

FORUM

Insect Taxonomy in Species-Rich Countries - The Way Forward?

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Taxonomia de Insetos em Países Ricos em Espécies - Que Caminho Seguir?

RESUMO - Há dois extremos no comportamento taxonômico - publicar tão rápido quanto os novos táxons tornam-se disponíveis e esperar uma vida toda para publicar resultados que não podem ter erro. Nenhum desses extremos vêm de encontro às necessidades dos biólogos contemporâneos em promover nosso entendimento da evolução e manutenção da diversidade biológica. Parte da razão para esses extremos é nossa incapacidade em definir objetivos apropriados para a taxonomia. Ao invés de enfatizar as unidades da diversidade biológica, devemos nos concentrar em investigar padrões - estrutural, biológico, ecológico, temporal e geográfico - porque esses padrões gerarão novas idéias sobre a história evolucionária dos organismos, e que serão de interesse para o futuro da nossa própria espécie. Para investigar esses padrões, precisamos nos concentrar em garantir que nossos métodos de obtenção de dados sejam consistentes com nossos métodos de análise. Mesmo se considerássemos seriamente como nosso objetivo a descrição de todas as espécies vivas, deveríamos planejar métodos de amostragem da diversidade natural estatisticamente aceitáveis, e não fortuitos. Entretanto, os comentários de Willis Jepson (1867-1946) na última edição do Manual Jepson de Plantas Superiores da Califórnia, parecem apropriados aos nossos problemas de taxonomistas de insetos: "O objetivo do botânico é o avanço do conhecimento das plantas vivas. Ele deseja descobrir novos fatos e estabelecer novos princípios. Se sábio, ele nunca tentará produzir um trabalho perfeito, completo e definitivo. Tal trabalho seria um paradoxo e um conflito de propósitos com o conhecimento das coisas vivas e com nossas idéias de evolução sem fim. O completo, o perfeito, o final, representam uma anomalia, uma contradição no campo da biologia. O botânico visionário terá sucesso em fazer trabalho inspirador, produtivo intelectualmente e promotor de progresso, de tal forma que a ciência botânica avançará sempre em áreas novas e mais produtivas".

PALAVRAS-CHAVE: Insecta, biodiversidade, sistemática, biologia tropical.

ABSTRACT - There are two extremes in taxonomic behavior - publishing quickly as new taxa become available, and waiting a lifetime in the hope of publishing results that cannot be faulted. Neither of these extremes meets the needs of contemporary biologists in furthering our understanding of the evolution and maintenance of biological diversity. Part of the reason for these extremes is our failure to define suitable objectives for taxonomy. Instead of emphasising the units of biological diversity, we should concentrate on investigating patterns,

structural, biological, ecological, temporal, and geographical, because it is these patterns that will generate novel ideas about the evolutionary history of organisms, and that will be most likely to be of interest to the future of our own species. To investigate these patterns, we need to give greater thought to ensuring that our methods of data acquisition are consistent with our methods of data analysis. Even if we take seriously as our objective the description of all living species, then we should be devising methods of sampling natural diversity that are statistically acceptable, not haphazard. However, the following comments, credited to Willis Jepson (1867-1946) in the latest edition of the Jepson Manual of Higher Plants of California, seem appropriate to our problems as insect taxonomists: "The botanist's objective is a furtherance of knowledge of living plants. He wishes to discover new facts and establish new principles. If wise, he will never try to produce a work which is perfect, complete and final. Any such work would be a paradox and at cross purposes with our knowledge of living things and our ideas of endless evolution associated with them. Completion, perfection, finality, represent an anomaly, a contradiction in the field of biology. The far seeing botanist will strive to do work which is inspiring, productive of thought and promoting the soundest progress, so that botanical science will ever advance into new and more fruitful fields".

KEY WORDS: Insecta, biodiversity, systematics, tropical biology.

