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SCALENET: A SEARCHABLE INFORMATION SYSTEM ON SCALE INSECTS.

ABSTRACT

ScaleNet: a searchable information system on scale insects.

Systematic information on the scale insects of the world is currently being compiled and synthesized in a database system called BASIS. The information is organized by scale insect family and is searchable at a site on the World Wide Web called ScaleNet (http:\\www.sel.barc.usda.gov\scalenet\scalenet.htm). The site provides general information on scale insects, including sections on economic importance, life histories, distribution and ecology, classification and biographies. A query system provides information on valid names and provides a complete systematic catalogue for any valid genus or species. For a particular taxon, queries will give the following information: all hosts of a scale, distribution of a scale, references for a scale, a checklist of all valid species in a family or genus, biological notes and remarks for a scale. It also will give the scales that occur on a particular host, all systematic references on scales that were published between two dates, all references published by an author, all references with any of five selected words in a title or annotations, a list of all scales described by a particular author, all scales from a particular zoogeographic region, country or country subunit, and the scientific name of any common name of a scale.

Key words: BASIS, Biological and systematic information service, Coccoidea, Coccinea, Aclerdidae, Asterolecaniidae, Beesoniidae, Cerococcidae, Coccidae, Conchaspididae, Dactylopiidae, Diaspididae, Eriococcidae, Halimococcidae, Kermesidae, Lecanodiaspididae, Margarodidae, Micrococcidae, Ortheziidae, Phoenicococcidae, Phenacoleachidae, Pseudococcidae, Tachardiidae.

INTRODUCTION

Literature on scale-insect systematics is scattered in more than 11,000 scientific articles and books and has been published in nearly every extinct and extant country in the world. Classification systems, the names of taxa, and taxon descriptions have changed dramatically since the early works in the middle 1700's and often it is difficult for persons interested in a particular group or species of scale insect to determine which concept is currently accepted by the scientific community. This situation results in frustration and confusion for individuals and organizations interested in finding information on scale insects, and often it is necessary for them to consult with a scale-

insect systematist to get an answer to their specific questions. In some situations, this is a workable solution but, in most regions of the world, there are few or no coccidologists available for consultation, and those who do exist could better serve humankind by developing more accurate information about scale insects rather than responding to enquiries prompted primarily because of difficulties in locating current, reliable, organized information on scale insects. A project designed to alleviate some of these problems is the subject of this paper. The project is a queriable website, called **ScaleNet** (http:\\www.sel.barc.usda.gov\scalenet\scalenet.htm), that provides immediate access to systematic, biological and bibliographic information on scale insects and is available to anyone who has access to the Internet. The query system is set up so that a client can discover the information needed in a matter of minutes without consultation with a scale-insect specialist. If additional consultation is still needed, ScaleNet allows clients to send questions to the developers of the system.

In comparison with many other groups of insects, the information on scale insects is relatively well organized. There are more or less up-to-date systematic catalogues on most of the major families, including the Coccidae (Ben-Dov, 1993), Conchaspididae (Ben-Dov, 1981), Diaspididae (Borchsenius, 1966), Eriococcidae (Hoy, 1963), Pseudococcidae (Ben-Dov, 1994), and Tachardiidae (Kapur, 1958). Bibliographies of scale-insect literature have been published covering the period from 1758 to 1985 (Morrison & Renk, 1957; Morrison & Morrison, 1965; Russell *et al.*, 1974; Kosztarab & Kosztarab, 1988) and a bibliographic database is kept up-to-date by the Systematic Entomology Laboratory, US Department of Agriculture, Beltsville, Maryland, USA, and the Virginia Polytechnic Institute and State University in Blacksburg, Virginia, USA. The genus-group names of all scale insects have also been compiled and updated to 1985 (Morrison & Morrison, 1966; Russell, 1970; Kosztarab & Russell, 1974; Kosztarab *et al.*, 1986).

The information described above has been the basis of the ScaleNet initiative, especially the scale-insect bibliographies and the Coccidae and Pseudococcidae catalogues as computerized databases. The process of developing ScaleNet was complicated and ultimately involved collaborators from industry and scientific organizations in Canada, Israel and the United States. Significant funding was provided by the Binational Agricultural Research & Development Fund (BARD). With appropriate financial support, the first step was to find a database system that could handle complex relational catalogue information and at the same time could be used as a resource for developing a queriable website on the Internet. Fortunately, Gary Gibson had already developed such a system called BASIS (Biological

and Systematic Information System) and, with a few scale-insect enhancements and modifications, it worked beautifully. The next step was to enter as many references of scale-insect publications into the BASIS system as possible because bibliographic information is the keystone of the BASIS system. Contracts were written to input data from the published bibliographies, to convert various bibliographic databases developed by co-operators from Procite into BASIS (Karen Veilleux and Michael Kosztarab from Virginia Polytechnic Institute and State University, USA) and to update and keep the reference files current. The next step was to develop an interface between the BASIS database and the World Wide Web and to write programs for the query system. Richard Carson & Associates, Advanced Research Division, Reston, Virginia, USA, was awarded the contract and, through the efforts of Jane Lemmer, Robert Todd and Arek Grantham, the system became available on the Internet in 1996. Enhancements will continue for the next year, when a complete system of queries will be available.

