al. (1942b) studied the seasonal activity of certain mosquito species. They were able to eliminate certain species as the possible vectors and were able to identify one species as the probable vector for western equine and St. Louis encephalitis.

In California during 1969 environmental conditions were very similar to those of 1952 when California experienced its largest epidemic of western and St. Louis encephalitis. It was feared that these conditions might lead to a similar epidemic. Surveilance was undertaken using CDC Light Traps to collect mosquito vectors. As a result of this study, Sudia et al. (1971) concluded that an outbreak of western and St. Louis encephalitis appeared likely to occur during the Summer of 1971, if precautions were not taken.

Insect Control

Because of the attraction many insects have for light, the idea has long existed that light traps might be used effectively to control certain of these insects. Bogush (1936), seeing the great numbers of insect pests attracted to his light traps in Central Asia, suggested that the traps might be a successful means of control against some species, particularly a cerambycid, Aeolesthes sarta.

Much of the early work was conducted with pests such as the codling moth. Collins (1937) felt that electrocuting light traps had been tested sufficiently to show that they reduced codling moth population and injury to a measurable degree. In the same year another study revealed that a trap baited with molasses and water was more effective at killing codling moth adults than an electrocuting light trap (Worthley and Nicholas, 1937). However, Collins and Machado (1943), feeling that Collins' 1937 results were valid, repeated the experiment and concluded the light trap was equal to two cover sprays of lead arsenate in controlling the codling moth.

Similar experiments were conducted with other injurious insects. Glick et al. (1956) revealed that one electrocuter grid trap in a caged twenty acre plot of cotton did not prevent a buildup to 100% bollworm infestation. Working with tobacco and tomato hornworms, Stanley and Dominick (1957) concluded that the light trap did not give the desired control but did cause a slight surpression of damage. They felt that the light trap was not practical for such use.

Behavioral Studies

Barr, Smith, and Boreham (1960) recognized the fact that light traps offer a potential for purely behavioral studies, however, they have not been used to any great extent in that field. The primary purpose of most of the behavioral studies to date has been to improve light trap efficiency. Most research has been carried out with economically important insects. Collins and Machado (1943) worked with the codling moths' response to artificial light. Similar research was carried out by Glick and Hollingsworth (1954, 1955) with the pink bollworms' response to ultraviolet and visible radiation. Glick et al. (1956) did still more work with the pink bollworm. Research on the response of tomato hornworm and tobacco hornworm moths to blacklight was carried out by Stanley and Dominick (1957). The corn earworm (Deay, Barrett, and Hartsock, 1965) and the spotted and striped cucumber beetles (Barrett, Deay, and Hartsock, 1971) were also studied for their response to light traps.

Some behavioral studies have been carried out on those insects not considered to be economically important. Some general work has been done on the flight behavior of nocturnal Lepidoptera near light traps (Robinson and Robinson, 1950 and Robinson, 1952). Other research has been more specific and a great deal of it has dealt with insect response to blacklight. Several experiments have been carried out by Frost (1953, 1954) dealing with the response of insects to black and white light. He has also studied such behavior with different sources of ultraviolet light (Frost, 1955). Pfrimmer (1955, 1957) undertook similar research. Hollingsworth, Hartstack, and Lindquist (1968) completed studies on the influence of near ultraviolet output of attractant lamps on catches of insects.

II. Light Traps and Their Structure

Several light trap designs are well-known and widely used. Among these are two traps designed primarily for the capture of Lepidoptera. These are the Rothamsted Trap (Williams, 1924, 1948) and the Robinson Trap (Robinson and Robinson, 1950). Due to the economic importance of mosquitoes, several traps have been designed for use in their capture. The most well-known are the New Jersey Trap (Headlee, 1932) and the CDC Miniature Light Trap (Sudia and Chamberlain, 1962). Two of the most popular traps designed for general use are the Pennsylvania Light Trap (Frost, 1957) and the Minnesota Light Trap, designed by the Department of Entomology at the University of Minnesota (Frost, 1952). These six traps are widely used in their original forms and all have undergone modification for specialized studies by their designers as well as by other entomologists.

A great many light traps have been designed and used successfully by entomologists. According to Frost (1952), there have been light traps designed specifically for collection of leafhoppers, mosquitoes, gnats, Scarabaeidae, cutworm adults, leaf-rollers, codling moths, bud moths, cornborers, cigarette beetles, fleas, and aquatic insects. The largest percentage of these have never come into wide popularity. The reason for this is twofold. First, some have been designed for use with some limited group of insects and second, some traps, although designed for general collections, have proved impractical for other reasons.

Entomologists have devoted a great deal of time and effort to studying light traps primarily with the intention of improving their efficiency. Many studies have dealt with testing existing and widely-used traps. The effectiveness of the Robinson Trap has been tested by H. S. Robinson and J. M. Robinson (1950) and by H. S. Robinson (1952). A comparison of the efficiency of the Robinson Trap with the Rothamsted Trap was carried out by Williams (1951) and Williams, French, and Hosni (1955).

The New Jersey Light Trap has undergone a great deal of study. Its designer continued to study its efficiency for several years after it was designed (Headlee, 1932, 1934). It was tested in Florida under very different conditions by Bradley and McNeel (1935). Rowley and Jorgensen (1967) compared the relative effectiveness of three versions of the New Jersey Trap for collection of certain _Culicoides_. Another mosquito light trap, the CDC Miniature Trap, was compared with the Malaise Trap by Gunstream and Chew (1967).

Several other studies have been carried out on traps for Lepidoptera. Worthley and Nicholas (1937) compared the efficiency of light and bait traps in collecting codling moths. Harrell, Young, and Cox (1967) compared fan and gravity traps for effectiveness in collecting Lepidoptera.

Structural Features of Light Traps

A light trap consists of two basic and essential features. These are a light source and a method of collection. The evolution of the light source for light traps is of interest. The kerosene lantern was one of the earliest sources of light and the development of the incandescent bulb of 1878 was only a small improvement. The earliest incandescent light had a yellow carbon filament. The replacement of this with a tungsten filament and the addition of frosted glass provided a much better light source (Frost, 1952). The incandescent light provides a continuous spectrum with a small amount of ultraviolet. It is rich in red, yellow, and infrared (Deay et al., 1965). An incandescent light may be used with filters in order to obtain a desired wavelength (Hartsock et al., 1966).

The acetylene lamp was developed in 1896. It is a white light, high in blue and violet and low in the red portion of the spectrum. The advantage that this light holds over the incandescent is its portability (Frost, 1952).

The gaseous discharge lamps were the first sources of near ultraviolet light (Frost, 1952). Included in this category are the mercury vapor and germicidal lights which, in addition to the near ultraviolet, also emit blue and green but very little infrared (Deay et al., 1965). Argon is sometimes used by itself in these lamps but is more often added to mercury vapor bulbs to facilitate their operation (Burks, Ross, and Frison, 1938).

Today's blacklight lamps radiate a large portion of their energy in the near ultraviolet or blacklight portion of the spectrum (Stanley and Dominick, 1957). Blacklight consists of wavelengths of 320-380 nm. Blacklight-blue is of the same wavelength but is filtered to absorb most of the visable light. The sunlamp is similar to both of these (Deay et al., 1965).

The second essential feature of a light trap is the method by which the insects are collected. There are two means by which this may be achieved—live collection or the use of a killing agent. Various methods of live collection have been attempted. Williams (1948) used a large box with a Rothamsted Light Trap. Bretherton (1954) used live window trapping and was also able to obtain live collections with a Robinson Trap. A modified New Jersey Light Trap was used by Reeves and Hammon (1942) in order to obtain live mosquitoes. Frost (1952) suggested the use of a large cloth sack for live collections of such insects as mayflies when large numbers are expected.

