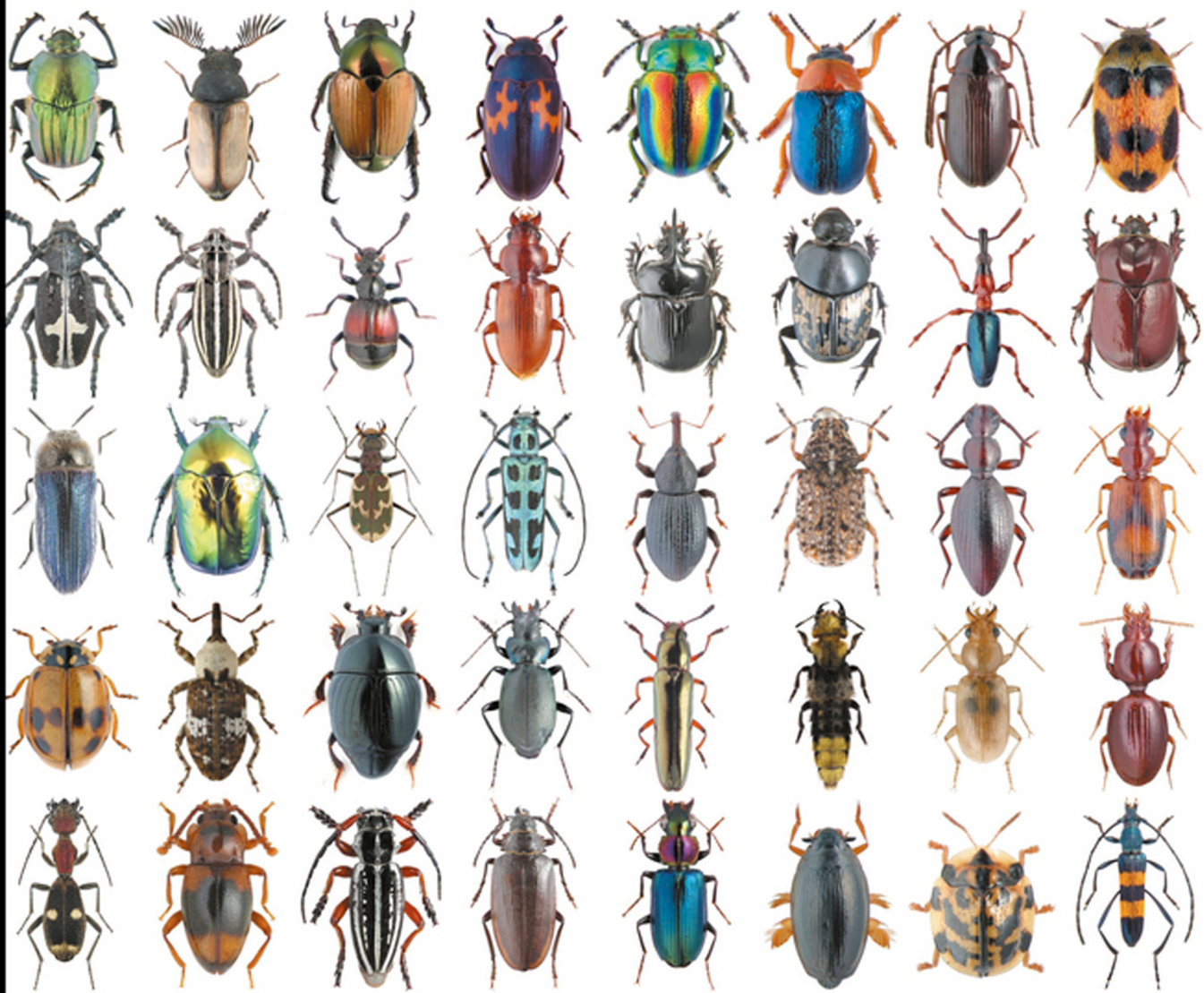
VOLUME I

INSECT BIODIVERSITY

SCIENCE AND SOCIETY

SECOND EDITION

EDITED BY ROBERT G. FOOTTIT • PETER H. ADLER



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Insect Biodiversity

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Science and Society

Second Edition

Volume I

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Foreword, Second Edition

Insects are the most exuberant manifestation of Earth's many and varied life forms. Their rather simple unifying body plan has become modified and adapted to produce an enormous variety of species, and insects exploit virtually all terrestrial and freshwater environments on the planet, as well as many brackish waters. However, as a paradox debated extensively a few decades ago, they are largely absent from the seas and oceans. Features such as wings and the complete metamorphosis of many species have been cited frequently as fostering this massive diversity. The "success" of the insects can be measured by many parameters: their long-term persistence and stability of their basic patterns, the variety of higher groups (with almost 30 orders commonly recognized) and, as emphasized in this book, the wealth of species and similar entities. Each of these species has its individual biological peculiarities, ecological role, distribution, and interactions within the local community. And each may differ in habit and appearance, both from its close relatives and across its range, to reflect local influences and conditions. Every species is thus a mosaic of physical variety and genetic constitution that can lead to taxonomic and ecological ambiguity in interpreting its integrity and the ways in which it may evolve and persist.

Entomologists will continue to debate the number of insect "species" that exist and the levels of past and likely future extinctions that edit any such estimate. The difficulties in gaining consensus have two main axes – first, lack of understanding of how these entities may be recognized and categorized and, second, that many insect groups remain substantially undercollected and are poorly known. The first of these themes dominates much of this book – gaining agreement over "what is a species" is difficult and sometimes contentious. Many taxonomists hold strong and individualistic views, molded by years of study, of the limits of species and the validity of infraspecific categories such as subspecies and races that in practice can function as "evolutionarily significant units" in their insect group. One widespread trend, often not appreciated fully, is that widespread generalist insect species may not persist as such as their environment changes – loss of resources and fragmentation of previously extensive biotopes may cause