Once a preliminary bibliographic file was developed, and web software was implemented, it was possible to begin adding systematic data on the various families. The Coccidae and Pseudococcidae data that had been used to generate the hard-copy catalogues by Ben-Dov (1993, 1994) were resident in a database system developed in The Natural History Museum in London, and these were converted to BASIS by Gary Gibson and Jennifer Read. It was a laborious task for the Israeli team of Yair Ben-Dov, Viktoria German and Yulia Bir to add new and modified data to the pseudococcid and coccid data files so that the information was brought up-to-date and consistent with the BASIS format. When this was accomplished, more than one third of the scale-insect species were available in ScaleNet. The Israeli team has also completed the Conchaspididae file which is available on the Internet and currently has preliminary files for the Aclerdidae, Asterolecaniidae, Beesoniidae, Dactylopiidae, Lecanodiaspididae and Tachardiidae. The United States team of Dug Miller and Maren Gimpel has completed the Eriococcidae and Ortheziidae files, which are now available on ScaleNet, and have preliminary files for the Cerococcidae, Halimococcidae, Kermesidae, Micrococcidae, Phoenicococcidae and Phenacoleachidae. A catalogue of the Margarodidae is currently being written by Imre Foldi (Museum National d'Histoire Naturelle, Paris, France), and it is anticipated that this will be the basis of the margarodid file in ScaleNet. Karen Veilleux is constantly adding new data to the bibliographic database which now comprises more than 11,000 records and is expanding at over 500 references each year.

The most important task remaining is to complete the Diaspididae. This

project has been divided between the two teams; the Israeli team is inputting the data for the Aspidiotinae and related groups and the US team is entering data for the Diaspidinae. Most of the armoured scale genera has been entered by the Israeli team and the US group is actively inputting data on the Diaspidinae. It is anticipated that this task will be completed by the end of 2000. In the interim, hard copy editions of each family will be published, and the entire electronic system will be updated annually. It is also anticipated that a new Coccoidea bibliography will be published after all families are available in ScaleNet.

RESULTS

ScaleNet provides various kinds of information on scale insects. The home page provides a number of options that allow access to information on scale insects. One section of ScaleNet deals with general information, providing an introduction to ScaleNet itself, a description of the BASIS database system, and information on collaborators and funding sources. In addition, there are general discussions about scale insects, including economic importance, life histories, distribution and ecology, classification and references to biographies of deceased coccidologists. A miscellaneous section provides a glossary of terms, maps of the world and publications that have resulted from the ScaleNet initiative.

The most valuable portion of the ScaleNet site is the query system. Specific instructions on the various queries are given in the background section of ScaleNet. As clients can link to these instructions from each query, they will not be repeated here. For the purposes of this paper, we will restrict ourselves to a brief description of the query system and the kinds of information that can be obtained.

In order to access a significant portion of the information available in ScaleNet, it is essential to know the valid or correct name of the taxon in question. To use this query, click on "**Find a Valid Name and Catalog**" on the query page. The client will be asked to provide a family, genus and species name (if the family is unknown use "ALL"). For example, if they wish to know the correct name of *Conchaspis baiensis,* they type "*Conchaspis"* in the genus field and "*baiensis*" in the species field, and choose "all" in the family field. The response will be *"Conchaspis angraeci* Cockerell (Family Conchaspididae) is the valid name." This query is useful for clients who need to know if a name used in the literature is still valid or if they need the author or family name of the taxon in question. Below the valid name statement are