A great many killing agents have been used in conjunction with light traps. Sodium cyanide, potassium cyanide, calcium cyanide, carbon tetrachloride, carbon bisulphide, and tetrachlor-ethane are widely used (Williams, 1948). Kerosene has been found an effective killing agent and will keep insects in good condition (Frost, 1957). Eighty per cent isopropyl alcohol has been found to be an excellent killing solution (Merkel and Fatzinger, 1971). An early method of killing insects which is still used under some conditions is a pan of water with a layer of floating oil upon it (Frost, 1952). The use of dry ice as a killing agent was suggested by Williams (1948). Barrett et al. (1971) experimented with cyanide and diesel fuel used as killing agents in order to see what effect, if any, they might have on catches of cucumber beetles. They found no difference in catch size or composition of catch with the killing agents. However, identification of diesel fuel-collected beetles was difficult.

The early light traps were rather uncomplicated and consisted of these two basic parts—the light and means for trapping. Modern traps, however, have become quite complex and often have many additional parts to aid their efficiency. Among these optional structures are funnels, baffles, fans, screens, and biological supplements (Hartsock et al., 1966).

III. Factors Affecting Light Trap Efficiency

The correct choice of trap is considered to be one of the most basic factors influencing light trap efficiency. If collecting mosquitoes is the intent, then the logical choice of trap would be the New Jersey Mosquito Trap or the CDC Miniature Light Trap. For collection of Lepidoptera, the entomologist would have the choice of several traps, although these vary in efficiency to some degree with the species sought. The Robinson Light Trap is more efficient for collection of noctuids and sphingids but may actually repel Lithosiinae (Bretherton, 1954). The Minnesota Light Trap, although often used for general collections, is a very effective trap for collection of geometrids and noctuids (Frost, 1952). Another light trap used primarily with Lepidoptera is the Rothamsted Trap.

A second factor to be considered is the light source. Many studies have been undertaken to determine which light source, on the whole, is most effective for general collection of insects. Williams (1951), in one of the earliest such studies, compared the Rothamsted and Robinson Traps with incandescent and mercury vapor bulbs. He found the Rothamsted Trap with the mercury vapor bulb the most efficient. In a second experiment, Williams et al. (1955) again compared the Rothamsted and Robinson Traps and incandescent and mercury vapor bulbs, using slightly different methods. They concluded that the ultraviolet light was more efficient for all orders of insects and that the Robinson Trap was more effective for large Lepidoptera but much less efficient for small Diptera.

Frost (1953) experimented using a 2 watt blacklight, a 15 watt white, a 100 watt blacklight, and a 50 watt white light. He found the total catches at white light slightly greater but some groups were more attracted to the blacklight than to the white light. In a later test, Frost (1954) compared 100 watt blacklight to white light with wattage varying from 10 to 100 watts. In practically all cases, the blacklight attracted more insects than the white light regardless of trap position or light intensity. In a third experiment, Frost (1955) studied the response of insects to ultraviolet light. A 100 watt blacklight, with all visable radiation filtered out, was compared to a 2.5 watt blacklight. The 100 watt ultraviolet was found to be far more attractive to insects.

Bretherton (1954) conducted a test of "window trapping" (incandescent bulb) with "window trapping" (mercury vapor bulb) with a Robinson

Trap (mercury vapor bulb). The "window trap" with the mercury vapor bulb provided an increase of 128% over the window with the incandescent bulb. The Robinson Trap, with the mercury vapor light, provided a further increase of 183% over the mercury vapor bulb.

Pfrimmer (1955) compared blacklight, blacklight-blue, and argon. The blacklight-blue captured 12.5 times the number captured by the argon, which captured 2 times the number captured by the blacklight. Pfrimmer (1957) conducted a second experiment with these three sources of light. In this study he determined that blacklight-blue attracted the greatest number of species, blacklight provided the greatest catch of some species, and mercury vapor caught the greatest number of a few species.

Today, ultraviolet blacklight is recognized as one of the most effective attractants for insects, however, different insects may be attracted to different wavelengths of light (Hartsock et al., 1966). This, in itself, is another variable influencing the effectiveness of light traps.

Due to the numerous economically important species, a great deal of research has been done with Lepidoptera in regard to the relative attractiveness of various wavelengths of light. When the intent of the entomologist is to collect the greatest number of species, Robinson and Robinson (1950) state that the optimum light source is that with highest possible surface brightness and correct wavelength emission in relation to the insects' sensitivity. In a study comparing 15 watt fluorescent (with visable radiation), 15 watt cool white, germicidal, 15 watt fluorescent filtered, and 100 watt mercury vapor, Belton and Kempster (1963) found that the most efficient was the 15 watt fluorescent with visible light.

Glick and Hollingsworth (1954) compared the attractiveness of blacklight and mercury vapor to the pink bollworm moth. They found blacklight to be more effective. In further studies of 23 sources of radiation, the pink bollworm most readily responded to a mercury vapor bulb with a blacklight transmitting filter, blacklight, and blacklight-blue (Glick and Hollingsworth, 1955). The following year, Glick et al. (1956) tested a blacklight trap and a two watt argon low intensity blacklight. The argon light was highly attractive to the pink bollworm and was desirable because it attracted smaller numbers of other insects.

The optimum light source for collection of corn earworm moths has been determined to be 15 watt blacklight and blacklight-blue over incandescent, gaseous discharge, and sunlamp (Deay et al., 1965).

Similar research has been carried out with Diptera. Hecht (1970), in his studies of Musca domestica, found the flies are attracted to the lights which seem brightest to them—white, violet, and blue being the best. The flies show a high responsiveness to wavelengths between 320-380 nm. with a strongest response to 365 nm. Rowley and Jorgensen (1967), in sampling Culicoides, compared the efficiency of 40 watt incandescent to 15 watt blacklight. The blacklight was the most attractive to the midges but also to many other insects and was, therefore, disadvantageous for collecting midges because of the great volume of other insects taken.

Some Coleoptera do not respond to lights as fully as other insects. However, regardless of intensity of light or trap position, they seem to respond more freely to blacklight, with some exceptions (Frost, 1954). In comparing the attractiveness of 100 watt ultraviolet and 2.5 watt ultraviolet, Frost (1955) found that 90% of the Coleoptera collected were taken by the 100 watt light trap. Barrett et al. (1971), in studying spotted and striped cucumber beetles, learned that the beetles were attracted to 15 watt blacklight, green, and incandescent bulbs but were not attracted to red fluorescent or gold lights.

Another factor which can affect the efficiency of light traps is luminous intensity. It is distinct from brightness, which is a measurement of intensity per unit area. Luminous intensity, according to Belton and Kempster (1963) is proportional to surface area. Therefore, an 18 inch blacklight tube has twice the luminous intensity of one 9 inches long. In their study Belton and Kempster found no significant difference in catch between the 9 and 18 inch lights. The exact significance of luminous intensity is not completely understood. Deay et al. (1965) found that five 15 watt blacklights caught more corn earworms than three 15 watt blacklights. Barrett et al. (1971) got very different results with cucumber beetles. They found that one 15 watt blacklight captured the same number of beetles as did a trap with five 15 watt blacklights.

Robinson (1952) observed that in all orders of insects bright lights brought about some inhibition from flying. The "inhibited" insects often settled near the light but in a shadow out of reach of its rays. Later, the insects taking wing were brought nearer the trap and finally into it. He stated that some of the insects were apparently repulsed by the light and were able to avoid the trap.

Glick et al. (1956) noticed that some Lepidoptera which approached his light trap seemed repelled by a high intensity bulb such as a mercury vapor light. Barr et al. (1960) observed a similar response by mosquitoes. They found that the number of mosquitoes captured increased in proportion to increased light intensity but that mosquitoes tend to be repelled by very high light intensities. Hartsock et al. (1966) summarized such behavior by stating that insect catch increases with wattage input but that the increase in catch is proportionally less than the increase in wattage.