populations to become isolated, and restricted to a limited subset of resources, such as particular host plants, on which they must then depend and specialize. Such situations may beget speciation, perhaps especially among phytophagous insects that display many examples of such localized but obligatory isolation. Populations involved commonly show haplotype differences and biological idiosyncrasies related to their local conditions, but otherwise are not easily separable. Generalist "species" may commonly comprise complexes of cryptic species masquerading as a single entity. Conventional "typological" taxonomists may tend to mirror the more conservative "generalist" approach, whereas other constituents (such as many butterfly collectors) may opt to recognize numerous isolated populations displaying small phenotypic variations as

distinct (specific or subspecific) taxa. Individual specialists in any large insect group are likely to occupy different positions along the gradient of "lumpers" to "splitters" in how they treat such variety, and may defend their stance energetically.

Biologists and philosophers alike continue to debate the merits of the numerous species concepts, drawing on the reality quoted by one recent commentator that "there are n+1 definitions of 'species' in a room of n biologists," with the most common inference that "a species is whatever a taxonomist says it is." All recognized categories, however, are dynamic. Any given figure for insect diversity (as numbers of species) is a working hypothesis, as is each of the contributing species – so that complete and enduring enumeration is perhaps impossible to achieve.

Documenting and cataloging insect biodiversity as a major component of Earth's life is a natural quest of human inquiry, but is not an end in itself and, importantly, is not synonymous with conserving insects or a necessary prerequisite to assuring their well-being. Despite many ambiguities in projecting the actual numbers of insect species, no one would query that there are a lot, and that the various ecological processes that sustain ecosystems depend heavily on insect activity. Indeed, "ecological services" such as pollination, recycling of materials, and the economically important activities of predators and parasitoids are signaled increasingly as part of the rationale for insect conservation because these values can be appreciated easily through direct economic impacts. All these themes are dealt with in this book, centered on questions related to our ignorance of fundamental matters of "how many are there?" and "how important are they?", to which the broad answers of "millions" and "massive" may incorporate considerable uncertainty; this uncertainty, however, is reduced by many of the chapters here.

