FOREST ENTOMOLOGY

Ecology and Management

ROBERT N. COULSON
Department of Entomology
Texas A & M University

JOHN A. WITTER
School of Natural Resources
The University of Michigan—Ann Arbor

A Wiley-Interscience Publication
JOHN WILEY & SONS
New York • Chichester • Brisbane • Toronto • Singapore

Library of Congress Cataloging in Publication Data:

Coulson, Robert N. (Robert Norris), 1943–
Forest entomology.

"A Wiley-Interscience publication."
Includes bibliographies and indexes.
1. Forest insects. 2. Forest insects—Control.
I. Witter, John A. II. Title.
SB761.C68 1984 634.9'67 83-23492
ISBN 0-471-02573-9

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

PREFACE

Forest entomology is a subject that draws on knowledge from several different academic specialties, including general entomology, forestry, and ecology. Forest entomology involves consideration of the roles that insects play in forest ecosystems, specialized forestry settings such as seed orchards and nurseries, and urban forests. Insects can have both positive and negative effects in these forest situations depending on the value system we use in judging their activities. Most forest insects play beneficial functional roles, which have been identified through basic studies in forest insect ecology. In some cases insects disrupt our planned uses of forests and are considered pests. During the last two decades our knowledge of forest insect ecology has increased dramatically. We have also witnessed the development of a component of forest management termed "integrated pest management" (IPM), which is the philosophy, concept, and methodology for dealing with insects when they threaten or actually damage our forests.

The subject of forest entomology is taught in departments of entomology and schools of forestry at both undergraduate and graduate levels. The course is presented under several different formats: as a service course for undergraduate forestry students, as a section of an undergraduate forest protection course, and as a specialty course for entomology undergraduate and graduate students. In some cases a laboratory is offered as part of the course. Therefore, a textbook in forestry entomology can serve a number of different purposes.

Our goal in this text is to address the fundamental issues of forest entomology. The book consists of 18 chapters divided into three sections. Each chapter contains a table of contents at the beginning, which is intended to serve as a guide to the subjects discussed; figures and tables to illustrate key points; and a contemporary literature cited section, which is intended to reference the work of other scientists and serve as a guide for further study. The first section consists of four chapters dealing with general entomology. The subjects covered include: introduction to insects (Chapter 1), insect structure and function (Chapter 2), insect classification (Chapter 3), and insect damage and sign categories (Chapter 4). This section is intended for students who have not had training in entomology and as a review for students with previous knowledge. The second section consists

of six chapters dealing with principles and concepts of integrated pest management of forest insects. Chapter 5 provides a general overview of the subject of integrated pest management and is the focal point of the section. The basic components of integrated pest management are defined in Chapter 5, and these components are discussed in detail in the remaining chapters in the section. The subjects discussed include population dynamics of forest insects (Chapter 6), population dynamics of forest trees in relation to phytophagous insects (Chapter 7), principles of population modification and regulation using artificial and natural agents (Chapter 8), impact assessment (Chapter 9), and monitoring pest populations and forest stands (Chapter 10). The third section consists of eight chapters dealing with the principal forest insect feeding groups: defoliators (Chapter 11); sapsucking insects (Chapter 12); terminal, shoot, twig, and root insects (Chapter 13); seed and cone insects (Chapter 14); phloem feeding insects (Chapter 15); wood boring insects (Chapter 16); gall forming insects (Chapter 17); and insects affecting recreational uses of forests (Chapter 18). The goal of Section III is to provide an overview of the primary insect species that impact on forest ecosystems, specialized forestry settings, and urban forests. We emphasize the ecological functions of the insects covered, examine case history examples for major pest species, define the treatment tactics and strategies used in regulating or modifying populations, and provide a contemporary reference section for each feeding group.

The organizational format for this text was selected to accommodate the various ways that forest entomology is taught. We have cross-referenced the chapters in each section in order to direct the student to pertinent definitions and concepts.

