TRAP RESPONSES OF FLYING INSECTS

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The Influence of Trap Design on Capture Efficiency

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ACADEMIC PRESS
Harcourt Brace Jovanovich, Publishers
London San Diego New York
Boston Sydney Tokyo Toronto

ACADEMIC PRESS LIMITED
24/28 Oval Road
LONDON NW1 7DX

United States Edition published by
ACADEMIC PRESS INC.
San Diego, CA 92101

This book is printed on acid-free paper

British Library Cataloguing in Publication Data
Trap responses of flying insects.
1. Insects. Behaviour
595.7051

ISBN 0–12–509755–7

Printed in Great Britain by St Edmundsbury Press Limited,
Bury St Edmunds, Suffolk
Typeset by Setrite Typesetters Ltd.

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Introduction

The use of capture, trapping and other sampling methods plays an essential part in all studies on the ecology and behaviour of insects in the field. Under certain favourable conditions a great deal of information about some aspects of insect activity can be gained from field observation alone. But there are obvious limitations to this when investigating other aspects of behaviour, or when studying insects which are mainly active at night. According to the different insects involved, and to the nature of the investigation, these capture and sampling methods have evolved along many different lines and proliferated into a multitude of different designs. Some of these trap designs, such as the light traps used for moths and the light traps used for mosquitoes, have undergone comparatively little alteration over the years, but in general the design and operation of most trapping systems are constantly being revised, improved and modified in the light of experience.

Against this constantly changing background any idea of laying down 'guide lines' or 'manuals of instruction' would be unrealistic. Methods developed for a particular species or for a particular purpose very often prove unsuitable for other, even closely-related species, or other environments. In addition, many research workers are reluctant to accept without question trapping or sampling methods which have been developed elsewhere, without first imprinting their own individuality on the design by modifications or improvements according to local requirements. In many cases these modifications are given names, either that of the research worker himself, the institute he is associated with, or the geographical location of the investigation. Alternatively, the design may carry a simple description, for example the biconical trap, or carry a code number, such as R3. Examples of this proliferating nomenclature of trap designs will crop up repeatedly throughout this book.

Not surprisingly, the bulk of the literature on trapping flying insects comes from the vast accumulation of knowledge about insects of economic importance, i.e. applied entomology, but in recent years significant contributions have come from work on faunal surveys, not necessarily concerned with insects as pests, but rather with the general ecology of endangered species in tropical environments at risk. Progress in that field has sometimes opened avenues of research still unexplored by applied entomologists.

In the field of applied entomology, the two main disciplines involved, namely agricultural and forestry, and medical and veterinary, continue to pursue rather separate and independent courses. Rapid advances in both of these fields have led to increasing specialization, making the task of keeping up with one's own subject so demanding that less and less time and energy can be spared for keeping up with allied subjects. This is well illustrated by two fields of very intense activity, namely the biology and control of tsetse flies with particular reference to insect response to trapping systems, and the even more explosive field of sex-attractants or pheromones of insects of agricultural importance, and the increasingly critical and penetrating research on insect response to pheromone-baited traps associated with this. There are few common meeting grounds for the specialists in these two divergent disciplines. Nevertheless, a striking exception is provided by the fact that increasing emphasis on animal odour-baited traps and on odour ingredients in tsetse research, for example, is inevitably directing research efforts on insect responses into fundamentally similar channels to those being explored in the field of sex pheromones, and the response of insects to different pheromone ingredients.

Traditional separation of agricultural from medical entomology has also in some cases resulted in a kind of language barrier. For example, to plant pest specialists, black flies or blackflies are plant sucking aphids of the bug order Homoptera. To the medical entomologist the same term applies to small two-winged blood-sucking flies (*Simulium*) of a quite different order, Diptera. In trap nomenclature too, the same term may mean different things to different people. To the agricultural and forestry entomologist 'window traps' are vertical sheets of glass or transparent perspex used to intercept the flight of bark beetles and their allies: to the medical entomologist 'window traps' are one-way traps in the form of net cages fixed over the windows of human or animal habitation, either to trap – through a funnel – mosquitoes leaving the habitation after feeding or resting indoors, or in reversed form, to intercept mosquitoes entering the habitation from outside.

