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Biodiversity

JOURNAL OF LIFE ON EARTH

INVASIVE ALIEN SPECIES

INVASIVE ALIEN SPECIES IN A CHANGING WORLD

To those dedicated to protecting Earth's living organisms.
May there be a place of shelter and refuge for all.

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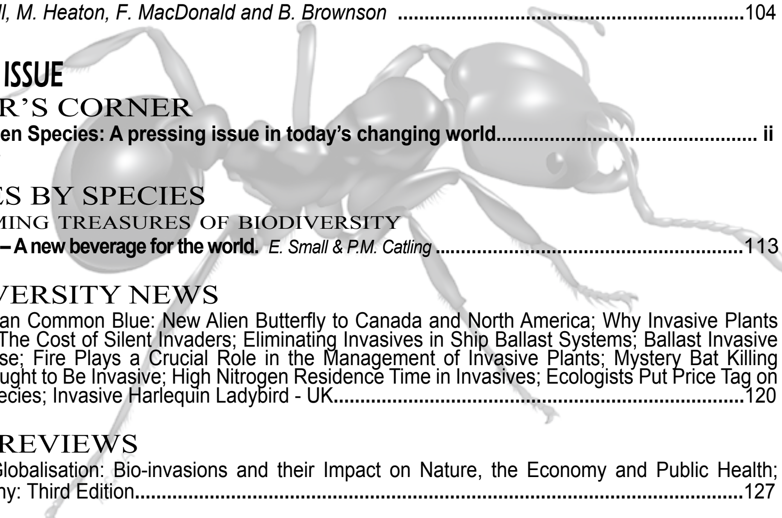

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Front Cover: The Red Imported Fire Ant, *Solenopsis invicta*. (Illustration by Koichi Goka; See article page 67).

Inside Front Cover Art: The Diversity of Life by *Roelof Idema*.

Welcome to Glennis Lewis!

Glennis Lewis has accepted the *Biodiversity* Publication Committee invitation to take on the position of Editor-in-Chief of *Biodiversity*. This special issue on Invasive Alien Species marks the first issue of her tenure. Glennis has been a *Biodiversity* associate for many years. She served on the Special Board of Editors for a special issue on Viruses in 2005 and wrote the Editor's Corner for that same issue.

Dr. Glennis Lewis (Ph.D., LL.B., LL.M) is a Senior Advisor in the Public Health Law and Ethics Program of the Public Health Agency of Canada. She is both a plant ecologist and a lawyer (member of the Alberta Bar). From 1995-96, she served as a temporary member of the National Energy Board and a member of the first joint environmental assessment panel appointed pursuant to the Canadian Environmental Assessment Act. In 1998 she joined the federal public service and worked at Health Canada on a number of important projects, including renewal of the Quarantine Act and establishment of a research ethics board. She also represented Health Canada in the international negotiations of the Cartagena Protocol on Biosafety. Recently, she completed a Masters degree in Law at the University of Ottawa. Her thesis analysed sub-national law applicable to invasive plants in natural ecosystems.

Glennis' research interests include public health law, invasive species law, grassland ecology and conservation of rare species. In 2002, she was awarded a Queen's Jubilee medal for her contributions to the federal public service.Welcome to *Biodiversity* Glennis!

P.T. Dang, Ph.D.
President, Tropical Conservancy

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Invasive species information networks: collaboration at multiple scales for prevention, early detection, and rapid response to invasive alien species

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Abstract. Accurate analysis of present distributions and effective modeling of future distributions of invasive alien species (IAS) are both highly dependent on the availability and accessibility of occurrence data and natural history information about the species. Invasive alien species monitoring and detection networks (such as the Invasive Plant Atlas of New England and the Invasive Plant Atlas of the MidSouth) generate occurrence data at local and regional levels within the United States, which are shared through the US National Institute of Invasive Species Science. The Inter-American Biodiversity Information Network's Invasives Information Network (I3N), facilitates cooperation on sharing invasive species occurrence data throughout the Western Hemisphere. The I3N and other national and regional networks expose their data globally via the Global Invasive Species Information Network (GISIN). International and interdisciplinary cooperation on data sharing strengthens cooperation on strategies and responses to invasions. However, limitations to effective collaboration among invasive species networks leading to successful early detection and rapid response to invasive species include: lack of interoperability; data accessibility; funding; and technical expertise. This paper proposes various solutions to these obstacles at different geographic levels and briefly describes success stories from the invasive species information networks mentioned above. Using biological informatics to facilitate global information sharing is especially critical in invasive species science, as research has shown that one of the best indicators of the invasiveness of a species is whether it has been invasive elsewhere. Data must also be shared across disciplines because natural history information (e.g. diet, predators, habitat requirements, etc.) about a species in its native range is vital for effective prevention, detection, and rapid response to an invasion. Finally, it has been our experience that sharing information, including invasive species dispersal mechanisms and rates, impacts, and prevention and control strategies, enables resource managers and decision-makers to mount a more effective response to biological invasions.

