BIOTAXONOMY OF TEPHRITOIDEA
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Preface — Biotaxonomy and Tephritoidea

Amnon Freidberg

INTRODUCTION

The idea to publish this book was conceived during the preparations for the "First Tephritidologist Meeting", which was held in Israel in the summer of 2000, and the book is thus a collection of papers delivered during that meeting. It deals with biotaxonomy of Tephritoidea, a relatively large superfamily of acalyptrate flies (Diptera) primarily known for its largest and most economically important family, the Tephritidae, or fruit flies. In addition to the Tephritidae, the Tephritoidea contains eight smaller and lesser-known families (Ctenostylidae, Lonchaeidae, Pallopteridae, Piophilidae, Platystomatidae, Pyrgotidae, Richardiidae, and Ulidiidae). This book deals primarily with biotaxonomy of the Tephritidae, but also contains a chapter on the Ulidiidae.

The 2000 meeting was a natural follow-up of a meeting organized by Martin Aluja and Allen Norrbom in Xalapa, Mexico in 1996, also focusing on the Tephritidae. However, the background and rationale of these two meetings differed substantially, resulting in the title "First Tephritidologist Meeting" accorded to the 2000 meeting.

A major impetus for the 2000 meeting stemmed from the sharp decline, during the second half of the twentieth century, of what is often called "traditional" or "classical" taxonomy. While most other branches of science have evolved through a peak into a decline or have been replaced by a daughter or sister branch, the current decline of traditional taxonomy does not seem to conform to the same kind of evolution. Actually, the decline of traditional taxonomy represents an apparent paradox, coinciding as it does with the peak need for its services ever experienced. More specifically, the infamous recent global "biodiversity crisis", together with growing global commerce, are definitely good reasons for traditional taxonomy and its various sub-disciplines, such as identification services, to flourish. However, this did not happen. In fact, the decline of traditional taxonomy is so dramatic that, at the present rate of loss of experts, the number of living experts will be nil or close to nil by the middle of this century. A possible reason for this situation could be the recent rise of molecular systematics and the growing notion that this relatively modern approach could replace traditional taxonomy. However, molecular systematics is still crucially dependent on traditional taxonomy, and will probably remain so for many years to come. Another explanation is the failure of decision-makers to

Department of Zoology, The George S. Wise Faculty of Life Sciences, Tel Aviv University, Tel Aviv 69978, Israel. E-mail: afdipter@post.tau.ac.il

realize the real threat created by the biodiversity crisis, as well as the general inability to cope with this crisis properly due to the already diminished taxonomist cadre. Whatever the explanation for this situation may be, the continuing existence of traditional taxonomy—and in fact taxonomy in general—is at stake and every effort should be made to save this scientific discipline for the sake of both humanity and nature. The present book is our humble contribution to the campaign.

THE PRESENT STATUS OF TEPHRITOID BIOTAXONOMY

Although several short and occasional publications dealing with the status of tephritid or tephritoid taxonomy (almost all of them are restricted to Tephritidae) have recently been published, this subject has never been treated comprehensively. White (1989) assessed the state of fruit-fly taxonomy and future research priorities in the context of demand and supply of taxonomic services. However, of the five needs that he discussed, little progress has been made in the preparation of host-plant catalogs and keys to larvae, whereas considerable progress has been made in the preparation of keys to adults, such as for species of Ceratitidini (e.g., De Meyer and Freidberg, 2006, this volume, and citations therein). In 1996 White referred to this topic again, this time stressing more the need and the means for disseminating taxonomic expertise, especially by using new technologies, such as the production of computerized interactive keys. Drew and Roming (2000) also reviewed the subject, emphasizing the economic importance of Tephritidae.

In view of this situation, the main goal of our "First Tephritidologist Meeting" was to put tephritoid taxonomy on the map and discuss both its classical and molecular practice as a full-time occupation independent of any related topics, such as economic importance or behavior. Why does the taxonomy of Tephritoidea deserve a separate meeting and book? To understand this we have to first focus our attention on the core family, the Tephritidae.