In view of this dichotomy, there would appear to be a real need to attempt an overall review within the compass of one book. The increasing specialization would suggest that logically this can only be achieved by a multi-author symposial type of publication, in which the contributors are specialists actively engaged in one or other of the many disciplines. The obvious advantage of that type of publication in providing up-to-date expertise is offset by the fact that few of the contributors would have sufficient space, or opportunity, to extend the scope of their review outside their own subject to any extent. The need for an objective overall review can still perhaps best be met on a single author basis, and such an approach may also offer the best opportunity for continuity of text and theme when passing from one specialized subject to another.

In view of the enormous amount of literature covering this extended field, selection has to be exercised in order to avoid the text from becoming simply a 'summary of summaries'. This selection of material is determined by the title or theme of this book, and consequently most space will be devoted to published work in which the experimental approach predominates, that is, with regard to the various problems encountered in insect response to traps and to trap design, and to attractants whether visual or olfactory. Some of these research projects seem to be particularly worthy of detailed description and assessment, and it is hoped that the additional space they merit may assist researchers in one field to appreciate progress in other unfamiliar fields from which their interest has been discouraged by the sheer mass of highly specialized reports and papers.

Selection of material inevitably means less space for other work, less relevant to the theme of this book, but nevertheless sufficiently important not to be ignored or overlooked. Undoubtedly, important contributions may inadvertently have been omitted, and in some cases overlooked. This is to be regretted, and must be attributed to the fact that the author falls far short of omniscience in undertaking such a formidable task.

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Acknowledgements

The preparation of this book was greatly assisted by generous donations from the Carnegie Trust for the Universities of Scotland (Professor J.T. Coppock), and from the Shell Research Laboratory, Sittingbourne, (Dr N.R. McFarlane). In compiling as impartial a review as possible I must make a comprehensive acknowledgement to all the research workers whose publications I have freely quoted, and whose figures have been used to illustrate the text. In the case of unpublished material – still in thesis form – I am particularly indebted to Dr W.J. McGeachie and Dr P.A. Gaydecki of the Cranfield Institute of Technology for the use of their research material on the reactions of moths to light traps. Because of the great significance of these contributions they have been reviewed as fully as is possible within the confines of this book.

Of the many colleagues-through-correspondence who have been so helpful in providing material and up-to-date information I am most grateful to the Australian researchers to Dr Keith Wardhaugh and Dr V.A. Drake of CSIRO Canberra, to Dr G.H.L. Rothschild, Director of the Bureau of Rural Resources, Canberra, and to Professor W. Danthanarayana of the University of New England, Australia. Professor S. Mukhopadhyay of the Bidhan Chandra Krishi Viswavidyalaya Plant Virus Research Centre, West Bengal has provided valuable information about the many developments in India highly relevant to the theme of this book. Among other helpful correspondents I am indebted to Professor M.J. Samways of the University of Natal, to Professor W.L. Roelofs of the New York State Agricultural Experimental Station, and to Dr G.M. Tatchell of Rothamsted Experimental Station.

In trying to achieve as accurate a review as possible of the many publications quoted, all text and diagram measurements dealing with length or area have been retained exactly as in the original, and no attempt has been made to impose a standardized metric equivalent, unless the author of that report has done so. Transforming these Imperial measurements automatically into their metric equivalent – which in many cases would involve five figures and three decimal places – would only give a confused presentation of the original clear-cut experimental lay-out. This could also apply to the alternative practice of following the original Imperial data by the metric equivalent in parentheses. This again could only lead to a proliferation of figures sufficient to detract from each author's original presentation.