The light source, although essential to the insect light trap, is not the only feature of significance in its structure. Traps vary a great deal in their complexity. There is disagreement between entomologists over the relative efficiency of unidirectional and omnidirectional traps. Deay et al. (1965) found omnidirectional traps more effective at capturing corn earworm moths than the unidirectional traps. However, the unidirectional traps were more effective at certain heights than the omnidirectional traps at the same heights. Hartsock et al. (1966) also felt that the omnidirectional trap was more efficient because of the greater exposure of the lamps. Barrett et al. (1971), working with spotted and striped cucumber beetles, concluded that omnidirectional light traps were significantly more effective for the capture of spotted cucumber beetles and although this trap also captured more striped cucumber beetles, it was not significantly more. Despite all the evidence supporting the omnidirectional trap, for certain purposes the unidirectional traps are more efficient. Merkel and Fatzinger (1971), working with pine-infesting Lepidoptera, found that unidirectional traps, placed pointing upward, were far more efficient than the omnidirectional traps. This, of course, was due to the fact that the species sought were arboreal.

A great deal of uncertainty has arisen regarding the significance of the optional features of light traps. Fans, baffles, funnels, heaters, screens, covers, and biological attractants have all been used at various times with light traps. Fans have generally proved to be successful. Frost (1952) states that at first fans were used primarily with mosquitoes and cigarette beetles. Eleven years later, while researching the factors affecting the efficiency of light traps in collecting mosquitoes, Barr et al. (1963) found that traps with fans did catch significantly more mosquitoes but did not catch many more other insects. The size of the fan blade did not seem to influence the catch.

Fans have been tested successfully with other insects. Glick et al. (1956) collected pink bollworms in traps with fans and without fans and found that a significant majority of the moths were taken in the traps with the fans. A greater percentage of corn earworms were taken with fan light traps than with gravity light traps (Deay et al., 1965). Harrell et al. (1967), working with corn earworms, cutworms, corn borers, armyworms, and hornworms found that during their study there was no instance when gravity traps caught more Lepidoptera than did the fan traps. They did note, however, that the fan traps were efficient only when a sufficient air velocity was maintained. Catches of cucumber beetles were significantly increased by small suction fans (Barrett et al., 1971). Hartsock et al. (1966) noted that fans can be utilized quite efficiently in order to increase catch size, but a major drawback is that specimens can be severely damaged.

Baffles are generally accepted as a successful addition to a light trap. Barrett et al. (1971) found that baffles, in general, tended to increase catch size of cucumber beetles, but not significantly. According to Hartsock et al. (1966), baffles increase the catch of most large insects but not the small ones which tend to land on them. The Pennsylvania Light Trap was the result of fifty different combinations of baffles, funnels, lamps, and killing jars. This trap has a central lamp with black baffles placed around it so as to produce little or no reflection. Reflections from baffles constructed of plastic, plexiglass, and bright aluminum tend to reduce the catch (Frost, 1957).

Of the optional trap components, funnels are frequently regarded as relatively desirable. Hartsock et al. (1966) suggest a two inch funnel opening and at least a 60 degree slope. Deay et al. (1965) suggest that positioning a 15 watt blacklight tube with one-fourth of its length below the lip of the funnel, or even with it, is more advantageous than positioning it with one-half of its length in the funnel. Hollingsworth et al. (1968) report that increased funnel diameter increases the catch size.

Frost (1957) found that a Pennsylvania Light Trap with a heater produced no significant difference in catch size or composition. Barr et al. (1963) obtained similar results while working with mosquito light traps. They found that the heat of the light bulb had no influence on the size of the catch despite the fact that female mosquitoes are attracted to warmth. Hollingsworth et al. (1968) carried this a step further. They covered a 15 watt blacklight bulb with opaque tape so that the bulb emitted only infrared. No insects were taken by the trap.

According to Barr et al. (1963), screens may be used to exclude large insects, particularly moths and beetles from light traps in which small insects are being collected. Screens are frequently used on mosquito traps but tend to reduce the catch of mosquitoes as well as the catch of larger insects.

Three other considerations which may influence light trap efficiency are covers on traps, trap color, and aperture size. Covers tend to reduce catch but are desirable in rainy weather (Frost, 1957). Barr et al. (1963) have found that trap color does not appear to be of much significance in the light trapping of mosquitoes. However, shiny surfaces seem undesirable (Frost, 1957). Belton and Kempster (1963) report that aperture size is of importance when live-trapping Lepidoptera. A one and three-fourth inch aperture is desirable for large moths but pyralids tend to escape at dawn. An aperture of one-half inch prevents the capture of larger moths as well as the escape of the pyralids.

It has been known for over thirty years that the use of certain attractants can increase catch size at light traps. Worthley and Nicholas (1937) mentioned this. Recent tests have shown that light trap catches of males of certain species can be greatly increased by the use of synthetic sex attractants or live virgin females in the vicinity of the trap (Hartsock et al., 1966). Headlee (1934) successfully used carbon dioxide as an attractant for mosquitoes in the New Jersey Light Trap. Newhouse et al. (1966) reported that dry ice, used as a supplement to the CDC Mosquito Trap, increased the catch four-fold and the total number of species by 20-25%. Some diurnal species and other species, not greatly attracted to light, were also taken. Newhouse suggests that a live animal could serve efficiently in combination with a light trap to attract mosquitoes. He concludes this because a CDC Trap, mounted above a chicken pen in Georgia, and another such trap in the immediate vicinity of a human-biting catch station in the Everglades, were much more efficient than identical traps in the same general vicinities. Carestia and Savage (1967) duplicated Newhouse's results with carbon dioxide and the CDC Light Trap.

External Influences on Light Trap Efficiency

Trap location, trap height, weather conditions, moonlight, and extraneous light are five external factors which are known to influence light trap efficiency. According to Barr et al. (1960), variations in collection due to trap position are very important sources of error in the evaluation of light traps. Large variation may exist in collections made even two or three meters apart. Frost (1962) notes that there is a definite relationship between the plants growing in the trap vicinity and the insects captured. More than 50% of insect species are herbivorous. Merkel and Fatzinger (1971) state that species composition of stands of pine had pronounced effect on the catch of certain species of moths. It was nearly possible to determine the stand's composition by examining the catch. Many insects are strongly photopositive, but use of a light trap will not attract Lepidoptera to ecological areas they do not normally occupy (Robinson and Robinson, 1950). Therefore, the capture of insects at light may be an indication that the species normally flies in that particular area.

Nicholls (1962) is among several authors who have developed machines which reduce the positional effect. Nicholls' device rotates a pair of unidirectional traps in order to obtain this result. Barr et al. (1960) and Belton and Kempster (1963) utilized a similar device with good results.

Several entomologists have experimented in an attempt to determine what effect height of the light trap has on composition and size of the catch. Nearly thirty years ago, Collins and Machado (1943) noted that larger collections of codling moths could be made at tree-top level than at lower heights. Glick et al. (1956) found that 39% of the bollworms collected were taken at the two foot level and 86% were taken below six feet. A greater number of spotted and striped cucumber beetles were collected at 12 feet than at any other height by Barrett et al. (1971). Deay et al. (1965) found that unidirectional traps took more corn earworms at 12 feet than at 4, 8 or 16 feet while omnidirectional traps were more efficient at 2.5 feet than at 7.5 or 10 feet. Merkel and Fatzinger (1971) ran light traps at 20 and 60 feet when first undertaking a study of pine-infesting Lepidoptera. They found the traps at 20 feet so much more efficient that, during the second year of the study, they ran traps only at that height.

The precise conditions which make particular nights favorable for light trapping are complex and difficult to analyze statistically (Bertherton, 1967). The abiotic factors which are usually analyzed by entomologists include temperature, precipitation, wind, baromatric pressure, and cloud cover.