What does make the family Tepritidae unique? Of the hundreds of families of insects, very few have received so much attention, scientifically and otherwise, as have the Tephritidae. The other insect families that receive similar attention are either large, of great obvious impact on mankind, or are unusually interesting to the public due to unique biological traits or aesthetic attractiveness. Few of them enjoy all three attributes. The Tephritidae, with about 4500 described species, is one of the largest insect families, and is among the ten largest families of the order Diptera, or true flies. The family has immense economic importance, both due to the large number of pestiferous species, and, conversely, because of its many actual and potential weed biocontrol agents. Finally, despite the superficial biological uniformity, the family is extremely diverse in many aspects, such as life history, mode of infestation, behavior and morphological and anatomical structure. Most of its member species, even the tiniest, are ornamented by brightly colored body or wing patterns and are aesthetically pleasing.

This rather unique combination of attributes is both augmented and highlighted by the other families of the superfamily. Although none of them are as diverse in number of species or appearance or as economically significant as the Tephritidae, these families shed additional light on the Tephritidae, and together with the Tephritidae comprise an extremely diverse and interesting superfamily.

The turn of the previous century has seen a dramatic advance in Tephritid biotaxonomy, reviewed by Norrbom *et al*. (1999) in the introduction to the Tephritidae world catalog (Thompson, 1999)—itself one of the main achievements of the previous century. Based on this catalog, as well as on other recent contributions, such as the book *Fruit flies (Tephritidae): Phylogeny and evolution of behavior* (Aluja and Norrbom, 1999), we now have a detailed higher classification for the family largely based on a more or less rigorous cladistic analysis. With three to six subfamilies, about 40 tribes and subtribes, approximately 500 genera and about 4,500 species, it seems that we already have enough supra-generic taxa and that not many additional genera are still to be discovered. However, based on material already housed in collections and on various extrapolations, the number of species is expected to eventually reach 6,000-9,000 (Freidberg, unpublished data). Many cladistic analyses (e.g., some chapters in Aluja and Norrbom, 1999, and several chapters in this volume) and a number of molecular studies (e.g., Han and McPheron, 1997; Smith *et al*., 2006, this volume) aiming to resolve the phylogeny of tephritids have been published particularly during the last two decades, and this trend is still growing. In addition, numerous biological and ecological studies have been published on various species of tephritids, albeit many of these focus on pest species. However, this information, except perhaps host-plant data, so far has limited significance for the domain of taxonomy. A breakthrough in communicating taxonomic information to the more general audience occurred through several interactive keys published as CD-ROMs (e.g., Thompson, 1999; White and Hancock, 1997; White and Hancock, 2004; Lawson *et al*., 2003), although again these were primarily designed to deal with pest species. Recently established websites (e.g., www.sel.barc.usda.gov/Diptera/tephriti/tephriti.htm, and http://projects.bebif.be/enbi/fruitfly) complement the CDs in putting tephritid taxonomy on the map through this broadly accessable electronic medium.

No similar progress has been made in the other families of the Tephritoidea. Although some of these families are rather small and taxonomically fairly well known, none have benefited from such diverse studies as have the Tephritidae. The Piophilidae, for example, is a family of about 70 known species, and the biology of several species has been studied in considerable detail. A cladistic analysis, albeit intuitive, was published within the framework of a rather comprehensive revision of the family (McAlpine, 1977). Probably no more than ten species are still awaiting discovery. On the other hand, the Platystomatidae and Ulidiidae are much larger families and together contain hundreds of undescribed species in addition to the approximately 2,000 already described. Because of their limited economic importance, the impetus for research beyond alpha-taxonomy in the other tephritoid families (i.e., excluding the Tephritidae) is relatively low, and cladistic analyses such as that of Kameneva and Korneyev (2006, this volume) are rare.