Chapter 1

Light Traps

1.1 Introduction and background

The use of artificial light to attract and trap moths and other nocturnal insects has long been practised by insect collectors in general, and by applied entomologists in particular. From its simple beginning as an electric bulb or a kerosene lamp in front of a white sheet, the development of light traps has progressed rapidly to the more sophisticated and automatic models now available. One of the great advantages of light traps, especially for night-flying Lepidoptera, is that no other trapping method has proved so consistently successful in capturing larger numbers or a greater variety of species. For example, in an 18 month light trap survey in Queensland, Australia, there was a total catch of 750 000 moths, of which 339 000 were noctuids, composed of over 300 species (Persson, 1976). In a survey at Mugugu, near Nairobi, Kenya, up to 49 000 moths have been taken in one trap on one night, at a time when other methods of trapping, using different techniques, only succeeded in capturing a single moth (Brown *et al.*, 1969). In fact, light trap captures of some pest species have been so strikingly high as to lead to attempted control of such pests as cotton bollworm and tobacco hornworm by means of a network of traps alone, with the object of producing a significant reduction in population (Hartstack *et al.*, 1968). At the other extreme, reports from such widely separated regions as Australia, Europe and the USA have shown that such a notorious and widespread pest as the oriental fruit moth is rarely taken in light traps, even in those providing a range of light sources (Rothschild, 1974).

Much of the critical work on light traps has been carried out on moth species whose larvae are important agricultural or forestry pests. But light traps are increasingly being used for a variety of plant pests such as plant bugs and aphids which are mainly important as vectors of plant virus diseases. This is a development which has been especially marked in India, which has a history of light trapping dating back to the first decade of the century (Nath and Banerjee, 1985; Pawar *et al.*, 1985).

In the course of these and other investigations it has become evident that, in addition to moths, a wide range of insect orders, genera and species are regularly attracted to light traps. For example, in one series of studies in Africa (Bowden and Church, 1973) practically all main suborders of insects were taken, including a wide range of beetles, wasps, bugs and grasshoppers. This wealth of species, and sheer volume of catch, could in fact prove an embarrassment to the specialist concentrating on the fluctuations of a few key species only.

Nevertheless, for a subject which seems to have been so exhaustively studied in so many countries, the main impression is that the whole subject of insect capture by light trap and insect response to these traps is one that needs continual re-appraisal and assessment. It is only comparatively recently for example that Australian workers, by making a simple modification to the conventional design of light trap, were able to capture successfully the migrant locust, never previously recorded by this capture technique (Farrow, 1974, 1977). No one can deny the success of light traps in capturing nocturnal insects. But the questions remain: what relation does the light trap catch bear to the total population exposed, and in what way are catches influenced by such imponderables as trap design and efficiency, nocturnal insect behaviour, changes in insect flight density, or variations in flight path? If we add to these variable factors the regular rhythmic changes in night-time illumination in the course of each lunar cycle, we are presented with an ecological challenge sufficient to test the ingenuity of a whole generation of dedicated research enthusiasts.

As in so many other fields of applied entomology, studies on agricultural and forestry pests have tended to follow lines of investigation quite independent of those pursued by entomologists concerned with insect pests of man and domestic animals, the vectors of human and animal disease. In that field, mosquitoes are the predominating night-flying winged insects, along with other small two-winged flies such as biting midges (Culicoides) and sand flies (Phlebotomus). The use of light traps to capture nocturnal mosquitoes and their allies also has a very long history, and continues to be one of the main standard methods for monitoring populations of mosquito vectors of disease, particularly those concerned with transmission of viral disease. The fact that these two main branches of applied entomology have continued to pursue independent courses, even on what appear to be basic insect capture techniques, may be associated in some way with their different origins. The systematic use of light traps for the study of nocturnal moths, including major pest species, originated in the classic studies at Rothamsted Experimental Station, Harpenden, England from the 1930s onwards, from whence its influence subsequently extended to other centuries of the Old World, mainly Africa and India. In contrast, the use of light traps for mosquitoes has long been preeminently an American concern and this has gradually spread to those other parts of the world of concern to American-based or American-influenced teams of research workers.

In the following sections it is hoped to emphasize, not so much the differences in approach adopted by these two different disciplines of applied entomology, but the existence of so many problems common to both which are still unresolved, and which urgently demand closer liaison. In this connection it is encouraging to note that recent studies on trapping night-flying insects in Australia have encompassed both moths and mosquitoes in their programmes (Danthanarayana, 1976). Although the basic capture technique in that study was the use of suction traps rather than light traps, the role of moonlight and moon phase was a major objective of that work, a factor of prime importance in the intepretation of light trap capture data.