

Using the tools of the information age to enhance research and management of the Southern Pine Beetle*

Scott M. Salom^{1,†}, Nicholas D. Stone¹, Stephen R. Clarke², Jeffrey G. Fidgen¹, Brian Ward¹,
Quintin McClellan¹ & Brinkley Benson¹

¹*Department of Entomology, Virginia Polytechnic and State University, 216 Price Hall, Blacksburg, VA 24061-0319, U.S.A.*

²*USDA Forest Service, Forest Health, 701 N. 1st. St., Lufkin, TX 75901, U.S.A.*

[†]*Author for correspondence: (Tel.: (+540) 231 2794; Fax: (+540) 231 9131; E-mail: salom@vt.edu)*

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Abstract

The Southern Pine Beetle (SPB) is a major pest in southern U.S.A., Mexico, and Central America. Enormous resources in terms of funding, personnel, and effort have been allocated for research and development of pest management tools for this pest over the past century. Access to information from journal articles, reports, fact sheets, etc. does require some effort and is often incomplete and difficult to obtain. The emergence of the Internet now allows rapid access to information from diverse sources. We have created a comprehensive website entitled, 'The Southern Pine Beetle Internet Control Center' (SPBICC) (www.spbicc.vt.edu). The goal of the site is to provide all available resources on SPB to anyone with access to the Internet. It is also designed to increase communication among researchers and professionals to help advance the management of this pest. The site is interactive, which permits constant updating without contacting a webmaster. Attributes of the site include background information in the form of fact sheets, reviews, and government handbooks; an interactive diagnostic identification key for SPB and other bark beetles; a searchable expertise directory; a calendar of SPB-related events; a discussion forum; an online SPB spot growth predictive model; a searchable bibliographic database; a webcrawler designed to search for SPB-related websites, and more. Web-based tools were developed to integrate relational databases as the functional base of this site. The dynamic nature of the SPBICC makes it a powerful tool and a model for development of websites for other major agricultural or forest pests.

Introduction

The Southern Pine Beetle (SPB), *Dendroctonus frontalis* Zimmerman (Coleoptera: Scolytidae), is considered the most serious insect pest of pine forests in the southern U.S. (Salom *et al.* 1998), with yearly losses estimated as high as US\$237 million (Price *et al.* 1992). The devastating impact of this pest led to a national federal research initiative in the 1970s called the Expanded Southern Pine

Beetle Research and Application Program (ESPBRAP) (Thatcher *et al.* 1980), followed by a second initiative in the 1980s called the Integrated Pest Management Research, Development, and Applications Program for Bark Beetles of Southern Pines (Branham & Thatcher 1985). These along with previous and more recent research and development efforts have resulted in over 2000 published articles on all aspects of SPB biology, impact, and control (Stone *et al.* 2001). This information has tremendous value to foresters, homeowners, researchers, and policy makers. However, access has been problematic because the information is dispersed among so many sources. Research results

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and impact information can be found in textbooks (Kulhavy & Miller 1989), textbook chapters (Flamm *et al.* 1988), journal articles (Clarke *et al.* 1999; Ungerer *et al.* 1999), compilations (Thatcher *et al.* 1980), government handbooks (Billings 1980; Goyer *et al.* 1985), factsheets (Salom 1997; Horton & Ellis 1999; Townsend & Rieske-Kinney 2000), videos (USDA Forest Service 1992), and more recently the Internet (McClellan & Salom 1996; Foltz & Meeker 1998). Practitioners who want access to existing pest management tools, like the Arkansas SPB Spot Growth Model (Lih & Stephen 1987), often need to contact the tool developer. Even such fundamental information as the current status of SPB infestations in the South is available only to a small group of professionals in state and federal agencies.

