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A BRIEF REVIEW OF THE PRINCIPLES OF LIGHT TRAP DESIGN WITH A DESCRIPTION OF AN EFFICIENT TRAP FOR COLLECTING NOCTUID MOTHS

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Recent entomological literature is replete with descriptions of insect light traps and discussions of the relative efficiency of various light sources in "attracting" nocturnal insects. Much has been published on various aspects of light trap design in both England and the United States. Apparently, however, workers in either country have been somewhat oblivious to light trapping investigations carried on by workers in the other. Entomologists in Great Britain, for example, at the time of the proposal of the Robinson trap (Robinson and Robinson, 1950) were apparently unaware that North American entomologists had been using for decades a simple trap consisting of a funnel to which a killing bottle was attached, and above which an unenclosed electric light bulb was suspended. Similarly, North American workers in assessing the value of various light sources have apparently been unacquainted with the 120–150 watt mercury-vapour lamp and its superiority in collecting many nocturnal insects to the ordinary tungsten-filament bulb or to the black light fluorescent tube.

SOME ASPECTS OF LIGHT TRAP DESIGN

Three major factors must be considered in the design of any light trap: the first is an efficient light source, the second is an efficient apparatus for confining the specimens, and the third is an appropriate reception chamber and poison distributing mechanism for killing specimens and retaining them in good condition until they can be recovered for sorting. The last factor is of particular importance if the specimens are for permanent retention in a formal collection.

Light Sources.

Light sources employed in the capture of nocturnal insects have changed through the years. The kerosene lamp was replaced by the gasoline pressure lamp and by the tungsten-filament bulb. In the last couple of decades, the tungsten-filament bulb has been largely replaced by various bulbs and tubes emitting a high percentage of ultra-violet light. The latter have been effective presumably because the spectrum visible to insects embraces shorter wave lengths than that visible to human beings. In North America, the black light fluorescent tube has been most widely employed in light trap construction. Mercury-vapour bulbs of the type suggested by Robinson and Robinson (1950) have not been subjected to comparative tests, and have had only very limited use on this continent. Other types of mercury-vapour bulbs, including one of the spot type (Pfrimmer, 1957) and the General Electric BH 4 (Frost, 1958b) have been tested, but have been found inferior to the black light fluorescent tube. The former bulb projects a cone-shaped beam of limited radius, and the latter bulb does not have the surface brilliance of the bulb suggested by Robinson and Robinson.

The 125-watt, Osram, mercury-vapour bulb, manfactured by General Electric of England, has proved extremely effective in "attracting" noctuid moths in faunal surveys conducted by the author over the last several years. The superiority of a bulb of this type to the tungsten-filament bulb has been demonstrated for the Macrolepidoptera as a whole by Williams (1951), and its superiority to at least one type of black-light tube has been indicated by Heath (1965).

Such results are not, however, universally applicable to all groups of insects. Neither small moths, beetles nor nocturnal parasitic wasps seem to reach the immediate vicinity of the light source in as great numbers as they do with a bulb or tube of lesser surface brilliance. When the Osram bulb is employed, representatives of these groups may be found fluttering or resting near the periphery of the circle of light created by the bulb. Harcourt and Cass (1958) have demonstrated that large numbers of Microlepidoptera may be taken with a relatively obscure light source. Moreover, even within the Macrolepidoptera, response to any particular light source will not be comparable for different groups. Thus in the data presented by Williams (1951), over four times as many specimens of noctuids were taken in the Rothamsted trap when a 125-watt mercury-vapour lamp was substituted for a 200-watt tungsten-filament bulb, but only slightly over twice as many specimens of geometrids were taken by the same substitution.

Any explanation of this differential response will depend on the cause of such response by an insect to a light stimulus. According to the classical theory, insects are "attracted" to light and differing responses among groups of insects may be attributed to different minimal and maximal thresholds of attraction. Thus certain groups may be attracted to a relatively weak light source and cease to be attracted when the light intensity becomes too great.