ROBERT N. COULSON
JOHN A. WITTER

College Station, Texas
Ann Arbor, Michigan
March 1984

ACKNOWLEDGMENTS

Numerous individuals have helped in the preparation and production of this text. Our colleagues have reviewed drafts of each chapter and made suggestions on content and have provided photographs and figures. We acknowledge and thank D. C. Allen, R. J. Allen, J. R. Baker, B. V. Barnes, C. W. Berisford, A. A. Berryman, R. F. Billings, J. H. Borden, M. H. Brookes, S. Buthman, R. S. Cameron, I. S. Cantrall, W. M. Ciesla, S. P. Cook, J. E. Coster, D. A. Crossley Jr., G. L. Curry, G. E. Daterman, G. L. DeBarr, C. J. DeMars, M. E. Dix, A. T. Drooz, N. Dubois, L. J. Edson, W. S. Fargo, C. W. Fatzinger, R. M. Feldman, M. D. Ferguson, R. O. Flamm, J. L. Flexner, J. L. Foltz, R. T. Franklin, J. A. Gagne, N. Gosling, P. B. Hennier, G. D. Hertel, W. Houser, K. M. Hughes, R. L. Hyde, P. J. Iwai, S. Jones, R. Kelly, C. S. Koehler, P. W. Kovarik, H. M. Kulman, D. Loh, R. Long, P. L. Lorio, A. M. Lynch, L. A. Lyons, C. T. Maier, B. Manoulian, W. J. Mattson, F. G. Maxwell, M. S. McClure, M. W. McFadden, J. R. McGraw, M. M. McKnight, J. A. McLean, R. Merritt, B. A. Montgomery, H. L. Morton, T. E. Nebeker, I. Otvos, T. L. Payne, F. W. Plapp, P. E. Pulley, R. B. Ryan, E. J. Rykiel, L. Safranyik, T. D. Schowalter, C. P. Schwalbe, P. J. H. Sharpe, G. A. Simmons, K. Simpson, L. Simpson, G. A. Snyder, J. D. Solomon, F. M. Stephen, M. W. Stock, R. L. Talerico, R. C. Thatcher, L. C. Thompson, H. Trial, R. H. Turnbow, S. B. Vinson, T. L. Wagner, W. E. Wallner, W. E. Waters, D. P. Webb, D. S. White, M. L. Williams, L. F. Wilson, S. L. Wood, and H. O. Yates III.

Special thanks are due to R. W. Stark and F. P. Hain for their candid review of the manuscript of this text, to Nancy Witter for providing artwork, and to M. M. Conway for her perseverance with us and expert editorial service.

We especially acknowledge and thank A. M. Bunting for her conscientious and thorough attention to the details of preparation of the manuscript. She assisted in preparation of figures and tables, editing, file management, and numerous other vital details.

We are indebted to and dedicate this book to our parents and families (Frances, Karah, and Amy Coulson and Nancy and Leslie Witter) for their encouragement and commend their patience during the preparation of this textbook.

R.N.C.
J.A.W.

CONTENTS

I GENERAL ENTOMOLOGY

Section I contains four chapters that provide an overview of general entomology. Chapter 1 is an introduction to the science of entomology. Chapter 2 considers basic principles of insect structure and function. Chapter 3 provides a treatment of classification of insects and other arthropods. Chapter 4 defines the various types of damage that insects cause to forest trees.

These four chapters serve as a basic course in general entomology for the student without training in entomology and a review for students with previous knowledge of entomology.

1 INTRODUCTION TO INSECTS

INTRODUCTION

This chapter is divided into four parts: (1) forest entomology, (2) shade tree entomology, (3) insects beneficial to human beings, and (4) insects harmful to human beings and their perceived needs.

FOREST ENTOMOLOGY

Definitions

Forest entomology is concerned with insects that affect the forest and forest products. Smith et al. (1973) provides information on the history of forest entomology in North America, whereas Coulson (1981) discusses the evolution of forest pest management. Wood product entomology is concerned with the protection of wooden structures, poles, posts, and wood by-products from insect damage. Although usually considered as part of forest entomology, its problems are quite different from most of those in forest entomology and is sometimes considered a separate field (Chamberlin 1953, Hickin 1975). This textbook emphasizes insects affecting live trees. Some of the important insects affecting wood products such as termites, powderpost beetles, carpenter ants, and the old house borer, however, are covered in Chapter 16.

