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# Biosystematic and Biological Control Information Systems in Entomology

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## Introduction

### BACKGROUND

Entomology is one of several biological disciplines that hold great promise of providing useful knowledge to man but that are hindered by major problems in delivering that promise. The promises and problems of entomology, especially those in biosystematics and biological control, primarily result from the immense numbers and diversity of insects and their relatives. However, application of computer technology will enable entomologists to surmount many of their problems and to deliver the knowledge that society needs. The use of computers and innovations in information development, analysis, and delivery systems are revolutionizing almost all aspects of entomology, as they are revolutionizing other fields. Researchers in two key, related areas of entomology—biosystematics and classic biological control—are beginning to take advantage of computer technology.

A special problem in biosystematics of insects is that we must deal with

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about one million described species, bearing perhaps twice as many valid and synonymical scientific names arranged in an hierarchical system of at least four levels. Thousands of common names also must be considered. A wealth of published taxonomic literature, in scores of languages, extends back to 1758. A special problem in biological control is the existence of a large amount of 'grey' literature, consisting of unpublished notes and documents and including literature from a diverse range of related disciplines and subdisciplines. Users of both biosystematics and biological control data are varied and numerous—individuals and groups throughout the world. Further complications, extensions and relationships could be cited with regard to the development and supply of research information in these areas.

Our review of information systems in entomology is divided into basic and applied biosystematic databases, tools, utilities and other currently non-automated information systems. In each section we describe what we are doing, then review what others are doing and what has been published. While we do describe a typical environment (ours) within which these information systems have been built and currently exist, we do not review the extensive field of computer equipment and systems.

### REVIEW OF MAJOR PUBLICATIONS

A realistic and sobering place to begin a discussion of computer databases is the classic publication, *Demythologizing Biological Data Banking* (Shetler, 1974). Most of the myths and fallacies related in that paper were reiterated almost a decade later (Sarasan, 1981; Sarasan and Neuner, 1983) and are still pertinent today. Gautier's paper (Gautier, 1978) on automation of biosystematics data is one of the few major publications devoted to automatic data processing and databases in biology. Except for a basic textbook written for use in a course on information sources in entomology (Arnett, 1970), none is restricted to entomology. Most are proceedings of conferences (e.g. Cutbill, 1971; Brenan, Ross and Williams, 1975). The recent book by Allkin and Bisby (1984) includes some excellent introductions to key topics. Bisby (1984) provides an overview of information services in taxonomy; Barron (1984) describes basic database designs (hierarchical, network and relational) and their advantages and disadvantages for use in biology; Freeston (1984) and White (1984) write about implementation of databases on microcomputers; Allkin (1984) and Dallwitz (1984) illustrate the use of automatic data processing (ADP) tools to generate biosystematic information in the form of taxonomic keys and descriptions; and the rest of the book describes various databases in biology, but none specifically mentions entomology.

## Description of a working system

### INTRODUCTION AND HISTORY

The computer environment for information systems may appear to be rather diverse as a result of the various trade names associated with their components. However, the environments are all very similar in basic structure, which consists of equipment (hardware) and programs (software) operated by people (personnel) and costing money. These environments vary greatly in size, ranging from a single personal computer operated by an individual to large mainframe systems operated by divisions of people. Because there is an abundance of literature available on computers and their environments, we restrict ourselves here to describing our computer environment as an example of an operational system being used by an agricultural research organization.



Over the past decade, the Biosystematics and Beneficial Insects Institute (BBII) of the Agricultural Research Service (ARS), US Department of Agriculture (USDA), has made a concerted effort to apply computer technology to the systematics and biological control aspects of its research and service programme. Thus a description of our experiences (failures as well as successes) provides a useful 'case history'. Much of this paper concerns the programmes of the BBII Beneficial Insects Laboratory (BIL) and Systematic Entomology Laboratory (SEL). Various sections were prepared by the BBII staff and associates listed after the titles; for further information, *see Table 1*.

The mission of the BBII, one of 10 Institutes at the Beltsville Agricultural Research Center, Beltsville, Maryland, is to conduct research and provide services in the taxonomy and biosystematics of insects, mites, nematodes, fungi and vascular plants; in biological control by introduced natural enemies; and in bee biology. Systematics research on insects and mites and research on biological control have had an especially close, long-term working relationship in the USDA, as they have in many other organizations (Knutson, 1981). Building on the needs and benefits of that relationship has provided us with a purposeful framework for applying computer technology in the BBII. Systematics of groups of organisms other than insects and mites, and research on bee biology, were added to the BBII programme in 1985; we are also finding programme interactions in these areas that are enhanced by computer applications.

### HARDWARE

The variety of computer systems in BBII, or which regularly communicate with BBII systems, are illustrated in *Figure 1*. While some applications are shared among mainframe computers, the focus here is on the hardware of the five Wang systems that are directly interconnected. The primary system (*Figure 2*) is a Wang VS-100® (Virtual Storage) minicomputer equipped with 2 megabytes of random-access memory (RAM) and some 800 megabytes of online disk storage. Coaxial cables connect the central processor unit (CPU) of this system to 19 data-entry terminals (workstations) and seven printers. The printers are physically located for optimal use by groups of users. In addition, the system is configured to allow simultaneous remote access by as many as 24 more terminals hard-wired to four peripheral CPUs. Also included in the system is a multiplexor that allows concurrent use by a

**Table 1.** Sources of additional information

APHIS/PPQ records on shipments and releases of natural enemies in the US (by biological control laboratories at Niles, Michigan and Mission, Texas): G. L. Cunningham, Chief Staff Officer for Biological Control, APHIS/PPQ, Room 600, Federal Center Building, Hyattsville, Maryland 20782, USA.

ARSEF (ARS Collection of Entomopathogenic Fungal Cultures), Ithaca, New York: R. A. Humber, ARSEF, c/o Boyce Thompson Institute, Tower Road, Ithaca, New York 14853, USA.

Biological Control Information Document: J. R. Coulson (see ROBO).

BIRLDATA: L. R. Ertle, BIRL, 501 South Chapel Street, Newark, Delaware 19713, USA.

BRS (Bibliographic Retrieval Services): Information Technologies, 1200 Route 7, Latham, New York 12110, USA or CABI, Farnham Royal, Slough, SL2 3BN, England, UK.

Coleoptera Catalog (*Catalog of Coleoptera of America North of Mexico*): J. R. Dogger, Systematic Entomology Laboratory, USDA, c/o Department of Entomology, US National Museum of Natural History, NHB 168, Washington, DC 20560, USA.

Common Names: L. Knutson (see WHIAD).

CRIS (Current Research Information System): US Department of Agriculture, National Agricultural Library Building, Beltsville, Maryland 20705, USA.

DELTA (DEscriptive Language for TAxonomy): [M. Dallwitz, CSIRO, Canberra, Australia].

DIALOG Information Services, Inc.: 3460 Hillview Avenue, Palo Alto, California 94304, USA.

DPMIAC: Chief, Defense Pest Management Information Analysis Center, AFPMB, Forest Glen Section, Walter Reed Army Medical Center, Washington, DC 20307–5001, USA.

FBC (Florida Biological Control database): J. H. Frank, Department of Entomology and Nematology, University of Florida, Gainesville, Florida 32602, USA.

Flies of the World (Biosystematic Database of Flies of the World): F. C. Thompson, Systematic Entomology Laboratory, USDA, c/o US National Museum of Natural History, NHB 168, Washington, DC 20560, USA.

maximum of six systems with six sessions per system. The primary system communicates with the peripheral systems via a digital circuit leased from the telephone company; for this purpose, all systems are equipped with 4800-baud digital service units.

The peripheral CPUs consist of two minicomputers (Wang models VS-15® and VS-65®) and two Wang Office Information System (OIS®) models 115. All peripheral systems have smaller disk-storage capacities than the primary system (8 megabytes each for the two OISs, 76 megabytes for the VS-15, and 150 megabytes for the VS-65). The OISs are word-processing systems with limited data-processing capabilities, but even in the case of the two peripheral VS systems, most data processing is performed on the primary system because of its greater data-storage capacity. All software developments and the majority of the databases reside on the primary system.



**Table 1** (*cont'd*)

Hymenoptera Catalog (Catalog of Hymenoptera in America North of Mexico): D. R. Smith, Systematic Entomology Laboratory, USDA, c/o US National Museum of Natural History, NHB 168, Washington, DC 20560, USA.

Inventories of Collections and Specimen Label Systems: F. C. Thompson (see Flies of the World).

ISAC (International Soybean Arthropod Collection): J. K. Bouseman, Illinois Natural History Survey, 607 E. Peabody Dr., Champaign, IL 61280, USA.

POUSNE (Pest Organisms in the U.S. and their Natural Enemies): J. R. Coulson (see ROBO).

PRIS (Pesticide Research Information System): Scientific Information Retrieval Section, Research Program Services, Research Branch, Agriculture Canada, Ottawa, Ontario, K1A OC6 Canada.

ROBO (Release of Beneficial Organisms): J. R. Coulson, USDA, Agricultural Research Service, BBII, Beneficial Insects Laboratory, Bldg. 476, BARC-East, Beltsville, Maryland 20705, USA.

SELGEM (SELf GEnerating Master): A multiple file management system written mostly in COBOL and developed at the Smithsonian Institution. The system is out of date and no longer in use at the Smithsonian. Custom software is required for conversion of each file of existing SELGEM databases to allow the data to be used by current database software. There is uncertainty about which SELGEM databases will eventually be converted. For further information, contact Gary Gautier, US National Museum of Natural History, Smithsonian Institution, Washington, DC 20560, USA.

Specimen Tracking System: M. A. Lacey, USDA, Agricultural Research Service, Biosystematic and Beneficial Insects Institute, Room 007, Bldg. 003, BARC-West, Beltsville, Maryland 20705, USA.

Tephritidae In-Depth Database Pilot Project: L. Knutson (*see* WHIAD).

WHIAD (Western Hemisphere Immigrant Arthropod Database): L. Knutson, Director, Biosystematics and Beneficial Insects Institute, USDA, Agricultural Research Service, Room 001, Bldg 003, BARC-West, Beltsville, Maryland 20705, USA.

Altogether there are now six CPUs, 51 workstations (including 26 microcomputers used as workstations), 11 printers (including two high-speed line printers), three tape drives, five disk drives (in addition to those included within the CPUs), and four telecommunications ports (in addition to the six dedicated to the Wang network). All of the equipment was acquired over the past eight years for a total cost of about US $750 000; more than half of the funds were provided by various ARS offices outside the BBII.

## SOFTWARE

Word processing is the most extensively used computer application in BBII (*see below under* Databases and ADP Tools and Utilities). One of the real strengths of Wang word processing is its capability for integration with data-processing operations. Through access to utilities, word-processing files can

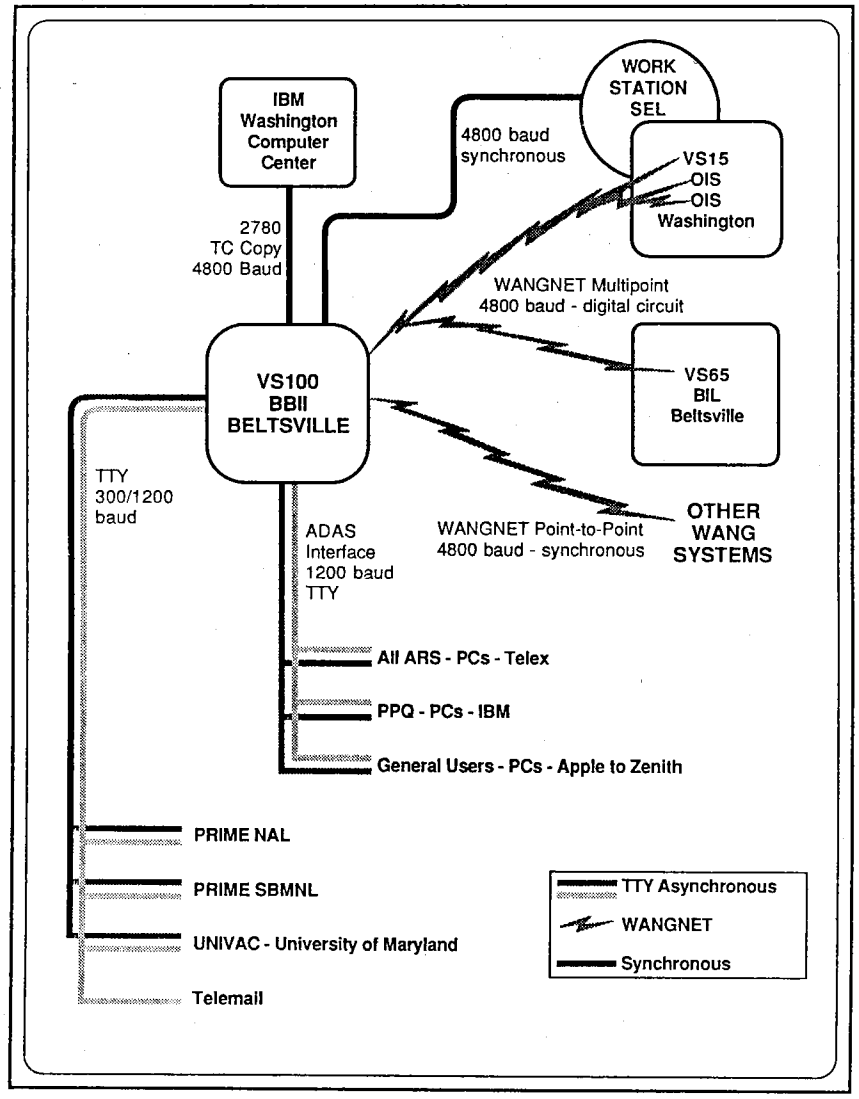


**Figure 1.** Communication paths of the BBII computer network.

be created, updated, or manipulated as data-processing files. Hence, data are easily moved between word-processing and data-processing environments.

Although a number of programming-language compilers are available for VS systems, these machines are designed for optimal execution of programmes written in Common Business-Oriented Language (COBOL). The system provides a data-management system (DMS) with data dictionary



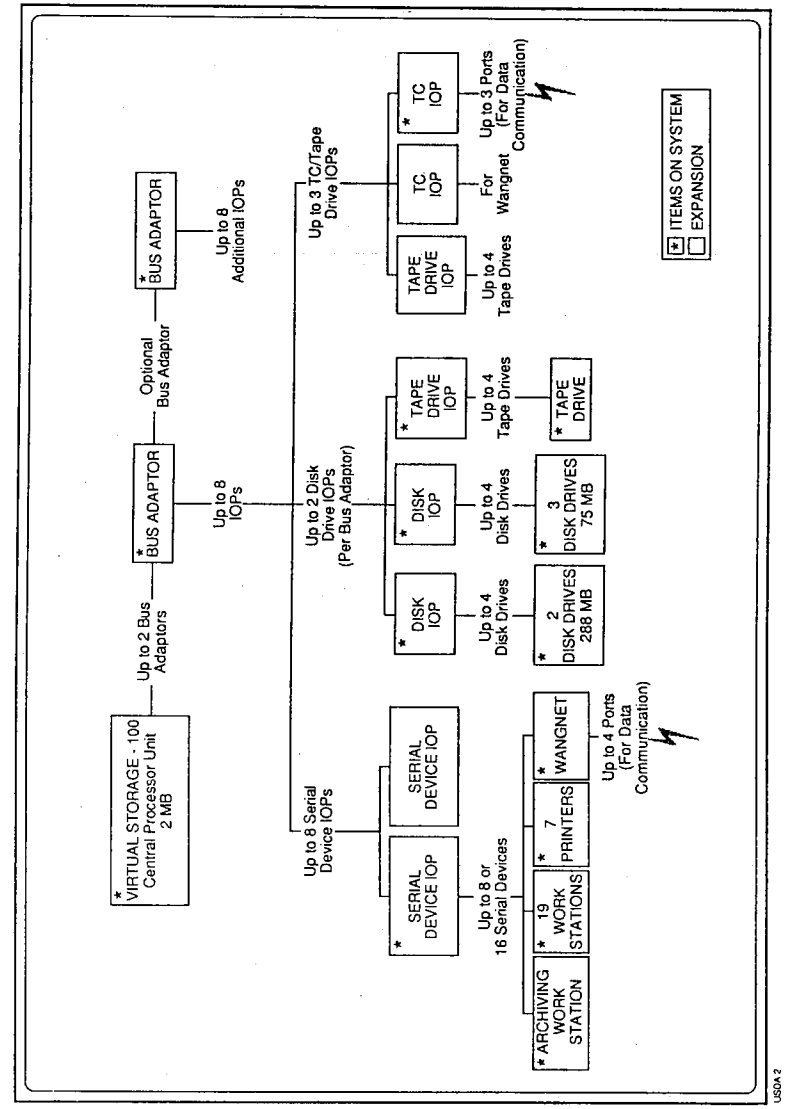


**Figure 2.** Configurations of BBII and associated computer hardware.

(CONTROL), data entry, inquiry and report facilities. Utilities are available to generate programming code in COBOL or RPG II automatically for all these facilities, thus allowing the users easily to customize their applications. An interpretative procedural language (a type of Job Control Language) allows linking of the various components into menu-driven systems. All of our current database applications and tools are built from this DMS base. We anticipate modernizing some of our data processing through conversion to relational databases that will run under recently acquired PACE® (Professional Applications Creation Environment) software published by Wang. Relational databases are those in which data entered once, in a single database, can be retrieved automatically by other databases, thus eliminating redundant data entry.