Robinson and Robinson (1950) and Robinson (1952) suggested another, almost diametrically opposed theory of the light response phenomenon. They suggested that nocturnal insects are actually repelled by light, but that if they are flying sufficiently quickly, they may come close enough to the light source to be "dazzled" by it and are then automatically deflected toward it. They explained the presence of specimens resting or fluttering near the periphery of the lighted area as not having been flying quickly enough to penetrate to the "dazzle" area before being repelled by the light. Such specimens are inhibited from further vigorous movement by a "desensitizing" of the eyes caused by the weak light in the peripheral area. There is much in the Robinsons' proposal that will serve to explain the observed behaviour of insects near a light source. The suggestion that an insect's response is governed only by its speed of flight, however, would seem an oversimplification and certainly some cognizance must be taken of varying thresholds of repulsion and "dazzle" for different species before the Robinsons' theory can be wholly accepted.

Trapping Mechanisms.

Two major types of trapping mechanisms have been employed in the construction of light traps. The two principles involved are exemplified in the box trap and the funnel trap. In the box trap, at least one outer wall of a chamber containing or adjacent to the light source, consists of two panes of glass sloping inward to a narrow horizontal aperture. Once an insect has gained entrance to the chamber by flying inward against one of the panes and through the aperture, it has little opportunity of escaping. The Rothamsted trap (Williams, 1948), although having four glass entrance walls, is essentially of the box type. Beirne (1951) considered a box trap more efficient than a funnel trap in collecting slender-bodied, weakly flying species of moths which are common in the Microlepidoptera and some groups of the Geometridae.

The funnel trap consists basically of a light source suspended over a funnel which leads to a lower chamber. Once in the lower chamber, the insects have difficulty in escaping because of the narrow diameter of the lower aperture of the funnel. Williams (1951) amply demonstrated the superiority of the funnel trap to the box trap for collecting Noctuidae and many other Macrolepidoptera. Electrically operated fans have been installed in various models of funnel traps in particular effort to capture small insects which do not have sufficient body weight to fall readily through the funnel.

Other trapping mechanisms have been employed. Parker *et al.* (1921) used a wash tub filled with water as a catch basin in early ecological work with the pale western cutworm, *Agrotis orthogonia* Morr. Various types of electrocutor traps, in which insects are killed by short-circuiting an electric current, have been designed and even marketed during the last decade or so.

Baffles. The use of baffles around the light source of a funnel trap has also been the subject of much controversy. The design and coloration of baffles have been discussed at length, and it is evident that the reflection of light from baffles is generally detrimental. However, baffles do eliminate the seemingly endless gyrations about the bulb in which many noctuids engage, and they do deflect into the mouth of the funnel swift flying insects which would otherwise pass within close proximity of the bulb and continue on their way. If the data presented by Frost (1958a) are valid of interpretation, then the use of baffles around the light source increases the catch of noctuid moths by about 25%.

Hoods. A further consideration in the design of a funnel trap is the use of a hood or roof over the light source and the mouth of the funnel, both to protect the bulb from damage and to prevent the catch from getting wet. Usually such hoods are in the form of a shallow inverted cone and are constructed of metal. Beirne (1951) suggested the use of a transparent plastic sheet to roof the trap. Such additions to the trap, however, can only decrease the number of rapidly flying insects taken. Frost (1958b) after conducting tests with both hooded and unhooded traps, concluded that the latter were more efficient in collecting many nocturnal insects. Observations of the behaviour of larger moths, when near a light source, offer a ready explanation. Many specimens descend toward the light at an acute angle, and if the trap is roofed, such an approach path is eliminated. Without a hood, however, the reception chamber of the trap must be provided with an efficient drainage mechanism to eliminate all water entering the funnel. Possible damage to the bulb by rain will probably depend on the nature of the bulb itself. The 125-watt Osram bulb used by the author has withstood several heavy rains in montane areas of western North America at temperatures close to the freezing point without having either shattered or cracked.

Trap Receptacles.

In the simple funnel trap, which has been used over the last several decades, a quart sealer jar has served as the standard receptacle for specimens flying to the light. Under conditions of heavy flight, however, such a small chamber may have the killing gas largely dissipated by the wing movements of a host of confined moths, and the gas-discharging surface itself may become so insulated with corpses that it can no longer function efficiently. Moreover the confining of specimens within such a restricted space, often causes very active individuals to do excessive damage to themselves and to already moribund specimens in the container. On nights of heavy flight, the quart sealer is of insufficient volume to contain the several quarts of specimens that may be taken in a trap employing a mercury-vapour bulb.