The Forest Entomologist

The forest entomologist studies insects in the forest, their damage to trees and shrubs, and the interaction of the insects with plants, animals, and the physical environment. The results from these studies in applied forest insect ecology must then be incorporated with the silvicultural, management, policy, and economic goals of forestry and resource management. Forest entomologists, therefore, need strong academic training and practical experience in both forestry and entomology. Although specific goals of forest entomologists are influenced by their employers, most of them would list some or all of the following as major goals: (1) collection of ecological information to reduce insect damage through forest management and silvicultural practices, (2) development of methods and conducting surveys to determine insect abundance and insect impact, (3) development or use of natural enemies and other pest management techniques—excluding chemical insecticides—to reduce insect damage, (4) public education on forest insect pests and sound pest management programs, and (5) development and/or use of chemical insecticides to reduce insect damage. Goals 1–3 usually provide a more permanent type of pest management program, whereas goal 4 involves the transfer of information from the literature and current research to the user groups. The last goal is primarily a temporary

stopgap method in pest management and is used with more specialized crops such as Christmas trees, planting stock, and seed orchards.

In the United States forest pest management operations are the responsibility of the following organizations: (1) the U.S. Department of Agriculture, Forest Service, State and Private Forestry, Forest Pest Management; (2) state forestry or natural resource departments; and (3) forest industry. These organizations plan and conduct insect surveys and insect impact evaluations and organize, supervise, and evaluate forest pest management techniques. Research work on forest insect problems in the United States is handled primarily by personnel at Forest Insect and Disease Units of Forest Service Experiment Stations and at state and private universities. Some land grant universities have entomologists involved in forest entomology extension work. For example, North Carolina State University has a very effective extension program in forestry, including forest entomology. Presently, very few forest entomologists are employed full-time as extension specialists. Most forest entomologists are involved with some extension duties as part of their total job responsibilities. A few forest industries have their own forest entomologists.

The Forester

The field forester or forest technician, who is in direct contact with the forest resource, is often the first person to notice new insect problems. The field forester or forest technician must be trained to recognize potential forest pest problems and must have the ecological training necessary to plan and carry out sound forest management and forest pest management practices. Specifically, a forester should be trained to (1) recognize and identify the common types of insect damage; (2) identify the common insects found in the forest; (3) recognize insect damage and the various stages of the most common forest pest problems in their region; and (4) understand the seasonal history, population dynamics, impact, and management strategies for the most common forest insect pests. A forester trained in the above skills will be able to recognize and identify the common types of insect damage present in the particular region and will be able to properly integrate many forest pest management techniques into the forest management practices used in the region.

SHADE TREE ENTOMOLOGY

Differences between Forest and Shade Tree Entomology

Shade tree entomology is concerned with insects affecting individual trees or groups of trees in the urban forest, including park trees, street trees, and yard trees. The insects present on these trees are generally the same

species that occur in forest stands. However, the unit involved, ecological conditions, economic values, and the amount of damage tolerated differs between trees in the urban forest and forest stands.

In shade tree entomology, the homeowner, city forester, or arborist is managing and caring for an individual tree or a small group of trees while the forester is managing and caring for a forest stand. A city forester is responsible for maintaining all trees on city property, including trees on lawn extensions. The city forester may be involved in managing a reasonably large number of trees, but is interested in the maintenance of individual trees. The homeowner is interested in individual trees that provide shade and aesthetic beauty on the home property. The forester or natural resources manager is rarely concerned about an individual tree within a forest stand. There are a few exceptions such as large highly prized trees within a forest stand such as black walnut or redwood, individual trees that provide nesting sites for endangered animal species (e.g., a large white pine tree with a bald eagle nest), and trees selected for seed sources.

The economic value of an individual tree in the urban environment is normally much greater than one tree in a forest stand. The homeowner or city forester is often willing to spend a considerable amount of time and money to maintain individual trees. The value of a city tree is determined by its size, condition, species, and location. For example, the value of a 63-cm DBH sugar maple tree and a 88-cm DBH elm tree in a city in the eastern United States in good condition and in a prime location are valued at $4909 and $1924, respectively (International Society of Arboriculture 1975). The costs of treatment, such as removing a large dead tree from a city lot, are much greater than any comparable action in the forest. The current costs of removing a large dead American elm or sugar maple tree from an urban environment varies from about $150 to $2000 depending on the size and location of the tree.

Ecological conditions normally vary considerably between urban forests and managed or unmanaged forest stands. Soil disturbances, changes in drainage patterns, damage to tree roots, nutrient deficiencies, air pollution, and mechanical injury to trees are much greater in urban areas than in forest stands. The urban areas are warmer and less humid than the surrounding rural areas because of the extensive asphalt surfaces and the massive combustion of fuels in cities. Also, trees are often planted in an urban environment on poor sites, or species are planted outside their native range.