Headlee (1934) observed that mosquito activity is slight at 50 degrees Fahrenheit and increases with rising temperature. A temperature of 70 degrees or above is most favorable for mosquito activity, according to Bradley and McNeel (1935). Bogush (1936), working in central Asia, found a distinct, positive correlation between December's mean temperature over a five year span and the number of Laphygma exigua captured by light trap. Pinchin and Anderson (1936) noted that nightly minimum temperature seemed of greater importance than maximum temperature in determining activity of Tipulidae. Concerning the nocturnal activity of insects in general, Williams (1940) felt that the effect of the maximum temperature alone is smaller than the effect of the minimum temperature. While light trapping the codling moth, Collins and Machado (1943) found that 60 degrees is the lower limit for collecting the moths because they are inactive at lower temperatures. They consider 80 degrees to be the upper limit.

S. W. Frost (1962), who has used light traps and recorded his observations for many years, suggests that the most important factor in regulating the abundance of insects is the temperature between 6 P.M. and 7 A.M. With temperatures over 60 degrees Fahrenheit, catches are very high, between 50 and 60 degrees they are somewhat high, between 40 and 50 degrees, catches are reduced, and below 40 degrees, the numbers of insects taken by light trap are considerably reduced. Frost (1963) summarizes by stating that above 60 degrees collecting is very satisfactory and below 50 degrees, numbers are reduced, especially in the orders Lepidoptera and Coleoptera. In Florida, where these observations were made, a slightly higher temperature is required to trap some groups of insects attracted further north at lower temperatures. Frost (1962) also notes that after a prolonged cool spell, recovery in numbers is delayed.

Hanna and Atries (1970a) as well as R. F. Bretherton (1967), have worked with Lepidoptera and the desirable conditions for their collection. Bretherton has observed that a temperature of 60 degrees Fahrenheit or above at dusk is most desirable for light trapping Lepidoptera. Hanna and Atries, working with three species of Egyptian moths, found that the activity of Agrontis ipsilon was determined largely by the mean night temperature, activity of Sesamia circumflexa was determined by a high minimum temperature, the activity of S. cretica was favored by a high maximum temperature.

Precipitation is the second meterological factor considered to be of significance in influencing the efficiency of insect light traps. Headlee (1934) observed that cessation of mosquito activity occurs during rain but high atmospheric moisture favors it. Reduced catches of codling moths are taken during rain, according to Collins and Machado (1943), but the nights following rainy nights are excellent for light trapping. Williams (1948) found that thunderstorms seemed to have no effect on total catch but he observed that noctuids were more abundant in light trap collections made during thundery weather.

Frost (1963) observed that heavy rains reduce collections consistently. A light drizzling rain may have little effect on catches, however, a foggy drizzling rain tends to increase collection size. Bretherton (1967) agrees that a drizzle or moderate rain is favorable for trapping, as is high humidity.

Frost (1955, 1963) and Bretherton (1967) agree that strong winds reduce collections and that absence of wind is favorable. Headlee (1934) has found mosquito activity ceases with a wind velocity over 10 MPH but that mosquito activity does occur with very slight air movements.

Barometric pressure is often ignored by entomologists. However, Williams (1940) states that a large catch can be expected with high pressure and small catches can be expected with low or falling pressure.

In regard to the significance of clouds, Williams (1940) concludes that insects fly later on cloudy nights probably because of the slow fall in temperature. Fog, according to Williams, has an uncertain effect on insect activity. It is usually accompanied by a poor catch due to the fact that fog often occurs on cold nights. When discussing the physical factors influencing light trap efficiency, it becomes necessary to separate actual insect flight activity from reduced insect response to light. Frost (1962) reports that cloudiness at sunset or dawn lessens activity of insects. However, clouds veiling the moon produce favorable trapping conditions, according to Bretherton (1967).

Over the past thrity-five years there has been much controversy among entomologists concerning moonlight and its influence upon insect behavior. Williams (1936) states that moonlight has an effect on the behavior of insects as determined by light trapping. In some groups, like the Noctuidae, the effect is that fewer insects are captured on moonlight nights. In other groups, such as Coleoptera, the effect is small. Williams (1936) feels that it is probably due to a physiological effect on insect activity and not merely due to a reduction in efficiency of the light trap. Pinchin and Anderson (1936) state that in Tipulinae they find activity at a minimum on clear nights with full moon and at a maximum on cloudy nights in the week of no moon. Neither Pinchin nor Anderson attempt an explanation.

Over ten years later, Williams and Singh (1951) carried out a study on the effect of moonlight on insect activity. They used a non-light suction trap. In the week of the new moon their catch was nearly five times that of the week of the full moon. They further state that the low catch in light traps at full moon is not only due to a reduction of the trap's efficiency, but also to low insect activity. Five years later, Williams, Singh, and El Ziady (1956) attempted to duplicate the 1951 results but were unable to do so. They explained their results by saying that the difference in number of insects captured must have been due to conditions in one or two lunar cycles. The majority show no regular cycles. They add that in some aquatic species the influence of moonlight is emergence from the water, therefore, increasing the size of the adult winged population. In the same year, Glick et al. (1956) state that moonlight increases insect activity in general but not the activity of Lepidoptera, which appear to be more active on dark nights.

Because Williams' results were never duplicated, M. W. Provost (1959) carried out research on the influence of moonlight on light trap catches of mosquitoes. He used non-attractant air sampling which revealed no lunar periodicity. He concludes that there is a lack of evidence for a moon-phase effect directly on flight activity. In mosquitoes and noctuids there is support for the theory that lunar periodicity in light trap captures of night-flying insects is not the result of increased flight activity at new moon but rather the result of a purely physical difference in attractant efficiency of light traps superimposed on night activity patterns governed by minute changes in natural, moon-determined night illumination.

Barr et al. (1963) support Provost's results. Barr's research reveals that definitely fewer mosquitoes are taken on full moon nights than on new moon nights. He adds that on new moon nights both sexes of all species of mosquitoes studied showed significant differences in response to different light intensities. Female Culex mosquitoes are affected to such a great extent that unlighted traps give a better indication of abundance than do lighted ones.

Using non-attractant sampling of mosquitoes, Bidlingmayor (1964) found that the presence of moonlight increased the number of female Aedes mosquitoes in flight above moonless periods by 95% at quarter moon and 546% at full moon. Females of other species showed 55% increase at quarter moon and 122% at full moon. He concludes that the indirect effect of moonlight on light trap collections of mosquitoes is reduction in the size of the collection. Since light trap collections are depressed at full moon, though the levels of flight activity are actually higher, the reduction of light trap efficiency by the moon is greater than previously estimated. Lack of moon, even if veiled by clouds, is favorable.

Gunstream and Chew (1967) summarize by saying that all light traps capture photopositive individuals and the attractiveness of their low intensity illumination is limited when the moon is bright. This is significant because flight activity of some species increases during periods of bright moon.

Gaskin (1970) has studied New Zealand Lepidoptera by means of light trap. He found that over a two year period the number of individuals and number of species decreased. Most factors involved remained constant. Trap position, bulb intensity, and weather conditions were very similar. The addition of street lighting fifty yards away was the one factor to which Gaskin attributed a decrease in size of collection.

Biotic Influences on Light Trap Efficiency

Effective light trapping is complex and subject to biotic influences as well as abiotic influences. Pfrimmer (1955) realizes this and states that each species or group of species is a separate problem requiring extensive study to determine the most efficient and most economical light source and trap design, if traps are to be successful survey devices.

From their observations, Robinson and Robinson (1950) concluded that there is no evidence of sexual or spectral selection. If collections contain a majority of any one sex or species, the habits of the species should be considered before attributing behavior to the character of the light source. For example, males and females of one species may prefer different ecological habitats.