INTRODUCTION

E.O. Wilson (1997) wrote, "Extinction by habitat destruction is like death in an automobile accident: easy to see and assess. Extinction by the invasion of exotic species is like death by disease: gradual, insidious, requiring scientific methods to diagnose." The old adage, "An ounce of prevention is worth a pound of cure" has been used in health advice and fire prevention, and also effectively describes the imbalance of costs associated with preventing versus responding to (and cleaning up after) biological invasions. In their 2005 article, Pimentel *et al.* found that in the US alone, up to $120 billion per year can be attributed to environmental damage and loss caused by invasive alien species (IAS).

Cooperative human networks for the detection of and rapid response to IAS can now be found across the globe, and are proving to be effective at raising awareness and increasing surveillance for IAS. But invasion prevention and IAS early detection by these networks, which usually have a sub-national geographic scope, are only as good as the information that initiates and drives them. Information sharing within and, more importantly, between networks may help shift the balance and reduce costs associated with biological invasions by improving these networks' prevention and early detection capabilities. Participation in early detection and monitoring networks by trained volunteers has greatly increased the amount of information collected about biological invasions, including data that can be used to test the efficacy of control methods and to develop more accurate models of present and future distributions of IAS.

Here we describe examples of IAS detection networks in the United States and beyond our borders, and success stories about effective rapid response. We advocate standardized data collection for effective international sharing of biodiversity and IAS information. This is because natural history information (life cycles, diet, predator/prey relationships, parasites, etc.) about a species where it is native can provide ideas for detection, assessment, and response to a species where it has become invasive. In addition, response and control methods that are effective in one location may also be effective elsewhere.

And finally, the most reliable indication that a species may become invasive is that it is an invader somewhere else (Mack *et al.* 2002). Clearly, sharing IAS data globally can help create reliable species watch lists for invasion prevention and IAS early detection and rapid response. Several comprehensive global indexes and compilations of known IAS, such as Rod Randall's Global Compendium of Weeds (Randall 2002) and Weber's Invasive Plant Species of the World (Weber 2003), have been developed after extensive and time-consuming research and literature review. However, these lists only provide a snapshot in time while new species with invasion potential continue to emerge. It is these species that human networks may not detect unless they have prior knowledge of them or, even better, access to real-time detection and invasion data for effective decision-making.

EXAMPLES OF INFORMATION NETWORKS

Invasive Plant Atlas of New England (IPANE): Created in 2001 to fill information gaps for non-native invasive plants known to occur across the six-state New England region

(Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont), IPANE's over-arching goal has been to establish an early detection network for New England (Figure 1). Volunteers are trained to look for new incursions of both known and anticipated alien invaders, and to gather and submit basic ecological information on invasive plants that encounter on the New England landscape via the IPANE Web site (http://www.ipane.org). IPANE also collects herbarium specimen data from major herbaria in the region. As part of IPANE's multifaceted approach, these data, along with the basic ecological data gathered by more than 700 trained volunteers, are coalesced to build the online information system available in map and database formats to give a composite picture of a species status and distribution in space and time (Figure 2). To date, IPANE volunteers have gathered more than 11,000 individual species occurrence records in New England. These data are used in scientific research to create predictive models, in regulatory actions, and as a basis for environmental monitoring and control efforts.

Figures 1. The Invasive Plant Atlas of New England is a volunteer citizen science network founded in 2001. (Logo used with permission).