In any investigations of insect biodiversity, the role of inventory tends to be emphasized, despite the impracticability of achieving complete enumeration. Documenting numbers of species (however they are delimited or defined) gives us foci for conservation advocacy and is pivotal in helping to elucidate patterns of evolution and distribution. Recognizing and naming species allow us to transfer information, but high proportions of undescribed or unrecognizable species necessitate the use of terms such as "morphospecies" in much ecological interpretation of diversity. Accompanying archival deposition of voucher specimens is then needed as the only reliable means through which the consistency of separations can be affirmed and cross-survey comparisons validated. Nevertheless, other than in some temperate regions, particularly in the northern hemisphere, many estimates of insect species richness and the naming of the species present are highly incomplete. Much of the tropics, for example, harbors few resident entomologists other than those involved with pressing problems of human welfare, and more basic and sustained documentation almost inevitably depends on assistance from elsewhere. Some insects, of course, have been explored more comprehensively than others, so that selected taxonomic groups (such as butterflies, larger beetles, and dragonflies) and ecological groups ("pests") have received more attention than many less charismatic or less economically important groups. Indeed, when collecting Psocoptera in parts of the tropics, I have occasionally been asked by local people why I am not collecting birdwing butterflies, stag beetles, or other "popular" (or commercially desirable!) insects, and my responses have done little to change their opinions of my insanity!

In short, many gaps in knowledge of insect diversity persist, and seem unlikely to be redressed effectively in the near future, other than by "guesstimates" extrapolating from sometimes rather dubious foundations. However, sufficient knowledge does exist to endorse the practical need to protect natural habitats from continued despoliation and, as far as practicable, from the effects of climate change. Citations of impressively large numbers of insect species can become valuable advocacy in helping to conserve areas with largely

unheralded wealth of biodiversity. The presence of unusual lineages of insects, of narrow-range endemics, and highly localized radiations and distributional idiosyncrasies (such as isolated populations beyond the main range of the taxon) are all commonplace scenarios, and may in various ways help us to designate priorities for allocating the limited conservation resources available. Many such examples from selected insect groups are revealed in this book – but evaluating the richness and ecological importance of the so-called meek inheritors, that vast majority of insects that do not intrude notably on human intelligence and welfare, remains a major challenge. Many such taxa receive attention from only a handful of entomologists at any time, and some are essentially "orphaned" for considerable periods. Progress with their documentation is inevitably slow and sporadic. Some hyperdiverse orders and families of insects exhibit daunting complexity of form and biology, as "black hole groups" whose elucidation is among the major challenges that face us.

Insect conservation has drawn heavily on issues relevant to biodiversity and appreciation of the vast richness of insects, not only of easily recognizable "species", but also of the occurrence of subspecies and other infraspecific variants, such as significant populations. This more complex dimension of insect biodiversity is receiving considerable attention as new molecular tools (such as DNA analysis) enable us to probe characters in ways undreamed of only a decade or so ago to augment the perspective provided by morphological interpretation, and assess relationships within lineages and their rates of differentiation. Applications of these tools proliferate, sometimes to the extent where small molecular differences treated in isolation may confuse, rather than clarify, relationships implied from more traditional approaches. The vast arrays of cryptic species gradually being revealed suggest that even our most up-to-date estimates of species numbers based on morphological data may be woefully inadequate. Insect diversity equates to "variety," but the subtleties of interpopulation variations in genetic constitution and ecological performance are difficult to appraise and to categorize formally – and perhaps even more difficult to communicate to non-entomologists whose powers may determine the future of the systems in which those insects participate. Education and communication, based on the soundest available information, are essential components of insect conservation. This book is a significant contribution to this endeavor, through indicating how we may come to interpret and understand insect biodiversity more effectively. In addition to providing a range of opinions and facts on insect richness in a variety of taxonomic, geographical, and methodological contexts, it helps to emphasize the scientific and political importance of accurate species recognition. Failure to recognize adventive alien species may have dire economic or ecological consequences, or confusion between biotypes or cryptic species may invalidate expensive management programs for their suppression or conservation.