In recent years, cooperative research efforts have not come close to the level of collaboration achieved in the federal initiatives mentioned above. An SPB workshop held at the 1998 Southern Forest Insect Work Conference in Asheville, NC, U.S.A., attended by over 40 researchers and professional entomologists, identified lack of communication among research and user groups as one of several important barriers to cooperation among professionals working with SPB. The same group made four important suggestions to enhance cooperative efforts:

1. Compile and analyze existing data.
2. Produce a directory of researchers and professionals involved in SPB research and control.
3. Update the SPB annotated bibliography (Kulhavy & Johnson 1983).
4. Enhance the ability of resource managers to respond to outbreaks.

The emergence of the Internet and especially the world-wide web in the mid-1990s has had tremendous impact on entomology education and research (Zenger & Walker 2000). Over 180 million people in the U.S.A. and Canada alone and an estimated 459 million people worldwide have access to the Internet (Featherly 2001). Information is now just a few clicks and keystrokes away for anyone with an Internet connection.

Most websites that provide forest entomology information do so in the form of fact sheets duplicated from hard copy versions (USDA Forest Service 2001) or created for the web (Douce 2000). There are a few sites that present comprehensive life history and pest management information for a specific forest insect pest such as gypsy moth, *Lymantria dispar* (L.) (Liebhold

1998; Roberts 2001), SPB (McClellan & Salom 1996; Foltz & Meeker 1998), and Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (USDA APHIS 2001). There are also numerous research sites that provide comprehensive reviews of specific forest entomology research programs (Byers 1996; Coulson 2000; Dahlsten 2001, and many more). All these sites are considered static – in that information flow is in one direction, from computer to the reader, and they require continued maintenance by a webmaster for updating information.

Current advancements in delivering information over the web have focused on making the web dynamic and integrated with other computer services. Web pages can access databases and can be the interface to programs running on remote servers. Based on these new capabilities, our objective was to build such a dynamic website for SPB: comprehensive, interactive, and collaborative web-based delivery system for all current information, and management tools concerning the prediction, evaluation and treatment of SPB. We believe that this approach can serve as a model for development of other websites for major forest pests, or for any dispersed group of researchers, managers, and others that require access to timely and comprehensive information. The site was also developed to enhance communication among SPB researchers and help forge cooperative research within the scientific community. This paper describes the site's development, attributes, and potential application.

Website Concept

The Southern Pine Beetle Internet Control Center (SPBICC), located at www.spbicc.vt.edu (Stone *et al.* 2001), is designed to be the repository for SPB information, control strategies, research, and other ongoing activities. It also emphasizes communication among the research and professional community that work on SPB. The site was developed as an integrated web-database application, in which most of the pages served are generated from a combination of HTML templates and data stored in a relational database. The site was designed to be maintained by its members. Site administration is handled through built-in forms and functions, allowing collaborators to log in and update information themselves, including descriptions of their own expertise as well as the ability to add content pages and links dynamically. Central updating and maintenance is therefore minimal.

Website Highlights

Home page

A one page introduction into the website. It provides links to the different sections, and continuously updated summaries from News and Announcements and SPB calendar sections. The contributor's login button (in the lower left) takes the user to a login screen (if necessary) and then to a personalized 'control panel' allowing that user to edit his or her information and update site information. This is described below in detail.

About SPB

The objective of this section is to provide an overview of the identification, biology, and control of SPB and its associates. Links to relevant information-based sites are listed. An interactive identification program was developed to help users identify different southern pine bark beetles, using *WhizID*[®], a diagnostic tool developed at Virginia Tech for building web-based identification programs. Experts have been invited to prepare in depth reviews on population dynamics, natural enemies, insect–fungal–host relations, chemical ecology, host-plant-resistance, and integrated pest management. At the time of this writing, four of the reviews have been completed and are included in SPBICC.

Networking

Using the *WhizCal*[®] utility developed at Virginia Tech (Stone *et al.* 1996), we created a *Calendar of Events* that provides information on upcoming meetings and events. We have tried to enter events occurring within the next two years. Up to seven upcoming events from the calendar are shown on the home page. Events are also searchable from the search menu and from the 'site search' feature (see below).