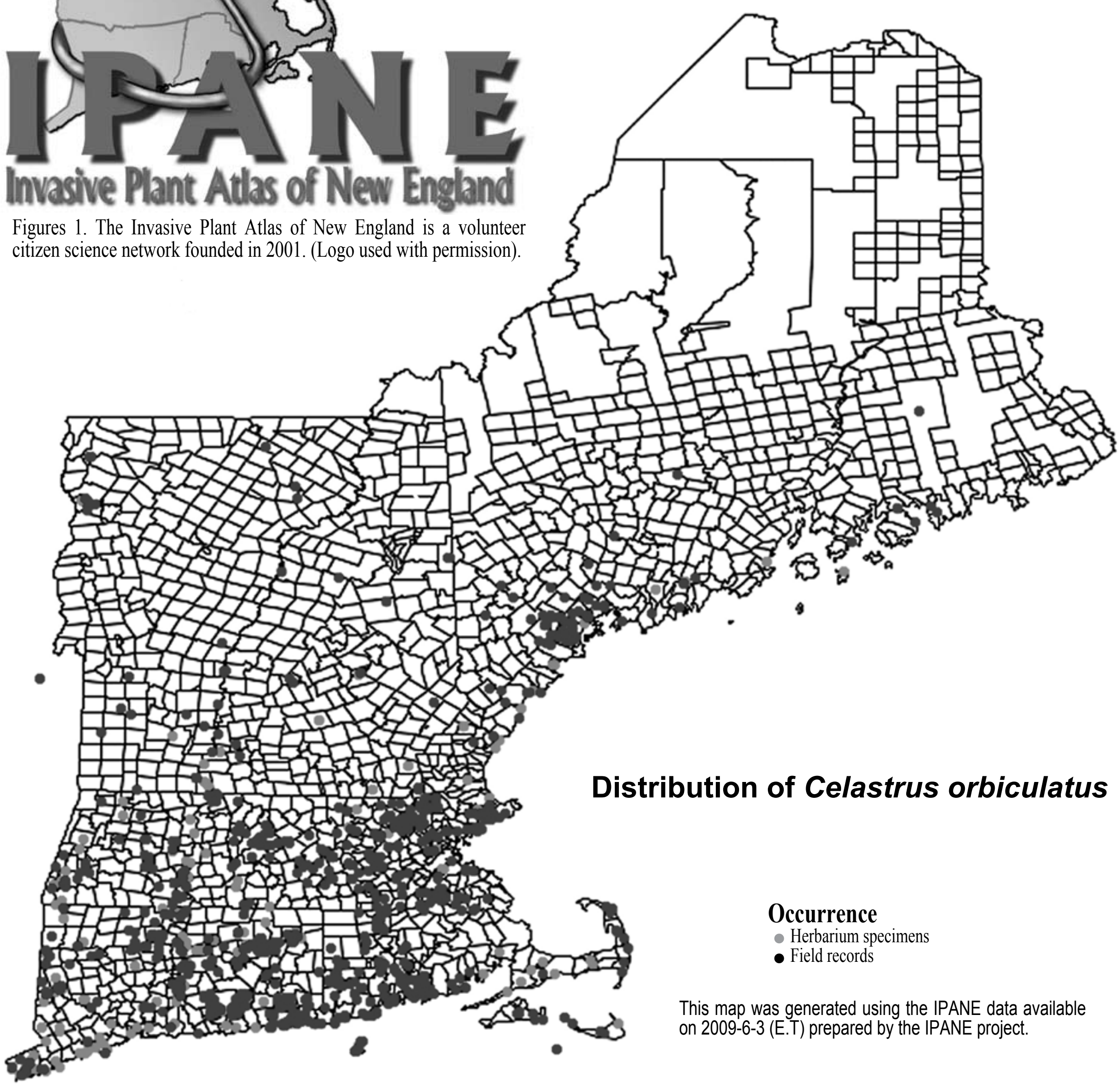


Figure 2. Distribution of oriental bittersweet in New England, based on herbaria and field records. (IPANE).

Invasive Plant Atlas of the Mid-South (IPAMS): The IPAMS database (http://www.gri.msstate.edu/ipams) is modeled after IPANE but centers on the states of Alabama, Arkansas, Louisiana, Mississippi, and Tennessee (Madsen and Ervin 2007). Species information, including management recommendations, forms an important part of the IPAMS Web site. There are more than 6,900 records for 136 invasive plant species from 29 US states, and all data is validated both spatially and taxonomically by an expert. IPAMS allows anyone to register as a user or sign up for e-mail alerts. Even unregistered users can view map features, download data, and report sightings for verification. IPAMS researchers are comparing the accuracy of volunteer data with the systematic survey data of professionals and also creating probabilistic species models. Survey data shows that some species, particularly cogongrass, are not randomly distributed and are utilizing road networks as corridors for dispersal (Ervin 2009a, b). IPAMS research has also examined effects of invasive plants on ecosystem processes (Holly *et al.* 2008) and generated tools to predict the distribution of invasive aquatic plants (Ervin 2008; Madsen and Wersal 2008).

The Cactus Moth Detection and Monitoring Network (CMDMN): The CMDMN (http://www.gri.msstate.edu/cactus_moth) features an online database for the mapping of the invasive Cactus Moth (*Cactoblastis cactorum*) in the United States and Mexico and the distribution of its potential hosts, the cactus species in the genus *Opuntia* (Figure 3). In Australia, the Cactus Moth was successfully used as a biological control of the invasive Pricklypear Cactus, *Opuntia stricta*, during the late 1800's (Zimmerman *et al.* 2000). With the arrival of the Cactus Moth into southern Florida and its initial detection attributed to a lepidopterist in the Florida Keys in 1989 (Solis *et al.* 2004; Simonsen *et al.* 2008), the potential for significant damage to rare native *Opuntia* cactus biodiversity was recognized. This threat, combined with that to cultural and agronomic uses of *Opuntia* cactus, has spurred efforts to control the Cactus Moth in the southeastern United States (Stiling 2002; Zimmerman *et al.* 2000). It has been recognized that dispersal of the Cactus Moth by commercial transport and human activity within the United States may be more significant than natural dispersal processes (Simonsen *et al.* 2008). The CMDMN assists in tracking the range expansion of the Cactus Moth, in mapping pricklypear locations to refine the search for the moth, and in training volunteers to report new infestations, especially along the leading edges of its invasion.