Networking runs under Wang multipoint telecommunications software residing on all systems. The network does not support word processing on the primary system by remote users, but documents can be rapidly shuttled electronically between systems for local editing, review, or printing. All other software can be run through terminal emulation. Although the network is primarily used for file transfer and data processing, it also permits the system manager to log on to any of the peripheral VS systems to perform emergency diagnostics or more routine system functions.

## PERSONNEL

Our experiences in the application of computer technology are probably similar to those of other research organizations. Our greatest continuing deficiency is the lack of sufficient personnel specialized in data processing, from data-entry personnel to systems analysts, computer programmers, database administrators and system managers. This deficiency was especially constraining in the start-up stage, when installation and operating difficulties were encountered and when the scientific and support staff had little experience or knowledge of computerization. However, that situation led many scientists to involve themselves directly in the use of the computer and also led to their development of substantial expertise. In the early stages, we were fortunate to have had the general advice and hands-on assistance of the ARS Communications and Data Services Division (CDSD) in developing a few systems. CDSD has since been eliminated because of cost cutting: all data-processing services are now provided by commercial contractors. Difficulties frequently were encountered in working with commercial organizations because of their nearly total lack of understanding of the science involved, their orientation toward business functions, rapid turnovers in personnel, and their generally high costs. That set of problems was most severe in our attempts to contract for programming. Lack of permanent ADP personnel in the BBII continues to be a roadblock now that we have entered a phase of extensive data entry and need to refine programs, interrelate existing and planned databases, and make them available electronically to user groups. All of our hardware and core applications (operating system, languages, database and utilities, network and word-processing software) are maintained by the vendor under contract at an annual cost of approximately $30 000.



## MANAGEMENT

Our management of the system has not been highly sophisticated from a technological viewpoint. It was obvious to us that areas of research and services as word-intensive as systematics and biological control would benefit immediately and immensely from computerization. We were advised at the initiation of our computerization project (1979) that Wang equipment provided the most advanced integration of word and data processing. At the outset, we decided not to try to design an overall system that was interrelated in the most advanced ways. We decided not to develop new areas of research and services but, rather, to emphasize the application of the computer to proven useful and productive areas of research such as production of taxonomic catalogues and use of our specialized, unique data resources. We placed highest priority on projects that elicited substantial interest from BBII scientists and the user community, and we realigned priorities as we felt our way through the development of the system. There are advantages and disadvantages to such an *ad hoc* approach, and although our current enterprise could be best described as a collection of substantially interrelated databases and computer tools, rather than as a highly integrated system, we feel that the cost/benefit ratio of our approach has been acceptable.

The BBII databases, systems and procedures consist of some 30 projects, most of a continuing nature, ranging from those in an early planning stage to those that are fully operational. The following descriptions, primarily of databases that can serve as sources of information for the scientific community or which might have value as models, are arranged according to general type of application.

### Databases and ADP tools and utilities (F.C. Thompson)

Biosystematics—what is its task, how is it achieved, and why is it of value? Biosystematics seeks to name, describe, distinguish and, most importantly, to interrelate information on organisms and to analyse their relationships and evolutionary history. Systematists collect and analyse data and produce various types of output. By analogy, the data flow in systematics is similar to that in computers (*Figure 3*). Specimens and associated data are collected by users or systematists themselves and 'input' (or funnelled) to the systematists. Systematists process the specimens and data by making identifications and conducting character analyses; they then output information in the form of publications or new databases (*see Figure 9*). Because many organisms are either beneficial or deleterious to man, information about them is of great value. Thus biosystematic information—by which we mean the full range of information, from behavioural to molecular, about living organisms—is a critical resource, especially to the areas of biological control and conservation.

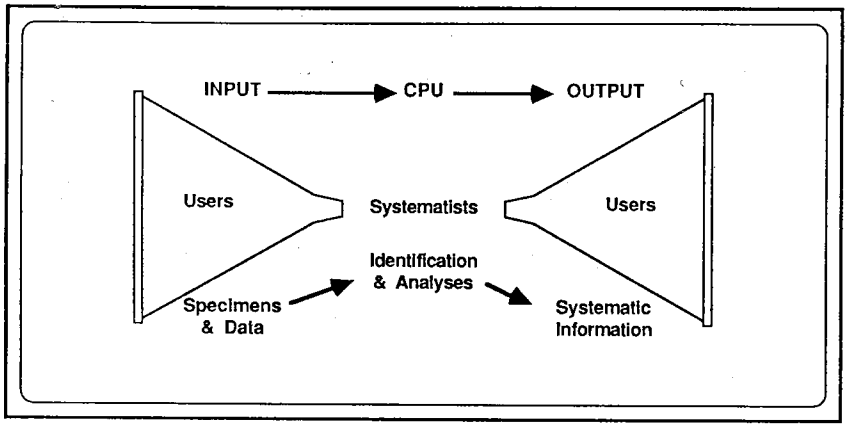


**Figure 3.** Data flow in systematics.

Computerized information systems and tools are important, but not essential, in handling biosystematic data on small groups of organisms such as mammals (some 2000 species) or even birds (some 9000 species). However, for the enormous amount of data associated with the estimated 30 million species of insects (Erwin, 1982) they are indispensable. The basic objective in using computer technology is to minimize data processing by people and to maximize that performed by computers. If a data item is to be used repeatedly, it should be captured once and made available to all users in a form that can be manipulated without redundant entry. An obvious benefit of computerization is the ability to process more data with precision and greater speed. For entomologists, the resultant increase in efficiency will allow a constant number of workers to deal with a greater number of insects and to deliver more and better organized information to the user community. That is the only realistic way, in today's world of reduced funding, to make headway with the task of systematizing the data on our enormous insect fauna.

Basic databases are comprehensive and cover all fundamental knowledge for a field, whereas applied databases are limited in scope and cover derived knowledge applicable to a particular activity. Basic biosystematic databases and applied biological control databases are closely related in the kinds of information they share. While in theory an applied database is only a specialized subset of a basic one, in practice truly comprehensive basic databases do not yet exist in entomology, so applied ones must answer the demands of the users. For example, the Western Hemisphere Immigrant Arthropod Database (WHIAD) is designed to provide much the same information as is found in our biosystematic databases on flies (BSDFW), hymenopterans (CHANM), and beetles (CCNA), but because no basic databases have been developed for the other major groups of insects, WHIAD remains the only source of specialized information for these groups.



## BASIC BIOSYSTEMATIC DATABASES (F.C. THOMPSON)

'Catalogues', or what we now prefer to call basic taxonomic databases, provide the critical synthesis of biosystematic information. Taxonomy (and its more modern and more comprehensive developments—systematics and biosystematics) dates from Linnaeus and his *Systema Naturae* (1758) where a system of hierarchical classification for synthesizing all information about the natural world was introduced. His works included all the basic data about plants, animals and minerals, such as keys for identification, diagnoses, short (binominal) names for easy unambiguous communication, literature citations to other, more detailed, information sources and biotic data such as phenology and distribution. Thus, while knowledge of the natural world remained limited, one man could provide all biosystematic information in a single work. The ability to do so, however, became more difficult as knowledge about the natural world increased: specialization became the trend. Comprehensive works became more limited both in geographic and taxonomic scope or in the amount of biosystematic information included in them. 'Catalogues', which provide a limited amount of biosystematic data but are broad in geographic and taxonomic scope, became the primary level of synthesis for biosystematics. Because of the broad scope of catalogues, most became co-operative enterprises of many specialists and usually were sponsored by large institutions. The systematic entomology community in Washington, DC, has been one of the leaders in this area during the last 40 years. Building on a knowledge of how to prepare catalogues manually, we quickly adapted automated methods when they became available. The Coleoptera and Hymenoptera catalogue projects described below were the first successful attempts to use computers to aid in the production of large systematic catalogues. Both of these projects used software specially created or modified for the *production* of printed catalogues. However, as computer technology continued to change rapidly, new approaches had to be developed. The Tephritid Pilot Test project explored the use of commercially available database software to produce specialized catalogues, and from that the Systematic Database of Flies of America north of Mexico (SDFAM) arose. These projects were designed, not only to produce printed catalogues, but also to create and maintain an easily accessible database and to define data standards, structure, and processing algorithms that could be used on all types of computer systems. From the SDFAM will emerge the Biosystematic Database of Flies of the World. The Linnaean hierarchy will be implemented in a modern relational database (*see Figure 4* for the model). Linking the various tables (files) will be the valid name of the taxon. This database model will bring the cycle back to Linnaeus as once again all the essential biosystematic information can be stored in a single system, the differences being greater and better accessibility to the information by more users because of the accumulative labour of many systematists and the information being more organized, more standardized, more comparable, more updatable and more retrievable.

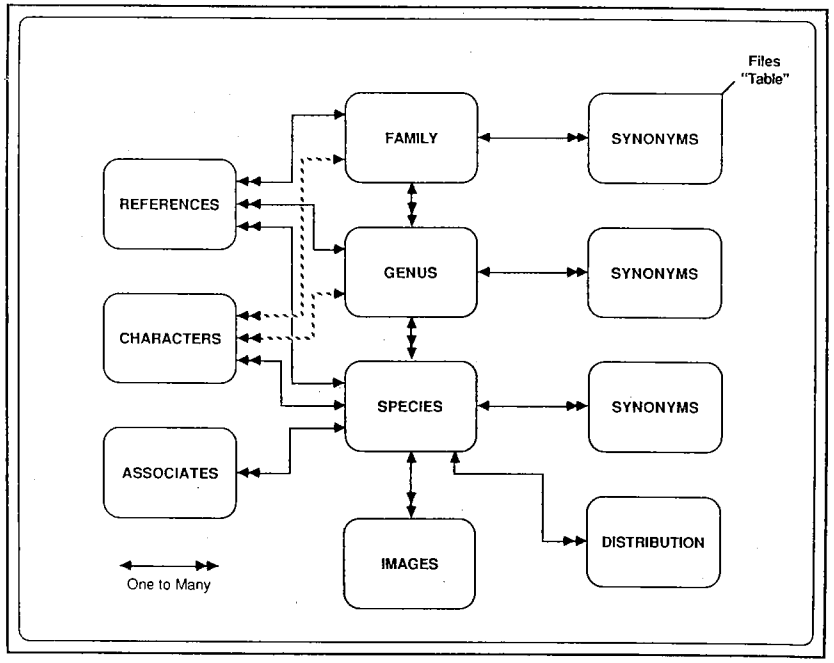


**Figure 4.** Relational database model for biosystematic information.

## Catalog of Hymenoptera in America North of Mexico *(D. R. Smith and R. W. Carlson)*

An early attempt to compile a computer-based catalogue of a large group of insects was the *Catalog of Hymenoptera in America North of Mexico* (Krombein, Mello and Crockett, 1974; Krombein *et al.*, 1979). The catalogue was designed for a broad spectrum of users in the agricultural and biological communities and is an indispensable tool in support of taxonomic and biological control research. The large amount of taxonomic and biological data included makes it one of the most comprehensive faunal catalogues extant.

The computerized catalogue was an outgrowth of the 1951 hardcopy Hymenoptera catalogue (Muesebeck, Krombein and Townes, 1951) and its supplements (Krombein, 1958; Krombein and Burks, 1967). Production of an additional supplement was not feasible so, in 1971, hymenopterists of the SEL and the Smithsonian Institution (SI) decided to produce a new edition. Because of the overwhelming amount of information, anticipation of a need for future editions, availability of computerized techniques, and a desire to pioneer in the area of computerization of biosystematic information, the project managers opted to use computer technology to store, update, search/retrieve, and format the basic systematic and biological information



to be included. In consultation with SI systems analysts and computer programmers, a SELGEM (SELF GEnerating Master) database format was devised to manipulate the data. The SELGEM system, developed by the SI, was believed to be superior to other data-management systems available at the time. Because the SI no longer uses SELGEM, the SELGEM data for the Hymenoptera catalogue are archived on magnetic tapes. Conversion of these data for use under the database software now in use at the SI is being considered (*see* SELGEM in *Table 1*).

The database format is a matrix consisting of specific data elements or fields and major record types in which these elements may occur. The data elements (scientific names, authors, dates, references, distributions, hosts, etc.) are the basic units of information included in a catalogue. The record types (genus-group and species-group categories) are the major subdivisions in which these elements are included. The program allowed for future updating, retrievability of various combinations of data and expansion for new elements. Data was input through a programmable punched paper-tape typewriter from manuscript prepared by taxonomists. Corrections were entered via punched cards. No terminals with visual display screens were available to data-entry personnel to ease the process of building and correcting the database: thus new errors were frequently introduced during attempts to eliminate previous ones, many of which had resulted from paper-tape read errors. Proofreading time could have been substantially reduced by printers capable of printing lowercase as well as uppercase letters. Data were stored on magnetic tapes, which were used to produce the printed version by computer-driven linotron processing (Mergenthaler Linotron 1010) by the Electronic Printing Division of the US Government Printing Office (GPO).

The completed catalogue contained hundreds of thousands of elements of information on 81 families, 2014 genera and 17 429 species of Hymenoptera in North America. The hardcopy publication (Krombein *et al.*, 1979) consists of three volumes totalling 2735 pages. It includes a list of all taxa for the region; their known distributions, hosts, parasites, predators, prey; whether introduced or adventive; synonyms; citations to original descriptions; references to other taxonomic, biological or morphological publications, and parenthetical annotations on the contents of the references. Further comments on certain groups were included to make the catalogue as informative and useful as possible. Each element in itself could constitute a volume of information: for instance, the pollen sources of a species of bee, hosts of a plant feeder or parasite, or distribution of a species, may amount to a comprehensive listing in itself.

Upon completion, the database remained available for updating for future use of production of new versions of the catalogue and for retrieving simple or complex data combinations. For example, specialized listings could be produced through searches for introduced species, species associated with a certain plant, wasp parasites of a certain destructive moth, references by a certain author, species described by a certain author, etc. The level of demand for information in this database, however, fell far short of expectations. Because the amount of effort needed to build it was probably far

greater than that which would have been required to produce the same catalogue by conventional means, and because the conversion of the SELGEM data for use with the database software in current use by the Smithsonian Institution is considerable, it is difficult to assess the ultimate value of this pioneering effort.

### Catalog of Coleoptera of North America *(J. R. Dogger)*

The number of species in the order Coleoptera exceeds 220 000, of which more than 24 000 occur in the US and Canada. The antecedent *Catalogue of the Coleoptera of America North of Mexico* (Leng, 1920, with supplements through 1947) is more of a checklist than a catalogue and is inadequate for modern research needs. Jackman and Wellso (1978) described an early attempt to develop a computerized catalogue in entomology (for the family Buprestidae of North America). The computer programs used to produce the ongoing catalogue of the Coleoptera were designed by personnel of the SEL and CDSD. Output is by family or subfamily fascicles, published by the GPO. The data resources are provided by 65 research entomologists in the US, Canada, and Mexico (including 6 SEL and 2 SI coleopterists).

