DRAKE, V. A., AND A. G. GATEHOUSE (eds.). 1995. Insect Migration: Tracking Resources Through Space and Time. Cambridge University Press, Cambridge. xvii + 478 p. ISBN 0-521-44000-9. Hardback. $74.95.

Migration is a fundamental component of many insect life cycles, and multidisciplinary studies have begun to clarify some major deficiencies in our understanding of it. Two recent books succeed in summarizing these studies and fitting them into patterns that are roughly complete or at least have the missing pieces identified. One is by Hugh Dingle and deals with all of animal migration (*Migration: the Biology of Life on the Move*, Oxford Univ. Press, New York, 1996, 474 p.). The other, the subject of this review, has 41 authors and deals only with insects.

Insect Migration stems from a symposium at the XIX International Congress of Entomology in Beijing (1992). The coherence of its 21 chapters and the currentness of its references demonstrate the editors' success in persuading the symposium participants to modify and update their contributions. The book has a slight geographical bias toward eastern Asia and Australia meant to counterbalance the biases toward Africa and North America of previous reviews. (Little is reported about insect migration in South America, but little is known.) The species discussed usually migrate above their flight boundary layer, where wind direction is the principal determinant of di-

rection of movement. Weak fliers have little choice but to use the wind for transport; strong fliers, such as Monarch butterflies and desert locusts, can progress in any direction near the ground or they can take advantage of favorable winds at higher altitudes and travel fast at low cost.

Many migratory species are most damaging in geographic areas they cannot occupy continuously because temperature or moisture is only seasonally or erratically favorable. One theme of the book is the evolutionary dilemma posed by insects that move into temporarily favorable habitats from which neither they nor their descendants are known to return (the so-called "pied piper" effect, proposed by Rabb & Stinner in 1979). Such one-way migration can be viewed as an inadvertent consequence of the insects using uncertain winds as a transport system, or it can be viewed as a consequence of our knowing too little about the insects' movements. Indeed, in a few cases further study has revealed return movements in what were thought to be pied piper species. In other cases, a nomadic life style may be a means of continually exploiting habitats of erratic suitability.

Insect Migration has three main groups of chapters. The first and largest group describes insect migration in relation to weather and climate, with one or more chapters on Africa and Europe, North America, eastern Asia, and Australia. In West Africa seasonal reversal of windborne migration has been demonstrated for bugs, moths, and flies as well as several species of grasshoppers. Much migration in Africa is more complex and involves seasonally changing wind patterns in area of shifting habitat suitability. The complexity of windborne migration is well illustrated by studies of desert locust (*Schistocerca gregaria*) and African armyworm (*Spodoptera exempta*). Their movements cannot be simply summarized, and there is no easily grasped return of migrant genes from their source areas. Some migrations are fatal, with insects carried into deserts, poleward in autumn, and out to sea. Yet staying put does not insure survival either.

Eastern North America is much more favorable for regular to-and-fro seasonal migration than is Africa and Europe, there being no Sahara or Mediterranean. Spring poleward migrations are on northward, fast-moving, low-level jets at altitudes of 200 to 1000 m and take 2 to 3 nights. Autumn equatorward migrations are nearer the surface (100-300m) on slower southward airflows and are limited by how rapidly temperatures fall behind the front. Passage of successive fronts may be required for migrants to reach overwintering areas. Circumstantial evidence supports a north-in-spring, south-in-fall migration for many pest species. Such migrations have been confirmed experimentally for potato leafhopper (*Empoasca fabae*) and black cutworm (*Agrotis ipsilon*).

Two planthoppers in eastern Asia migrate northward and northeastward in spring and summer attacking rice in areas where they cannot overwinter. Some migration to the southwestward in autumn has been detected, but whether these are significant contributors to the gene pool of individuals that move northeastward the following year is uncertain. Three chapters deal with migrations of the oriental armyworm (*Mythimna separata*) in northeastern China, Korea, and Japan. In China there seems to be enough return migration to make the northward migrations adaptive. Whether the outbreaks in Korea and northern Japan are an adaptation is not addressed.

Three chapters deal with important Australian migrants: common armyworm *(Mythimna convecta*), native budworm (*Helicoverpa punctigera*) and Australian plague locust (*Chortoicetes terminifera*). In each case adaptive return migration is possible but unproved. Especially in the case of the native budworm, which is adapted to the ephemeral environments of the arid inland, migration may be the only way to maintain a permanent, though nomadic, population.

A second group of chapters concerns adaptations for migration. A. G. Gatehouse and X. -X. Zhang review the literature on potential for migration, including when migration occurs relative to reproduction, reproductive status of migrants sampled during flight, duration of pre-reproductive period, and free or tethered flight performance. They conclude that not much is known but that females of some species vary extensively in what it takes to initiate facultative migration and in migratory potential itself. K. Wilson outlines types of temporal and spatial variation in habitat and their expected effect on the evolution and maintenance of migratory potential. He reports that many studies suggest adaptive variation in migratory potential, but that few provide a convincing association with habitat heterogeneity and these mostly with temporal heterogeneity. J. Colvin describes laboratory studies of the genetics and ontogeny of two correlates of migratory potential in the cotton bollworm (*Helicoverpa armigera*): duration of tethered flight and of the pre-reproductive period. J. N. McNeil et al. discuss the physiological integration of migration in Lepidoptera—specifically, the roles of juvenile hormone titer and the accumulation and mobilization of lipids. R. Dudley, in a chapter dealing with the aerodynamics and energetics of migratory flight, notes that data on free flying migrants are few and describes how a motorboat can be used to collect such data on butterflies and day-flying moths as they migrate across large lakes.

A third group of chapters treats forecasts of migrant pests. Two chapters in this group concern general problems and techniques of forecasting, specifically operational aspects and the use of computer-based geographic information systems. Other chapters deal with specific forecasting systems—for brown planthopper in China, rice planthoppers in Japan, locusts and grasshoppers in West Africa and Madagascar, and desert locust throughout its invasive area.

The book concludes with a "holistic conceptual model" of insect migration by V. A. Drake, A. G. Gatehouse, and R. A. Farrow. They identify these four components of a migration system and list for each the processes that are involved: *migration arena* (the space, geographical and vertical, within which a population's migration takes place), *population trajectory* (space/time population demography that results from migration), *migration syndrome* (the physiological, morphological, and behavioral traits that implement migration and determine the fitness of the migrants), and *genetic complex* (the genes that underlie the migration syndrome and their interactions and modes of inheritance). In this manner they succeed in describing, classifying, and illustrating the complexities of insect migration. Their conceptual model becomes an organizing framework for migration studies that accommodates what is known and reveals what is not.

In words borrowed from the title, this book tracks studies of insect migration through space (worldwide) and time (the past 25 years). It summarizes and integrates the results of these studies and cites the important primary literature. *Insect Migration* belongs on the bookshelf of those interested in insect ecology and life histories as well as those who must propose control strategies for migratory insect pests.

Thomas J. Walker
Department of Entomology and Nematology
University of Florida
Gainesville, Florida 32611-0620