However, according to Frost (1962), behavioral differences between species and between the sexes of the same species are factors which must be considered. Glick et al. (1956) found that bollworms were more attracted to argon light than other insects and a much higher percentage of female bollworms could be collected with argon than with blacklight. In studying the effect of light intensity on mosquito catches, Barr et al. (1960) found that the number of mosquitoes taken was directly proportional to light intensity, except with females of certain species. Culex females show low response to light on dark nights but not on light ones. Gunstream and Chew (1967) have observed that the degree of photopositivity varies from species to species in mosquitoes. Engorged females are less receptive to light and some are even photonegative. The response of houseflies to different light sources was studied by Morgan (1968). He found a difference in response to lights between the sexes at different temperatures.

A second factor to be considered is the type of flight used by the insect. This, according to Frost (1962), is a behavioral factor which can influence light trap efficiency. Frost states that there are two types of flight. Some insects, particularly Coleoptera, fly directly into the trap and drop immediately into the killing jar. Other insects, such as moths, tend to circle, some come to rest, and others escape from the light's rays.

Another biotic influence on light trap efficiency is the time of activity of certain insects. From his years of light trap work, Frost (1963) concludes that there are periods of the night when certain species are most active. Therefore, in attempting to collect particular insects, it is highly desirable to operate the light trap at the most opportune time. Headlee (1934) observed that mosquitoes are most abundant from sundown to 9 P.M. and again near dawn. Bradley and McNeel

(1935), also working with mosquitoes, found that the best time for collection of Mansonia is during the early night and for Anopheles is during the middle of the night.

Williams (1935) designed a light trap which made eight collections during the night. During his study he observed that Diptera and Coleoptera are abundant only during the first one-eighth of the night and Lepidoptera, after a slow start, may be collected most easily during the first half of the night.

The codling moth is present in greatest numbers at twilight but is nearly absent at complete darkness, according to Collins and Machado (1943). Another economically important moth, the pink bollworm, was found by Glick et al. (1956) to be most active between 2 and 4 A.M.

A minor biotic influence on trap efficiency, but of possible significance to collection size, is the production of certain chemicals by some insects. Frost (1962) suggests that Staphylinidae and Meloidae, as well as others, may produce odors which attract others of the same species, thus increasing the number captured. Some of these odors might repel other insects.

Insect abundance is another major source of variation in light trap collections (Frost, 1962). According to Bretherton (1967), the buildup in numbers in any year is much affected by the earliness or lateness of the season. This is particularly true of March and April. Some years exceptional weather conditions in late September seem to pull forward what are normally October numbers so as to reduce the totals that month.

Bretherton (1967) also has observed that yearly fluctuations in insect populations do occur. During a 12 year study he observed three good years, three average years, and six bad years for light trapping Lepidoptera. In studying these fluctuations, he reports that trapping conditions are not the decisive influence and that the causes are not clearly evident. Correlation of sunshine (excess and deficiency) with number of moths gave the highest correlation of any factors considered. Temperature and moth numbers gave the lowest correlation. Merkel and Fatzinger (1971) found annual fluctuations in totals of moths they collected but drew no conclusions as to the causes. Annual fluctuations do occur in woodland caddisflies, according to Poole (1970). He determined that the fluctuations of species populations are not entirely random with respect to other members of the community.

Methods

I. Description of the Collection Sites

The floodplain and bluff collection sites were located near the Embarras River in Coles County, Illinois, three miles southeast of Charleston. The floodplain collection site is within the area which would be incorporated into the proposed Lincoln Reservoir. The bluff collection site is above the expected water level.

The two locations were examined by Dr. John E. Ebinger in 1970. He described the floodplain collection site as a streamside forest consisting of silver maple, cottonwood,, box elder, and willow. This forest is limited by cultivation to a narrow band on the east side of the river and because of its width cannot be considered a typical floodplain forest. The bluff collection site, located approximately 110 feet above the river, was also examined by Ebinger. He described the area as a typical upland east-facing slope with the dominant vegetation consisting of oaks and hickories.

II. Location of Traps

During the entire study the bluff light trap was operated at the same location. It was located 15 feet below the top of the Embarras River bluff in a ravine. It was mounted five feet high on a black oak tree. The collection site was on the opposite side of the river and slightly north of the floodplain collection site. The trap faced the direction of the river but the author observed that the light from the trap did not penetrate to the river through the forest.

The light trap in the floodplain collection area was mounted four feet high on a box elder tree approximately eight feet from the edge of the river bank. The tree was located at the convex bank of a meander in the Embarras River above a well-established sandbar. The trap faced the river. The floodplain trap was operated at this location during the entire study with the exception of March 16 at which time flooding necessitated moving the collection site one-half mile downstream.

III. Description of the Light Traps

Two identical light traps constructed entirely of sheet aluminum were used throughout the study (Fig. 1). Each trap was 26.5 inches long with an 18 inch top to shed rain. The lower portion of the trap consisted of a funnel formed by forewardly folded, overlapped sides of the trap. The very front of the funnel measured 7 inches in depth. It narrowed to a 3 inch opening at the bottom which was fitted with a threaded Mason jar lid to accommodate a half gallon, wide-necked jar. During operation of the light trap, a Mason jar containing approximately 1 quart of ethanol was attached to the trap. Each trap was provided with a 15 watt G.E. blacklight fluorescent lamp. The lamps were located centrally and vertically on the traps. The traps were unidirectional.

The light trap located on the floodplain was battery-operated using a 12-volt automobile battery and a transistorized Felco Model

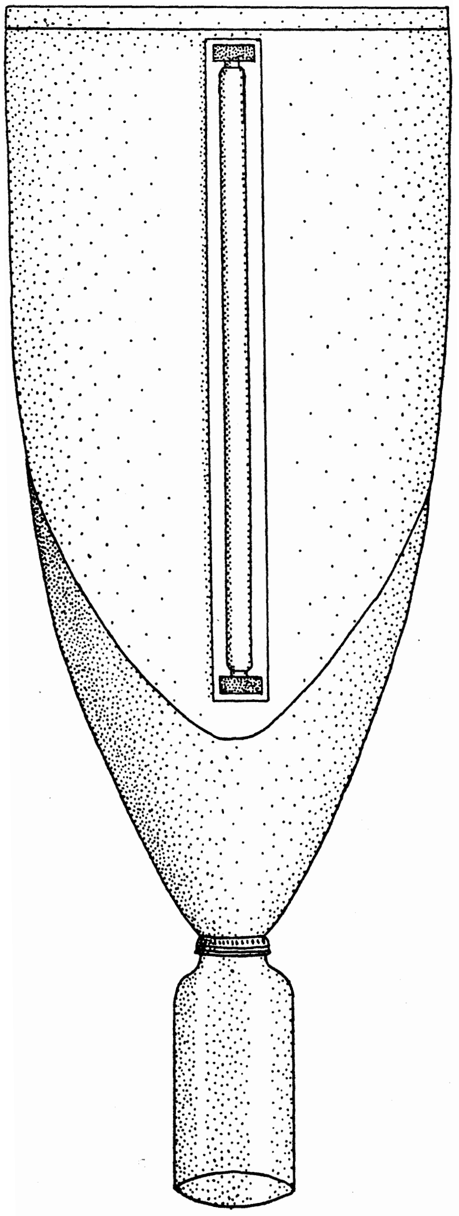

Fig. 1. Front view of light trap used in the study of the Coleoptera of the Embarras River floodplain and bluff.

TR-101 current inverter. Between collection dates the 12-volt battery was recharged. A fully-charged battery was capable of providing enough power to operate the light trap for a minimum of fourteen hours. The bluff light trap was run on house current via 150 feet of cord. The trap was located approximately 100 feet from the source of electricity.

IV. Procedure

The first collection was made 15 September 1969 and the last was made 1 September 1970. With a few exceptions the light traps were operated twice a month at approximately two week intervals. Access to the floodplain collection site during May was effected only once due to difficulties with the landowner. Due to adverse weather conditions, neither trap was operated during January.