Data entry, manual editing and storage are currently performed on the Wang VS-100 minicomputer. Three components of the data are used to produce a fascicle: genus–species data, bibliographic data, and header data. These data, properly formatted, are transferred to the Washington Computer Center (WCC) for batch (non-interactive) data processing. All new and updated genus and species data are edited by a computer program that lists machine-detectable errors, which are usually associated with missing or improperly used fields. Data that successfully clear the edit program are passed through an update program to create a new family master file suitable for editing by the author.

When the genus–species master file is free from errors, it is merged with the header and bibliographic files to produce a file from which the body of the catalogue is created. Entered early in the procedure are qualifying precedence codes, which do not appear in print but control the appearance of the printed page by indicating type style, margins and vertical placement of the data. The final catalogue body file is sent to the GPO for processing on their video-composition equipment. Galley proofs prepared by the GPO are sent to the author, editors and information specialists for final editing, including pagination and indexing. Corrected and accepted galley proofs then are sent to the publisher.

The current size of the database is estimaed at 240 megabytes. The programme is designed to handle 25 000 valid species, 3000 valid genera, and 14 000 specific and generic synonyms.

By 1986, 18 fascicles of the Coleoptera catalogue had been completed and published. Four additional fascicles were published during 1986, bringing the total number of published fascicles to 22. Seven additional fascicles are in the final stages of editing and review prior to transfer to the WCC mainframe computer.



### *Tephritidae in-depth database pilot project (L. Knutson and R. W. Hodges)*

A pilot project was conducted over a 3-year period (Hodges and Foote, 1982) to develop a computer-based information system to enable systematists to provide biosystematic data to user groups by means of a commercial linkage. Published and unpublished information on the fruit fly family Tephritidae was captured and entered online to test the feasibility of the information system. The database was developed on a Univac® system 1108 by contract with a commercial organization. For economy, the database was stored on magnetic tape during periods of relative inactivity and brought online for varying periods during updating or retrieval. The project was probably ahead of its time as far as the interests of the user community are concerned and was not cost effective, primarily (we believe) because it was performed on a contract basis rather than by the BBII. However, it was an important learning experience that improved the efficiency of development of subsequent projects. The data standards and data entry forms, described in Hodges and Foote (1982), were adapted for use in later information systems.

### *Systematic Database of Flies of America North of Mexico (F. C. Thompson)*

About three years ago, publication of a *Checklist of Diptera of America North of Mexico* was formally proposed. With the *Catalog of Diptera of America North of Mexico* (Stone *et al.*, 1965) more than 20 years out of date and with the need for the nomenclature to be compatible with the *Manual of Nearctic Diptera* (McAlpine, 1981, 1987), a new Diptera catalogue was required. The 1965 *Catalog* has now been reprinted, and its valuable bibliography is again available; however, no attempt was made to update it by incorporating taxonomic information discovered since 1965 because the new *Manual* includes references to sources of such information. Thus all that is needed is a checklist that includes and revises only the nomenclatural and distributional data of the 1965 *Catalog*: such a checklist can be produced by automated methods in about one year. Data entry for the checklist project began in May 1984 and, by the completion of data entry in early 1985, some 20 000 species names and 3400 generic names had been entered. The data are now being revised by the contributing authors. By mid-1987, the preliminary manuscript should be ready for final review. The checklist should be published in early 1988, within one year of the publication of the second volume of the *Manual*. Thus for the first time a nomenclatural database will be published before the classification upon which it is based has become obsolete.

The Biosystematic Database of Flies of the World project and the Systematic Database of Flies of America North of Mexico are closely related. In the beginning, the checklist project was designed merely as a means to produce a revised list of names of North American flies to be used in conjunction with the *Manual*. Later, it was realized that the checklist project could serve as a pilot test of the automated methods that would be used to

produce the Biosystematic Database. Although the Systematic Database will include only a small subset of the data items to be included in the Biosystematic Database, it will use the same data and file structures, programs and computer equipment. The data are contained in three files, which will become the core nomenclatural tables in the Biosystematic Database (*see* the next section). Thus beyond the immediate benefit of having a new *Checklist of North American Diptera* available to taxonomists world wide, the Systematic Database will serve as the basis of the first comprehensive database of taxonomic information on a major order of insects.

### *Biosystematic Database of Flies of the World (F. C. Thompson, L. Knutson and W. N. Mathis)*

The order Diptera (true flies) is close to becoming the first major order of insects catalogued on a world basis. A series of taxonomic catalogues, starting with the *Catalog of the Diptera of America North of Mexico* (Stone *et al.*, 1965) and followed by those for the Americas south of the US (Papavero, 1966–present), Oriental Region (Hardy and Delfinado, 1973–77), Afrotropical Region (Crosskey, 1981), Palaearctic Region (Soós, 1984–present), and Australasian/Oceanian Region (Steffan and Evenhuis, in progress, targeted for 1988) will have, in effect, summarized our knowledge of flies. Nevertheless, during the span of years between the first and last of these catalogue projects (as with any catalogue project), contemporary taxonomic discoveries have revealed many inconsistencies, omissions and errors. A Biosystematic Database of Flies of the World is planned as a solution to these problems. This project will consolidate the information in the various regional catalogues, rectify inconsistencies, correct omissions and errors, and allow for the inclusion, on a day-to-day basis, of extensive additional information not included in previous catalogues.

The objective of the Biosystematic Database of Flies of the World project is to produce a basic taxonomic catalogue and computerized database of the more than 100 000 species of flies of the world. Automatic data-processing methods will be used to establish a database that can be updated and searched and to print fascicles of each of the 60+ families of flies. Approximately five years will be required to establish the preliminary database.

Potential benefits expected to be derived from production of a Biosystematic Database of Flies of the World are extensive. The planned printed catalogue and database will: (1) provide, for the first time, a single, comprehensive, and authoritative source of taxonomic information, in hardcopy and electronic formats; (2) update and correct information that is now as much as 20 years out of date; (3) integrate diverse classifications into a more uniform, useful and world-wide system of classification; (4) result in the establishment of a permanent computerized database that can be efficiently and routinely maintained, updated and improved; (5) highlight the existence of homonyms and other conflicting or missing data in the literature on the classification of flies; (6) provide a computerized database that can be searched from remote locations to answer questions by *non*-taxonomists, as well as by taxonomists, on geographical distribution, hosts, establishment status etc., and (7) result in the development of a more modern methodology for producing taxonomic catalogues in general.



Catalogue work involves gathering, editing and printing information. The Biosystematic Database of Flies of the World project will include these aspects as well as that of building a computerized database. The two major time-intensive tasks in cataloguing are *data entry* and *editing*. Traditionally, authors have submitted 'manuscripts' (cards, forms, papers, etc.) that were edited and entered into the production system, edited again, sent back to the author for more editing, returned to be entered into the master, etc. The traditional cycle has usually been required because most catalogue projects have not been based on recent catalogues; this will not be so for the Biosystematic Database of Flies of the World: instead of being handled in the traditional manner, the basic data will be entered into a computer, printed out, then sent to the authors for editing and subsequent manipulation online.

Publication will be by fascicle, usually family-level units, to ensure the timely release of major portions of the information rather than delaying it until the database is completed. A master bibliography will be published as a separate set of fascicles. The publication format to be used will be that developed by the SEL Cataloging Committee. Existing sets of geographical, collection acronym, and abbreviation standards will be used or modified as need arises. A traditional-style hardcopy publication will be typeset from computer output and printed by the GPO. Other forms of 'publication' are being investigated, including the use of laser (compact disk, read-only-memory (CD-ROM)) technology. By the time that the database is complete, the cost of producing CD-ROM disks will have been greatly reduced and, because of their mammoth capacity for data storage and exceptionally versatile format, CD-ROMs may well have become the media of choice for dissemination of biosystematic information.

## APPLIED BIOSYSTEMATIC AND BIOLOGICAL CONTROL DATABASES

### *Research reporting and tracking databases—CRIS and ARS research database (F. C. Thompson)*

A number of databases are designed to track ongoing research and report research results. The Current Research Information System (CRIS) operated by the ARS, state agricultural experiment stations and Forest Service, tracks current research and, because research funds are allocated by CRIS project units, this system is used for fiscal accountability. This USDA database contains about 30 000 descriptions of current, publicly supported agricultural and forestry research projects. Updates are made monthly and more than 3000 new project descriptions are added annually. Information services are available to all: participating institutions have free access, and commercial access is through DIALOG online retrieval services. ARS, in conjunction

with the USDA Extension Service, also has developed and implemented the Research Results Data Base (RRDB). When results of projects are approved for publication in scientific journals, the manuscripts are reviewed and their value assessed for use by the international agricultural community. Reports judged to be of practical use are incorporated in an electronic information network where they can be retrieved by faculty and students at land-grant universities or by farmers through the Extension Service (Dik and Travieso, 1986). The Interagency Development Research Information System (IDRIS International) was created in 1983 by the Canadian International Development Research Council in co-operation with the Swedish Agency for Research Cooperation with Developing Countries, the German Appropriate Technology Exchange, the International Foundation for Science, and the US Board on Science and Technology (Toomey, 1986). As of October, 1986, this database contained records of 4000 projects.

### *Biological control databases*

*Release of beneficial organisms (J. R. Coulson).* In 1978, a study team co-ordinated by the USDA Office of Environmental Quality strongly recommended the development of a national information storage and co-ordnating system designed to assemble and collate domestic and international information relevant to biological agents with potential use in pest control (US Department of Agriculture, 1978). This high-priority recommendation was one of a series intended to strengthen research on the use of biological agents for pest control and in integrated pest management (IPM) programmes. It led to the establishment in 1982 of the ARS Biological Control Documentation Center (BCDC) in the precedent Beneficial Insect Introduction Laboratory at Beltsville.

The rapid transfer of extensive and diverse information on pests and natural enemies is essential to decision-making in biological control and IPM programmes and as critical support for biological control exploration and research. This is especially true for programmes that involve the introduction into the US (or any country) of exotic natural enemies of pest arthropods, nematodes, weeds and plant pathogens. The BIL and its predecessor organizations historically have been charged with the major responsibility for documenting USDA biological control activities. The voluminous Documentation Center files contain correspondence, reports, literature and records on USDA and state importation programmes dating back to at least 1934. These unique files are important data sources for the development of a computerized database of biological control information.

The overall goal of the Center's programme is to develop information-delivery and documentation systems to provide bionomic and economic data on arthropod, weed and other pests and their endemic, introduced and foreign enemies. Emphasis is placed on data of use in research and management decision-making for biological control and IPM programmes. The Releases of Beneficial Organisms in the United States and Territories (ROBO) database is the primary database in this system.

In 1982, a user information and survey document, presenting plans for the ROBO database, was sent to numerous state, federal and university biological control research and action agency personnel. The greater than 50% response to that survey resulted in numerous positive program changes. The database is now available to the scientific community.



ROBO is a computerized system for recording and disseminating data on the importation, interstate movement, release, establishment, recolonization, dispersal and culture of exotic beneficial organisms, including pollinators and biological control agents for use against insect, weed and other pests in the US and its territories. The database has three primary functions. First, it serves as a central repository of information on foreign beneficial organisms (invertebrates and pathogens) introduced into the US and its territories. In this respect, ROBO parallels the Germplasm Resources Information Network (GRIN) of the US National Plant Germplasm System (Perry, Stoner and Mowder, 1987) that contains records, among other data, of the introduction of plant germplasm into the US. Second, ROBO provides US and foreign biological control workers with information helpful for exploration, collection, importation and domestic field recovery of exotic pollinators and biological control organisms, and other information helpful for the exchange of such organisms, as well as up-to-date taxonomic and nomenclatural information. Third, ROBO provides taxonomists with information on the introduction and establishment of new exotic invertebrates in the US and its territories and on their distribution in the US and on availability of representative specimens, information useful in compilation of faunal surveys, catalogues and taxonomic revisions and reviews.

Data now being entered in ROBO include information on original collection (collection sites, dates, original hosts/prey, host plants or animals, collectors); initial and subsequent releases and recolonizations (release sites, dates, original and target hosts/prey, affected crop plants or animals, releasers); availability and location of cultures and of voucher specimens; taxonomic determinations; nomenclatural and other taxonomic changes; and on identifiers of the beneficial organisms. The database soon will include programs dealing with information on recoveries, establishments and dispersal of the introduced beneficial organisms.

Data for ROBO are derived from three biological shipment record forms (*Figures 5, 6, 7*), two of which have been in use by most ARS and some other federal and state biological control scientists since 1976. The three forms are now being used by many other federal, state and foreign biological control workers who voluntarily co-operate in the project. The forms provide a standard framework for documenting importations and releases of beneficial organisms on a national basis, provide source information to the recipients of shipments, and provide feedback information to the shippers. Two other forms, designed to record importation and release of exotic insect and weed pathogens, are being developed.

The basic ROBO system includes computer software programs that will produce the following types of reports: (1) annual reports of releases in individual states and US territories or by individual facilities, and individual release reports that contain more detailed source and release information than the annual reports; (2) annual reports of domestic shipments made by, or received by, individual US or state/territory facilities and individual

(a)

OMB NO. 0518-0013 (EXP. 2/28/87)

U.S. Department of Agriculture

**Biological Shipment Record — Foreign/Overseas Source**

[ ] To Quarantine Facilities in Contiguous U.S. [ ] To Locations Outside Contiguous U.S.

37. FINAL DETERMINATION-Gen.,sp.,subsp.,auth. M NC a b c

38. V S (see files) a b c

**Section I — REPORT OF MATERIAL SHIPPED** *(To be completed by Shipper)*

1. FROM *(Facility or Explorer)*
2. ORGANISM SHIPPED-A. Gen.,sp.,subsp.,auth. [M]
   B. Order:Family
   C. Determined by *(names & affiliations)*
3. SHIPPER'S FILE NO.
4. TYPE OF ORGANISM-explain Mi & OT in blk. 18: [ ] PArasite [ ] WEed feeder [ ] PRedator [ ] POllinator [ ] Microbial [ ] OTher
5. NOS. & STAGES SHIPPED *(see codes)* [Est] [Est] [Est] TOTAL:
6. DATES TRANSFORMED TO STAGES SHIPPED *(month, day, year)*
7. MATING OBSERVED [ ] Yes ____ % [ ] No
8. HOST/PREY/PEST MATERIAL PRESENT: [ ] Beneficial with host/prey [ ] Host/prey/pest only [ ] None
9. DATES ORIGINALLY FIELD COLLECTED *(m,d,y)*
10. LOCATION Country & Province/State & nearest Town or physical feature
11. COLLECTORS
12. ORIGINAL HOST/PREY *(or other food sources)* [M] A. Gen.,sp.,subsp.,auth. C. Determined by *(name and affiliation)*
10. Specimens retained [Yes] [No] E. Stage/part (code) of host/prey attacked
[ ] Shipped directly [ ] Emerged in Lab
13. LAB CULTURED (Fr.) A. B. Culture Facility *(use acronym)*-explain in blk. 10 [Yes] [No]
B. Order:Family
14. LAB HOST/PREY-Gen.,sp. *(if different from blk. 12)*
15. FOOD PLANT/ANIMAL OF HOST/PREY A. Field *(at collection)* B. Lab *(when cultured)*
16. SHIPPED TO
17. INTENDED TARGET HOST/PREY-Gen.,sp. *(if different from blk. 12)*
18. REMARKS
19. DATE SHIPPED *(m,d,y)*
20. REPRESENTATIVE SPECIMENS RETAINED [Yes] number:
21. PACKING/HANDLING [ ] Usual [ ] Other *(explain in blk. 18)*
22. SHIPPED VIA
23. SCREENED OR PACKAGED BY

**Section II — REPORT OF MATERIAL RECEIVED IN QUARANTINE** *(Or in facility outside contiguous U.S.)*

24. DATE OF RECEIPT *(m,d,y)*
25. DATE OPENED *(m,d,y)*
26. CONDITION RECEIVED A. Container B. Contents
27. RECEIVER'S FILE NO.
28. RECEIPT AND EMERGENCE RECORD (use codes)
A. Number and Stages Received *(block 2)*: Beneficials: Alive, Dead; Host/Prey or Parasitized Hosts: Alive or PH Intact, Dead; or Parasites Emerged
B. No. & Stages of Individuals of each Species Emerged Enroute and in Quarantine *(alive and dead)*: • Hosts/Prey • Beneficials • Other • Dates of Emergence • Notes
TOTALS [Est] [Est] [Est] [Est] [Est]
29. REMARKS
30. REPORTED OR EXAMINED BY

**Section III — FINAL RECORD OF RECEIPT, EMERGENCE, AND DETERMINATION IN QUARANTINE** *(Or in facility outside contiguous U.S.)*

A. Genus, Species, Subspecies, Author | B. Order:Family | C. Determined by *(name, affiliation, & date)* | D. Number *(stage: use codes)* | L. Specimens Retained numbers

31. BENEFICIAL SPECIES
a [M] [Est] [Yes]
b [M] [Est] [Yes]
c [M] [Est] [Yes]

32. OTHER SPECIES *(including other beneficials)* M NC
d [Est] [Yes]
e [Est] [Yes]
f [Est] [Yes]

33. ORIGINAL HOST/PREY *(final determination)* [Est] [Yes]

34. REMARKS
35. RELEASED, SHIPPED, CONSIGNED *(enter file numbers)* a [Yes] b [Yes] c [Yes]
36. FINAL REPORT BY A. Name B. Date *(m,d,y)*

Form AD 941 (10/83) Part 1- DOCUMENTATION CENTER COPY

**Figure 5.** USDA Biological Shipment Record—Foreign/Overseas Source. (a) Front; (b) reverse.

shipment reports containing more detailed source and shipment information than the annual reports, and (3) annual reports of foreign shipments made by foreign explorers and foreign and ARS overseas facilities to the US and its territories, or received by US and territorial receiving facilities, and individual foreign shipment reports with more detailed collection and shipment information than the annual reports. Also included in these annual and individual reports is the information on shipments made from the US



(b)

**— CODES —**

*NOTE:* Use combination of **Invertebrates** and **Plants** codes for weed feeders and other phytophages shipped in or with plant host material *(e.g.,* **L** in **SH**, **A** with **FO**).