CitSci.org: The CitSci.org Web site, geared toward citizen scientists, hosts tutorials on invasive species issues, data collection, and Web site use (Graham *et al.* 2007). The site is a data repository for invasive species field data, including species sightings locations and metadata, and species and location attributes (e.g., percent cover, soil type). As a means of quality control, citizen science coordinators create projects for their controlled-membership groups. Coordinators also create customized online data entry forms that mirror the paper sheets their volunteers use to collect data. These forms translate the data into a standardized format, efficiently integrating data across projects. Once on the Web, data can be viewed and utilized by anyone using the online mapping application and analysis tools, including resource managers interested in what species are within their area and researchers modeling the distribution of a species (Jarnevich and Stohlgren 2009).

Invasives Information Network of the Inter-American Biodiversity Information Network (IABIN-I3N): In much of the Americas, information on IAS can be nonexistent, unavailable, inaccessible, or incompatible with other datasets. Recognizing these barriers to accessing IAS information, the IABIN endorsed I3N as its first Thematic Network in 2002. I3N offers training workshops on the use of its data management tools; provides small seed grants for digitizing data; and freely distributes a tri-lingual IAS database template upon request. I3N today is a distributed network of interoperable databases on invasive species, experts, projects, and datasets served by national information providers. Each country's information is digitized and controlled locally using the standard I3N IAS database template (described at: http://i3n.iabin.net/tools), and is freely provided via the Web to the international public. Tools that predict the invasive potential of a species and pathways traveled by known invasive species are also available on the I3N Web site. The I3N, which is coordinated by the US National Biological Information Infrastructure (NBII), has attempted to facilitate successful early detection, prevention, and management of IAS throughout the Americas and is an internationally recognized example of successful national and regional collaboration (Simpson *et al.* 2006).

Global Invasive Species Information Network (GISIN): The GISIN (http://www.gisin.org) provides a platform for sharing invasive species data and information at a global level via the Internet and other digital means. Using simple Web services, the GISIN links freely available online invasive species databases and combines IAS data with biodiversity data, such as that served by the Global Biodiversity Information Facility (GBIF). The basic components of the GISIN include at least one, with potential for more, internet portals that allow users to search across multiple data providers; a registry of data providers; and a specification for a Web services protocol to exchange basic IAS data types between servers. When possible, GISIN uses existing biodiversity data exchange standards for content such as species names and geographic locations. The GISIN, which is coordinated by the NBII and numerous other partners, also maintains a comprehensive registry of online information systems that contain freely-available IAS data and information (derived from Sellers *et al.* 2004).

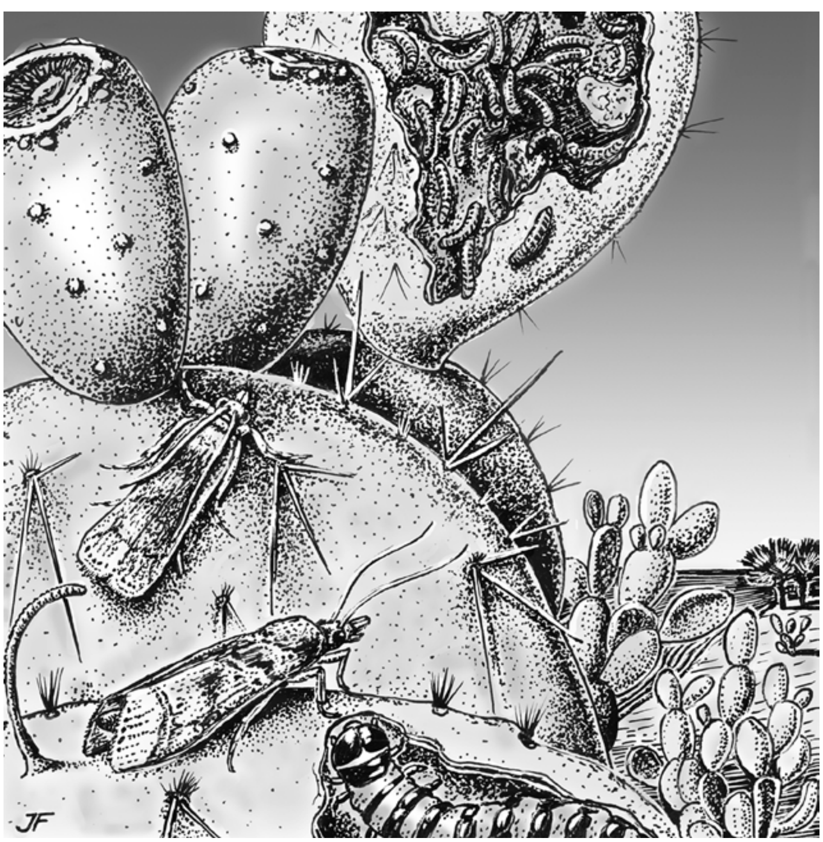
OVERCOMING OBSTACLES

DATA INTEROPERABILITY:

- **Freely-distributed, standardized database template:** The template for the I3N Database on Invasive Alien Species is designed to collect and share standardized information on IAS taxonomy, introduction, biology, ecology, impacts, control methods, occurrence (including geographic data), contacts, projects, and references. The database complies with the Dublin Core and Darwin Core Metadata Standards and allows owners to export their IAS records in the widely accepted Extensible Markup Language (XML). Both the I3N database template and a Web template are made freely available in English, Portuguese, or Spanish to anyone requesting a copy.