A large receptacle is necessary if specimens are to be maintained in good condition during a heavy flight, or if the trap is used to obtain living insects for experimental work. To obtain specimens in better condition, Edmunds (1961) recommended the replacement of the quart sealer in a simple funnel trap by a cloth sack filled with crumpled newspaper so that specimens could crawl away into various diverticula and remain quiescent until morning. The specimens were then killed with chloroform or ether. In the more commonly employed trap, in which the receptacle also serves as killing chamber, a larger receptacle will require the use of a larger amount of gas-forming chemical and probably a more efficient method of gas production, especially under conditions of low temperature. Heavy flights of noctuids have been encountered by the author when the air temperature was only a few degrees above the freezing point.

Although the use of a large killing chamber greatly reduces the damage that an individual specimen may do to itself, it does not eliminate the damage that may be done to quiescent specimens by still active occupants of the trap. Particularly troublesome to lepidopterists are the many beetles which trample the catch for protracted periods before becoming inactive themselves.

To reduce beetle damage, double-chambered traps have been designed by Common (1959) and by Denmark (1964), the lower chamber of each serving to accommodate the beetles. The trap described by Common is also provided with transparent walls which in themselves evidently provide an effective mechanism for excluding beetles from the trap. The damage occasioned by beetles may be alleviated in yet another way, however. If the bottom of the killing chamber is compartmentalized, beetle movements are greatly restricted so that the advantage of several discrete receptacles is obtained. Further, if a thin pad of cheesecloth is placed on the floor of the reception chamber, the beetles usually burrow into this or at least become entangled in it so that they are essentially immobilized.

At least two other factors must be considered in the design of a receptacle to contain the specimens diverted to a light source. Firstly, the number of specimens leaving the chamber through the entrance aperture must be reduced to a minimum. This may be accomplished in a funnel trap in two ways: by having a small entrance aperture and by reducing the amount of light entering the killing chamber from the bulb above. Both of these requirements may be met by having a screen-lidded "rain-drain" of sufficient diameter set shortly below the bottom of the funnel. This limits the size of the entrance apertures and also prevents light from shining directly into the killing chamber. Another important factor is the ease with which specimens may be recovered from the trap. If a removable tray is contained in the bottom of the chamber, this may be lifted out with the night's catch intact so that the specimens may be more readily sorted.

Killing Agents. The obviously best method of obtaining a quick "knock-down" is by employing the most rapid-acting poison and by maintaining it at a high level of concentration. Hydrogen cyanide, generated by treating one of cyanide salts with a weak acid solution, acts most quickly and leaves the specimens in a relaxed condition. The material is so excessively toxic, however, that it cannot be left with any equanimity in an unattended trap. This is particularly true of a trap with a large receptacle in which a large amount of poison must be used. Tetrachloroethane, a substance first proposed for light trap use by Williams (1948), makes a reasonable substitute for cyanide if it can be vaporized at a sufficiently rapid rate. Moreover, unlike some of the other anaesthetics, such as chloroform and ether, tetrachloroethane leaves specimens in a nicely relaxed condition. On cool nights, tetrachloroethane does not vaporize well, however; specimens in the receptacle remain active for long periods, and once quiescent may again become active during the sorting process the following day, or even after they have been pinned. Robinson and Robinson (1950) proposed the use of a vaporizer to dispense the tetrachloroethane. A perhaps more effective method of maintaining a lethal concentration of gas, however, is by having a large pad saturated with the chemical in the bottom of the receptacle with a small heating element located below it. This not only vaporizes the killing agent but warms the whole chamber so that the chemical will remain in a vaporized condition.