The traps were set out at the collection sites early and care was taken to have them functioning before dusk. The bluff trap was always set out before the floodplain trap. The traps were always picked up after dawn, usually between 6 and 8 A.M. Small collections were sorted the day they were brought to the laboratory. Larger collections which could not be sorted immediately were temporarily stored in 70% ethanol.

Various pieces of simple equipment aided in the sorting process. White enamel dissection pans were useful to spread the material for general inspection. From these pans the largest insects were removed—Coleoptera, which were saved, and other insects which were discarded. Following this preliminary examination, small portions of the collections were thoroughly examined in the pan and in petri dishes. At this time all Coleoptera were removed from the collection and stored in 70% ethanol in vials or baby food jars. Broad-tipped forceps, a soft paintbrush, and an eyedropper were used to transfer and handle the insects.

In some cases the Coleoptera, usually large specimens, could be immediately sorted to family from the dissection pan. However, in most cases all Coleoptera were removed from the original collection before any sorting to family was undertaken. In sorting and keying to family the Coleoptera were placed in petri dishes and watch glasses and examined under magnification. A Bausch and Lomb 7-30 power dissecting microscope or an A. O. Spencer Microstar microscope was essential for identification. The primary key used in this study was Ross Arnett's (1960) Key to the Families of Coleoptera of the World. In some cases reference was made to keys constructed by Dillon and Dillon (1961), Edwards (1949), and Borror and DeLong (1964). The arrangement of families adopted by Arnett (1960) was employed except for the inclusion of the Trogidae as a distinct family.

In analyzing each collection the following procedure was used to determine the number of species present. All specimens previously identified as belonging to a particular family were examined and sorted into groups of insects with similar phenotypes. These groups were reexamined and subdivided whenever necessary to produce homogeneous groups of specimens. The author attempted to use only taxonomic characteristics rather than characteristics which might be due to ecophenotypic variation or infraspecific variation. Throughout the study care was taken to determine as nearly as possible the exact number of species. However it is probable that the number of "species" as determined by the author is exceeded by the number of actual species in the collections.

Results

The light traps were operated at the Embarras River floodplain and bluff locations a total of 22 nights. Insects were taken on 20 of the dates. Table 1 lists these collection dates and indicates on which nights insects were trapped.

Thirteen orders of insects were taken by light trap during this study. Table 2 lists these orders and gives their relative abundance. From this table it may be noted that Coleoptera was among the four orders of insects most frequently trapped.

Tables 3 and 4 list the families of light-trapped Coleoptera and the total number of "species" of each family for all collection dates. These data indicate a total of 62 families were trapped at the Embarras River, 49 families were collected on 13 nights by the floodplain light trap, and 59 families were taken on 12 nights at the bluff collection site. Total numbers of families and species for each of the 22 collection dates at both collection sites are summarized on Table 5. This table indicates the bluff collections ranged from 1 to 39 families and from 1 to 218 species and the floodplain collections from 1 to 31 families and 1 to 154 species.

Of the 62 families collected, Cerophytidae, Dascillidae, and Oedemeridae were taken exclusively at the floodplain collection site.

Table 1. The nights during which insects were taken at both collection sites on the Embarras River, 15 September 1969 - 1 September 1970.

Date	Floodplain	Bluff
September 15	+	+
September 29	+	+
October 15	+*	+*
October 27	+	+*
November 10	+*	+
November 21	+	+
December 2	+*	+*
December 18	0	+*
February 6	0	0
February 26	0	0
March 2	+	0
March 16	+*	0
April 13	+*	+*
April 28	+	+
May 12	+	+
June 1	+	+
June 15	+	+
July 7	+	+
July 27	+	+
August 10	+	+
August 24	+	+
September 1	+	+

+ Insects taken by light trap
0 No insects taken
* No Coleoptera

Table 2. Embarras River floodplain and bluff: the orders of light-trapped insects and their relative abundance.

Order	Abundance
Collembola	rare
Ephemeroptera	uncommon
Orthoptera	uncommon
Plecoptera	uncommon
Dermaptera	rare
Hemiptera	rare
Homoptera	uncommon
Neuroptera	rare
Coleoptera	abundant
Trichoptera	abundant
Lepidoptera	abundant
Diptera	abundant
Hymenoptera	uncommon

rare - fewer than 25 total individuals
uncommon - less than 10% of total numbers
abundant - more than 10% of total numbers

Table 3. Coleoptera of the Embarras River floodplain. The families of Coleoptera which were encountered during the period of 15 September 1969 to 1 September 1970 and the number of species taken on each collection date.

Family	Collection dates and numbers of species																				
	15-IX	29-IX	15-X	27-X	10-XI	21-XI	2-XII	18-XII	6-II	26-II	2-III	16-III	13-IV	28-IV	12-V	1-VI	15-VI	7-VII	27-VII	10-VIII	24-VIII	1-IX
Alleculidae																				1		
Anobiidae																	3	2		3		2
Anthicidae	5														5	5	8	4	9	1	3	5
Bostrichidae														1	1				4	1		1
Bruchidae																				1		
Cantharidae															3							
Carabidae	20	9												20	25	20	17	24	37	14	7	23
Cerambycidae														1	1	1	1	3	3	2		
*Cerophytidae														1								
Chrysomelidae	3													1	3	2	1	6	2	3		4
Coccinellidae														1			1	1	1			1
Cryptophagidae		1																				2

Table 3--Continued.

Family	Collection dates and numbers of species																					
	15-IX	29-IX	15-X	27-X	10-XI	21-XI	2-XII	18-XII	6-II	26-II	2-III	16-III	13-IV	28-IV	12-V	1-VI	15-VI	7-VII	27-VII	10-VIII	24-VIII	1-IX
Cucujidae															1	3			6	3	1	
Curculionidae	2													1	5	2	3	2	4	5		3
*Dascillidae																						1
Dryopidae																		1	1	1		
Dytiscidae															1	1	1	2	2			
Elateridae														1	4	5	2	8	8	4	2	3
Elmidae	1															1	1	1	1	1	1	1
Erotylidae														1		1		1		1		
Eucinetidae																		1				
Eucnemidae																1						
Gyrinidae															1							
Haliplidae																	2	3	1			
Heteroceridae	3	1												3	6	7	6	5	8	4	6	5

Table 3--Continued.

Family	Collection dates and numbers of species																					
	15-IX	29-IX	15-X	27-X	10-XI	21-XI	2-XII	18-XII	6-II	26-II	2-III	16-III	13-IV	28-IV	12-V	1-VI	15-VI	7-VII	27-VII	10-VIII	24-VIII	1-IX
Helodidae																				1		
Histeridae																1						
Hydrophilidae	4	1												2	9	9	11	9	15	4	2	3
Lampyridae																		2	1			
Lycidae																		1				
Melandryidae															2	1		1		2		
Meloidae																1		1				
Mordellidae																1	3					
Mycetophagidae															1	1			2			1
Nitidulidae		1													2	4		2	1	1		1
Noteridae																	1	3	1	1		
*Oedemeridae																		1				
Ostomidae															1							

Table 3--Continued.

Family	Collection dates and numbers of species																					
	15-IX	29-IX	15-X	27-X	10-XI	21-XI	2-XII	18-XII	6-II	26-II	2-III	16-III	13-IV	28-IV	12-V	1-VI	15-VI	7-VII	27-VII	10-VIII	24-VIII	1-IX
Pselaphidae														1		2	1	1	3	1		
Ptilodactylidae																		1	1	1		
Pyrochroidae																		1				1
Rhizophagidae	1	1															1			1		1
Scarabaeidae	3										1			7	13	9	6	5	9	6	1	8
Scolytidae		1													3	1	1		1	4	1	3
Silphidae														2	2			2	1			
Staphylinidae	6	1	1											3	16	19	14	9	27	15	10	24
Tenebrionidae														2	4	1		3	4	1		2
Trogidae														3	5					2		
Throscidae																1	1	1	1			

*families collected exclusively on the Embarras River floodplain

Table 4. Coleoptera of the Embarras River bluff. The families of Coleoptera which were encountered during the period of 15 September 1969 to 1 September 1970 and the number of species taken on each collection date.