- **Information protocol for database cross-search**: The GISIN has developed a specification for a Web services protocol to share disparate datasets. The protocol covers different types of IAS data, including: 1) species status (e.g., non-native species list for a country); 2) a Species Resource URL (URLs for species fact sheets, photos, and other Web resources); 3) occurrence data (with location information like in IPANE, IPAMS, CitSci.org, and I3N); 4) management status for data about actions taken (prevention, eradication, control, etc.) and the status of the action (proposed, being executed, complete); 5) impact status for data about mechanisms and magnitude of invasive species impact (e.g., strongly harms the environment in natural terrestrial systems); and 6) dispersal status for vector and pathway data. The protocol provides a cross-walk for database managers to use to integrate and share their data through the GISIN.
- **Information management solution for the variable use of the word 'invasive':** Policy-related definitions of the word 'invasive' tend to emphasize the harm caused by introduced organisms to biodiversity (and sometimes to economies and human health), while more explicit scientific definitions focus on the process of establishment and spread. The GISIN's Species Status data model includes data provider-defined concepts for persistence, abundance, population trend, and harm, thus enabling different communities to share data meaningfully even if definitions differ.

Figure 3. Cactus moth (*Cactoblastis cactorum*) depicted as the adult moth (left), egg stick (lower left), and feeding larvae (upper right and lower right) on a pricklypear cactus pad (*Opuntia* sp.). (Original line drawing by Joel Floyd; used with permission).



ACCESSIBILITY:

- **Most countries have little IAS data available.** According to National Reports to the Convention on Biological Diversity (http://www.cbd.int/reports/search), most countries have preliminary lists of invasive species, but they do not have formalized IAS data collection programs and have not begun to develop invasive species lists to manage imports. With fewer than 30 of the world's countries possessing online IAS information systems (Sellers *et al.* 2004), and a lack of support for efforts to capture and mobilize data and information about IAS problems in the more than 160 remaining countries, it is clear that the world faces threats from many IAS that are poorly known. With increasing global movements of people and products, it is only a matter of time before unrecognized or poorly known IAS cause problems elsewhere.
- **Much available IAS data has restricted access.** In a survey of IAS databases in the US, 43% of the 319 databases identified were not available online (Crall *et al.* 2006). Additionally, of the 252 datasets with survey responses, only 46% were available to the public without restrictions. Further research into the reasons behind off-line and unavailable datasets is required to alleviate these accessibility issues.

FUNDING:

- **Progress in IAS information management is hampered by funding availability.** The speed of development of any system or network is related to funding availability. For example, the GISIN (network) was initiated in 2004 but the system only came online in 2008. There are numerous references to the importance of information exchange in the fight against IAS (Ricciardi *et al.* 2000; Simpson 2004; Simpson *et al.* 2006; Graham *et al.* 2008). One of the supporting activities in the Programme of Work on Island Biodiversity as adopted by COP8 of the Convention on Biological Diversity (CBD 2006) is to "Collect baseline data on invasive alien species introductions, and support regional and global databases providing comprehensive information on invasive species." The practical steps required to achieve effective collection and dissemination of information are often poorly understood. Existing international information exchange mechanisms are, in effect, already implementing proposed priority actions and can provide immediate, low-cost support for local, national, and regional invasive species programs. However the role that these tools and services play is often taken for granted. They need sustainable financial support to continue in this role.

EXPERTISE:

- **Lack of technical expertise by many invasive species data managers:** The GISIN conducted a needs assessment survey in 2007 (accessible online at http://www.gisinetwork.org/Survey/SurveyResultsFinal.pdf), with 137 respondents from 41 countries. It was found that most invasive species data providers had limited technical personnel and nearly half of respondents did not know what kind of Web services their organization used. When asked about other technical details they would like to see in the GISIN system, 75% selected the option 'I don't know.' Overall, these results indicated that invasive species data providers are more focused on collecting data than on the technical details associated with data exchange. These results led to a simplification of the GISIN protocol and toolkit to ensure appropriate support for the largest number of providers.
- **Need for molecular taxonomic expertise:** Microscopic and ultrastructural studies of the cactus moth and native cactus-feeding species have given us the means to distinguish the invasive moth from similar-appearing native insects (Lee and Brown 2006). Morphological and molecular taxonomic approaches have also improved the ability to identify distinct species of pricklypear cactus in the eastern United States (Majure and Ervin 2008).
- **Continuity in training personnel:** Since its inception, I3N has trained information managers in 16 countries on the issue of IAS; how to collect and manage standardized IAS information; and the use of I3N risk analysis and pathways prevention tools for decision-makers. Virtually all workshops have been lead by Dr. Sergio Zalba of the Universidad Nacional del Sur in Argentina and Dr. Silvia Ziller of the Horus Institute in Brazil. The sustained involvement of these professionals has been key to the widespread implementation of the I3N.
- **Diversity of training:** IPANE runs four different kinds of training courses for its volunteers. The "Introductory training" is mandatory for everyone wishing to become an IPANE volunteer. This is a day-long training session that covers between 35 – 50 species. The "Getting-started Workshops" are offered in the field to give first-time volunteers a chance to both sharpen their identification skills, and become comfortable with their site choice and habitats to be surveyed; and as a forum for general start-up questions. IPANE's "Advanced Training Workshops" traditionally focus on fewer species in greater detail and usually include a short field trip to see one or more of the species where they occur in actual invaded habitats. The increasingly popular "Early Detection Workshops" cover taxa for which there are few occurrences or that have not yet been detected but are likely to occur in a given area based on its proximity to known or potential propagule sources.