The expense of documenting tropical biological diversity has been borne, so far, largely by northern temperate countries. This is evident from the extensive collections of specimens stored, and the many books published on this subject, in Europe and North America. But this situation seems unlikely to continue, for various sociological and political reasons, and increasingly, the problems of investigating and understanding the large but still largely unknown faunas of species-rich tropical countries, including Brazil, will need to be solved by their indigenous entomological communities. This raises the question of how these faunas can best be investigated (Coddington et al. 1991). The small fauna of Britain is now reasonably well known, but this is the result of the efforts of thousands of people over a period of 300 years. In contrast, our understanding of the insect fauna of continental Europe, or of much of North America (Kosztarab & Schaefer 1990), is far less complete. Thus, the essentially haphazard and protracted accumulation of information that has occurred in the Northern Hemisphere may not be appropriate for developing an understand-

ing of the vastly larger insect faunas of tropical countries, at least not within a time-span that is useful to other scientists, or responsive to the perceived urgency of the task. The purpose of this article, first presented as an invited talk at the 16^o Congresso Brasileiro de Entomologia at Salvador in March, 1997, is to consider the objectives of taxonomic work, particularly on groups of very high diversity, and how these might be realised.

One problem for planning the future of insect taxonomy is that, even in the short term, we rarely state what we want to do, why we want to do it, how we will do it, at what cost, and to whose benefit. Perhaps the roots of our subject lie so deep within the traditions of the privately-funded amateur that we find it difficult to accept the disciplines that apply to publicly funded professionalism, that is the system within which most modern scientists are employed. In general in this system we are funded out of the public purse with the expectation that we will achieve specified ends that are directed to the public good. In such a system, to attract suitable funding to insect taxonomy we need to define our re-

search objectives, and estimate their cost within a suitable time-frame, in such a way that they can be evaluated by other scientists, bearing in mind that we operate alongside them in a market for research funding that is highly competitive. A few taxonomists work in this way, notably specialists on fresh-water insects or in public health. But all too often insect taxonomists simply assert that they need more money because taxonomy is basic to the rest of biology. Such claims arouse limited enthusiasm amongst other members of the scientific community with whom we will always be in competition for scarce financial resources.

In essence, the problem is to ensure that taxonomic work achieves, as a science, sufficient credibility from the rest of the scientific community, whether at local, national or international level. To obtain such credibility, the taxonomic community must be seen to be carrying out work that is appropriate to the needs of the rest of society, whether these are purely intellectual needs, or are needs more directly concerned with manipulating and exploiting the biosphere. Our taxonomic work, whether for academic or for practical purposes, needs to be targeted at specific audiences. Taxonomy is expensive, our collections and libraries particularly so. To optimise this investment by society we need to make our products of interest to, and usable by, other biologists, not simply indulge our limited personal interest in naming an eclectic sample of the end products of evolution.

The Ultimate Objective of Insect Taxonomy

Do we, as taxonomic entomologists, have an ultimate goal for our science? If so, are we devising appropriate methods for achieving that goal? World-wide, taxonomists complain that their subject is essential, but that it is not valued as a science, that it receives too little funding, and that the best students commonly find it largely irrelevant to main-stream modern biology. Given such a difference in value judgements, perhaps we ought to reflect on

our position. Is it possible that we, the taxonomists, have got it wrong? Are we so busy with our taxonomic studies that we are not thinking carefully enough about our objectives; where we want our science to go, and thus what investigative strategies would be most appropriate?

There can be many short-term objectives within insect taxonomy, but many taxonomists apparently assume that an ultimate objective is realistic of describing all the species that we can find in the world. Three major problems impinge on this as an achievable, or fundable, objective; the logistics, the evident irrationality of human behaviour, and the scientific problem itself. The logistic problems of printing, publishing, distributing, and holding in libraries the descriptions of at least another 4 million species of insects have never been seriously evaluated. However, we do know that throughout the present decade the number and diversity of biological books and periodicals has increased vastly, and libraries are now highly selective in their holdings, one of their selection criteria being the frequency of customer demand. The costs of a major taxonomic information explosion on printed pages would be far beyond the resources of even the richest institutes world-wide. Most universities can afford only limited library facilities, yet paradoxically the objective of any expanded descriptive activity by taxonomists would be to communicate information. Even now, I am acutely aware that most of my own publications on Thysanoptera are not readily available to my specialist colleagues in many countries unless I purchase and distribute copies myself.