**INVERTEBRATES**
- **A** — adults
- **M** — male
- **F** — female
- **E** — eggs
- **L** — larvae (for holometabola)
- **N** — nymphs (for heterometabola)
- **J** — juveniles (for nematodes)
- **P** — pupae, puparia
- **C** — cocoons (can also be **A** in **C**, or **P** in **C**)
- **MU** — mummies, cadavers
- **PH[ ]** — parasitized host give stage and estimated % parasitized *(e.g.,* PHA, PHL, PHE, etc., 70%)
- **H** — host

**PLANTS**
- **PL** — whole plant
- **SD** — seeds
- **SH** — seed heads
- **SP** — seed pods
- **RS** — rosette
- **FL** — flowers
- **ST** — stems
- **RT** — roots
- **TU** — tubers
- **FO** — foliage
- **LV** — leaf, leaves

**MICROBIAL ORGANISMS** — *not* including nematodes
- **MI** — cultures or isolates of microbial pathogens, antagonists, and competitors; fungi, bacteria, viruses, rickettsia, protozoa
- **DI[ ]** — disease suspects for pathogen diagnosis *(e.g.,* DPL, DFO, etc. — plant and plant parts; DHA, DHE, etc. — invertebrate stages.)

**— ROUTING and COPY DISTRIBUTION —**

**SHIPPER** *(shipping facility or explorer)*
1. Retain *Shipper (Pending) Copy* (Part 4).
2. Send remaining 3 copies and original cover sheet to quarantine or other receiving facility with material shipped.
3. If AD-941A is used — photocopy for your records and/or request photocopy from receiving facility.

**RECEIVER** *(quarantine or other facility)*
1. When Section III is completed, or within 1 year after receipt of shipment — send *Documentation Center Copy* (Part 1) and original cover sheet to — Beneficial Insect Introduction Laboratory, BARC-E, ARS, USDA, Beltsville, MD 20705.
2. Send *Shipper Copy* (Part 2) to shipping facility or explorer.
3. Retain *Receiver/Quarantine Copy* (Part 3) for your records.
4. If AD-941A is used — photocopy for your records, and for shipper if requested.

**INSTRUCTIONS**
**SECTION II — MATERIAL RECEIVED**

28. **Receipt and emergence record** —
    A. **Number received** — Record number of **Organism shipped** (block 2A) received alive or dead, and any live host/prey. Check **Est** for estimates. Totals should relate to those in block 5.
    B. **Number emerged** — Record numbers that "emerge" from material received *(e.g.,* **L** or **A** from the **E** or **L/P** shipped; **L** or **A** from the **PHE/PHP** or **PL/SH** shipped). Give total number of species that emerged. Use this block for running account or use AD-941A or a separate sheet (mark with **shipper's file number**).

**SECTION III — RECEIPT, EMERGENCE, and DETERMINATION**

31 – 33.
- If more than 6 species are obtained from a single shipment, or additional comments are needed, use AD-941A.
- Use **block 32** to list other beneficials that will likely not be shipped/consigned from quarantine, and hyperparasites and other miscellaneous species that emerged or were included in the incoming shipment.
- Use **block 33** to record final determination of original host/prey; refer to instructions for block 12.
- In **column C**, give name of person providing identification of the material received with institutional affiliation (use acronym) and date (year) of determination. If identification of this material is based on comparison with specimens identified by another person *(e.g.,* a taxonomist), give that person's name, institutional affiliation (use acronym) and date (year) in parentheses following the determiner of the material received *(e.g.,* L.R. Ertle, BIRL, 1981 (P.M. Marsh, SEL, 1979)).
- In **column D**, check **Est** for estimates.

34. **Remarks** — Include remarks on intended use *(e.g.,* for *culture in quarantine*, intended final destination, intended host, etc.).
35. **Released, shipped, consigned** — Record file numbers *only if material from this shipment* was removed from quarantine (shipped/consigned) or field released.

AD-941 (Reverse)

**Figure 5** *(cont'd)*

to foreign locations. Such reports are now available for 1981 shipments and releases.

In addition, an annual publication will be produced to document all introduced beneficial organisms released by federal and state quarantine and non-quarantine biological control research and action agency personnel in the US and its territories and all shipments of beneficial organisms to foreign locations. This will begin with 1981 records (to be published in 1987). Such an annual 'release bulletin' has been published on insect liberations in Canada

(a)

U.S. Department of Agriculture

BIOLOGICAL SHIPMENT RECORD – QUARANTINE FACILITY

(Shipment/Consignment from Quarantine)

OMB NO. 0518-0013 (EXP. 2/28/87)

4B. FINAL DETERMINATION - Gen., sp., subsp., auth. M NC 4B. V.S. (see files)

SECTION I – REPORT OF MATERIAL SHIPPED, CONSIGNED or RELEASED

1. FROM (Quarantine facility - name and address)

2. ORGANISM SHIPPED - A. Gen., sp., subsp., auth.

B. Order; Family

C. Determined by (names & affiliations)

3. QUARANTINE FILE NO.

4. TYPE OF ORGANISM - explain MI & OT in blk. 20: ☐ PArasite ☐ WEed feeder ☐ PRedator ☐ POllinator ☐ Microbial ☐ OTher

5. NOS. & STAGES SHIPPED (see codes) [Est] [Est] [Est] TOTAL:

6. DATES TRANSFORMED TO STAGES SHIPPED (month, day, year)

☐ Shipped directly ☐ Emerged in Quarantine

7. MATING OBSERVED ☐ Yes ____ % ☐ No

8. HOST/PREY/PEST MATERIAL PRESENT ☐ Beneficial with host/prey ☐ Host/prey/pest only ☐ None

9. DATES ORIGINALLY FIELD COLLECTED (m,d,y)

10. LOCATION - Country & Province/State of Origin

11. ORIGINAL COLLECTORS (names & affiliations)

12. FOREIGN/OVERSEAS SOURCE FILE NOS.

16. LAB CULTURED (F, +) ☐ Overseas ☐ No ☐ In Quarantine ____ (number of generations)

13. ORIGINAL HOST/PREY - Gen., sp. (or other food source)

14. STAGE/PART OF HOST/PREY ATTACKED

15. ORIGINAL FOOD SOURCE OF HOST/PREY

17. LAB HOST/PREY - Gen., sp. (if different from blk. 13)

18. INTENDED HOST/PREY - Gen., sp. (if different from blk. 13)

19. SHIPPED/CONSIGNED TO

20. REMARKS

21. DATE Shipped/consigned (m,d,y)

22. REPRESENTATIVE SPECIMENS RETAINED number: [Yes]

23. PACKING/HANDLING ☐ Usual ☐ Other (explain in blk. 20)

24. SHIPPED VIA

25. SCREENED OR PACKAGED BY

SECTION II – REPORT OF RECEIPT AND INTENDED USE

26. DATE OF RECEIPT (m,d,y)

27. DATE OPENED (m,d,y)

28. CONDITION RECEIVED A. Container B. Contents

29. REPORTED OR EXAMINED BY

30. INVENTORY OF MATERIAL RECEIVED (use codes)

| A. Number and stages received (blk. 2) | | B. Number Emerged (stages) Beneficials | | Host/Prey | | 31. OTHER SPECIES INCLUDED OR EMERGED A. Order; Family and Genus, species, author, if known | B. Determined by (name & affiliation) | C. No. and Stages (use codes) |
|---|---|---|---|---|---|---|---|---|
| Alive | Dead | Alive | Dead | Alive | Dead | | | |
| TOTALS [E] | [C] | [E] | [E] | [E] | [E] | | | |

32. REMARKS

33. SPECIMENS FROM SHIPMENT RETAINED BY RECEIVED ☐ Yes ____ number ☐ No

34. INTENDED USE A. ☐ Immediate release (complete Sec. III) Lab culture/study B. ☐ Release intended C. ☐ No release intended

35. INTENDED LAB HOST/PREY - Gen., sp.

SECTION III – REPORT OF RELEASE

| | SITE 1 | SITE 2 | SITE 3 |
|---|---|---|---|
| 36. Types of release | ☐ Field ☐ Greenhouse ☐ Cage ☐ Other: | ☐ Field ☐ Greenhouse ☐ Cage ☐ Other: | ☐ Field ☐ Greenhouse ☐ Cage ☐ Other: |
| 37. Locations (State, County, nearest Town or physical feature, map coordinates) (Use AD-942A for more details) | | | |
| 38. Number and stages released, (see codes) | [Est] | [Est] | [Est] |
| 39. Dates of release (m,d,y) | | | |
| 40. Target hosts/prey at release A. Primary - Genus, species | | | |
| B. Other - Genus, species | | | |
| C. Families | | | |
| 41. Food (plant/animal/other) of target host/prey at release. | | | |
| 42. Released by (Name & affiliation) | | | |

43. REMARKS (use AD-942A for more details)

44. REPORTED BY A. Name B. Date (m,d,y)

Form AD-942 (10/83) Part 1 – DOCUMENTATION CENTER COPY

**Figure 6.** USDA Biological Shipment Record—Quarantine Facility. (a) Front; (b) reverse.

for many years (*see* section below on some non-BBII databases) but has not hitherto been possible in the US.

Compendia reports will be published to include the data in five consecutive annual reports, updated as to current nomenclature of the organisms released and including any information on additional releases received since initial publication. These compendia will also include (1) data on any recoveries and reports of establishments, by county and date, of the introduced beneficial organisms included in the report, and (2) data on the number and location of voucher specimens representing released and recovered material.



(b)

– CODES –

*NOTE:* Use combination of **Invertebrates** and **Plants** codes for weed feeders and other phytophages shipped in or with plant host material *(e.g.,* **L** in **SH**, **A** with **FO***)*.

**INVERTEBRATES**

**A** – adults
**M** – male
**F** – female
**E** – eggs
**L** – larvae (for holometabola)
**N** – nymphs ( for heterometabola)
**J** – juveniles (for nematodes)
**P** – pupae, puparia
**C** – cocoons (can also be **A** in **C**, or **P** in **C**)
**MU** – mummies, cadavers
**PH[ ]** – parasitized host - give stage and estimated % parasitized *(e.g.,* **PHA, PHL, PHE, etc., 70%***)*
**H** – host

**PLANTS**

**PL** – whole plant
**SD** – seeds
**SH** – seed heads
**SP** – seed pods
**RS** – rosette
**FL** – flowers
**ST** – stems
**RT** – roots
**TU** – tubers
**FO** – foliage
**LV** – leaf, leaves

**MICROBIAL ORGANISMS** – *not* including nematodes

**MI** – cultures or isolates of microbial pathogens, antagonists, and competitors; fungi, bacteria, viruses, rickettsia, protozoa

**D[ ]** – disease suspects for pathogen diagnosis *(e.g.,* **DPL, DFO,** etc. – plant and plant parts; **DHA, DHE,** etc. – invertebrate stages*)*

– ROUTING AND COPY DISTRIBUTION –

**QUARANTINE FACILITY**

1. Retain *Shipper (Pending Copy) (Part 4)*
2. Send remaining 3 copies and original cover sheet with material shipped.
3. When copies of completed form are returned by receiver –
   - Send *Documentation Center Copy (Part 1)* and original cover sheet to Beneficial Insect Introduction Laboratory, BARC-East, ARS, USDA, Beltsville, Maryland 20705.
   - Retain *Quarantine Facility Copy (Part 2)* for your records; discard *Shipper (Pending) Copy*.
   - If Form AD-942A is used – photocopy for your records and for receiver, if requested.

**RECEIVER**

1. When form is completed (Section III is completed, or blocks 32B or C are checked) – return copies 1 and 2, and original cover sheet, to originating Quarantine Facility.
2. Retain *Receiver Copy (Part 3)* for your records.
3. If Form AD-942A is used – photocopy for your records or request photocopy from Quarantine Facility.

**Figure 6** *(cont'd)*

The ROBO database eventually will include importation and release information dating back to 1934. The database will be updated continually by specialists. For example, taxonomists in the BBII and elsewhere will monitor and update the taxonomic nomenclature on vascular plants, fungi, arthropods and nematodes, and workers at biological control quarantine facilities and research and action agencies will provide updated information on arthropod recovery, establishment and dispersal by way of reports or publications, all of which are closely monitored by the BCDC.