Family	Collection dates and numbers of species																					
	15-IX	29-IX	15-X	27-X	10-XI	21-XI	2-XII	18-XII	6-II	26-II	2-III	16-III	13-IV	28-IV	12-V	1-VI	15-VI	7-VII	27-VII	10-VIII	24-VIII	1-IX
Alleculidae																1	3		2			
Anobiidae	1														1	6	1	1	6		3	1
Anthicidae	4	1												1	2		3		3	1	2	2
*Anthribidae														2	1		1		1	1	1	
Bostrichidae														1	3	2	3		1	1	1	1
*Brentidae															1		1					
Bruchidae																1						
*Buprestidae															1							
Cantharidae														2	3	4	5	1				
Carabidae	17	7												16	35	31	18	19	39	13	21	9
Cerambycidae														1	5	21	3	7	6			1
Chrysomelidae	2													8	3	4	4	3	5	3	3	2

Table 4--Continued.

Family	Collection dates and numbers of species																					
	15-IX	29-IX	15-X	27-X	10-XI	21-XI	2-XII	18-XII	6-II	26-II	2-III	16-III	13-IV	28-IV	12-V	1-VI	15-VI	7-VII	27-VII	10-VIII	24-VIII	1-IX
*Cleridae																2	2	1	3		1	
Coccinellidae	1													1	2							
Cryptophagidae															1							1
Cucujidae	2													1	4	5	5	1	6	1	7	2
Curculionidae	1	5												8	14	15	6	3	8	2	5	3
*Cupedidae																		1				
*Dermestidae														1								
Dryopidae	1																			1		
Dytiscidae															2	2	1	2	3			
Elateridae														4	8	14	10	2	7	5	6	
Elmidae																2		1	1	1	1	
*Endomychidae																				1		
Erotylidae															1	2	1	1		1		
Eucinetidae															1	1		1	1			

Table 4--Continued.

Family	Collection dates and numbers of species																					
	15-IX	29-IX	15-X	27-X	10-XI	21-XI	2-XII	18-XII	6-II	26-II	2-III	16-III	13-IV	28-IV	12-V	1-VI	15-VI	7-VII	27-VII	10-VIII	24-VIII	1-IX
Eucnemidae																3	3					
*Euglenidae																					1	
Gyrinidae															1	1						
Haliplidae	1															2			3	1		
Heteroceridae	5													2	2	4	3		5	4	3	3
Helodidae															1			1				
Histeridae																					1	
Hydrophilidae	7													4	7	11	7	3	9	9	8	2
Lampyridae															2	4	3	4	2			
Lucanidae																1	1					
Lycidae																		1				
Melandryidae														1	1	4	6	1	2	1	1	
Meloidae																			1	1		

Table 4--Continued.

Family	Collection dates and numbers of species																					
	15-IX	29-IX	15-X	27-X	10-XI	21-XI	2-XII	18-XII	6-II	26-II	2-III	16-III	13-IV	28-IV	12-V	1-VI	15-VI	7-VII	27-VII	10-VIII	24-VIII	1-IX
Mordellidae																7	7	1				
Mycetophagidae	1														2		1		4		3	
Nitidulidae	1														10	5	4		2	1	6	1
Noteridae															1	2	1		1	1	3	
Ostomidae															1	2	2		2			
*Passalidae																1						
Pselaphidae																1	2		2		4	
*Ptilidae																	1					
Ptilodactylidae																1	1	1	1			
Pyrochroidae																2	1	1				
*Rhipiceridae																			1			
Rhizophagidae	1														1		1	1	1	1	1	1
Scarabaeidae	1													17	17	17	14	11	7	9	5	1

Table 4--Continued.

Family	15-IX	29-IX	15-X	27-X	10-XI	21-XI	2-XII	18-XII	6-II	26-II	2-III	16-III	13-IV	28-IV	12-V	1-VI	15-VI	7-VII	27-VII	10-VIII	24-VIII	1-IX
Scolytidae		2													6		4	1	1	3	7	
*Scydmaenidae																					1	
Silphidae														2	2	1	1	1	1	2	1	
Staphylinidae	18				1										17	26	18	4	18	12	17	8
Tenebrionidae															7	9	2	2	3	1	3	1
Trogidae		1												1	3		3			2	1	1
Throscidae															1	1	1				1	

Collection dates and numbers of species

*families collected exclusively on the Embarras River bluff

Table 5. Coleoptera of the Embarras River floodplain and bluff. The total numbers of families and species which were taken on each collection date 15 September 1969 to 1 September 1970.

	Floodplain		Bluff	
Date	Total No. Families	Total No. Species	Total No. Families	Total No. Species
Sept. 15	10	48	16	64
Sept. 29	8	16	5	16
Oct. 15	-	-	-	-
Oct. 27	1	1	-	-
Nov. 10	-	-	1	1
Nov. 21	-	-	-	-
Dec. 2	-	-	-	-
Dec. 18	-	-	-	-
Feb. 6	-	-	-	-
Feb. 26	-	-	-	-
March 2	1	1	-	-
March 16	-	-	-	-
April 13	-	-	-	-
April 28	17	51	18	73
May 12	23	114	36	170
June 1	25	100	37	218
June 15	21	85	39	154
July 7	31	107	28	77
July 27	26	153	34	158
Aug. 10	29	86	26	79
Aug. 24	10	34	29	118
Sept. 1	22	96	17	40

Thirteen families were taken exclusively by the bluff light trap. Of these, Anthribidae, Brentidae, Cleridae, and Lucanidae were collected more than once. The remaining 9 families—Buprestidae, Cupedidae, Dermestidae, Endomychidae, Euglenidae, Passalidae, Ptilidae, Rhipiceridae, and Scydmaenidae were collected only once.

Discussion

Certain differences existed in the insect collections made by the light traps on the Embarras River bluff and floodplain during this study. One of these differences was the date of appearance in the spring of insects at the collection sites (Table 1). The first insects to be trapped in 1970 were several individuals of one species of Scarabaeidae. These were collected March 2 on the floodplain. At the bluff site the first beetles were taken April 28, although insects belonging to other orders were trapped April 18. There were 17 families of Coleoptera present April 28 on the bluff.

The collections increased in size through the spring and reached their greatest volume during May and June (Tables 3, 4). The floodplain collections maintained their large size throughout the summer months because of great numbers of Trichoptera taken by the light trap. The bluff collections never exceeded the floodplain collections in size. The largest volume of floodplain insects was taken May 12 and June 1 and was primarily due to great numbers of scarabs.

During the following months the collections gradually decreased in size (Tables 3, 4). Coleoptera were relatively abundant through

September 15 but quickly declined to a few individuals during the subsequent months. The last Coleoptera to be taken during the Autumn of 1969 were staphylinids. One individual was taken October 27 on the floodplain and one individual November 10 at the bluff collection site. Insects belonging to Diptera and Lepidoptera were collected as late as December 2 on the floodplain. December 18 was the last date that insects were taken by the bluff light trap.

Analysis of the light trap collections revealed some basic differences between the Coleoptera of the bluff and floodplain. The most obvious of these was the relative size of the collections from the two sites. The collections of beetles from the bluff were almost consistantly larger than the floodplain collections.

The floodplain light trap collected a total of 49 families of Coleoptera (Table 3). Of these, three were taken exclusively at that location. Cerophytidae, Dascillidae, and Oedemeridae were each collected only one time. Because these families were trapped only once on the floodplain, the author does not feel that from these limited data the families can necessarily be considered to occur exclusively on the floodplain. It appears more probable that collection of these families was limited by scarcity of individuals and/or low photopositivity on the part of the insects.