An *Expertise Directory* lists scientists and professionals having working experience with SPB. Users can join the SPBICC by filling in a form online, and once registered, they then enter information about themselves and their SPB expertise. The input to the database can be as extensive as the person wishes, within some limitations. By describing their expertise, including relevant keywords, regions, and species or taxa which they are familiar with, the person makes it possible for others to find experts by searching for information or asking for help on a topic. The SPBICC members can access the directory at anytime to edit or

add information through their personal control panel which is accessed via the 'Contributor's Login' button at the lower-left corner of each page. Access to an individual's information in the database is password protected.

A *Discussion Forum* allows the SPBICC members and guests to carry on discussions on several topics over time. The forum is a 'threaded discussion' meaning that people can create new discussion topics by posting a message, or they can add their input to an existing topic by responding to a message already posted. The site keeps track of the messages and their responses in a hierarchical list that's easy to navigate. People posting messages can mark them, 'requests for help,' in which case people who have relevant expertise on the topic of the request are sent e-mail notifications about the request. A link to the site in the e-mail lets them easily read the posting and respond, if appropriate. Additionally, people who have posted messages are notified when others post responses to their messages.

Infestations

Links to current pheromone trapping data for predicting SPB regional trends (Billings 1988) are in place as well as websites developed and maintained by individual state agencies. An effort to develop an interface through the SPBICC with USDA Forest Service Southern Pine Beetle Information System (SPBIS) (Peacher 1999) has not yet been accomplished but is planned for the future when a PC version of SPBIS becomes available. This will allow access to continually updated information on specific SPB infestations on National Forests throughout the southern U.S.

Workshops

Links are provided to online training workshops, which at this time includes only the Verbenone Online Workshop (McClellan & Salom 1997). Other workshops will be added as they become available.

Toolbox

Online USDA Forest Service publications on direct and indirect control of SPB are linked here. The Arkansas SPB Spot Growth Model (Lih & Stephen 1987) has been rewritten in Java as a servlet and is now online (Satterlee *et al.* 2001). This model can be used to

predict growth or decline of individual SPB infestations based on required data input. Once submitted, the graphical prediction is immediately presented to the user.

Library

The annotated bibliography of SPB from 1868 to 1982 (Kulhavy & Johnson 1983) was put online in 2000. It was electronically scanned, converted to text, parsed into data fields (authors, title, abstract, keywords, etc.), and incorporated into the database. Since then we have added as many SPB-related publications as we can find, published since 1982. Over 2000 references have been compiled in the bibliography. Users can search these by author name, keyword, or organism. The result is a list of all the relevant citations and abstracts from the database. The SPBICC collaborators can also add new references to the system after logging in.

Search

The search option is available on each main topic page, and there is also a page dedicated solely to search. Users can search separately or together for events, people with a particular expertise, relevant web links, discussion topics, and bibliographic entries. For the web search, LiveLink[®] is used, a web spider and indexing tool available at Virginia Tech.

Functional Components that Drive the Website

Database

A website that requires little maintenance, yet is automatically kept up-to-date, relies on most of its content being stored in a database. This allows the separation of the content from the format so that authorized contributors to the site can easily add and edit information (tutorials, fact sheets, reference information, SPBIS data sent to us, calendar events, bibliographic entries, expertise entries, SPB URLs, and much more) solely through the web. Using this interface model, we eliminated the trials of keeping track of multiple versions of documents, requiring users to use FTP, and of having an author or webmaster edit HTML code when all they want to do is correct a spelling error. Using a database ensures that only 'Hot or New' information is displayed on the homepage and that the list of current calendar events is kept current.

Oracle 8[®] was chosen as the database management system (DBMS). This decision was influenced by the fact that the USDA Forest Service already uses *Oracle* for some databases (i.e. SPBIS). We also installed and evaluated *Informix[®]*, *Access[®]*, *Filemaker[®]*, and *Frontier[®]* DBMSs, and found *Oracle* to be the best choice. *Oracle* is the most powerful and most flexible for our needs.