Users will be able to query the ROBO database and/or request reports

(a)

U.S. Department of Agriculture

BIOLOGICAL SHIPMENT RECORD – NON-QUARANTINE

OMB NO. 0518-0011 (EXP. 2/28/87)

24. FINAL DETERMINATION - Gen., sp., subsp., auth. M NC a. b.

25. V. S. (see files) a b

SECTION I – REPORT OF MATERIAL RELEASED OR SHIPPED

1. FROM (Name & address of Shipper/Releaser)

2. BENEFICIAL - A. Gen., sp., subsp., auth. M

B. Order/Family

C. Determined by (Name and affiliation if known)

3. SHIPPER/RELEASER FILE NO. (see instructions)

4. TYPE OF BENEFICIAL: PArasite, PRedator, Microbial, WEed feeder, POllinator, OTher (Explain M1 or OT):

Part A. From U.S. Field Collection (Collected (or held) to field reconolonization or laboratory culture)

And/Or

Part B. From Laboratory Culture

5. COLLECTION LOCALITY (St-State, County, nearest Town (If more than 2 collection sites, give State & County only))

9. SOURCE FILE NOS. AD 942, AD-943: Nos. Part A Other:

10. COUNTRIES/REGION/STATE OF ORIGIN

6. DATES OF COLLECTION (m,d,y)

7. COLLECTORS (Names and affiliations)

11. ORIGINAL COLLECTORS (Names and affiliations)

12. NO. LAB GENERATIONS (At shipper/releaser location) $F_1$ - $F_{10}$ $F_{51}$ + $F_{11}$ - $F_{50}$

8. U.S. FIELD HOSTS/PREY AT COLLECTION A. Genus, species

B. Stage/part attacked (see codes)

13. LABORATORY HOST/PREY A. Genus, species

C. Stage/part attacked (see codes)

SECTION II – REPORT OF SHIPMENT

14. SHIPPED TO (Name & address)

VIA:

15. NO. & STAGES SHIPPED (see codes on reverse) [Est]

16. DATE SHIPPED (m,d,y)

17. SHIPPER'S REMARKS

18. SPECIMENS RETAINED BY SHIPPER No Yes _____ nos.

19. DATE RECEIVED (m,d,y)

20. NO. & STAGES (see codes) A. Rec'd. Alive [Est] B. Emerged (Beneficials) [Est]

21. RECEIVER'S REMARKS

22. SPECIMENS RETAINED BY RECEIVER No Yes _____ nos.

23. INTENDED USE A. Immediate release (complete Sect. III) Lab culture/study (complete Blk. 24) B. Release intended C. No release intended

24. INTENDED LAB HOST/PREY - Gen., sp.

SECTION III – REPORT OF RELEASE/RECOLONIZATION (See instructions on cover sheet; use Form AD-943A for more details)

| | SITE 1 | SITE 2 | SITE 3 |
|---|---|---|---|
| 25. Types of release | Field, Greenhouse, Cage, Other: | Field, Greenhouse, Cage, Other: | Field, Greenhouse, Cage, Other: |
| 26. Locations (State, County, nearest Town or physical feature, map coordinates) (Use AD-943A for more details, see instructions on cover sheet) | | | |
| 27. Number & stages released (If 0 codes, see instructions for recording multiple releases.) | [Est] | [Est] | [Est] |
| 28. Dates of releases (m,d,y) (See instructions for recording multiple releases.) | | | |
| 29. Target hosts/prey at release A. Primary - Genus, species | | | |
| B. Other - Genus, species | | | |
| C. Lambies | | | |
| 30. Food (plant/animal/other) of target host/prey at release | | | |
| 31. Released by (Name and affiliation) | | | |

32. REMARKS (Use AD-943A for more details)

33. REPORTED BY A. Name B. Date (m,d,y)

Form AD-943 (10/83)

Part 1 - DOCUMENTATION CENTER COPY

**Figure 7.** USDA Biological Shipment Record—Non-Quarantine. (a) Front; (b) reverse.

and files of information of the types noted above. Any person who can justify a need to access the database can obtain permission to use the system. Access to the database can be gained by submitting a request to the BCDC. An additional password is required to add, change or delete data. Users wishing to query the database will find it essential to understand some basic principles of the Wang database management system, of how to run ROBO reports and queries, and of the relationship among the various types of information contained in ROBO. These topics will be thoroughly discussed



(b)

– CODES –

*NOTE:* Use combination of **Invertebrates** and **Plants** codes for weed feeders and other phytophages shipped in or with plant host material (*e.g.*, **L** in **SH**, **A** with **FO**).

**INVERTEBRATES**

A– adults
M– male
F– female
E– eggs
L– larvae (for holometabola)
N– nymphs (for heterometabola)
J– juveniles (for nematodes)
P– pupae, puparia
C– cocoons (can also be **A** in **C**, or **P** in **C**)
MU– mummies, cadavers
PH[ ]– parasitized host – give stage and estimated % parasitized (*e.g.*, **PHA**, **PHL**, **PHE**, etc., **70%**)
H– host

**PLANTS**

PL– whole plant
SD– seeds
SH– seed heads
SP– seed pods
RS– rosette
FL– flowers
ST– stems
RT– roots
TU– tubers
FO– foliage
LV– leaf, leaves

**MICROBIAL ORGANISMS** – *not* including nematodes
MI– cultures or isolates of microbial pathogens, antagonists, and competitors: fungi, bacteria, viruses, rickettsia, protozoa
D[ ]– disease suspects for pathogen diagnosis (*e.g.*, **DPL**, **DFO**, etc. – plant and plant parts; **DHA**, **DHE**, etc. – invertebrate stages)

– ROUTING AND COPY DISTRIBUTION –

**IF NO SHIPMENT IS MADE –**

1. Releaser complete Sections I (Part A and/or B) and III (*see instruction cover sheet; use Form AD-943A on the reverse of cover sheet to record more details of releases.*)
2. Retain Shipper/Releaser Copy (*Part 2*).
3. Shipper (Pending) Copy (*Part 4*) may be discarded.
4. Forward Documentation Center Copy (*Part 1*) and all copies of AD-943A Form to:
   Beneficial Insect Introduction Laboratory
   USDA, Agricultural Research Service
   BARC-East
   Beltsville, Maryland 20705
5. If Form AD-943A is used – photocopy for your records or request photocopy from Documentation Center.

**IF SHIPMENT IS MADE –**

**SHIPPER –**

1. Complete blocks 1 - 18 as appropriate.
2. Retain Shipper (Pending) Copy (*Part 4*).
3. Send remaining copies to Receiver with material.
4. When copies of completed forms are returned by receiver–
   - Retain Shipper/Releaser Copy (*Part 2*) for your records, discard Shipper (Pending) Copy (*Part 4*).
   - Forward Documentation Center Copy (*Part 1*) and all copies of AD-943A Form to:
     Beneficial Insect Introduction Laboratory
     USDA, Agricultural Research Service
     BARC-East
     Beltsville, Maryland 20705
   - If Form AD-943A is used, photocopy for your records and for Receiver if requested.

**RECEIVER –**

1. Complete blocks 19 - 24, and if immediate release, complete Section III (*see instruction cover sheet; use Form AD-943A on reverse of cover sheet to record more details of releases*).
2. Retain Receiver Copy (*Part 3*).
3. Return remaining 2 copies and all copies of AD-943A Form used to Shipper.
4. If Form AD-943A is used, photocopy for your records, or request copy from Shipper or Documentation Center.
5. If all or part of material received is cultured for later release, use separate AD-943 forms to record subsequent releases from these cultures.

Form AD-943 (Reverse)

**Figure 7** (*cont'd*)

in the ROBO Data Retrieval User Manual.

The US National Voucher Collection of Introduced Beneficial Arthropods has been established to document introduction activities further. The practice of designating voucher specimens has been seriously neglected in most areas of biology (Knutson, 1984). Designation of voucher specimens should be encouraged, if not demanded, in the area of biological control, because shipments of apparently identical insects or mites may include cryptic species with undesirable characteristics.

*International exchange of natural enemies (J.R. Coulson)* Another documentation project to be developed in the BCDC is the International Exchange of Natural Enemies Database (IENE). The purpose of IENE will be to develop and maintain a retrieval capability whereby files are set up for several countries with retrieval of matching pests and natural enemies across countries. IENE will be designed to respond to queries such as: what countries have pest X in common; what natural enemies of pest X are available in which countries; are these natural enemies native; are they grown in culture? Development of this database will depend heavily upon the ROBO, POUSNE (*see below*) and other BBII databases.

*Biological control information document (J.R. Coulson)* Since 1981, the BDCD has been issuing an annual document that includes rosters of USDA biological control workers with brief descriptions of their ongoing work and a great deal of additional information of interest and benefit to biological control research and action personnel and administrators. The 95-page 1985 edition was completed in September 1985 (Coulson and Hagen, 1986). In addition to rosters of ARS biological control workers, this document now includes (1) rosters of biological control workers in Canada and in the Forest Service and Animal and Plant Health Inspection Service/Plant Protection and Quarantine of the USDA; (2) information on procedures for importation of exotic natural enemies into the US, including BBII identification services, documentation procedures and a list of approved quarantine facilities in North America; and (3) information on the CAB International Institute of Biological Control, the USDA Office of International Cooperation and Development, and other items of interest to biological control programmes.

*Other biological control databases and systems (J.R. Coulson)* The annual publication by Agriculture Canada of information on the release of beneficial organisms in Canada, beginning in the 1930s, was one impetus for the development of the annual ROBO publication. The most recent publication is for 1982 releases (Williamson, 1986). According to this publication, data from the 1959–82 publications have been computerized. Data from 1977 to 1982 form part of the Pesticide Research Information System (PRIS) of Agriculture Canada, which can be accessed for a fee from anywhere in the world. Searches can be conducted on the basis of liberated species, target pest, Canadian province, or a combination of these.

Other databases similar to ROBO have been, or are being, developed by individual biological control quarantine facilities. The most comprehensive of these is BIRLDATA, developed at the ARS Beneficial Insects Research Laboratory (BIRL) at Newark, Delaware. Many additions and improvements have been made since an early description of BIRLDATA was published (Dysart, 1981). Records are now included on importations, shipments and releases of exotic beneficial organisms received at BIRL from 1952 until the present, of information on identifications and availability of voucher specimens, and of field recoveries of introduced species (R.J. Dysart, personal communication). Several other, generally simpler, computerized systems for recording importations are planned or are being developed at other biological control quarantine facilities in the US. For example, the Department of Entomology at the Texas A&M University has developed a database that covers importations from 1981 to the present. The APHIS/PPQ biological control laboratories at Niles, Michigan and Mission, Texas also maintain computerized records of their shipments and releases of natural enemies in the US. In a related area, a computerized record of accessions of entomopathogenic fungi is maintained by the ARS Collection of Entomopathogenic Fungal Cultures (ARSEF) at Ithaca, New York.



A different type of database, rather similar to the POUSNE database discussed below, is being developed at the University of Florida. The Florida Biological Control database (FBC) contains information on the major invertebrate pests in Florida, including their natural enemies throughout the world, estimated crop losses attributable to the pests, and the current cost of their control (J. H. Frank, personal communication).

In discussing biological control information systems, the CAB (Commonwealth Agricultural Bureaux) International Institute of Biological Control (CIBC) in London must certainly be mentioned. CAB International is an international non-profit organization which provides agricultural information services throughout the world. In addition to the CAB ABSTRACTS database, CAB International publishes over 50 abstract journals, primary journals, books and annotated bibliographies. CAB International also provides scientific and development services. The CIBC publishes *Biocontrol News and Information* (BNI), a quarterly abstracting and news journal which draws upon the CAB International Abstracts Database (CABIA). This database service abstracts papers on agricultural and related fields from 15 000 journals, as well as from books, conference proceedings, reports and theses. Nearly 2 million records reside on DIALOG Files 50 and 53 (as of October, 1986). This wide coverage enables BNI to provide a thorough and up-to-date abstract database in biological control. The BNI database started in 1984 and included 6500 records as of October, 1986. For specific enquiries, CIBC can search this computerized database for records back to 1973. CABIA records from 1980 to the present are accessible through Bibliographic Retrieval Services (BRS), DIALOG, and other vendors.

In addition, CIBC maintains a Natural Enemy Databank (NED), containing all host records for arthropod natural enemies of insects cited in CABI's *Review of Applied Entomology* (Series A and B) since 1913, as well as records from other sources. NED is complete, in published form to 1962, and CIBC has recently undertaken the updating and continuation of this database. Records since 1962 will be computerized as will, ultimately, all records since 1913. In the future, CIBC is planning an International Biological Control Database (IBCD), which will contain records of past and present 'classical' biological control programmes world wide. Records of past introductions of entomophagous arthropods against insect pests, currently totalling 5000, have already been computerized. A similar database on the

biological control of weeds is compiled by the CSIRO Division of Entomology (Australia) and published by CIBC in book form. The most recent revision covers introductions of agents to 1984 (Julien, 1987), and records are computerized and regularly updated at CSIRO.

Another literature-based biological control information system is the *Catalog of Viral Diseases of Insects, Mites and Ticks*, developed by the USDA Forest Service and now in the BCDC. A description of the database and the fourth edition of the records it contains was published recently (Martignoni and Iwai, 1986). The database program lists more than 1100 species of arthropods with their viral pathogens as recorded in the published literature.

Many other smaller databases of importance to biological control researchers, action agency personnel and administrators, probably are being developed by individual scientists at various locations throughout the US and elsewhere. A 'catalogue' of such databases will be developed for inclusion as a special section of the BCDC's *Biological Control Information Document*.

*National and international pest information systems (L. Knutson and J.R. Coulson)* We do not attempt to review the extensive current activity in computer-aided decision making, information accessing or models for pest management, which encompasses many kinds of information not directly related to biosystematics and biological control. However, because biosystematics and biological control information are two important subsets in overall pest information systems, we briefly refer here to certain systems and plans that have a close relationship to biosystematics and biological control.

One of the major problems in plant protection is the lack of information on the distribution of native pests, especially those that are not major pests of major crops. In some countries, basic information is lacking about the occurrence of pests, their hosts and distributions, and in most countries the available information is neither well organized nor readily available. Computerization of such information would be a major step forward: for example, Section 28 of the *US Federal Insecticide, Fungicide, and Rodenticide Act* of 1978 (revised) called upon the USDA and the US Environment Protection Agency (EPA) to prepare a list of pests that need to be controlled. In the same vein, at the 1983 International Meeting for the Strengthening of Regional Plant Protection Organizations with Special Emphasis on Latin America and the Caribbean (Anonymous, 1983a), it was recommended

1. that IICA [International Institute for Cooperation in Agriculture] coordinate the development of a list of pests of the major crops of the western hemisphere for transmittal to FAO [Food and Agriculture Organization], showing the distribution in each country,
2. that regional organizations in the western hemisphere develop a list of pests of plant quarantine concern...,
3. that the lists of pests be forwarded to FAO through IICA and that FAO be requested to develop a worldwide list of pests of major crops,
4. that each regional organization form committees so that the lists are reviewed and modified as necessary on an annual basis, and
5. that a similar approach could be followed by regional plant protection organizations in other parts of the world, and that FAO develops a computer system to relay information on pest lists worldwide.



Kim (1979) described how a national plant pest information system might be structured. The US Cooperative National Plant Pest Survey and Detection Program (CNPPSDP) (Johnson, 1986; Wallenmaier, 1986), established in 1981 by APHIS/PPQ in collaboration with state units, is primarily a pest-monitoring and information system. A database management system, the National Agricultural Pest Information System (NAPIS), has been developed to manipulate the data; the system shares software and hardware with the National Pesticide Information Retrieval System at Purdue University. Emphasis is placed on pests (insects, nematodes, pathogens, weeds) of 12 major crops or crop groups, although a large number of other crop species are included. During 1986, the system collected 325 000 crop/pest records (Schall, 1986; T. E. Wallenmaier, personal communication). The system depends on extensive identification services at state and federal levels and could serve as a major source of biosystematic data as it develops. An additional benefit of CNPPSDP will be its ability to monitor the distribution and abundance of certain biological control agents and thus to improve the effectiveness of programmes involved with the release of natural enemies.

A computerized National Agricultural Pest Register for the US was proposed by Knutson *et al.* (1984) to provide core data (nomenclature, host–vector relationships, pest status, distribution and key references on biology) on pest species to all users and to identify the diverse supporting or related databases that could be used to compile data rapidly for evaluation of pest management problems. As an index or directory to the species in various databases, such a register could be of significant value to plant quarantine activities. Major difficulties need to be resolved relative to compatibility and telecommunications between diverse databases. Such technical problems are gradully being overcome, but obtaining information about the existence of databases and protocols for their use is expected to be a continuing problem. Databases being planned or developed for national biological surveys could also be important adjuncts to plant quarantine and national plant pest survey and detection databases (Johnson, 1986). We describe below certain databases that are, or could be, related to overall national pest information systems.

*Pest Organisms in the US and their natural enemies (J.R. Coulson and J.R. Dogger).* A database on Pest Organisms in the US and Their Natural Enemies (POUSNE) is being developed at the BCDC. It is recognized that not all pests are introduced, nor are they all arthropods. While ROBO becomes functional and while data are being gathered and entered for WHIAD (described below), initial steps are being taken to develop this broader database. POUSNE will include information on US endemic and introduced pests (arthropods, weeds, nematodes, plant pathogens and other agricultural, forest, veterinary and medical pests). It will contain data on geographical origin, distribution, establishment and spread of introduced pests; ecological data (host plants/animals, soil types for weeds, etc.); and a limited amount of economic impact data to aid in cost/benefit analyses and project priority allocations. Basic information on US and foreign natural

enemies and antagonists of an estimated 10 000 pest species eventually will include cross-indexed records of geographical distribution and other ecological data, including hosts for US and foreign biotic agents and such data for the hosts, and the natural enemies, of the biotic agents themselves. With the inclusion of such data, POUSNE would be a key component of the projected National Agricultural Pest Register (*see above*). POUSNE will share WHIAD data to provide information on introduced arthropod pests and natural enemies. The EPA *List of Insects and Other Organisms* (Sutherland and Brassard, 1987) will be used as a source of information about native arthropods and pests other than arthropods. To facilitate interagency use, EPA codes for the organisms are being used for both WHIAD and POUSNE.