A new generation of skilled insect systematists – whose visions encompass the wider ramifications of insect biodiversity, its importance in understanding the natural world, and the accelerating impacts of humans upon it – is an urgent need. They enter an exciting and challenging field of endeavor, and the perspectives included in this volume are essential background to their future contributions. The first edition of this book was a foundation and a stimulating working tool toward that end, and I expect many of the renewed chapters to become key references as we progressively refine and enlarge the bases of our understanding of insects and their activities in the modern world.

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Preface, First Edition

Insects are the world's most diverse group of animals, making up more than 58 percent of the known global biodiversity. They inhabit all habitat types and play major roles in the function and stability of terrestrial and aquatic ecosystems. Insects are closely associated with our lives and affect the welfare of humanity in diverse ways. At the same time, large numbers of insect species, including those not known to science, continue to become extinct or extirpated from local habitats worldwide. Our knowledge of insect biodiversity is far from complete; for example, barely 65 percent of the North American insect fauna has been described. Only a relatively few species of insects have been studied in depth. We urgently need to explore and describe insect biodiversity and to better understand the biology and ecology of insects if ecosystems are to be managed sustainably and if the effect of global environment change is to be mitigated.

The scientific study of insect biodiversity is at a precarious point. Resources for the support of taxonomy are tenuous worldwide. The number of taxonomists is declining and the output of taxonomic research has slowed. Many taxonomists are reaching retirement age and will not be replaced with trained scientists, which will result in a lack of taxonomic expertise for many groups of insects. These trends contrast with an increasing need for taxonomic information and services in our society, particularly for biodiversity assessment, ecosystem management, conservation, sustainable development, management of climate-change effects, and pest management. In light of these contrasting trends, the scientific community and its leadership must increase their understanding of the science of insect biodiversity and taxonomy and ensure that policy makers are informed of the importance of biodiversity for a sustainable future for humanity.

We have attended and contributed to many scientific meetings and management and policy gatherings where the future, the resource needs, and importance of insect taxonomy and biodiversity have been debated. In fact, discussion of the future of taxonomy is a favorite pastime of taxonomists; there is no shortage of "taxonomic opinion." Considerable discussion has focused on the daunting task of describing the diversity of insect life and how many undescribed species are out there. However, we felt that there was a need for an up-to-date, quantitative assessment of what insect biodiversity entails, and to connect what we know and don't know about insect biodiversity with its impact on human society.

Our approach was to ask authors to develop accounts of biodiversity in certain orders of insects and geographic regions and along selected subject lines. In all categories, we were limited by the availability of willing contributors and their time and resources. Many insect groups, geographic regions, and scientific and societal issues could not be treated in a single volume. It also was apparent to us, sometimes painfully so, that many taxonomists are wildly overcommitted. This situation can be seen as part of the so-called "taxonomic impediment" – the lack of available taxonomic expertise is

compounded by an overburdened community of present-day taxonomists with too much work and perhaps too much unrealistic enthusiasm.

In Chapter 1, we introduce the ongoing challenge to document insect biodiversity and develop its services. Chapter 2 provides a comprehensive overview of the importance and value of insects to humans. The next two sections deal with regional treatments and ordinal-level accounts of insect biodiversity. These approaches were a serious challenge to the contributors who had to compile information from a wide array of sources or, alternatively, deal with situations in which accurate information simply is insufficient. In Section III, we document some of the tools and approaches to the science of taxonomy and its applications. Perspective is provided on the past, present, and future of the science of insect taxonomy and the all-important influence of species concepts and their operational treatment on taxonomic science and insect biodiversity. Contributions on the increasing role of informatics and molecular approaches are provided, areas with ongoing controversy and differences of opinion. These chapters are followed by contributions on the applications of taxonomic science for which biodiversity information is fundamental, including the increasing impact of adventive insects, pest detection and management, human medical concerns, and the management and conservation of biodiversity. The book ends with an historical view of the continuing attempts to document the extent of world insect biodiversity.

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