

Systematics: Science or Service?

John Heraty

Department of Entomology, University of California, Riverside, CA 92521

Abstract

Providing identifications, information and support for biological control programs is generally regarded as a service. The reciprocal information supplied in the form of reared material or new collections is valuable, but the present form of cooperation needs to be reassessed for resources to remain available. Four recommendations are proposed to promote better interactions: (1) create a directory of systematists working on taxa relevant to biological control, (2) rank critical research areas to stimulate funding, (3) include systematists as active participants in biological control programs, and (4) find ways to increase the amount of funding for systematics in areas related to biological control.

Introduction

"Accurate systematics is the basis on which all meaningful research in biology is based" (Rosen & DeBach 1973, p. 215).

No doubt the systematist's single most important contribution to a biological control program is providing a correct scientific name for a species, whether the species was previously described or is new. This is generally viewed as a "service" to other disciplines, as opposed to other aspects of the "science" of systematics which cover the collection, discovery, classification and analysis of relationships. The correct species name is critical information that immediately provides access to information, where available, on geographic distribution, host records, behavior, and other aspects of the biology of the species (Hardy, 1982). An incorrect name can waste valuable time and resources, and clutters the literature with misinformation.

The importance of valid identifications for successful establishment and cost-savings in biological control programs have been discussed numerous times, and for those that still need convincing of the importance of a supportive union between systematics and biological control, I refer you to Clausen (1942), DeBach (1960), Schlinger & Douth (1964), Delucchi (1967), Compere (1969), Rosen & DeBach (1973), Gordh (1977), Hardy (1982), Danks (1988), LaSalle (1993) and Gordh & Beardsley (in press). Most of these papers deal with the importance of taxonomy, a more restrictive definition applied to the naming and classification of species, for biological control. However, the "perfected classification arranged in ascending order and based on phylogenetic systematics" (Compere, 1969; p. 5) allows for greater stabilization and predictive power, and "predictability, on the basis of taxonomic correlations, becomes more important as pest control tactics become more complex" (Hardy, 1982; p. 233). The distinction between systematics and taxonomy is not always clear, as was emphasized in a relatively new definition of systematics, which is "the study of species and of the phylogenetic relationships among them and, ultimately, the proposal of a predictive classification consistent with phylogeny" (Wheeler, 1995; pp. 31). The "science" of defining monophyletic assemblages and the study of taxa not included within an agricultural framework ultimately has a tremendous impact on the service side of systematics for predicting host relationships, distribution, area of origin, diversity of related taxa, and other parameters related to evolutionary divergence (Delucchi, 1967; Hardy, 1982; Danks, 1988).

The issue of interactions between systematists and biological control workers was raised recently through a series of discussions on internet LISTSERV (parahym@nhm.ac.uk; various comments quoted in the following text). John LaSalle (IIE, London) posed the initial question "Why are systematists being excluded from biological control programs?" The discussion was quickly diverted to questions of what services systematists should provide to biological control programs, and how they, or the discipline, should be rewarded for those services. I doubt that anyone would find fault with a strong association, but perhaps it is time to open dialogue on the expectations of each partner and the means by which to advance both disciplines.

Several of the papers reviewing the association between systematics and biological control have focused largely on mistaken identifications, usually by field biologists, that could have saved both time and money if competent systematists were involved with the project from the beginning (Rosen & DeBach, 1973). Certainly, there is a strong legacy of workers in biocontrol that were competent systematists who produced admirable revisionary works (David Annecke, Paul Timberlake, Harold Compere, Jim McMurtry), but as John Noyes (TMNH, London) pointed out "in most cases they do not". Poor identifications can result from inadequate resources or insufficient time spent studying a group to be able to recognize important diagnostic characters - traps that can include both systematists or biocontrol workers alike. Clausen (1942; p.796) states that field biologists are often "unduly critical of [systematist's] mistakes, this being due, to a considerable extent, to the lack of appreciation of the difficulties that confront them".