three options to retrieve a taxonomic catalogue: 1) the species, 2) the genus, and 3) all of the species in the genus. If the first option is selected, the output will be a catalogue of *Conchaspis angraeci* that includes the following sections: Synonymy, Common Names, Distribution, Associations (hosts), Citations, Keys (references to any time that the species or genus was used in a key) and Remarks. The "valid name and catalog" query also outputs information on homonyms or misidentifications involving the entered name, so that the client has the option of selecting the valid name that is pertinent to their query. For example, if a client wanted information on the name *Opisthoscelis globosa*, based on some literature record or identification, they would type *"Opisthoscelis"* in the genus field, *"globosa"* in the species field, and Eriococcidae (or "ALL") in the family field. They would receive the following reply: "*Opisthoscelis globosa* Rübsaamen (Family Eriococcidae) is the valid name (originally described from AUSTRALIA: New South Wales, on *Eucalyptus*) BUT there is another species that once had the same name *Opisthoscelis globosa* Froggatt (Family Eriococcidae) (originally described from AUSTRALIA: Victoria, on *Eucalyptus* sp., by C. French and New South Wales, by Honsby) and its valid name is *Opisthoscelis ruebsaameni."* Therefore, if the client was looking for information about *Opisthoscelis globosa* Froggatt, they would need to locate a catalogue of *Opisthoscelis ruebsaameni* not *O. globosa* Rübsaamen. Catalogue options for the valid name of the homonym or misidentification can be accessed directly from the valid name statement without the need to run another query. If a request is made for a valid subspecies (and the subspecies is valid), clients will be given four catalogue options, including a catalogue of the subspecies.

After the valid name of the taxon in question is known, several specific queries can be made, such as "**Hosts of a Scale**," "**Distribution of a Scale**," "**References for a Scale**," or "**Remarks for a Scale**." These queries are straight forward, requiring the client to fill in the genus field and species field, and to choose a name from the choices in the family field. Output is all of the known hosts, distribution, references or remarks for a scale. **The known hosts and distribution queries include links to one or more references that validate each record**. The "remarks" query outputs separate sections giving information on the systematics, structure, biology, economic importance and control, and general remarks for any scale species. The "Scales in a Family/Genus" query requires input of a valid family or valid family and genus name and the output is a checklist of the valid species in the taxon requested.

In addition, there is a series of queries that do not require a valid name. For the "**Scales on a Host**" query, the client has the option of entering one or more of the host family, host genus and host species. The client can enter only a Host Family (and be given a table including all of the scales on the selected family), or a Host Genus alone (and be given a table of all of the scales on the selected genus), or a Host Genus and Host Species name alone (and be given a table with all of the scales that occur on the selected host species). The resulting table has column headings for: Scale Family, Genus, Species, Subspecies, Author (of the scale species) and Validation Source (reference where the host record was published). The validation source is hot linked (i.e. by clicking the mouse on the source, a full reference will be provided) so that the complete reference and associated annotations that describe the contents of the publication can be retrieved. Each species name is hot linked so that the client can immediately produce a complete catalogue for any of the scale species.

A query for "**References Between Two Dates**" was designed for clients to find all of the scale-insect literature published between two dates. Click on this choice and the client is given a screen that allows entry of a Begin Date and End Date. If the latter is not filled in, the default is the current year. There is a restriction of no more than a 10 year span. The result of this query is a list of all of the references in the database between the years selected, including the associated annotations for each reference.

The "**Reference for a Citation Code**" query was programmed to allow clients to find a complete reference for any citation code that is encountered in ScaleNet. Each reference in the BASIS database is designated by a unique code that is formed from the names of the authors and the date. For example, the citation code for Cockerell & Bueker 1930a is CockerBu1930a. In most query outputs this code is hot-linked to the reference, so that a client can simply click on the code to receive a complete citation and associated annotations. In a few instances, however, direct hot-linking was not possible, so a query was developed to allow clients to determine the complete reference citation for any unknown citation code. If a citation code is found that is not already hot-linked to a reference, the client can either use the Internet browser's "copy" option to copy it, or "<Control> C." Then go to the "Reference for a Citation Code" selection. When this option is selected, the next screen is a blank field to enter a citation code, in which the client pastes the copied citation code with "<Control> V" or the browser "paste" option. Thus, if "CockerBu1930a" is entered in the "Reference for a Citation Code" query, ScaleNet will return the complete reference and any associated

annotations. Please be aware that when entering citation codes, they are case sensitive. That is, you must have capital letters in the correct positions. This is another reason for "copying" and "pasting" the codes.

When a client clicks on the "**References for an Author**" option, the resulting screen provides blank fields for the last name of an author. When entering this information, be certain that the capitals, hyphens and diacritical marks are in the correct place. Directions for obtaining diacritical marks to place in the blank field are given in the instruction section for the query. The output for this query is a list of references by the author selected, including junior author papers. The client is given the option of including begin and end dates. The list includes the complete reference and associated annotations and gives papers of all authors with the selected last name. Clients should be aware that multiple authors with the same last name will be obtained in this query. Therefore, if a request was submitted for papers by Williams, the resulting output would include papers by D.F. Williams, D.J. Williams, J.R. Williams, K.S. Williams, L. Williams, M.L. Williams, P. Williams, and R.N. Williams!