Figure 4.
The first interagency state invasive species council, the Delaware Invasive Species Council, Inc., formed as a nonprofit in 1998. (Logo used with permission)

- **Concentrate training on key species:** The IPAMS training program centers around forty invasive plant species of importance to the Mid-South region (see Table 1) and on training individuals to enter the locations of these species into the online database. The species were selected from six habitat types, and because they are on the federal or state noxious weed lists or listed as a top invasive weed by the state or regional Exotic Pest Plant Council. To date, there are 250 IPAMS-trained Master Gardeners in Mississippi, and the program is expanding.

COORDINATION:

- **Interagency Coordination through State Invasive Species Councils and Committees:** An important goal of the US National Invasive Species Management Plan that was first developed in 2001 is interagency partnering. At the state and regional levels in the United States, this is being accomplished through interagency councils and committees. Such councils, which are typically composed of about 30 federal, state, and local agencies, as well as non-governmental organizations, provide a forum where the full range of invasive species issues and problems can be discussed and addressed. Ideally, each council is composed of four closely coordinated sub-groups including a State Aquatic Nuisance Species Panel, a State Weed Team, a State Insect/Disease Team, and a State Injurious Wildlife Team.
- **Mechanisms of coordination:** The four types of state councils that have been established so far in the US include a **State Interagency Invasive Species Council** formed under state law (e.g., the Oregon Invasive Species Council); a **Governor's Invasive Species Council** created by executive order (e.g., the Pennsylvania Invasive Species Council); a **State Interagency Task Force** formed by a Memorandum of Understanding between member agencies and organizations (e.g. the Maryland Invasive Species Council), and a **State Invasive Species Council** formed as a non-profit organization (e.g., the Delaware Invasive Species Council, Inc.) (Figure 4). **Ad hoc**

coordination can come into play when a group coalesces to combat a specific invasion. For example, partners of the NBII are currently providing listserv and wiki support to the Wavyleaf Basketgrass Task Force, a diverse group of invasive species resource managers from federal, state, non-governmental and academic organizations, all cooperating to control *Oplismenus hirtellus* subsp. *undulatifolius* (Ard.) (Figure 5), an invader of natural areas in the mid-Atlantic region of the US.

- **Success Stories**

IPANE and Mile-a-minute vine (**Persicaria perfoliata*****):*** A roadside invasion of mile-a-minute vine caused a passing IPANE volunteer to swerve and stop her car suddenly after she noticed the extensive population growing alongside a well-traveled road in the northwestern corner of Connecticut. The volunteer correctly suspected that this was the most northeastern known occurrence of this species, re-drawing its "invasion front" well inland into New England. A few photographs of the plants that were submitted by the volunteer allowed for their easy verification, followed by prompt mobilization of control efforts. With permission from adjacent land owners, arrangements were quickly made by the Connecticut Department of Transportation to spray the area with herbicide. Within an appropriate time after the herbicide application, the volunteer organized a weed pulling event, involving other IPANE volunteers, to remove any surviving individuals of the species (Figure 6). Newspapers covered the activity, and the resulting articles increased public interest in the problems caused by IAS and led some citizens to notify IPANE about other occurrences of mile-a-minute vine, or to become volunteers.

Table 1. The Invasive Plant Atlas of the MidSouth's forty species used in training volunteers.