In addition to the DBMS, tools for designing and building the database were evaluated. *Oracle Designer[®]* was originally chosen for building the entity relationship diagram (ERD) and server model. It seemed to perform well initially, but over time, the lack of good documentation and problems linking the Designer and the database caused us to abandon this tool and use SQL (standard query language) statements to manipulate the database design.

Middleware

Middleware is the software that provides the link between the database and the Web. Middleware processes database information into web pages and conversely takes data entered into a web page form and stores it in the database. Choosing the proper middleware solution was the key to making our idea of a dynamically generated website with separated content, formatting, and functionality a reality. There are many commercial middleware packages for such things as e-commerce and other business functions. We needed one that was full-featured, customizable, easy for a non-programmer to use, and reasonably priced. We looked at many and focused on four packages: *WebObjects[®]*, *ColdFusion[®]*, *Oracle WebDB[®]*, and *Frontier*. None of the commercial packages served our needs well. Therefore, we chose to combine the strengths of each by creating our own middleware solution, *StoneFission[©]*. *StoneFission* is a Java servlet (taking advantage of the power of the *WebObjects* solution) that is customizable. This approach allowed us to create our own tags (as in *Cold Fusion*) that the author can insert into their web pages. Many of these tags provide the functionality of *Frontier* so that authors can be involved solely with the content and let designers take care of the website design (format and function). *StoneFission*, since it is simpler than the other packages, should be much more stable. Because it is written in Java as a standard servlet, it is a cross-platform solution that integrates smoothly with the standard web servers, like *Apache[®]*.

Search engine

Our site makes use of a search engine that locates and catalogs relevant SPB and related material that is published on the web, and then makes that information available to our users in the form of a 'sub-web' to search. Thus user searches for SPB information will be much faster and have a much greater chance of finding relevant information than when using the commercial search engines available on the web. Ideally, our search engine would compile the catalog (or index as it is often called) into hierarchical categories that would allow the catalogue to be both 'searched' and 'browsed'. 'Browsing' is what one can do at *Yahoo* by clicking on general keyword categories and 'drilling down' to more specific categories until you reach the desired information. We found this capability in two search engines: Infoseek's *UltraSeek* (done automatically) and Netscape's *Compass Server* (requires more manual direction).

We are currently using a much less powerful search engine, OpenText's *LiveLink*[®] Search and Spider. This search engine does not have the capabilities described above. We can specify where it searches for information by giving it a list of starting URLs of known good sources of SPB info and then letting *LiveLink*'s spider follow links as it finds them for a predetermined distance. This works fairly well for picking up information, but does not do a good job at eliminating superfluous material. *LiveLink* was an expeditious choice: Virginia Tech had a site license for the search engine, so it gave us the best benefit for the cost.

We do not use *LiveLink* to build an index of our own site. Instead, since the rest of our site is served out of a database, we use database queries to find relevant pages and topics within SPBICC.

Bibliography

There are several 'standards' for how to store bibliographic material in databases (one example being the *MARC* standard used by the Library of Congress). We looked at the costs and benefits of using such standards. The chief benefit of a standard is the ease in moving bibliographic material from one database to another, because all the fields are the same (in name and type). The primary cost of using such standards is twofold. First, there is the time required to break down each bibliographic entry into that level of detail. This is very time/labor intensive, especially when a large bibliography already exists that is not already described

in such a fashion (as is our case). The second cost is the programming effort required to create the display and downloading engine required to allow users to download the bibliographic entries as text files in that detailed format. Whether detailed standards are used or not is important in how the results of a bibliographic search can be displayed. We opted for simplicity over standardizing to a complex specification. Our data-model stores the year, title, citation source, and abstract in four fields for each publication. The list of authors is recorded in another table, and keywords and relevant taxa are optionally recorded as well. This simple design lets us handle a wide variety of publication types and permits reasonable formatting for output.

Another reason for using our own limited standard was that it allowed us to integrate our bibliography database with our expertise database. Authors could also be experts *without* having to enter data such as name and publications more than once.