Recent publications, especially the *Manual of Nearctic Diptera* (McAlpine *et al*., 1981), the Tephritidae world catalog (Thompson, 1999), and the fruit fry evolution of behavior book (Aluja and Norrbom, 1999) have done a great service to the tephritoid cause. The glossary of Tephritidae terminology (White *et al.*, 1999), refining and augmenting the terminology proposed in the "Manual" (McAlpine *et al*., 1981), is almost unique for the Diptera. However, neither the "Manual" nor the "Glossary" has the final word, and Sueyoshi's chapter (2006, this volume) on the male terminalia is an example of the dynamic nature of terminology. Although there is considerable communication and cooperation among tephritoid taxonomists, there is limited direct research collaboration, and we co-author papers more commonly with other colleagues than with our fellow taxonomists. This may result from the enormous alpha-taxonomic work that still remains to be done, primarily because of the large number of new taxa that await discovery and description. Examples from this volume are De Meyer and Freidberg

(2006); Freidberg and Merz (2006); Han (2006); Korneyev (2006); Norrbom (2006)—together describing about 50 new species and thus more than doubling the number of species for the treated genera. On the other hand, tephritid taxonomists committed to the study of pest groups (e.g., *Bactrocera* Macquart*, Anastrepha* Schiner, Ceratitidina) usually work together on long-term, single-taxon studies.

Recent years have seen a dramatic increase in the number of studies dealing with the higher classification of the family, and with it a dramatic increase in the number of higher categories, especially tribes and subtribes, 12 of which were proposed in the last two decades. While the proposal of new tribes can set the framework for detailed studies on the subordinate taxa, it should also conform to the accepted standards of consistency and stability for taxonomic units and classifications. A perhaps more logical approach would be a study of categories from the bottom up, e.g., from species to genera, such as in revisions of single genera. Hernandez-Ortiz's work (2006, this volume) on the phylogeny and classification of *Hexachaeta* Loew provides an example of how to integrate the two approaches when studying single groups.

To demonstrate the need as well as opportunities for taxonomic work, I shall focus on the status of the genera of Tephritidae, as the genus is probably the most appropriate operational category for revision. Based on Norrbom *et al*. (1999), there are 471 tephritid genera world-wide, averaging nine species per genus. Of these genera, 184 are monobasic and therefore may not require generic revisions. The nearly 300 remaining genera, each containing between 2 and approximately 200 species (the exceptionally large genus *Bactrocera* contains 552 species, and *Dacus* Fabricius contains 247 species), are liable for revision. Of these, only about 10% have been revised, and most of these are restricted or almost restricted to single zoogeographic regions. Furthermore, there are about 20 tephritid genera that have unusually wide distribution, and eight of them (*Rhagoletis* Loew*, Chetostoma* Rondani*, Trypeta* Meigen*, Campiglossa* Rondani*, Dioxyna* Frey*, Ensina* Robineau-Desvoidy*, Tephritis* Latreille*, Trupanea* Schrank) occur naturally in both the New World and the Old World. None of these have been revised comprehensively, although partial (regional) revisions exist for some of them. Of these eight genera, three relatively small ones (*Chetostoma, Dioxyna* and *Ensina*) exhibit peculiar distributions (the last two probably have not expanded their distribution via Beringia), and should therefore prove to be fascinating subjects for revision. The reluctance so far to revise these three genera, as well as some other widespread genera, probably stems from reservations of taxonomists to undertake projects involving non-homeland taxa. This situation calls for more cooperation.

Revisions and monographs are two of the most highly valued kinds of contributions to taxonomy. However, they are not the only valuable contributions. Catalogs are extremely useful tools for taxonomic and other studies, and the recent world catalog of Tephritidae (Thompson, 1999) is a fine example. Like many other similar catalogs, it is arranged alphabetically, in a user-friendly manner, albeit leaving room for the production of more modern partial catalogs that deal with single lower categories, such as tribes. Such is the new catalog of the Gastrozonini (Kovac *et al*., 2006, this volume), based on a re-arrangement and updating of data primarily taken from the world catalog.