Response time for identification and cost were cited in the discussion as important factors precluding systematics support. Of course, the time for identification depends not only on the systematist but on the quality of the material submitted for identification and how well the group has been studied in the past. John Noyes estimated that a competent systematist could make an accurate determination of a species (named or at least identified as a new species) after 25 hours of work. Of

course this is going to depend entirely on resources, which include access to literature, adequate descriptions or revisions, and type material or representative specimens identified by an expert for that group. The amount of time for an identification must also be balanced against other responsibilities, not the least of which is the new trend for museum staff to be involved in cost-recovery ventures not related to revisionary systematics. The identification of parasitic Hymenoptera is not trivial. LaSalle (1993) estimated that fewer than 5% of the 18,000 described species of Chalcidoidea could be recognized to species on the basis of available descriptions, and often the comparison to representative material may be the only way to guarantee an identification. Identifications are further complicated by an estimated number of 80,000 undescribed species of Chalcidoidea. Problems of similar magnitude exist in many insect groups, both pests and beneficials. Unfortunately, there are not enough systematists and the further afield the expert is to the group being submitted, the more difficult it will be to obtain a correct determination.

Taxonomic problems in biological control programs that waste money and delay control are not merely historical events. Whiteflies of the genus *Bemisia* are currently one of the major pests in the southern United States, resulting in economic losses totalling 2 billion dollars over the last decade (Toscano *et al.*, 1998). Recent releases of *Encarsia* (Aphelinidae) against these whiteflies were made without adequate identification or survey of resident species. Also, the quality of cultures of imported *Encarsia* have not always been maintained (I have examined representative material from cultures that are obviously contaminants, and not the original species imported). Hopefully, adequate vouchers have been deposited in collections for future research. Funding for systematic research on *Encarsia* has been largely through the National Biological Control Institute, but the proportion of funding with respect to the economic cost is incredibly small (somewhere around 0.000085%). For a 1% investment of the economic loss, I am sure that by now the world species of *Encarsia* would be described, mapped, sequenced and their phylogenies resolved.

Because of their small size and general lack of external characters, *Trichogramma* remain one of the most difficult groups to identify to species (see Pinto, this volume). Clausen (1942; p. 796) stated the "common forms in Europe and North America are indistinguishable morphologically in any stage, and it is customary to separate them on the basis of their habits and by their developmental responses to experimental conditions. The uncertainties and doubts that have arisen as a result of this condition have clouded much of this work that has been done in testing the value of these parasites in the biological control of a series of pests". Fifty-six years later we have not made much progress in the identification or quality control of *Trichogramma* being released, and the results of biological control are probably just as suspect as there were in 1942. This year will see the first comprehensive revision of the species of North American *Trichogramma* (Pinto, in press). Species are segregated almost entirely by male genitalia, and identifications will be laborious but at least possible, although the *minutum*-complex, one of the most economically important groups, will still be difficult. Currently, commercial insectaries are unregulated. Will these insectaries sponsor at least one parataxonomist to use this new information to monitor the species in culture?

Even the identification of pest species remains problematic. Recently, an introduced wasp was found galling the leaves of *Ficus microcarpa* in Orange County, CA. The Californian species was considered to be the same as a Hawaiian species first discovered on Oahu in 1989, and initially presumed to belong to either *Acophila* (Epichrysomallinae), based on a reference in Boucek (1997) to a Hawaiian leaf-galler, or *Camarothorax*, based on an examination of material by Jack Beardsley. Both genera include species distributed widely in the Australasian region, but not in India. An outbreak of the *Ficus* galler in the Canary Islands prompted an exchange of information and specimens, resulting in placement of the species as a member of *Josephiella*, a genus not included in any of the existing keys to genera, and as a new species that is currently being described. *Josephiella* is known only from the type locality in India. For either of the initial determinations of *Acophila* or *Camarothorax*, the foreign exploration for parasitoids would have been centered in the wrong countries.