Location of Trap

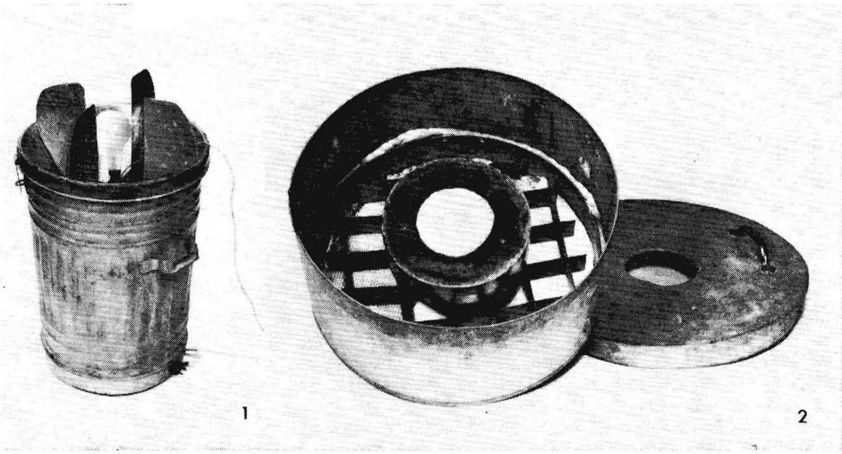
One other factor besides the design of the trap and the nature of the light source must be considered in any light-trapping program. This is the placement of the trap. Nominally a broad open area should prove most effective because it allows the widest field for the penetration of the light from the trap. More confined situations may prove equally productive, however, because of the fact that such situations serve as insect fly-ways in a region otherwise congested with timber or brush.

The height above the ground at which the trap is operated may also affect the response of various insects. The data presented by Frost (1958c), although not conclusive, suggest that within the range of a dozen feet or so the numbers of specimens of groups such as the Polyphaga may be sharply reduced with increased altitude of the trap. In other groups, such as the Noctuidae, however, differing altitudes of the trap cause little difference in the numbers of specimens taken.

An Efficient Noctuid Trap

The light trap illustrated in Figs. 1–3 has been used with good success for collecting noctuid moths during several years of survey work. Minor modifications to the original design have been made from year to year. The outer shell of the trap is a 20-inch high, galvanized steel garbage can to which other components have been designed to fit. The light source (a, of Fig. 1) is a 125-watt, 200–220 volt, Osram mercury-vapour globe manufactured by the General Electric Company of England. It is enclosed by four baffles (b) which extend somewhat above the level of the top of the bulb. The rather sharply sloped funnel (c) situated below the light leads into an inner metal chamber (d). The inner chamber, which serves to confine as much as possible the gas generated, may be lifted out of the shell of the trap once the funnel has been removed.

Within the inner chamber and shortly below the lower end of the funnel is a small screen-lidded container, the "rain-drain" (e) with a tube leading from it down through the bottom to the exterior of the trap; the container receives and eliminates any water entering through the funnel. The screened lid of the "rain-drain" must be sufficiently close to the lower end of the funnel and of sufficiently large diameter



Figs. 1, 2. A light trap designed for the collection of noctuid moths. 1, Exterior view. 2, Reception chamber showing "rain-drain," removable specimen tray, and metal lattice dividing tray into compartments.

that no rain can be distributed on the floor of the reception chamber. A circular, one-half inch thick, disc of sponge rubber (f) is secured to the upper surface of the screened lid of the "rain-drain"; this serves as a cushion for larger noctuids descending into the trap at a sharp angle and at a high rate of speed. Noctuids entering the trap in such a manner collide with the cover of the "rain-drain" with such force that a clearly visible cloud of ascending scales can be seen above the funnel of the trap.

Beneath the basin of the "rain-drain" in the reception chamber is a removable metal tray (g) with a one-eighth inch mesh hardware cloth bottom; the floor of the tray is covered with a thin pad of cheesecloth. A removable metal lattice (h) which divides the tray into a number of compartments rests on the cheesecloth. Below the metal tray, immediately on the floor of the reception chamber, is a one-half inch thick pad of cheesecloth (i), which is saturated with the killing agent, tetrachloroethane.

A hundred-watt heating element (j), the heat from which serves to vaporize the tetrachloroethane, and to warm the reception chamber so that the chemical will remain vaporized, is located in a separate chamber at the bottom of the trap. It is separated from the pad containing the tetrachloroethane only by the thickness of the metal forming the bottom of the reception chamber.