Scientific name	Common name	Primary Habitat
Commelina benghalensis L.	Benghal dayflower	Row crop
Crotalaria spectabilis Roth	showy rattlebox	Row crop
Digitaria ciliaris (Retz.) Koel.	southern crabgrass	Row crop
Digitaria sanguinalis (L.) Scop.	large crabgrass	Row crop
Galinsoga quadriradiata Cav.	shaggy-soldier	Row crop
Sorghum halepense (L.) Pers.	Johnsongrass	Row crop
Xanthium spinosum L.	spiny cocklebur	Row crop
Carduus nutans L.	nodding plumeless thistle	Pasture
Imperata cylindrica (L.) Beauv.	cogongrass	Pasture
Rosa multiflora Thunb. ex Murr.	multiflora rose	Pasture
Solanum viarum Dunal	tropical soda apple	Pasture
Sorghum halepense (L.) Pers.	Johnsongrass	Pasture
Sporobolus indicus (L.) R. Br.	smut grass	Pasture
Alliaria petiolata (Bieb.) Cavara & Grande	garlic mustard	Managed Forests
Elaeagnus pungens Thunb.	thorny olive	Managed Forests
Hedera helix L.	English ivy	Managed Forests
Lonicera maackii (Rupr.) Herder	Amur honeysuckle	Managed Forests
Lygodium japonicum (Thunb. ex Murr.) Sw.	Japanese climbing fern	Managed Forests
Mimosa pigra L.	black mimosa	Managed Forests
Nandina domestica Thunb.	sacred bamboo	Managed Forests
Pueraria montana (Lour.) Merr.	kudzu	Managed Forests
Wisteria sinensis (Sims) DC.	Chinese wisteria	Managed Forests
Ailanthus altissima (P. Mill.) Swingle	tree of heaven	Rights of way
Albizia julibrissin Durazz.	silktree	Rights of way
Ligustrum japonicum Thunb.	Japanese privet	Rights of way
Ligustrum sinense Lour.	Chinese privet	Rights of way
Rottboellia cochinchinensis (Lour.) W.D. Clayton	itchgrass	Right of way
Triadica sebifera (L.) Small	tallowtree	Right of way
Arundo donax L.	giant reed	Wildland
Cayratia japonica (Thunb.) Gagnepain	bushkiller	Wildland
Lonicera japonica Thunb.	Japanese honeysuckle	Wildland
Microstegium vimineum (Trin.) A. Camus	Nepalese browntop	Wildland
Vitex rotundifolia L. f.	beach vitex	Wildland
Alternanthera philoxeroides (Mart.) Griseb.	alligatorweed	Aquatic
Eichhornia crassipes (Mart.) Solms	common water hyacinth	Aquatic
Hydrilla verticillata L.f. Royle	waterthyme	Aquatic
Ludwigia uruguayensis (Camb.) Hara	Uruguayan waterprimrose	Aquatic
Lythrum salicaria L.	purple loosestrife	Aquatic
Myriophyllum spicatum L.	spike watermilfoil	Aquatic
Rotala rotundifolia (Buch.-Ham. ex Roxb.) Koehne	roundleaf toothcup	Aquatic
Salvinia molesta Mitchell	kariba-weed	Aquatic

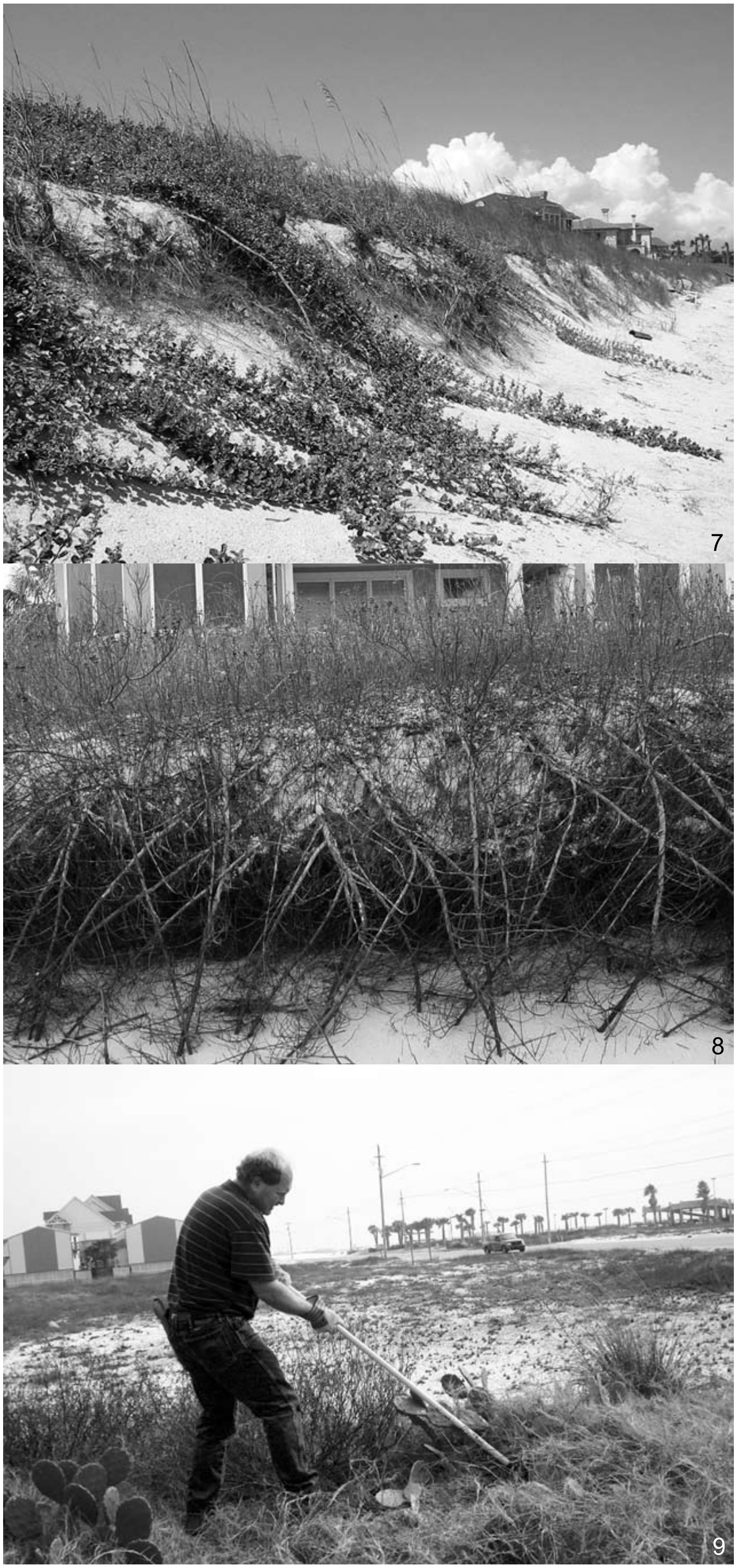
Single-agency-led weed eradication effort: Witchweed [*Striga asiatica* (L.) O. Kuntze] is a weed from Asia and Africa that parasitizes the roots of grass weeds such as Crabgrass (Digitaria), Johnsongrass, Sorghum halepense, Corn, Zea mays L., and grass crops such as Corn (Iverson 2009). First discovered in the United States in 1956, it infested more than 432,000 acres of cropland in the eastern Carolinas (Figure 10). In 1957, a federal/state quarantine was established in 38 counties of North and South Carolina to regulate the movement of soil contact commodities, contaminated vehicles, and equipment out of the quarantine area (Sand *et al.* 1990). In the 1990s, a $25 bounty was instituted to provide an incentive for land owners and others to report new infestations of witchweed. However, unlike many present day invasive plant eradication efforts that depend primarily on volunteers to assist in detection and reporting of target species, the Witchweed Program still relies primarily on surveys that are conducted by seasonal technicians. Federal and state plant quarantine inspectors over the past 50 years have reduced the infestation to about 2,100 acres in North Carolina and 80 acres in South Carolina (Iverson *et al.* 2009).