Electronic methods may yet help with the modern publications avalanche, despite the reservations of many in the taxonomic community, but the logistical problem of housing expanded collections of insects remains formidable. For various political reasons, the largest museum collections are housed in the largest cities, and in such cities the annual rent for the floor space occupied by a single pinned butterfly is not inconsiderable; the rental value of the total floor space of the Entomology

Department at the Natural History Museum in London was estimated at more than US\$ 4 million (Mound 1992). The possibility of society greatly expanding the size of such major museum facilities, with all the run-on costs that this implies, is remote. Within the taxonomic community, the reaction to such problems is commonly, not to reconsider the objective, but to insist that the problems are themselves evidence that taxonomy needs much more money in order to finance the bigger collections and bigger libraries that our science self-evidently needs.

The problems caused for taxonomy by human nature are frequently accepted as inherent in the principal of academic freedom. But all too often taxonomists insist that a species in front of them is different from one which another taxonomist has described in an adjoining country, without attempting any rigorous examination of patterns of variation within and between populations. In part this stems from a healthy independence of viewpoint, but also involved is the urge to publish quickly for reasons of promotion or personal prestige. Subsequent generations of workers are left to carry out the more extensive, and inevitably more expensive, studies on variation that are needed to establish the synonymy involved, and to assess the distributional and biological ranges of the redefined taxa. In many groups where there are large numbers of taxonomists, at least 25% of all names are subsequently recognised as synonyms, and the total cost of providing a basic system of names for a particular group is thus considerably higher than it need be. This is not simply, as some professional taxonomists like to claim, the result of the activities of amateur taxonomists! Nor is it simply a problem of history that we have inherited from our predecessors. Many of the species being described this year will fall as synonyms in due course. The reason for this, and for the resultant excessive expenditure involved, is that the prime objective of taxonomy is commonly accepted as the naming of the units, the species, rather than investigation of the patterns of biological diversity in which these units are involved.

The third major problem for taxonomy is the identity and equivalence of the units that we recognise as 'species'. We know of some species that vary in structure and biology within and between populations. We also know of species that exist as a series of demes between which there is limited gene flow, and some of these result in clines or even ring species. And we know of some species, often pest insects, that are widespread and relatively constant in biology and appearance, although we do not know if this is the result of extensive panmixis or an inherent lack of variability in a particularly successful genotype. But for most described species we have almost no information on any aspect of their variation, and nothing about the structure of their breeding populations. Moreover, the interpretation that we place on variation in different groups of insects varies according to our requirements, and the biological questions that we are seeking to ask. Thus the 'species' that we recognise range from coarse-grained 'morpho-species' in biogeographic analyses, sometimes based on colour differences, to fine-grained 'population-level' concepts in disease vector studies that are based on DNA or behavioural analyses. These species, our units of biological diversity, are thus not equivalent. Hence, trying to understand tropical biological diversity by first describing the 'units', when we do not know the significance of most of them, may not be the best use of our scientific resources.

The 'ad-hoc' Approach to Insect Taxonomy

The ad-hoc approach is the most common strategy adopted in insect taxonomic work. This involves describing new taxa as material becomes available, rather than planning a project and sampling an area or system to acquire suitable data. Most descriptive taxonomy is carried out on material that has been collected haphazardly. Even modern systematic studies, using the most sophisticated of mathematical protocols, are often based on *ad-hoc* collections of primary data, haphaz-

ard accumulations of specimens that have been acquired by museums over many years, not on samples of natural diversity that have been taken with the intention of analysis.

Description of new species on single specimens is often criticised, but it is not the uniqueness of the observation that is the problem. Uniqueness may well be worth reporting. Rather it is the failure of particular species descriptions to contribute to our broader understanding of biological diversity. If all that is known about a species, whether represented by one or a hundred specimens, is that it exists in a collection, and if by naming it an author does not contribute to any broader understanding of structural diversity in the group, or of its systematic position, or of host-plant associations, or of geographic relationships, - then publication of the description is probably not a good use of available resources.

The concentration of taxonomic effort on the description of the units of diversity is a possible weakness in our science. As biologists we find the recognition of patterns, and the elucidation of processes, to be exciting aspects of our profession, but many taxonomists seem to think that they should actually limit their efforts to recognising the units, rather than investigate the significance of these units in broader patterns. But it is the patterns that our taxonomic studies reveal, be they structural, biological, ecological, temporal, or geographical, and the ideas that they give us about the evolutionary history of an organism, that are most likely to be of interest to other biologists. Given the enormous diversity of life on earth, surely we should be using our funding to attempt to recognise patterns (Eldredge & Cracraft 1980), not just to put dots haphazardly onto the biological map, in the hope that these dots will some day indicate a pattern?