In disassembling the trap to inspect the catch, the funnel is first removed, the reception chamber is lifted from the outer shell and its

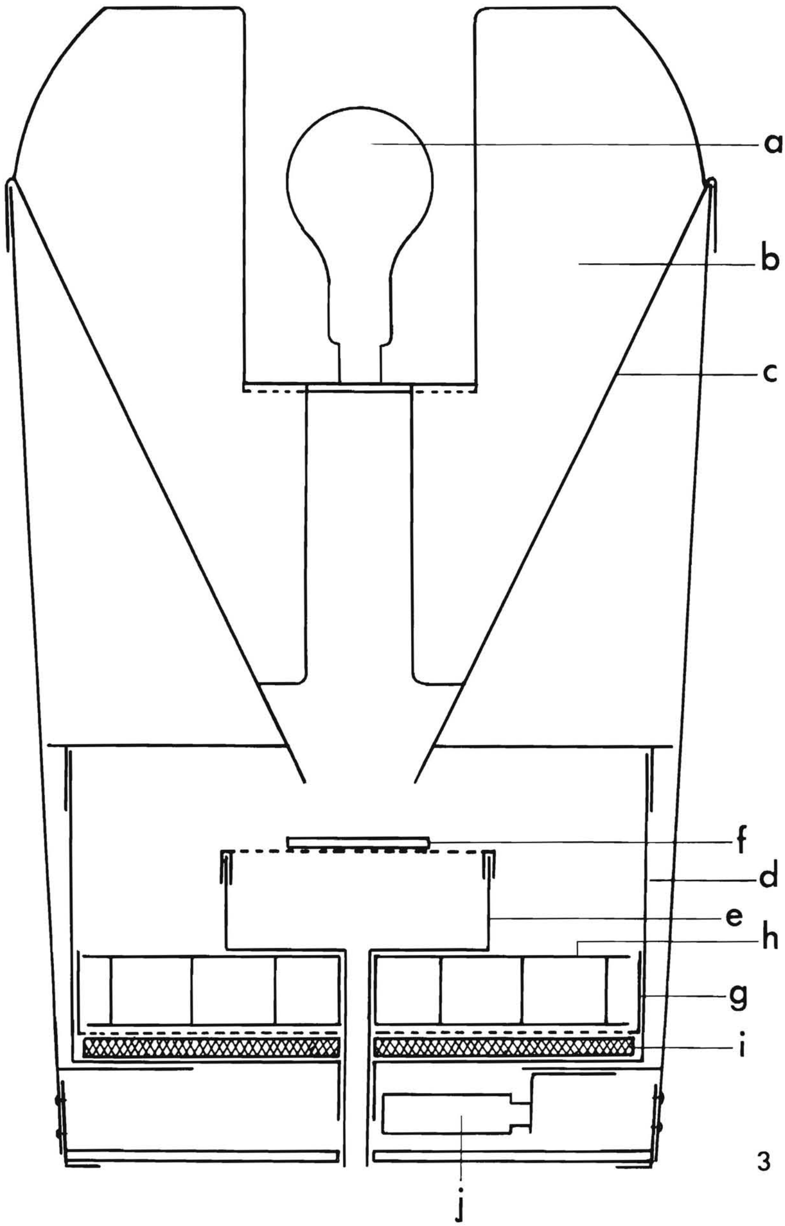


Fig. 3. Vertical section of trap with components in position for operation. *a*) light source; *b*) baffle; *c*) funnel; *d*) inner metal chamber; *e*) screen-lidded rain drain; *f*) disc of sponge rubber; *g*) removable metal tray; *h*) removable metal lattice; *i*) cheesecloth pad; *j*) heating element.

lid removed. The "rain-drain" is then removed so that the tray containing the night's catch may be lifted out of the killing chamber. In a well-ventilated room, the specimens may be sorted and pinned directly from the tray. When reassembling the trap prior to use, the cheesecloth pad in the bottom of the reception chamber is charged with 40 to 50 c.c. of tetrachloroethane.

On nights in which particularly heavy flights are anticipated, a greater concentration of tetrachloroethane vapour may be obtained in the reception chamber by inserting a wad of cheesecloth in the basin of the "rain-drain" and saturating this with the killing agent. One commonly encountered problem, when employing a trap with a large reception chamber in arid areas, is the drying out of specimens before they can be sorted and pinned. This may be alleviated to some degree by maintaining the humidity in the reception chamber at a high level by adding water, in quantity equal to that of the tetrachloroethane, to the pad at the bottom of the chamber and to the wad of cheesecloth in the basin of the "rain-drain." In areas or at times that electrical power is not available for operating the bulb of the trap, the bulb may be removed and a Coleman lamp substituted.