"**References with Words in Article Title/Journal Title/Notes**" is a powerful query, but is a bit complicated. Click on this selection and the client will be given a screen with the option of entering from one to five words that they would like to search for in the article title, journal title, or associated annotations of the references. The client also has the opportunity to limit the search with the last name of an author and the begin and end year of publication. Thus, if the first word field is filled in with "apple", the output will be a list of approximately 115 references and the associated annotations. Several of these will have hits on the word "pineapple." This problem can be alleviated by putting a space before the word apple, i.e. if "_apple" is submitted, the output will include about 80 hits. Adding new words in the word fields will restrict the number of hits. Please be aware that this query is case sensitive, i.e. if all papers with apple in them are required, separate searches with "_Apple" and "_apple" must be made. The alternative is to search for "pple" but this might add other inappropriate references with words like "supplement." If a person wanted to find literature on the pink hibiscus mealybug (*Maconellicoccus hirsutus*), a search using the words "Maconellicoccus" and "hirsutus" would give a list of 34 references. A query using "ealybug" for a person interested in the literature on mealybugs gives more than 700 references and a search using "ealybug" with a year restriction of 1980 to 1990 gives 258 references. Use of "itrus" and "ealybug" for someone interested in the citrus mealybug gives 48 references.

"**Scales Described by an Author**" is a query designed to list all of the taxa described by a particular author. If a client chooses this selection, they will be given a screen that requires the last name of an author. When entering this information, it is important to put capital letters, hyphens and special characters in the correct place. The query can be restricted by including a begin and end date. If this isn't included, the default is to provide all of the scales described by the author. By clicking on the appropriate circle, the client is given the option of receiving the generic names described by the author, the species names or the subspecies names. The output for this query is a list of scales described by the selected author. The list includes the cited name, year, current status of the name and the valid name. We did not distinguish between authors with the same last name, so a list might include species described by more than one person.

"**Scales from a Zoogeographic Region/County or Country Subunit on a Host"** provides a checklist of all of the species of scale insects that occur in a specified geographical area. Click on this selection and a client is given the option of choosing any of the geographic units listed in a picklist. The choices will include any of the zoogeographic regions, countries within the selected zoogeographic region, and subunits within the selected country. The results will give all of the scale species that occur in the selected zoogeographic region, country or country subunit. Clients also have the option of restricting the query by choosing a host plant and will be able to fill in any of host family, host genus and host species. The same selection criteria are used for this query as were used in the "Scales on a Host" query described earlier. Clients also have the option of choosing a scale family to restrict the query further. The results give all of the scale species in one or "ALL" scale families that occur in a particular zoogeographic region, country or country subunit on a particular host plant (host family, host genus, or host species).

"**Find a Scientific Name of a Scale Known only by a Common Name"** is a query designed to assist clients who want more information about a scale insect but know only a common name. Selection of this query gives a screen with a common name field which is filled in by the client. Capital letters should only be used when a proper name is part of the common name, e.g., Putnam scale; small letters should be used when there are no proper names, e.g., white peach scale. Output from this query is one or more valid scientific names. These names will be hot-linked and a catalogue for the species will be displayed when the scientific name is clicked. Currently, most common names in ScaleNet are in English, but we are constantly adding names in

other languages. A scale-insect species may have several different common names. For example, *Saissetia oleae* (Olivier) is called "the black scale" in North America and is "the olive scale" in Mediterranean areas. If a client fails to retrieve information under one common name, it may be necessary to try another one, if known.

DISCUSSION

ScaleNet is a valuable and easily accessible information resource on scale insects. As more families are included in the system, it will become more and more comprehensive and thus more and more useful. Current (optimistic) plans are for the first round of data entry to be completed by the end of the year 2000. After that time, the system will be updated on an annual or more frequent basis as needed. Future enhancements of the system might involve additional query options; or increasing the information content of ScaleNet by including a companion database covering all of the natural enemies of scale insects; or a system of images with an illustration or photograph of each species and a description; or unpublished specimen-label information from all of the various museums with scale-insect holdings. There are numerous other possibilities. The primary issue, of course, is funding

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INTERPRETIVE SUMMARY

Scale insects cause millions of dollars in damage each year, but information relating to the group is found in thousands of scientific journals and books and is difficult or impossible to locate. A new web site called "ScaleNet" provides access to this diverse information through a series of synthetic and user-friendly queries. In order to put information in ScaleNet, it is necessary to validate certain taxonomic changes in print. The purpose of this paper is to describe the ScaleNet system and give instructions on how to use the query system. This information will benefit all who are interested in the control, ecology, life history, pest exclusion and pest management of scale insects, including home-owners, nurserymen, quarantine specialists, extension agents, and state and university researchers.

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