Although the economically important species account for only about 5% of all tephritid species, they are a driving force for various tephritid studies, including taxonomic ones. However, studies on economically important and unimportant species spur each other, because all species are best understood in the context of related species. Hence, the revision of *Ceratitis* (*Pterandrus*) by De Meyer and Freidberg (2006, this volume), although treating only a small number of serious pests, puts these pests in context with all 36 species that currently comprise this subgenus. Frías *et al*. (2006, this volume) provides information on immature stages of several pest species, a significant contribution in view of the paucity of information on tephritid immatures and the fact that the actual damage to plants is usually inflicted by the larvae. Kapoor (2006, this volume) provides an overview of the relatively large number of economically important tephritids in India. Finally, Smith *et al*. (2006, this volume) is an example of a molecular systematic study conducted on a large group of taxa (Carpomyina) that contains a small number of pestiferous species. Most current molecular studies involve pestiferous species, although it appears that the methodology used in such studies is spreading to less economically significant taxa.

Because Tephritoidea occur predominantly in the tropics and hence in developing countries, faunistic treatments for this group are scarce as are comprehensive revisionary studies on economically unimportant taxa (e.g., Tephritoidea other than Tephritidae, and the numerous taxa of the subfamily Tephritinae). Such studies, especially revisions, are crucial for the understanding of entire families and of the superfamily as a whole. A detailed example concerning one of the key groups, the tribe Tephrellini, might be appropriate here. The hosts of this tribe differ from those of all other tribes of its subfamily, the Tephritinae, by not being Asteraceae. Morphologically, these flies possess a mixture of attributes of the Trypetinae and Tephritinae, and although a revision was published by Munro (1947), it treated only 29 genera and 128 species out of the approximately 40 genera and 174 species currently recognized, and did not offer conclusions about the taxonomic placement and phylogenetic relationships of Tephrellini. Additional known but undescribed species indicate that the total species diversity for this tribe is about 200 (Freidberg, unpublished information), but this number will definitely grow with more collecting. A molecular study of Tephrellini, coupled with a cladistic analysis, could help resolve relationships among its subordinate taxa and between this tribe and other tribes in the subfamily.

As noted above, the other families of Tephritoidea have been less studied than Tephritidae. However, understanding Tephritidae is strongly dependant on understanding these other families. Tephritidologists are therefore encouraged to follow the lead of Kameneva and Korneyev (2006, this volume) and study the taxonomy of other tephritoids in addition to Tephritidae, which would not only be crucial for understanding Tephritidae but would also be rewarding in itself.

The First Tephritidologist Meeting (2000) led to the Geneva meeting of 2004, which attracted even more participants. The next conference, planned for Washington, D.C. in 2008, will hopefully be just the third in an ongoing tradition that will continue for many years to come.

CHALLENGES FOR THE FUTURE

Much of what is required and anticipated from tephritoid taxonomists has been stated or implied in the previous section. The following is thus a brief summary of the main recommendations only.

A key factor for a more comprehensive approach to tephritoid taxonomy is that of cooperation between scientists in as many ways as possible. One of the ways to achieve this is through periodic meetings between scientists. Additional conferences should be organized, and the organizers should consider how to improve the scientific level of these meetings. No less important is the training of junior staff and raising the next generation of tephritoid taxonomists.

Both these goals can be assisted by creating special funds for the study of tephritoid taxonomy, such as a fund to support future periodic meetings, and especially to subsidize scientists who cannot afford to participate, including graduate students.

As for the routine work, in view of the disappearing habitats a special effort should be made to intensify field-work and collecting, and especially to discover as many new taxa as possible before they vanish forever. In addition, we should stress the necessity for high quality specimen preservation procedures, which are a prerequisite for high quality collection-based studies. The importance of work on non-pestiferous taxa, including both traditional and molecular studies, should also be stressed. Finally, the endeavor begun by composing the "Glossary" (White *et al*., 1999) and implementing it should continue with the regular publication of updates agreed upon by the scientists, perhaps through a specially nominated committee.

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