The above are just a few of the many current examples of, again, systematics as a service and the importance of involving systematists in the early stages of program. Limited availability of funds have prevented the development of revisionary studies, identification keys and catalogues necessary to provide the immediate information requests for very complex groups such as *Trichogramma* and *Encarsia*. For *Trichogramma* we now have a Nearctic identification key, but it will be impossible to provide accurate identifications for many of the species elsewhere in the world. Phylogenetics has probably had the least impact on biological control programs, although definition of monophyletic groups such as the *strenua* species-group of *Encarsia* has allowed for a much stricter definition of their host relationships. Studies of the phylogenetic placement of *Josephiella* could be used to identify closely related genera for survey of parasitoids and identifying related host species that may be attacked in the area of release. In short, systematic studies continue to be useful and important for the advancement of biological control programs. The question remains of how support can be increased in areas that are beneficial to both disciplines?

What about other critical contributions of systematics to biological control programs? Catalogues that list information on taxonomic changes, identification keys, host associations (hopefully valid ones), and distribution are extremely valuable for both biological control workers and systematists. Unfortunately, they are extremely laborious to produce and maintain, and the funds necessary to support this kind of endeavor are difficult to find. Noyes again points out the problems associated with compiling a catalogue or other database that incorporates misidentified parasites or hosts, *Tetrastichus* sp. being referred to

as probably one of the most abused identifications for what could be any member of the Tetrastichinae (Eulophidae). Fitzgerald & Simeone (1971) refer to *Tetrastichus* sp. (Entedoninae) as a parasitoid of early-instar larvae of *Marmara* (Gracillariidae). Is this a misidentified tetrastichine or entedonine? Is voucher material available for re-identification? A poor identification can stymie future biocontrol efforts just as easily as poor rearing protocols that do not correctly associate a host and parasite!

Maintenance of general collections of insects is extremely important for understanding the diversity and distribution of both economic and related species of insects, and serve as a reference for making identifications. The costs associated with curation can be enormous. The University of California, Riverside (UCR) has a collection of 30,000 *Aphytis* (Aphelinidae) mounted on 4,000 slides, almost all of which are in various stages of deterioration. This material is based on diaspid rearings from over 73 countries, many of which are now inaccessible for political reasons. Representative material, often voucher specimens from earlier or ongoing biocontrol programs are extremely important. Noyes noted an example from the coffee mealybug program in Kenya, for which there is no voucher material for the main agent of control *Anagyrus* near *bugandensis* Compere. The responsibilities of the biocontrol worker in depositing or maintaining voucher material cannot be overemphasized. Also, the importance of non-economic collections cannot be overestimated. From a single canopy fogging sample in Sulawesi, Noyes (1990) estimated that he obtained 156 species of *Encarsia*, a number almost equal to the approximately 200 species previously described, mostly from material reared as part of an applied program. The collecting emphasis of the systematist (general collections from native habitats) and biological control specialists (reared material from agricultural habitats) are bound to differ, but together they can lead to a better understanding of any particular group.

Notably, systematics is not an inexpensive venture. Charging for identifications has been seen as a means to recoup these support costs. Unfortunately, the change to fee-for-identification by the International Institute of Entomology had a "nullifying effect on this service" (Hardy, 1982; p. 234). The decrease in identification load resulted in a loss of systematic positions within that organization, and under the present state of attrition and shifting responsibilities, the unit will probably cease to provide any identifications within a few years. Other organizations such as the CSIRO in Australia and the Eastern Cereals and Oilseed Research Center (formerly the Biosystematics Research Unit) in Ottawa are pressuring research scientists to be involved in economically sustainable projects rather than revisionary studies. Luckily, the Systematic Entomology Laboratory in Washington, DC maintains a free identification service (for reared material) and a strong emphasis on revisionary systematics. However, several positions have not been replaced in Washington, DC that would directly serve the biological control community.

Systematics provides an invaluable service to biological control, and this is reciprocated by information on host associations, biology and distribution fundamental to refining concepts of species, and hierarchical phylogenies. Systematists not only provide identifications but stimulate ideas and make information available by synthesis, association, and prediction (Danks, 1988). However, systematics must also be respected as a science, with consideration of its needs for financial support and academic collaboration in ways that increase its profile within institutions that train and hire students of systematics. Below are a few suggestions on how to promote a closer association between biological control workers and systematists, and how to take positive steps toward more collaborative research.