Applying Taxonomy to Other Entomological Studies

One alternative to the ad-hoc approach to taxonomy is to concentrate efforts on insect

species that are associated with one or more crops and their surrounding plants. Such studies place the taxonomist in collaboration with other biologists, and this collaboration yields information on hosts, periodicity, and life histories. Taxonomic studies are thus enriched with additional biological data, and these data can be further used to test the validity of taxonomic hypotheses. Similarly, taxonomic studies on human disease vectors and their relatives are enriched by collaboration with epidemiologists and specialists on the disease organisms, and taxonomy focused on water quality studies, comparing the species in different types of water bodies, streams and rivers, ponds and lakes, polluted or clean water, involves similar collaboration between specialists. It is significant that such collaborative and focused studies are often better funded than what is sometimes called 'pure taxonomy'.

Some taxonomists see little merit in, for example, studying the egg parasites of insects associated with crops, even though this involves biological information on sibling species, host-specificity and habitat preferences. Such taxonomists prefer to study the diversity of adults that can be caught in traps in forest, because this involves a wider range of taxa and thus appears to give more information about systematic diversity. This is an important difference in scientific approach. But the question becomes, should we focus our efforts and available funding on subject areas that we can ensure will yield a rich set of data that is interesting and useful to other biologists, or should we spread our taxonomic efforts thinly through taxa of which we have little or no biological knowledge hoping that serendipity will yield something interesting. The difference between these strategies might be compared to the difference between investment and gambling; the latter is more exciting and can be profitable serendipitously, but must be approached with caution when using public funds.

Taxonomy and Biodiversity Surveys

In recent years, biodiversity surveying has

become very popular, although the driving force is often the simplistic question: 'How many species are there?'. But to attract long-term funding from within the scientific community it is essential to erect suitable quantifiable questions and testable hypotheses. This requires standardising sampling methods to facilitate comparisons between sites, seasons and habitats (Coddington *et al.* 1991). Sampling programmes like this are based on the view of faunas as dynamic systems in which processes can be studied, rather than as static systems in which units need to be described. Carefully designed surveys, that examine species accumulation curves with time, that incorporate life-history studies of representative taxa, and involve the analysis of food-webs - these can all yield so much more information than just material for descriptive taxonomy. The species-richness of tropical countries is particularly suited for such multidisciplinary studies, and taxonomic components within such multidisciplinary studies are more likely to attract funding than the isolated revision of selected insect taxa. Again, it is the recognition and investigation of patterns in natural history that makes the taxonomic component of interest to a wider range of biologists.

The number of insect species is so large that few countries have ever made any real effort to discover the extent of the fauna within their borders. One exception is Australia, where such an effort was made by the Federal Government agency CSIRO several years ago. This led to remarkable successes for at least two major groups, Lepidoptera and Orthoptera. The Australian National Insect Collection now contains 75% or more of the Australian species of these two insect Orders, although vast numbers of these species remain undescribed. The lack of description is of less importance, because most of the species are sorted to genera, and for many the life history, host-plants, phenology and distributions are established; the objective being to estimate the richness of the fauna. Thus, a survey of the insect species in a rich fauna is technically possible. But the success of the Australian venture was the result of the fortunate

concatenation of three resources; a few scientists of exceptional clarity of purpose and ability, excellent technical and logistic support, and outstanding political leadership that secured and maintained the funding. It is rare in science for scientific, technical and political objectives to be so closely harmonised and focused. Under more normal circumstances, taxonomists must rely on their own resources. Even so, with foresight and careful planning of repetitive sampling, reliable data on a rich fauna can be accumulated within a few years, as was demonstrated by the work of the editors of the book *Hymenoptera of Costa Rica* (Hanson & Gauld 1996).

Taxonomy and Inter-Disciplinary Studies

A taxonomic revision by itself is commonly of interest only to a few other specialists, but a taxonomic revision undertaken as part of a multidisciplinary study can be designed to be of interest to many more scientists. If taxonomy is to attract more of the best young biologists, then the level of questions asked must be raised above how do two taxa differ from each other in structure. Suitable questions are more likely to arise through the interaction of different types of minds than will be developed by taxonomists working in isolation on their own collections. Thus taxonomists need to incorporate themselves into research teams along with other scientists who are studying any of a wide range of subjects involved in biodiversity, such as behaviour and ecology, physiology and genetics, disease transmission and crop variety resistance, and wind systems and rainfall patterns (see Grandcolas 1997).