During four seasons of field use, power for operation of the trap was provided by a small 500-watt, 220-volt, gasoline-powered generator. The equipment was transported in a small laboratory-trailer in which bench facilities are available for sorting and pinning material taken in the trap. The trap was operated nightly on the top of the trailer so that the light source was about eight and one-half feet above ground level. This eliminated the creation of a large shadow area when the trap was operated in close proximity to the trailer. As mentioned previously, the altitude probably had little effect on the numbers of noctuids taken in the trap but may have reduced the numbers of specimens representing some other groups.

During a period of 200 nights of operation, the numbers of non-deltoid noctuid moths taken in the trap had a nightly arithmetic mean of 525, and a nightly geometric mean of 198; the maximum catch on any single night was 14,144. In nightly catches of less than 800 noctuids, specimens were in generally good condition. Under circumstances of very heavy flight, however, the killing chamber was evidently so well ventilated by wing movements that the killing gas was severely diluted, and specimens recovered from the trap were often rubbed.

Because of the weight of the trap and its ancillary equipment, the unit described cannot be considered a portable one. Its relatively high efficiency in "attracting" and capturing specimens, and in maintaining them in good condition, however, may render it of value to workers concerned with various aspects of noctuid ecology.

Literature Cited

Beirne, B. P., 1951. Some notes on the design of light traps. Ent. Gaz., 2: 259–262.

Common, I. F. B., 1959. A transparent light trap for the field collection of Lepidoptera. J. Lepid. Soc., 13: 57–61.

Denmark, H. A., 1964. Evaluation of an insect light trap designed to separate beetles and moths. J. Lepid. Soc., 18: 1–10.

Edmunds, G. F., 1961. A modification of the New Jersey insect light trap to reduce damage to specimens. Bull. Brooklyn ent. Soc., 56: 31.

Frost, S. W., 1958a. Insects captured in light traps with and without baffles. Canad. Ent., 90: 566–567.

1958b. Traps and lights to catch night-flying insects. Proc. 10th int. Congr. Ent. (1956), 2: 583–587.

1958c. Insects attracted to light traps placed at different heights. J. econ. Ent., 51: 550–551.

Harcourt, D. G. and L. Cass, 1958. A controlled-interval light trap for Microlepidoptera. Canad. Ent., 90: 617–622.

Heath, J., 1965. A genuinely portable M.V. trap light. Ent. Rec., 77: 236–238.

Parker, J. R., A. L. Strand, and H. L. Seamans, 1921. Pale western cutworm (Porosagrotis orthogonia Morr.). J. agric. Res., 22: 289–321.

Pfrimmer, T. R., 1957. Response of insects to different sources of black light. J. econ. Ent., 50: 801–803.

Robinson, H. S., 1952. On the behaviour of night-flying insects in the neighbourhood of a bright light source. Proc. R. ent. Soc. Lond., (A), 27: 13–21.

Robinson, H. S. and P. J. M. Robinson, 1950. Some notes on the observed behaviour of Lepidoptera in flight in the vicinity of light-sources together with a description of a light-trap designed to take entomological samples. Ent. Gaz., 1: 3–20.

Williams, C. B., 1948. The Rothamsted light trap. Proc. R. Ent. Soc. Lond., (A), 23: 80–85.

1951. Comparing the efficiency of insect traps. Bull. ent. Res., 42: 513–517.

LIFE HISTORY OF *DRYAS JULIA DELIA* (HELICONIINAE)

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Although *Dryas julia* (Fabricius) is at times abundant in southern Texas and Florida, little seems to have been published concerning the early stages other than that the larval foodplant is *Passiflora*. Sietz (1921: 400) says, "larva pale grey or grey-brown, the incisions darker, the fore part of the head marked with darker, the spines blackish." He remarks that the pupa is similar in color. Klots (1951) is admittedly even more indefinite: "larva—poorly known; possesses long branching spines." It is the purpose of this paper to give a more exact description.