We explored the impact of our decision about standards on how users could enter bibliographic entries found in our database into their own personnel bibliographic databases such as *ProCite*, *EndNote*, or *Reference Manager*. Our standard would not allow automated entry into these applications without the use of a filter, which the user can generate. If there is sufficient demand, it will be possible to create filters and place them on our website for download.

Other web utilities

The Information Systems and Insect Studies (ISIS) lab at Virginia Tech has already developed numerous web-based utilities including *WhizQuiz*[®] (self-assessment tool), *WhizQuest*[®] (questionnaire tool), *WhizCal*, and *WhizID*. Using the power of *StoneFission*, we have integrated these tools into our web site in such a manner so as to greatly facilitate the sense of community, involvement, and the amount of learning that can take place at the SPBICC website.

Potential Scenarios

The SPBICC is not just a site to be used by researchers or professionals. Rather, it aspires to provide something for everyone. While the following scenarios are fictional, we drew on our past experiences and interactions with the public and our colleagues to make them as realistic as possible. Of course they only provide a sample of the possibilities.

High school student

Charity Boles, a 10th grade student from Alabama, has chosen to write a report on SPB as a term paper for her science class. She wants to emphasize information on the identification, biology, control of SPB, and its recent impacts within the state of Alabama. Charity's school and town library have very little information to offer her. Therefore, she decides to 'surf' the web and see what information she can find. Her search leads her to a number of sites with information on SPB, some are brief presentations and some provide more detail. Quickly, however, she comes upon the SPBICC. Once at the site Charity realizes she has access to all the information she could possibly need to prepare her report.

Charity clicks on the *About SPB* section to learn basic information on the insect. She notes a list of fact sheets prepared by various state and federal agencies. She reads through them and is able to get a good background on SPB biology, life cycle, appearance, and practical control tactics. She also clicks on the subject reviews to get more in depth descriptions of some of the different topics.

She finds information on recent activity of SPB in Alabama by clicking on the *Infestations* section. From there, she clicks on *Infestations by State* and then on *Alabama*. Charity reviews a page maintained by the Alabama Forestry Commission that reports on Alabama's latest SPB activity. She clicks back and then to *Infestations in National Forests*, where she finds a listing of the number of infestations reported by County in Alabama in 2000. She notices that there is a historical record of SPB activity in Alabama from the *Forest Health Atlas* located in the *Forest Health Protection Southern Region* link in the *Networking* section. Alas, the *Atlas* information for SPB is not yet online. But under a publications link from the same site, she finds *Forest Insect and Disease Conditions in the South* dating back to 1996.

Armed with all this information, Charity visits the *Networking* section and clicks on the *Expertise Directory*. Using the key word 'biology' and setting her region to the state of Alabama, she gets the name, 'Wesley Nettleton,' along with his contact information. Charity sends him an e-mail and receives a reply the next day. She then decides to send a message out to the *Discussion Forum* (also in the *Networking* section). She posts the message, and marks the 'request for help' box. Automatically, six SPB experts with experience and knowledge about SPB biology in Alabama are

sent e-mails alerting them to Ms. Bole's request. Two experts respond within the hour and Charity gets an e-mail telling her that someone has answered her posting. One SPBICC visit has brought the world of SPB to this student's computer. Charity Boles gets an A+ on her paper.

Absentee landowner

Forest Cutter, a resident of Florida, owns several hundred acres of land in western North Carolina adjacent to the Grandfather Ranger District in the Pisgah National Forest, in western North Carolina. Mr. Cutter uses the land for summer recreation, but also manages the timber for financial return with the help of a consulting forester. Seventy percent of the forest land is comprised of pine with a high proportion of the species susceptible to SPB. The landowner is very concerned about his pine stands because western North Carolina was under heavy attack by SPB in 2000.