*Western Hemisphere Immigrant Arthropod Database (L. Knutson and W.L. Murphy)* Immigrant organisms are of special interest for practical and academic reasons because of their real or potential economic and/or environmental impact as pests or beneficials and because they serve as ideal subjects for studies of colonization and dispersal. For example, foreign species comprise 35% of the 700 most important arthropod pests present in the continental US, and nearly 50% of all agricultural losses in the US caused by arthropods are inflicted by introduced or immigrant species. About 1500 beneficial arthropods—including parasitic and predacious natural enemies of insects and mites, pollinators and weed feeders—have been introduced intentionally or accidentally into the US and Canada, primarily since the 1880s. A need exists for the creation of an international database covering all immigrant organisms—plants, animals, and micro-organisms. In 1980, the BBII began to develop such a computerized database for arthropods immigrant to the western hemisphere.

The objectives of the Western Hemisphere Immigrant Arthropod Database (WHIAD) are (1) to develop a computerized database of essential information on insects, mites and related arthropods immigrant to or introduced into the western hemisphere, with emphasis on taxa in North America, especially the US; (2) to develop a system for obtaining, maintaining, analysing and documenting this information, and (3) to provide the information to a broad spectrum of users, including regulatory agencies, research and state extension units, agribusinesses, international organizations and individual scientists.

In 1968, the late Reece I. Sailer began developing a card file of the insects and mites known to be immigrant to North America. Each record included about 12 fields of essential data for each species. Information on 1660 species immigrant to North America had been accumulated by 1978 (Sailer, 1978). WHIAD was initiated in the BBII in 1980, with the co-operation of Dr Sailer. We estimate a rapid increase to about 3000 species in WHIAD during the first 2–3 years of its development. Thereafter, 10–25 species per year may be added and two or three deleted as our knowledge of the establishment of certain species improves.

Information on immigrant arthropods is scattered throughout a voluminous body of published and unpublished information, including handwritten records in entomologists' files, while some immigrants are represented only by a few specimens in museum collections. We are continually updating the hardcopy database of WHIAD information by reviewing published and unpublished literature. The BBII identification service and taxonomic research produced by the SEL are major sources of new information, as is the ROBO database in the BIL.



After information has been obtained on an immigrant species, a data sheet containing 51 subject fields is prepared and submitted to the appropriate specialist for review. The information is then entered into an interactive, expandable database on a WANG minicomputer. All data files on the system may be manipulated or updated remotely from a Wang workstation through WANGNET®. Recently acquired asynchronous communication software will allow access to WHIAD data from almost any TTY terminal. The database currently includes a listing of the 1800 species documented in the hardcopy file, with detailed information entered on about 300 species of Coleoptera, Diptera and Lepidoptera. After completion of review and editing, a compilation of the entire database will be distributed to selected entomologists who will be asked to contribute information to fill the many gaps that will undoubtedly appear. A revised compilation will be published subsequently for broader distribution. Although geographical coverage may eventually be expanded to include the entire western hemisphere, initial emphasis is being placed on arthropods in America north of Mexico.

The capability to analyse the origin, dates and modes of entry, sites of establishment, host and habitat preferences, vectored pathogens, dynamics of geographic spread and related information, is of immense value in the exclusion, containment and biological pest control activities of regulatory and research units. Such knowledge should aid in the development of approaches for excluding additional foreign pests (an estimated 10 000 species are considered capable of establishment but do not yet occur in North America) and expediting the distribution of introduced beneficial species into North America. Information on introduced arthropods will contribute to broader basic studies on the biological phenomena pertinent to immigrant organisms.

A Cooperative Immigrant Arthropod Voucher Specimen Collection of species immigrant to the western hemisphere is being established in the BBII to further document this database. Specimens representing the earliest recognized establishment are obtained from various sources, uniquely numbered and labelled, and shared as far as possible among the collector, the BBII, the US National Museum of Natural History, and, where appropriate, with Agriculture Canada and Sanidad Vegetal in Mexico. The collections are designed to (1) authenticate records of occurrence, (2) provide reference material for subsequent identification, (3) enable subsequent taxonomic study if error is suspected in the original identification, and (4) provide visibility and draw attention to the importance of discovering and recording information on immigrant species of arthropods.

For more effective documentation, especially of economically unimportant species, it would be appropriate for professional societies to establish regular

procedures to publish detailed records of the occurrence or establishment of pest, beneficial and non-economic species new to their areas of interest. The advantages of such procedures would be to elicit timely and broad dissemination of the essential information in a consistent format and to ensure appropriate recognition for the discoverer of the new record.

### *Common names (L. Knutson and D.W.S. Sutherland)*

Effective international communication is essential at many levels. The use of common names of organisms can be an important means of communication, particularly when specialists communicate with the public. Common names also can be useful in the development of universal methods for retrieving information. There are a few major lists of common names of insects and mites (e.g. Sutherland and Brassard, 1987; Werner, 1982; Greiff, 1985) and many specialized lists of various kinds. An essential requirement for common names lists is that they provide access to the valid equivalent scientific name, a function difficult to achieve because scientific names are not as stable as common names, and common names almost always change from country to country. A continually updated list is needed to achieve some consensus on the formation of common names and stability in their use. Maintenance by an entomological society or other organization appears to be the best approach. Computerization is needed of common names lists, such as the list of about 7000 names maintained by the EPA (Sutherland and Brassard, 1987), which includes certain key information (e.g. higher taxonomic category and code numbers).

Computer abbreviations of names of pests could be useful: for example, the European Plant Protection Organization (EPPO) (Anonymous, 1983b) recommended the use of the Bayer system of computer abbreviations of pest names. From an international viewpoint, multilingual synonymic lists of arthropods would be particularly useful. Excellent English–Spanish (Greiff, 1985) and English–French (Benoit, 1975) lists have been published. Such a list for the western hemisphere might include about 8000 scientific names and about 30 000 common names. An international register of lists of common names is an identified resource needed for more effective and broader use of common names of pests of all groups.

### *Inventories of collections and specimen label systems (F.C. Thompson and L. Knutson)*

Unlike collections of most vertebrate groups and plants, only a few major insect collections have been extensively computerized, to the authors' knowledge. The reasons for this are (1) the poor state of insect classifications, (2) the large number of specimens and species of insects and mites, (3) the large percentage of specimens unidentified or incorrectly identified, (4) the complexity, variability, inconsistency and diversity of the data and the lack of standards, (5) unrealistic expectations of computer technology and inadequate system design and (6) the chronic problem of insufficient support



staff to enter data. Most museum inventory projects start with a cursory study of what is needed, experience a period of intense data entry, and then fail when the project sinks into an endless cycle of data entry, verification and software modification. Failures result from attempts to capture ever more data with little regard for quality control or standardization of data-entry formats; useful retrieval soon becomes impossible (Sarasan, 1981; Sarasan and Neuner, 1983).

Of the few publications in entomology that exist on these kinds of databases and systems, examples of some of the more successful ones are given below.

Researchers at the Bernice P. Bishop Museum in Honolulu developed the most comprehensive collection inventory database to date in entomology (Steffan, 1977, 1985, 1986) and captured data on more than 6000 specimens of mosquitoes before the project was abandoned for many of the reasons listed above. The USDA Forest Service in 1899 initiated a card catalogue system to record field data on insects and associated plants. The more than 162 000 cards that now exist were recently microfilmed, a computerized index to them was designed, and some 10% of the cards indexed. Whether the index will be completed and whether the system will be converted and continued as a distributed database is being considered by the Forest Service (Hopkins, 1894; M. McKnight, personal communication). The Smithsonian Institution (SI) now maintains two computerized inventories of the US National Entomological Collections. One database contains all the information associated with especially valuable specimens, such as primary types and rare birdwing butterflies; the other contains data on the extent, location and type of storage of family-level units. A more comprehensive species-level inventory is being planned.

At the bench level, some systematists have developed databases for their own research needs. Two examples are the Central America carabid beetle database (Erwin, 1976) and the Mosquito Information Project (MIP) (Faran, Burnett and Erwin, 1984). Both databases were based on SELGEM and were designed to store and manipulate all relevant biosystematic data (taxonomic, ecological and distributional) to enhance the research productivity of the specialists. The MIP began in September 1979 as a collaborative effort between the US Army Biosystematics Unit and the SI Department of Entomology. The purpose of the project was to develop a computer-based, systematic and ecological master file of the National Mosquito Collection to be used (1) to provide public health organizations, the Army and other scientific or environmental agencies, with co-ordinated systematic, ecological and distributional data on mosquito species that are vectors of diseases, (2) to enhance and support mosquito research, (3) to identify gaps in the collection and allow formulation of new collection strategies and (4) to alleviate managerial problems by providing timely, cost-effective inventories. Data were stored in a SELGEM database and are currently archived on magnetic tapes. Conversion of the data for use under a current database management system is unlikely.

Among other related projects, the International Soybean Arthropod Collection (ISAC) at the Illinois Natural History Survey, Urbana, Illinois, houses

about 150 000 identified specimens of over 2300 species from the US and 25 other countries (Kogan and Bouseman, 1980). A database service on the literature of soybean-related arthropods, currently containing about 17 000 documents, is maintained in conjunction with the ISAC. The US National Institutes of Health, Public Health Service, is responsible for one of the world's leading programmes in biosystematics research and services with regard to ticks. The programme centres around the research information and international collections developed by the late Dr Harry Hoogstraal. All the data on the tick collections of Hoogstraal, Bishop Museum, and Nuttall (British Museum, Natural History) have been entered into the database. About 120 000 records (36 fields) of ectoparasite and host data have been entered on the SELGEM system of the Smithsonian Institution. The collection and database are currently (May, 1987) maintained by the Smithsonian Institution. A bee and wasp reference collection is maintained at the ARS Bee Biology and Systematics Laboratory, Logan, Utah. In the SEL, special software was developed to capture all kinds of data associated with specimens and to be used by individual scientists for their research.

In many other organizations where microcomputers are available, scientists have developed their own research databases: for example, the systematists at the California Department of Agriculture now have more than a dozen specialized databases (T. Seeno, personal communication). Database-management software operating on minicomputers and specifically designed to meet the unusual requirements of use with museum collection data also is becoming available: CURATOR is one such currently available commercial package (*see Table 1*).

With increasing international concern about the decline of biological diversity, interest has been increasing in documentation of the world's biota through published biological surveys of various kinds and at various levels. This literature, which encompasses ecological and environmental information as well as taxonomic information, is essentially 'biosystematic' literature. Comprehensive papers by Steffan, Loucks, Dyer and Farrell, Morin, Jenkins, and Kennedy and Kelly (all in Kim and Knutson, 1986) review computer applications in an analysis of foundations for a US national biological survey.

Computers have long been used to process faunistic data and to produce distribution maps. The first major biotic programme to use computers was the British Biological Recording Network (Perring, 1970; Heath and Perring, 1975; Heath and Scott, 1977). From this programme arose the present International Commission for Invertebrate Survey, sponsored by the International Union of Biological Societies. Many countries, especially those in Europe, are now actively capturing distributional data for their insect faunas. Initially the US federal government, through the Fish and Wildlife Service of the US Department of the Interior, established a central office to encourage and co-ordinate these invertebrate recording schemes (Opler, 1981). However, that programme was abandoned as a result of budget cuts and only two states, Maryland and Washington, currently operate programmes. For the Maryland Insect Survey (MIS), the BBII developed a database and provided disk storage space. Co-operators can access the MIS data files



remotely with personal computers and can add, modify and delete records as well as generate reports. Eventually the data files will be published in the more traditional atlas format.

### *Defense Pest Management Information Analysis Center (F. Santana)*

The Defense Pest Management Information Analysis Center (DPMIAC), originally designated as the Military Entomology Information Service, was established in 1962 as the information and communication service of the Armed Forces Pest Management Board (AFPMB) of the US Department of Defense. DPMIAC collects, stores and disseminates pertinent published and unpublished information on arthropod vectors and pests, and natural resource information of importance to the Department of Defense. Its personnel index, abstract, analyse, summarize and disseminate information on the biology, control, ecology, geographical distribution, and taxonomy of vectors and pests. Other areas include vector-borne diseases, stored-products pests, structural pests, vector/pest surveillance, chemical and biological control and toxicological information on selected pesticides and other chemicals. The DPMIAC database also contains information on rodent and bird control, venomous plants and animals, snail-borne disease, marine fouling organisms, medically important toxic flora, biology and control of plant pests of landscape and forest, fish and wildlife management, outdoor recreation, grounds and maintenance, weed control and conservation of natural resources.

DPMIAC uses a thesaurus of descriptors to index various topic areas, and a computerized storage/retrieval system that provides both data processing and word processing capabilities. Current hardware and software configurations consist of a WANG VS-100 CPU with associated tape drive and 976 MB of disc storage with standard WANG operating system and utilities programs. The Literature Storage/Retrieval System (LRS) consists of customized COBOL software programs for data entry, storage and retrieval using a closed keyword system. Application builder program (SPEED II®) is used for customized applications. To facilitate 24-hour service and rapid information dissemination, both automatic telephonic recorder and facsimile transmission equipment are in operation.

The current DPMIAC information base includes approximately 167 000 accessions, 123 000 of which are stored in a computer database for rapid retrieval, and a comprehensive reference library of over 1200 books and 229 periodicals. DPMIAC has established liaison with other Federal agencies, libraries, and information systems, including the National Library of Medicine, National Agricultural Library, Defense Technical Information Center (DTIC), and DIALOG; if requested information is not available in-house, it can usually be obtained through these additional sources. As a primary benefit to users overseas, or in areas where library facilities are limited or non-existent, complete copies of pertinent articles may be obtained.

DPMIAC serves all DoD professional pest management and natural resource personnel, and ancillary personnel responsible for and/or dealing

with problems generated by disease vectors and pest organisms. Professional personnel of other federal agencies and government-sponsored contractors may also use DPMIAC.

DPMIAC services include the following: (1) technical consultation on vectors and pests, as well as management of natural resources within the scope of the Department of Defense and other federal agencies; (2) provision of retrospective bibliographic literature searches on pest management and natural resources as requested (searches can be conducted by date, accession number, author, or topic using appropriate combinations of keywords and search modes); provision of Selective Disseminations of Information (SDIs) in specific areas of coverage (users may request one or more SDI categories on which they wish to receive periodic bibliographic updates); distribution of a monthly *Technical Information Bulletin* which highlights current information on pesticides, hazardous waste, natural resources, and medical entomology; (5) dissemination of a *Global Pesticide Resistance Inventory* for countries throughout the world; (6) development and distribution of *Disease Vector Ecology Profiles* (DVEPs) of foreign countries throughout the world: DVEPs provide tabular summaries on the epidemiology, mode of transmission, and bionomics of arthropod disease agents and their vectors, and other epidemic diseases as well as information on hazardous and venomous animals; (7) maintenance, publication, and distribution of the Directory of DoD Pest Management Professionals and Natural Resource Managers.

## BIOSYSTEMATIC TOOLS AND UTILITIES (F.C. THOMPSON)

When the SEL acquired a minicomputer in 1979, a committee of scientists investigated how the computer could be used to improve our overall research productivity. Purchase of the computer was justified on the basis of enhancing two special activities—the insect identification service and the cataloguing programme (*see* STS, Coleoptera Catalog, and Tephritid Pilot Project, *above*). The committee divided its task between two components, hardware and software. With regard to hardware, we recognized that unless the scientists had easy and convenient access to computer resources, the ultimate success of the automation project would be severely jeopardized. Computer access via batch processing had been available to our systematists for more than a decade but had been only marginally utilized; only for the most complex mathematical analyses would scientists leave their workbenches to use an inconveniently located computer. Thus, while word-processing, bibliographic and character-analysis programs on the mainframe computer were available in the late 1960s, they were not being used by most systematists. Hence the hardware goal of the SEL was to place a workstation in the office of each scientist: this goal was achieved in the fall of 1986. Our scientific workstation is a Wang PC (MS-DOS microcomputer based on the Intel 8086 microprocessor) with dual 360-kilobyte diskette drives. Each workstation can be used as a stand-alone microcomputer or as a workstation linked to the network of BBII minicomputers or via telecommunications to other computer networks.