The amount of insect damage normally tolerated by most homeowners and the general public on trees in the city is much less than the amount of damage tolerated by foresters on trees in forest stands. Many homeowners and the general public envision a "perfect tree" or "perfect leaf" with no damage, or they believe in the dead insect syndrome (i.e., the only good insect is a dead insect) or have an entomophobia problem. For these reasons, insect species normally not considered forest pests, such as many

species of aphids, scales, and mites, are considered to be pests in urban areas.

The City Forester or Arborist

The city forester or arborist is involved with planting, growing, maintaining, and protecting urban trees, whereas the shade tree entomologist concentrates on the protection of urban trees. The goals of these professionals are similar to the goals of a forest entomologist or forester. In the urban environment, professionals in the past often relied more on chemical insecticides as a control tactic because very little insect damage and low numbers of insects were tolerated by the general public. Shade tree extension specialists or horticultural extension specialists are employed by city, state, and federal governments. They provide information on shade trees and ornamental plants to the general public. Research on shade tree pests has been limited. The only two shade tree pests that have received substantial federal research support have been Dutch elm disease, *Ceratocystis ulmi* (Buisum) C. Moreau, and gypsy moth, *Lymantria dispar* (Linnaeus). There will be increasing emphasis on research in shade tree pest management programs as the public uses and places more value on urban forests, including protection of shade and park trees. The minimal research work on shade tree insect problems has been conducted primarily by scientists at USDA facilities and at various state and private universities.

The Nonforester and Nonarborist

Some students and individuals are not planning careers in forestry or arboriculture. The information in this textbook will give these readers a better understanding of insect interactions within our environment. It will enable them to be more informed regarding insects and insect pest management and help them to cope better with insects in the urban and rural forest environment. For example, the public is becoming more involved in issues such as the broad-scale use of pesticides and the effects of pollution on public lands. The U.S. Forest Service must consult with the public (requirement of the National Forest Management Act) before any major land use activity occurs.

INSECTS BENEFICIAL TO HUMAN BEINGS

This textbook concentrates on and emphasizes insects that cause damage to forest and shade trees. It is erroneous to regard all insects as pests. Estimates of the number of insect species that occasionally cause damage in the United States vary from about 500 to 1000 species depending on

the evaluation criteria used. Less than 1% of all the described insect species in North America are major insect pests. The majority of insects are either directly or indirectly beneficial or neutral in their relationship to human beings. Insects pollinate plants; provide food for other animals and products for human consumption; serve as natural control agents of other pests, including insects and weeds; enrich the soil; and contribute to the aesthetic and educational experience of human beings.

Insects as Pollinators

Sexual reproduction in flowering plants occurs when wind or insects transfer pollen from the anther of a male flower to the stigma of a female flower. Well-known examples of wind-pollinated plants are many species of trees such as oaks, willows, pines, and many species of cereals such as corn and wheat. Most of our fruit crops; many ornamental flowers; many vegetables such as beans, peas, tomatoes, and onions; and many field crops such as alfalfa, clover, cotton, and tobacco depend on insects for pollination. There are thousands of species that pollinate plants. Most insect pollinators are found in the orders of Hymenoptera (bees), Lepidoptera (butterflies), Diptera (true flies), Coleoptera (beetles), and Thysanoptera (thrips). The flowers of plants and the insects that visit them have co-evolved. Wild pollinating insects were sufficient to pollinate our food crops until recently. Large monocultures, clean cultivation, and the intensive use of chemical insecticides in agriculture have reduced the numbers of wild pollinating insect species so that they cannot now maintain an adequate level of pollination in many of our commercial crops. Provision of pollinators is now a big business. Honeybees, alkali bees, and leafcutter bees are commonly reared for pollination of approximately 80% of our commercial crops. Insect pollination is a very important and complex subject that covers many ecological and evolutionary principles (Proctor and Yeo 1972, Gilbert and Raven 1975, Daly et al. 1978).

Insects as Food

Insects are an important source of food for other insects and for many other animals such as birds, fish, mammals, amphibians, and reptiles. Swan (1964) reported that at least 50% of the food consumed by North American land birds consists of insects. Most land birds are primarily insectivorous while rearing their young regardless of their food habits during the rest of the year. It is probably not a coincidence that the nesting period of most birds parallels the peak emergence periods of many insects. Insects are rich in proteins and lipids necessary for the rapid growth of young birds.

Immature and adult insects such as midges, mayflies, stoneflies, and caddisflies are an important food source for fresh-water fish. Many anglers