In an effort to be proactive, Forest finds information on SPB from the SPBICC. He is most concerned about the potential for SPB activity occurring on his land. He goes to the *Infestations* section and checks the pheromone trapping link which reports on activity in NC from 2000 and also predicts increased activity on the Grandfather Ranger District in 2001. Mr. Cutter calls his consulting forester and asks him to check his land out and come up with a plan for reducing the susceptibility of his pine forests. The consulting forester goes online to the SPBICC and under the *Toolbox* section clicks on a USDA Forest Service Handbook link on how silviculture can reduce losses to SPB. The forester also surveys Mr. Cutter's land and finds three small and one large infestation. The forester has a general idea of what to do but goes back to the site to read the *IPM Review* of SPB in the *About SPB* section. He has also heard of a new pheromone technique for suppressing small SPB infestations, so he goes to the *Search* page and types 'pheromone suppression.' The first link takes him to the *Verbenone Online Workshop*. When he has questions from reading through the workshop, the forester goes back to the *Networking* page and to the *Expertise Directory* and enters 'verbenone' (the pheromone used in the suppression tactic). Three names come up and the consultant sends an e-mail to each person listed, resulting in a phone call back from an expert the next day. The forester and Mr. Cutter both now feel they can handle the infestations and develop management plans for reducing susceptibility of these stands to SPB attack in the future.

Other Site Users and Uses

Professional Forest Entomologists, typically employed by Federal and State government agencies, can use the SPBICC to train summer technicians by having them read and review the *About SPB* section. In addition to the fact sheets and review sections, they would also spend time running the interactive web-based ID link, until they felt they new how to differentiate between the *Dendroctonus* and *Ips* bark beetle species present in the South. They would also go to the *Toolbox* section to learn more about how to control for SPB.

Professionals can keep track of upcoming meetings by periodically scanning the *SPB Calendar of Events* in the *Networking* section. On call to survey several infestations on National or State Forests, the professional can collect infestation information and then run it through the *Hog Model on the Web*. The professional can use the prediction to help them decide what advice to give the forest manager of the area. Occasionally during routine survey work, professionals or technicians will see certain things within an infestation they have not seen before and would like to know if anyone else has seen the same thing or if anyone can explain what is going on. The professional can go to the Discussion forum in the *Networking* section and post a message making the query with keywords listed to help direct e-mail messages sent out to individuals listed in the Expertise Directory to visit the Discussion Forum and help the person who posted the message. The professional can also contact some experts directly with the help of the Directory.

Research scientists and graduate students will find the Online Annotated SPB Bibliography a useful resource. It is searchable by author or keyword, and will provide the citation and an abstract of all SPB publications ever produced through the year 2000. In addition, if there are publications that were missed or new ones coming out, members of the SPBICC will be able to add them directly to the site. This allows the Directory to remain current with minimal maintenance by the webmaster.

Current Status and Expected Impacts

The use of the Internet to provide information and expand communication among a community of scientists and resource managers is a powerful way to enhance research opportunities and collaborations. The SPBICC site is not designed to replace group meetings,

but rather, to make them more efficient and the time spent between meetings more productive. There are communities of scientists that work on other major forest pests that could also benefit from this level of interaction and information transfer. We believe that the SPBICC can serve as a model for the development of similar sites for these pests. An international meeting such as this is invaluable for increasing communication and interaction among international scientists with similar interests. The SPBICC and similar sites will only serve to enhance our communication and collaborations within the international community.

At this stage, the SPBICC is fully operational, with a few additions planned for the future, including an interface to SPBIS, allowing users instant access to current infestation activity on National Forest lands. Several biological reviews on SPB population dynamics, insect associates, and tree resistance will also be completed within the year. Following these additions to the site, most updating will come from site members, who will have opportunities to add information to the site, with personnel at Virginia Tech responsible for oversight.

Static websites with unidirectional information flow will continue to remain valuable. However, sites using 'distributive maintenance', where contributors of information to the site could edit and update their own documents at the source and the html pages would immediately display this information without requiring 'webmaster' involvement, will be the standard for future website development. With the tools in place for developing such sites, it is only a matter of time before communication among IPM specialists and scientists is elevated to the next level.

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