Inter-disciplinary research groups that include insect taxonomists can be found in several parts of the world. Two such groups with which I am familiar are exploring the diversity of the insect fauna associated with the flowers of Asteraceae plants in parts of Brazil, and the diversity of thrips associated with *Acacia* and *Casuarina* trees in Australia. Both of these studies will lead, not just to taxonomic results, but to a rich data-set of host-plant as-

sociations, phenology, predators and parasites, and the expanded evolutionary perspective that such data provide (Lewinsohn, 1991; Crespi & Mound 1997). Traditional systematic studies on these same insect groups could not yield the same richness of evolutionary insights. In addition to the essential descriptive taxonomy, these projects involve collaboration with specialists on ecology, insect behaviour, DNA analyses within and between species, mathematical modellers, and botanists. The Australian team with which I am associated now includes three main investigators, two post-doctoral students, four PhD students, and honours students at first degree level. The taxonomic component of this project is demonstrably more interesting, to students as well as to other biologists and their funding agencies, than traditional approaches to descriptive taxonomy and systematics.

Training for Taxonomists

The future of any branch of science must depend, largely, on the quality of young students that can be attracted to work within a particular discipline. The process of attraction and subsequent training of such individuals is complex. Some professional taxonomists emphasise the importance of teaching the significance of holotypes, the interpretation of formal synonymies, and the methods of cladistic analysis. Other taxonomists emphasise the importance of maintaining within universities collections of specimens, to inspire students to think about the patterns and processes of biological diversity. Both views have validity, but the essence of science ultimately is the generation of testable ideas. In biology, original ideas are particularly likely to arise through looking at the complexities of the systems within which organisms survive. Thus the processes of attracting and training young biologists are likely to be most effective when they involve field experience in areas of high diversity. Perhaps we should remember that Charles Darwin was a field biologist before he became a descriptive taxonomist, and he was a taxonomist long before he emerged as

biology's primary theoretician. And we might also remember the sterile arguments by taxonomists concerning the validity of the Galapagos Islands bird species known as Darwin's Finches, and the exciting resolution of these arguments and enrichment of our ideas on speciation through intensive field work in recent years (see Weiner, 1994).

Networking

There are also practical measures that we can take to raise the profile of taxonomy. We have been remarkably slow in making our data available to other biologists in the form of lists of the described insect species of the world. Part of the reason for this is that many taxonomists consider that a check-list should be an accurate record of a fauna. But there is an alternative and more positive view - that a check-list can be the starting point for a range of investigations. The British check-list of the 20 000 insect species recorded from those islands is not fully accurate. But its accuracy increases yearly, it is widely used, and current plans to make it available on computer will increase the number and range of users who are interested in the British fauna. Similarly, a list of Brazilian insects could become a focus for studies on the Brazilian fauna, as well as a focus for generating information, for generating ideas, and for attracting funding for further work.

Check-lists of insect species from particular tropical countries could be used to draw attention to areas where the knowledge base is sound, and where interesting biological questions could most profitably be asked. They would also draw attention to areas where knowledge is weakest, and stimulate consideration of why this should be so. If developed on computer, such a check-list of Brazilian insects could quickly attract contributions from many different countries, particularly if organised centrally by a suitable committee of the Brazilian Entomological Society and made available on the Society's internet home page. Moreover, such a list need not be limited simply to names, it could be cross-refer-

enced readily to a bibliography of pertinent works, thus stimulating further interest at all levels in the biological richness of this vast country, where library facilities and the scientific community are dispersed over such a wide area. Since 1985 Brazil has been taking a major lead in the use of on-line information systems in biodiversity studies, through the Tropical Data Base - a department within the Fundação Tropical de Pesquisas e Tecnologia "André Tosello", at Campinas (<http://www.bdt.org.br>). Although this web-site contains a wealth of information, including lists of endangered species, amongst entomologists only the biological control workers are maximising their use of this communication system. The Iowa State University web-site (<http://www.ent.iastate.edu/List/>) includes much useful information on entomology worldwide, but the possibilities within this type of communication are being realised only slowly by most taxonomists.

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