Recommendations for Stimulating a Better Interaction

(1) *Create a Directory of Systematists and Services Available.* An internet directory may be a way of providing non-systematists better access to experts available to identify certain groups. A partial list of taxonomic expertise has been published on the internet (http://www.cnr.berkeley.edu/biocon/id_insects/taxlist.htm; R. Zuparko & S. Trijapitsyn [see this volume]). However, this concept for stimulating associations will only be viable if the directory includes restrictions placed on submissions by investigators, including the way that material is submitted (point/pin mounted, preserved in alcohol or slide-mounted), what material will be accepted (e.g., only reared material), or what charges or exchange of services will be levied for identifications. Unfortunately, a simple list does not guarantee the quality of identifications provided by the included individuals. Choosing a systematist to work with is critical, and should be based on the potential political, economic, or environmental liabilities associated with misidentifications.

(2) *Rank Critical Needs for Revisions of Economically Important Taxa Through Joint Consultation.* Will this work? How do you coach someone to work on a research area near your own program? Is it better to suggest projects for research, or to identify areas of basic importance and then find ways of maintaining the funding or profile within these areas? For example, the requirements for identification or need to do further research on Coccinellidae will vary for different hosts. An expert in Coccinellidae with good access to resources (collections and literature) should be able to provide an accurate identification within a relatively short period of time. However, to do this, it is essential to have someone working in this area. Vocal support from the biological control community could also direct administrative support for revisionary studies of large complex taxa that require several years or more to complete - administration needs to be convinced of the value in setting aside normal processes of evaluation (publish or perish) to recognize efforts placed on large monographic works.

(3) *Include Systematists as Active Participants in Biocontrol Programs.* The amount of time spent on identification needs to be recognized academically and financially. Mention of the identifying systematist in the acknowledgements,

frankly, does nothing to advance their career or increase their profile with their administration. What does count is active participation in the grant process as a consultant or participant, fees for services rendered, or, where the identifications have a strong impact on the results, include the systematist as an author on the resulting papers. In the review process, papers or grant proposals that include identifications but do not acknowledge the identifier should be rejected.

(4) *Increased Funding for Systematics in Areas Applicable to Biological Control*. The most common thread of the PARAHYM discussions was that funding drives research. There is little impetus for a systematist to do requested but unfunded research on organisms that are less than spectacular, and usually the chosen groups are not agriculturally related. For work on parasitic Hymenoptera, the association with biological control has been extremely beneficial for obtaining grant funds from a variety of sources, although not necessarily on a group of biocontrol agents of immediate interest. Short-term grants and changing views on the importance of a particular group make it difficult to carry out work on some of the large, diverse taxa that need to be revised. Perhaps we need to approach funding for systematics and biological control from a different perspective than merely chasing short-term money. Lynn Kimsey (UC Davis) mentioned the collective voice of other scientific communities that is "effective at ... promoting their projects and needs to the public and to the funding community". Perhaps we, both systematists and biological control specialists, need to look at ways of influencing the amount of funding being allocated to research in systematics and biological control in general (see the *Systematics Agenda 2000* brochures). Can Congress be influenced to triple or quadruple the funding available for competitive grants in the U.S. Department of Agriculture? Can the World Bank be influenced to support the International Institute of Entomology infrastructure to maintain a pool of systematists that can address the immediate needs of most of the Old World tropical regions? Additionally, pools of unrestricted funds offered to institutions already providing service identifications could help to remove the need for identification fees and divert resources towards monographic revisions rather than the production of profitable paraphernalia.

Acknowledgements

First, thanks to the people that provided discussion of this topic on the parahym LISTSERV that stimulated production of this paper. Hopefully I have accurately represented their comments. John Pinto, Dick Goeden, Dave Hawks, Mark Hoddle, and Laura Heraty (UCR), Lynn Kimsey (UC Davis), John Noyes (The Museum of Natural History, London), and Gary Gibson (ECORC, Ottawa) provided additional comments, criticisms and ideas. To join parahym send the message "subscribe parahym" to "listserver@nhm.ac.uk".

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