A total of 59 families of beetles were trapped on the Embarras River bluff (Table 4). Of these 59, 13 were taken exclusively by the bluff trap. Nine of these 13 families were collected only once and as with Cerophytidae, Dascillidae, and Oedemeridae of the floodplain, the author will not necessarily consider them to be exclusively bluff families but rather they will be considered as uncommon and/or of low photopositivity. However, the author feels that four bluff families which were collected more than once could be considered as typical or possibly index families of the upland forest. These families are Anthribidae, taken on six occasions, Lucanidae and Brentidae, collected twice, and Cleridae, which was trapped five times.

Other than the existance of exclusive families on the bluff and floodplain, the light trap collections revealed that the majority of families of Coleoptera seemed to be present in approximately equal abundance at the two collection sites. However, several families of beetles, which were also present at both locations, were far more abundant at one site than the other (Tables 3, 4). Although no complete counts were made of the numbers of individuals, the greater abundance of a particular family at one collection site was revealed in two ways. The first of these was the presence of greater numbers of species belonging to that family at that particular collection site. The second indication of greater abundance, although of less significance than the first method, is the number of instances that one family was trapped at one site in contrast to the number of times it was taken at the other location.

Very few of the families which were present at both collection sites showed greater abundance on the floodplain. Elmidae and Heteroceridae were the only families which, from the author's own observations and from collection data, showed such abundance. Tables 3 and 4 indicate that both families were collected more frequently on the floodplain and more species of heterocerids were taken on the floodplain. Although two species of elmids were trapped on the bluff and only one on the floodplain, the second species taken on the bluff was represented by only one individual.

Many of the families which were recorded for both floodplain and bluff locations showed a slightly greater diversity and were taken slightly more frequently on the Embarras River bluff. However, only a few families showed distinctly greater abundance on the bluff. Cerambycidae is one such family. Members of this family were taken an equal number of times by the traps on the bluff and floodplain. However the cerambycids were far more abundant on the bluff and this was revealed by the number of species taken at this site. A total of 21 species were taken June 1 by the bluff light trap. The greatest number of species trapped on the floodplain during any one night was three.

Curculionidae and Nitidulidae are two other families which were more abundant on the bluff, as revealed through collection data. Both families were trapped with a slightly greater frequency on the bluff but their greater diversity on the bluff is better revealed through contrast of the number of species taken at the collection sites. For Culculionidae 15 species were recorded for the bluff June 1 and five was the largest number of species collected during any night on the floodplain. Similarly four species were the greatest number of nitidulids taken any night on the floodplain but a total of ten species were trapped on the bluff May 12.

For some families equal numbers of species were recorded from the bluff and floodplain. In certain cases, as with Cucujidae and Eucinetidae, greater abundance on the bluff was revealed only by the frequency of collection. For example cucujids were trapped ten times on the bluff and only five times on the floodplain. Also, the small family Eucinetidae, with only eight U.S. species (Arnett, 1960), was taken four times on the bluff and only once on the floodplain.

S. W. Frost (1962) has concluded from his years of light trapping that there is a definite relationship between the vegetation which is present in the vicinity of a light trap and the insects which are captured by it. Robinson and Robinson (1950), state that use of a light trap will not attract Lepidoptera to an ecological area they do not normally occupy.

Assuming that Frost's statement is fact and that Robinson and Robinson's contention is applicable to Coleoptera as well as to Lepidoptera, then several conclusions in reference to the results of the study of the Coleoptera of the Embarras River floodplain and bluff can be drawn. It can be assumed that the majority of insects taken by the bluff and floodplain light traps normally inhabited the areas surrounding their respective traps. Because the majority of families taken during this study contain at least some species which are phytophagous as either adults or larvae, then it is logical to assume that the occurrence of many species was determined by the vegetation in the vicinity of the traps. Some of the herbivorous families to which this would apply are two of the three families exclusively collected on the floodplain, 10 of the families collected only on the bluff, and Cerambycidae, Cucujidae, Curculionidae, and Nitidulidae which were definitely more abundant on the bluff.

Knowledge of the life histories of certain other families aids in explaining their presence in greater abundance at one of the collection sites rather than at the other. For example insects belonging to some families are associated with water during part of their life cycles. Adult dascillids frequently occupy bushes in the vicinity of water (Arnett, 1960). Likewise oedemerid larvae are sometimes classed as being littoral due to their preference for moist decaying wood and driftwood. Larval elmids are aquatic and heterocerids commonly occupy galleries in mud banks along streams. The collection data from this study indicate that some aquatic families such as Dytiscidae, Gyrinidae, Halpilidae, Hydrophilidae, and Noteridae were equally abundant on floodplain and bluff. This author contends that this may be due to migratorial behavior as is known to be exhibited by these families.

It is important to remember that the results of this study were subject to certain abiotic and biotic influences. Among the most significant of these is the nature of the light traps used in this research. The two traps used were identical in structure. Each had as its light source a 15 watt blacklight. This light source radiates most of its energy in the near ultraviolet portion of the spectrum (Stanley and

Dominick 1957) and is generally regarded as a very effective attractant for positively phototropic insects. Although omnidirectional light traps are considered more efficient (Hartsock et al., 1966), the unidirectional structure of the traps used in this study was more desirable because light from the traps could penetrate in only one direction thus ensuring that the insects attracted to the trap were from one particular area. This virtually eliminated the possibility that insects were attracted to the trap from the old field located behind the streamside forest. In the same manner insects from the cleared bluff top were excluded from the bluff collections.

Two other features of the traps that might have influenced the results of this study were the covers and sides of the traps. It is accepted that covers reduce catch size (Frost, 1957). The sides of the traps were necessary for it to be unidirectional yet they might have reduced catch size. Construction of shiny aluminum was found by Frost (1957) to be undesirable.

Of the biotic influences upon this study, the author has previously recognized that there is a definite relationship between the plants growing in the vicinity of a light trap and the insects captured by it. Barrett et al. (1960) reported that large variation may exist in collections made even two or three meters apart. During the Embarras River study, this author attempted to place the bluff and floodplain light traps in such a way to reduce the "positional effect". Insects' behavior is another biotic influence. Frost (1954) has observed that some Coleoptera do not respond to lights as fully as do other insects. However, he finds that most beetles seem to respond more freely to blacklight. There is great variation in flying behavior of insects, according to Frost (1962), but unlike many other orders, Coleoptera tend to fly directly into the trap. He mentions that small insects tend to land on lighted portions of the trap.

In addition to these biotic factors and to trap structure, the author feels that it is necessary to mention certain external abiotic factors which influenced the results of this study. Bretherton (1967) recognized that the precise conditions which make one night favorable for collecting and other nights unfavorable are complex and difficult to analyze statistically. However temperature, precipitation, and moonlight are three factors for which there is at least a basic understanding. Frost (1963) has concluded that the temperature between 6 P.M. and 7 A.M. is of greatest significance and collecting is satisfactory above 60 degrees and numbers of insects, especially Coleoptera and Lepidoptera, are reduced below 50 degrees. Frost has also concluded that heavy rains consistently reduce collections and foggy drizzling rains increase collection size. The nature of moonlight's effect on light trap collections has been the center of controversy for years. However Gunstream and Chew (1967) summarize by saying that all light traps capture photopositive insects and the attraction of low intensity illumination is limited when the moon is bright. This is especially significant because flight activity of some species increases during periods of bright moon. One last external abiotic factor which may have influenced the collection of insects on the bluff was the presence of a security light approximately 100 feet behind the light trap. Over a two year period Gaskin (1970) observed a decrease in numbers of New Zealand Lepidoptera at his light trap and he attributed the decrease to the addition of street lighting 50 yards away.

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