The committee also investigated the software tools that the systematists would need to handle their data. Most of the data used by systematists are derived from examination of specimens or are in some other way associated with specimens. From these data (called 'characters') systematists derive classifications, descriptions, and keys. Because systematists need to relate their observations and conclusions to those of their predecessors, bibliographic programs are needed to allow access to the literature. Finally, all the analyses, conclusions, literature reviews, etc. need to be woven together into a manuscript for peer review and eventual publication. Word-processing programs are ideal for this final step. Beyond managing data, communications are another essential area for computerization. Standard protocols, such as Teletype emulation (TTY), provide the scientists with access to on-line databases and, while not yet in use in entomology, electronic bulletin boards (for how bulletin boards are being used by systematic botanists, *see* Zander and Eckel, 1987). Naturally, the more these individual programs are integrated so that data can be easily passed from one to another, the more efficient is the overall system.

In summary, our strategy to increase research productivity was to provide immediate access to computer resources at the scientists' workbench and to provide the special applications needed to automate each step in the research process—from data acquisition, analysis and literature review to result reporting.

### *Descriptive Language for Taxonomy (DELTA) (R.D. Webster)*

In a recent paper on expert systems in entomology, Stone *et al.* (1986) define expert systems as

> ...computer programs that offer solutions to complex problems by mimicking known reasoning processes (heuristics) and employing a knowledge base of information extracted from human experts... In thinking of an appropriate expert system application, one should look for a problem that is well defined in scope, but which requires scarce human expertise to solve. Problems that involve incomplete data and require judgment, approximation, or opinion in their solution are well suited to an expert system approach. Agricultural pest management decisions, insect and general pest identification, and crop production are all good examples of such problems.

The hierarchical nature of animal and plant classification lends itself well to the use of computerized expert systems such as DELTA (DEscriptive Language for TAxonomy) for decision-making in diagnosis. DELTA is a computer system designed as an efficient mechanism for editing, analysing, presenting and updating descriptive scientific information. This advanced technology can be effectively applied in all areas of biology and can treat or analyse all the types of data normally collected in various scientific disciplines. DELTA was developed by M.J. Dallwitz, a research systems programmer with the Division of Entomology at Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) (Dallwitz, 1986). CSIRO continues to fund further development of this technology. Application of the DELTA system in systematics has been validated by the success of extensive database projects of Watson (1981) and Webster (1987).

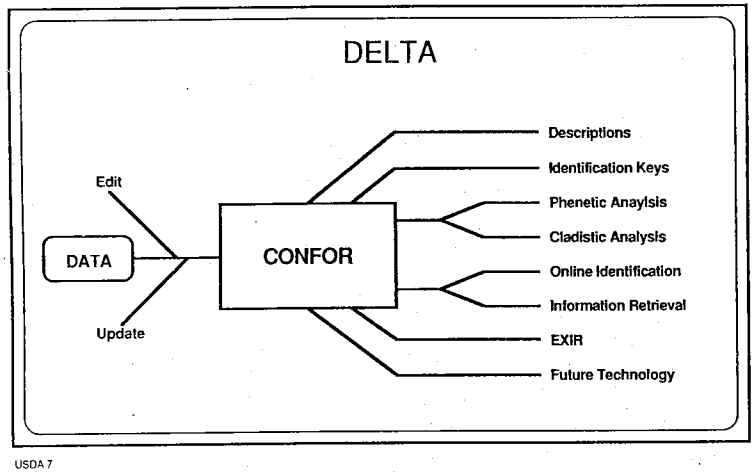


**Figure 8.** Relationships of data input and information output for DELTA system.

Initially, DELTA offers a cost-effective means of recording data in an easy-to-write computer format. Once recorded, the data can be edited and updated easily. Data in DELTA format can be automatically converted to other computer formats by the program CONFOR (*Figure 8*). Keys and descriptions, the components of traditional taxonomic manuals, are generated automatically by the system. Descriptions produced from the system are well organized, consistent in punctuation sequence and terminology, and fully comparative. Identification keys produced from the system are well designed and make efficient use of the characters and placement of taxa. The system allows for interaction with the database to produce the most practical key for a particular purpose. The flexibility of DELTA allows for the production of output on any subset of the data, i.e. special-purpose treatments can be generated automatically: for example, the system could produce a treatment of taxa from a specific geographic region which possess a certain set of physiological characteristics; after a translation of the characters, DELTA can automatically generate output in different languages.

Data in DELTA format are easily converted for analysis by cladistic and phenetic analysis programs. Taxonomists may use the database to produce and compare classifications, to compare taxa quantitatively and to analyse relationships among taxa. Scientists in other areas of biology also can use the system in their research: for example, a plant breeder could use the database to produce a list of native taxa that are close relatives of a particular crop species. Moreover, a DELTA database would be a valuable tool for the biologist studying evolutionary processes or developing improved germplasm.

The most significant application of a DELTA database is the automatic conversion to online identification and information retrieval programs. These expert systems are particularly valuable for identifying material and for producing lists of taxa exhibiting or lacking certain characteristics and in



seeking correlations between conventional taxonomic data and characteristics in ecology, anatomy, physiology, cytology, geography and economic value, for which conventional taxonomic publications are unsuitable. If a multipurpose database were produced and the online conversion made available to universities, experiment stations and other research facilities, we believe that it would soon replace conventional technical manuals as the standard information source.

DELTA provides an excellent means of integrating knowledge from various disciplines into a single multipurpose format. This system functions as a cost-effective mechanism for producing different types of taxonomic manuals, information retrieval, and data analysis and conversion for special purposes. DELTA facilitates the efficient transfer of information to different user groups.

Further development of special systems such as DELTA will predictably lead to networks of research taxonomists contributing to the development and improvement, on a daily basis, of databases that at the same time are being used by personnel at remote locations throughout the world for decision-making in quarantine activities, pest management, etc. Such integration of the identification process with the quarantine decision-making process has been proposed by F. R. Gaeta, Interamerican Institute for Cooperation in Agriculture of the Organization of American States (F.R. Gaeta, personal communication) for use on personal computers in southern South America, and others (J. Lebbe, personal communication) have developed expert systems (based on XPER) for the identification of sand flies (Phlebotomidae) of French Guyana.

### *PHYSYS, A character analysis program (M.E. Schauff)*

With regard to computer programs to analyse character data, Wiley (1981) wrote,

> The actual internal workings of these programs ... are likely to be incomprehensible to all but the most knowledgeable computer person. It has taken many years to derive the programs which fully implement Hennig's methods. These efforts have left programs strewn around the country. Some are better than others. Some are worse than nothing. Most are defective in one respect or another.

PHYSYS was selected for use in SEL because it appeared to be the best implementation of the cladistic approach (Luckow and Pimentel, 1985). PHYSYS is a fully interactive software package designed to aid the taxonomist in character analysis and the construction of classifications. It contains a number of algorithms for investigating phylogenetic and phenetic groupings as well as programs for analysing distance data. While generally used to investigate newly acquired data, it can also be used to analyse any predefined matrix of distance or character data. The program also has the ability to run in batch mode and to accept data either from the run stream or from user files. The data source can be changed interactively simply by specifying a file name in the data command; likewise, output can be directed either to a terminal or to a user file through use of a simple interactive command.

PHYSYS takes its name from the systematic methodology known as PHYlogenetic SYStematics or cladistics. Based largely upon investigations of systematic methods by S. Farris and M. Mickevich, who coauthored the program, these techniques have been shown to provide the most natural system of classification and one that most efficiently summarizes the available information (for discussion, *see* Kluge and Farris, 1969; Farris, 1979, 1980, 1982).

The main body of the software package is dedicated to phylogenetic analysis and allows one to investigate, optimize, plot, and output trees by several means. The PHYSYS command language has been designed to minimize user effort. Several types of programs and utilities can be strung together on a single command line, which allows the user to order multiple analyses concurrently. The program can accept character-data input either as a numbered matrix or as alphanumeric fields. The ability to read alphanumeric data sets has greatly facilitated the ability of the taxonomist to understand better the diagnostic information produced. Character diagnoses can list changes of states on trees, consistency indices, and a variety of other information about the changes that characters are undergoing among the taxa being investigated.

The programs also allow the user to investigate a number of alternative character-state trees (i.e. diagrams of the relationships between the states) and to apply advanced multistate character techniques such as successive weighting and analysis of transformation series to the data set. Using the numerous available utilities, the taxonomist can specify the number of trees saved from a given run, whether or not branch swapping (either local or global) is invoked, the direction of character-state change, and many other options.

### *Word processing and automated publishing (F.C. Thompson)*

Word-processing (WP) programs are now almost universally known and available to modern authors and therefore are not reviewed here. However, WP is the most widely used computer application in the BBII and is an indispensable tool for building biosystematic information systems. WP has led to an increase in research productivity as measured by number and size of publications and by savings in publication costs. WP alone almost justifies expenditures on computer technology. One point, however, needs to be emphasized about word processing. While word processing is most often used to generate manuscripts that are handled in the same fashion as those produced manually, the process creates machine-readable documents. Thus, manuscripts need not be typeset by re-keying the documents but instead can easily be disseminated through other media, such as online data services, disks and magnetic tapes. One of the great problems facing biosystematics is the high cost of publishing data, a cost that stems from the immense amount of data to be published. *Figure 9* illustrates the history of methods of dissemination of systematic knowledge. Truly comprehensive monographs cover hundreds of species and run into thousands of pages. For example,



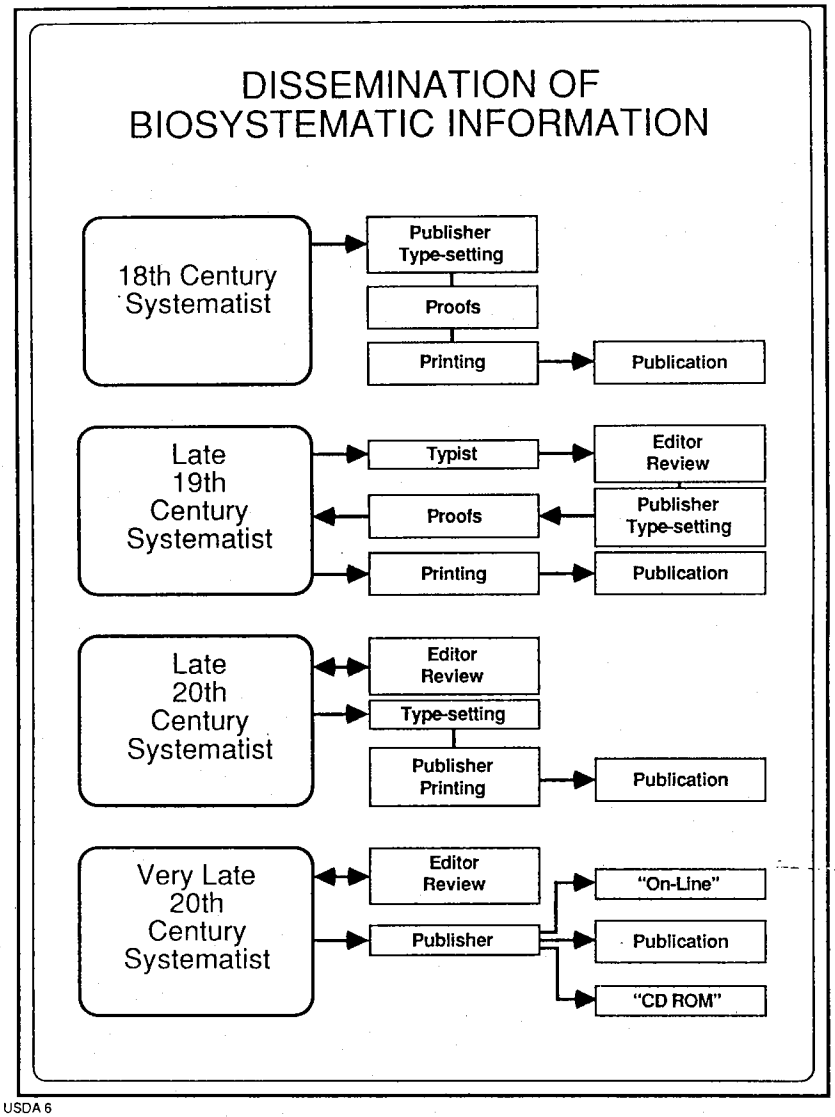


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**Figure 9.** Information flow in 'publications'.

the still incomplete monograph of the flies of the Palaearctic region (*Die Fliegen*, Lindner, 1924-present) is over 16 000 pages and sells for more than US $2800. Publication costs for the parts produced to date, based on current rates for printing, would be approximately $960 000. By typesetting directly from word-processing documents, we have been able to save nearly 30% of the publication costs of large works of this kind. The potential for cost

cutting with the use of new media such as CD-ROM is much greater. All of *Die Fliegen* could fit on a single 13.3 cm CD-ROM disk that, once mastered, could be reproduced for less than $10 a copy and cost less than $30 000 to produce from a WP data file. (For a current vision of what CD-ROM technology means to information systems, *see* Lambert and Ropiequet, 1986).

### *Bibliographic systems (F. C. Thompson)*

A large and diverse array of bibliographic databases exists in the biological sciences. These include the USDA National Agricultural Library's AGRICOLA, BIOSIS® (*Biological Abstracts* and related titles), CAB (Commonwealth Agricultural Bureaux—*Reviews of Applied Entomology*) and the online version of the *Zoological Record*. Detailed information on these sources and other specialized entomological sources can be found in Gilbert and Hamilton (1983). Although all of these are now computerized, they began as manual sources and the bulk of the pre-1970 literature is not contained in the databases. Hence users have easy access to current literature but must still search manually for older literature. Unfortunately, much essential biosystematic information is to be found in older publications, and the indexing of these comprehensive bibliographic sources tends to be rather coarse and directed toward the general user. Thus specialists still need to develop their own bibiliographic files. To assist scientists in automating their own bibliographic databases, the USDA developed a program called FAMULUS (Ashley, 1981), which still is used widely despite its age. FAMULUS was written in COBOL and was designed as a batch-orientated program for use on mainframe computers, the only environment extant in the 1960s when it was written. From the FAMULUS model we built an interactive menu-driven bibliographic system for our VS-100 minicomputer. This system permits users to build bibliographic files, to retrieve references and to pass them to their word-processing documents.

### *Specimen tracking system (L. Knutson and M.A. Lacey)*

There are three large multipurpose internationally orientated research and identification centres for insects and mites: Biosystematics Research Centre, Agriculture Canada, Ottawa; CAB International Institute of Entomology, London; and this Institute. All three are associated with the national insect collections of the three respective countries. About 25% of the time of the 27 research scientists in the SEL is spent providing identifications and related biosystematics information (distribution, hosts/prey, biology, etc.) to users throughout the western hemisphere. About 20% of the identifications are provided for researchers in Latin America. About 150 000 specimens are identified annually, comprising about 40 000 scientific names, submitted as about 16 000 lots.

Over the years an elaborate manual system was developed in the Taxonomic Services Unit (TSU) of the BBII Institute Office to track identification requests and to document the identification work. The TSU is staffed by a



graduate non-research entomologist, one technician and two data-entry clerks. In 1980 we began streamlining the manual system in preparation for computerization. The objectives of the Specimen Tracking System (STS) were (1) to track (inventory) the requests; (2) to use word-processing procedures, including a variety of prepared statements, to produce identification reports for submittors of specimens; (3) to document and analyse the identification activities to improve their management, and (4) to build a scientifically useful database of the identification and biological data supplied and the incoming information. Special software was written primarily in COBOL for a computerized system designed using the manual system as a model (*see Figure 10* for diagram of data flow). An identification request form, *Figure 11*, was finalized after several years of testing. Many of the fields on this form appear on the computer terminal screen and are used to enter the data required for items 1–4 mentioned above. An identifier's report form (*Figure 12*) also was developed. The inclusion of an 'incomplete identification' code provides an effective means of informing the user why a specimen could not be identified to species level; this inclusion has significantly improved the usefulness of the reports. A form used at the state level by survey entomologists for input into the APHIS/PPQ pest survey program has been revised to conform with the BBII identification request form (*Figure 13*).

The computerized system proved so successful that we terminated the manual system within a few months. Since then we have further improved the STS by enhancing existing COBOL programs and by using Wang utilities

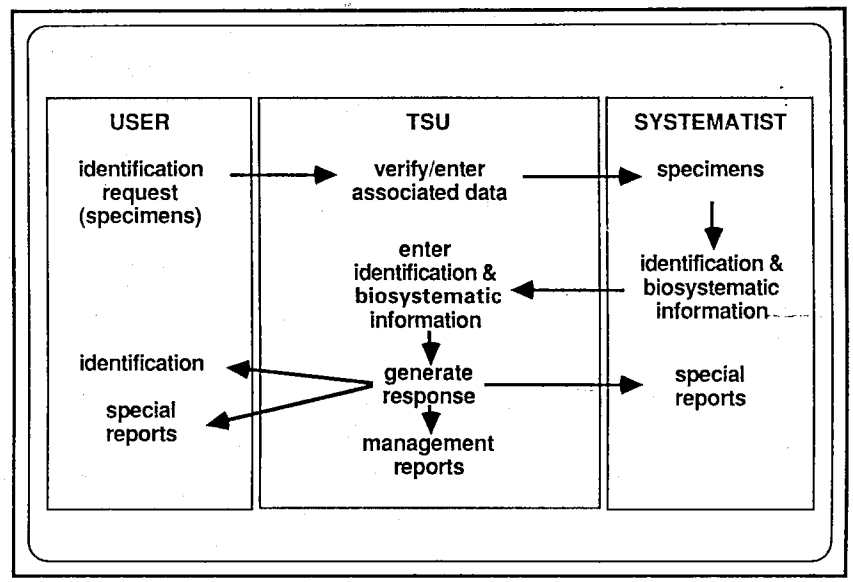


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**Figure 10.** Specimen Tracking System.

U.S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
INSECT IDENTIFICATION AND BENEFICIAL INSECT INTRODUCTION INSTITUTE

IDENTIFICATION REQUEST

NOTE: • Please *type or print* all information.
• Do not write in shaded areas.
• Give explanations where requested in "Remarks" section at bottom of form.
• Attach additional pages if more space is needed.

LOT NO. | PRIORITY
DATE | Sender's Reference No.
DATE IDENTIFICATION REQUIRED *(month, day, year)* If less than one month, explain below.
TOTAL NUMBER SENT Pinned: Vials: Slides: Other:

NAME & COMPLETE MAILING ADDRESS OF SENDER *(Include Zip code)*

RETURN TO *(If other than sender)* *(Include Zip code)*

SOURCE
AR ☐ ARS
AP AQ ☐ APHIS - PPQ
FS ☐ FS
DD ☐ U.S. Military
OF ☐ Other Federal
SA ☐ State Agricultural Agency
SU ☐ State University
OS ☐ Other State
PU ☐ Private University
IN ☐ Individual
CO ☐ Commercial Organization
FN ☐ Non - U.S.
CI ☐ CICP

LEVEL/TYPE OF IDENTIFICATION NEEDED
☐ Family ☐ Genus ☐ Species
☐ Positive or negative verification of:
Ecological group: ☐ phytophagous ☐ parasitic ☐ saprophagous ☐ aphidophagous ☐ predaceous ☐ other *(specify)*

OTHER INFORMATION REQUESTED — Will be supplied as conditions allow, as determined by taxonomist.
a ☐ Pest status
b ☐ Geographical distribution
c ☐ Usual hosts (prey)
d ☐ Best reference
e ☐ Identifying characteristics
f ☐ Other *(Specify)*

SOURCE OF PROJECT SUPPORT
☐ ARS ☐ APHIS ☐ FS ☐ CSRS Regional project no.:
☐ Hatch ☐ EPA ☐ INTR ☐ NIH ☐ NSF ☐ FAO
☐ USAID ☐ Other *(Specify)*

REASON FOR IDENTIFICATION *(Check and complete as appropriate)*
a Biological control
1 ☐ Scientific name of target pest:
2 ☐ General quarantine or biocontrol research
3 ☐ Identity of host of natural enemy
4 ☐ Recovery of released natural enemy
5 ☐ Suspected contaminant in culture
6 ☐ Quarantine reference collection
7 ☐ Voucher specimen of field release
8 ☐ Holding living material pending identification
b ☐ Damaging crop, plants – *identify host plants:*
c ☐ Suspected pest of regulatory concern
d ☐ Stored product pest – *commodity affected:*
e ☐ Livestock, domestic animal pest – *host:*
f ☐ Danger to human health
g ☐ Household pest – *damage:*
h ☐ Possible immigrant – *new to:*
i ☐ Reference collection
j ☐ Survey – *explain in detail below*
k ☐ Thesis problem – *describe project below* ☐ M.S. ☐ Ph.D.
l ☐ Other – *explain below*

SPECIMEN DISPOSITION
☐ Return ☐ Place in National Collection
☐ Keep part of series ☐ Other *(Specify)*

VOUCHER SPECIMEN(S) INCLUDED
How marked?
Will be deposited in:

TELEPHONE REPORT REQUESTED
If yes, give number – include area code and extension

DESCRIPTION OF PROJECT – Include Project Title and name of Project Leader. *(Reference previous communications.)*

REMARKS *(Explanations, tentative identification, collection data, etc.)*

FOR IIBIII USE
DATE RECEIVED
NO.
LABEL
SORTED
PREPARED
DATE ACCEPTED
RR

Form NER-625 (Jul 83) PART I – IIBIII Copy

**Figure 11.** BBII identification request form.

software in place of some of the custom-designed software. Telecommunications via TELENET® is being used increasingly to report identifications to USDA users on the system, and ADAS® (Asynchronous Data Access System) software residing on the VS-100 permits dial-up access to reports and other information for some non-USDA users. The data are being used increasingly for internally managing the identification service and for documenting and communicating with the user community and higher-level USDA management. Objective 4, in which the STS tapes would be searched for biological information by making an exact match on genus-species names,



IIBIII IDENTIFICATION REPORT

Page of
TAXONOMIST
LOT NO.

SENDER

MATERIAL FORWARDED | DATE FORWARDED | PRIORITY | TEL. REPORT Tax.: TSU:
Pinned: Vials: Slides: Other:

Incomplete Identification Code (II)
1 – Species is apparently undescribed
2 – Group now under revision *(Optional – enter name and address of revisor below identification)*
3 – Group needs revision; species are not identifiable
4 – More precise determination depends on characters found in other sex or caste
5 – More precise determination depends on characters found in other life stage
6 – More precise determination depends on genital characters that must be dissected and/or mounted on a slide to be seen
7 – Specimen *(Code)*: C – Critical parts missing P – In poor condition I – Improperly prepared
8 – Known habits of this group suggest specimen is irrelevant to your project; if relevant, resubmit with details
9 – More precise determination depends on knowledge of host
10 – Other *(Specify)*:
11 – No comparable identified specimens in U.S. National Collection

| Specimen/ Vial/Slide/ No. | Family – Genus – Species – Author | Total Number Specimens | No. Specimens Kept | II Code | DB |
|---|---|---|---|---|---|
| | | | | | |

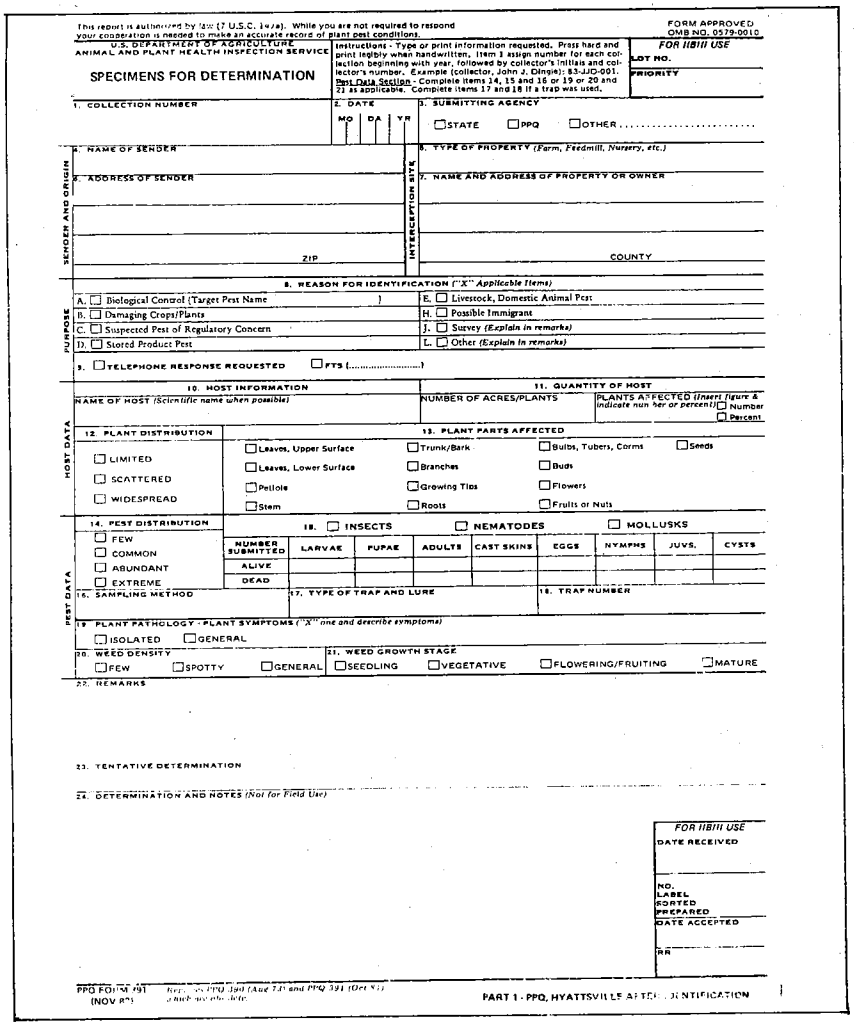
IDENTIFIER DATE

Form NER-626 (Jul 83) USDA-ARS

**Figure 12.** Identifier's report form.

has not been extensively used to date, although we expect that it will see greater use as the database expands.

The active STS database currently requires a dedicated 75-megabyte disk. Information for the current year is maintained online; thus telephone inquiries concerning the status of outstanding requests can be responded to easily and quickly. Data for previous years are archived or maintained on other disk packs as space permits. We plan to adapt and expand the system for computerization of the identification service for fungi, nematodes and vascular plants.



This report is authorized by law (7 U.S.C. 1926). While you are not required to respond your cooperation is needed to make an accurate record of plant pest conditions.

FORM APPROVED OMB NO. 0579-0010

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE

SPECIMENS FOR DETERMINATION

Instructions - Type or print information requested. Press hard and print legibly when handwritten. Item 3 assign number for each collection beginning with year, followed by collector's initials and collector's number. Example (collector, John J. Dingle): 83-JJD-001. Pest Data Section - Complete items 14, 15 and 16 or 19 or 20 and 22 as applicable. Complete items 17 and 18 if a trap was used.

FOR IIBIII USE
LOT NO.
PRIORITY

1. COLLECTION NUMBER
2. DATE MO DA YR
3. SUBMITTING AGENCY ☐STATE ☐PPQ ☐OTHER .....

SENDER AND ORIGIN
4. NAME OF SENDER
5. ADDRESS OF SENDER
ZIP

INFESTATION SITE
6. TYPE OF PROPERTY (Farm, Feedmill, Nursery, etc.)
7. NAME AND ADDRESS OF PROPERTY OR OWNER
COUNTY

PURPOSE
8. REASON FOR IDENTIFICATION ("X" Applicable Items)
A. ☐ Biological Control (Target Pest Name )
B. ☐ Damaging Crops/Plants
C. ☐ Suspected Pest of Regulatory Concern
D. ☐ Stored Product Pest
E. ☐ Livestock, Domestic Animal Pest
H. ☐ Possible Immigrant
J. ☐ Survey (Explain in remarks)
L. ☐ Other (Explain in remarks)

9. ☐ TELEPHONE RESPONSE REQUESTED ☐ FTS (.....)

HOST DATA
10. HOST INFORMATION
NAME OF HOST (Scientific name when possible)
11. QUANTITY OF HOST
NUMBER OF ACRES/PLANTS
PLANTS AFFECTED (Insert figure & indicate number or percent) ☐ Number ☐ Percent
12. PLANT DISTRIBUTION
☐ LIMITED
☐ SCATTERED
☐ WIDESPREAD
13. PLANT PARTS AFFECTED
☐ Leaves, Upper Surface
☐ Leaves, Lower Surface
☐ Petiole
☐ Stem
☐ Trunk/Bark
☐ Branches
☐ Growing Tips
☐ Roots
☐ Bulbs, Tubers, Corms
☐ Buds
☐ Flowers
☐ Fruits or Nuts
☐ Seeds

PEST DATA
14. PEST DISTRIBUTION
☐ FEW
☐ COMMON
☐ ABUNDANT
☐ EXTREME
15. ☐ INSECTS ☐ NEMATODES ☐ MOLLUSKS

| NUMBER SUBMITTED | LARVAE | PUPAE | ADULTS | CAST SKINS | EGGS | NYMPHS | JUVS. | CYSTS |
|---|---|---|---|---|---|---|---|---|
| ALIVE | | | | | | | | |
| DEAD | | | | | | | | |

16. SAMPLING METHOD
17. TYPE OF TRAP AND LURE
18. TRAP NUMBER
19. PLANT PATHOLOGY - PLANT SYMPTOMS ("X" one and describe symptoms)
☐ ISOLATED ☐ GENERAL
20. WEED DENSITY
☐ FEW ☐ SPOTTY ☐ GENERAL
21. WEED GROWTH STAGE
☐ SEEDLING ☐ VEGETATIVE ☐ FLOWERING/FRUITING ☐ MATURE
22. REMARKS
23. TENTATIVE DETERMINATION
24. DETERMINATION AND NOTES (Not for Field Use)

FOR IIBIII USE
DATE RECEIVED
NO.
LABEL
SORTED
PREPARED
DATE ACCEPTED
BY

PPQ FORM 391 (NOV 85) Replaces PPQ 391 (Aug 73) and PPQ 391 (Oct 74) which are obsolete.
PART 1 - PPQ, HYATTSVILLE AFTER IDENTIFICATION

**Figure 13.** APHIS/PPQ identification request form.

## Conclusions

After reviewing the subject of biosystematic and biological control information systems in entomology, several salient points stand out. Systematic entomology is an immense and diverse subject that requires computer technology for mastery of its informational needs. Many ADP projects have been initiated; most are still being developed; some have failed; but for all of the activity, co-ordination among these projects is still very limited. This was the conclusion reached by the Office of Technology Assessment study on biotic diversity data (US Congress, 1986). With the advent of increasingly powerful and less expensive microcomputers, this lack of co-ordination is



becoming an increasingly serious problem. Whereas moving from a paper-orientated information environment to a digital one is essential, creating a modern Tower of Babel where data abound in diverse and incompatible formats must be avoided. The critical task now is to discover who is doing what and to establish common data standards. We hope that by letting others know what we are doing, and what we know about what others are doing, we have made a start on co-ordination.

Enormous information resources exist around the world in the form of unpublished, special-purpose, hardcopy files. Of these, card files are probably the most common. Many of these fall into disuse when the specialist who developed the file becomes inactive. Files become disorganized, forgotten and eventually lost. Management and use of these resources is a major challenge. In the SEL alone, we estimate that there are about 4 million data cards in a variety of files, primarily but not exclusively taxonomic in nature. Files pose no special problems if they are being used or will be used soon as raw material to develop computerized and published catalogues and databases. Other card files, especially those that might have multiple uses, present a more difficult problem.

Seldom, if ever, can databases be made available to as wide a community of users as have use for the information. If the manpower is available, then the funds to procure necessary hardware or software might not be. If databases of interest to large numbers of external users are stored on systems inadequate to support such numbers of remote users (in addition to local users) without significant investments in disk storage, telecommunications ports, or modems, then potential users are likely to remain just that—potential users.

Vast amounts of important potentially valuable data remain locked up in obsolete formats and require costly, difficult conversion for use by newer and more sophisticated software or hardware. Often an organization's personnel may be so completely occupied with the creation and fine tuning of new databases that no time is left to bring old ones up to date. To surmount such challenges will require the concerted, co-ordinated efforts of the scientific community. Yet with all of its promises and problems, computerization in biosystematics and biological control has proved to be indispensable—the single, most important means known of dramatically increasing scientific production.

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