Cooperative early detection and rapid response: Beach vitex (*Vitex rotundifolia*) is a woody vine imported from the beaches of Korea in the 1980s as a beach stabilization plant in the southeastern United States (Figure 7). It began to spread from landscape plantings on dunes along the South Carolina coast in the 1990s, crowding out native Sea Oats (*Uniola paniculata*) and Sea Beach Amaranth (*Amaranthus pumilus*). Beach vitex has long tap roots that actually do little to help protect the dunes against erosion (Figure 8), yet entangle and prevent sea turtles from nesting on primary dunes. In 2003, concerned sea turtle volunteers collaborated with the US Geological Survey to host the first Beach Vitex Symposium, and to establish the Carolinas Beach Vitex Task Force (http://www.beachvitex.org). The task force has made significant progress to date in eradicating beach vitex from communities along the Carolina coast, and utilizes volunteers to detect, report, and remove it. There is no doubt that volunteer field data collection has been a major factor in the success of the Carolinas Beach Vitex Task Force (Westbrooks and Brabson 2009).

Cactus Moth on barrier islands: The Cactus Moth management effort is an integrated approach to contain Cactus Moth to its current range. Fringe cactus moth populations on the Gulf of Mexico barrier islands, such as Dauphin, Little Dauphin, Petit Bois and Horn Island, as well as isolated populations at Fort Morgan, are managed through a combination of sterile moth releases and removal of infected Pricklypear Cactus plants (*Opuntia* spp.) (Figure 9). Intensive surveys, using both traps and monitoring of remaining *Opuntia* cactus, are performed frequently to monitor for the presence of both wild and sterile insects. Infested plants are removed and carried to landfills, which are in turn monitored for escape of Cactus Moth using attractor traps. Thus far, intensive activity by partners including the US Department of Agriculture Animal and Plant Health Inspection Service Plant Protection and Quarantine program (USDA-APHIS-PPQ),

Figures 5-6. 5**,** Recreation of the Wavyleaf basketgrass *Oplismenus hirtellus* subsp. *undulatifolius* (Ard.) invasion over time in Patapsco Valley State Park, Maryland, USA. 5A, Department of Natural Resources; used with permissiondegree of infestation typical in 1996; 5B, 0in 2007. (Kerrie Kyde, Marylan); 6, IPANE weed pulling party for Mile-a-minute Vine (*Persicaria perfoliata*) in Connecticut. (Photo by Les Mehrhoff, IPANE).

state agriculture departments, Mississippi State University, the Mexican National Commission for the Knowledge and Use of Biodiversity (CONABIO), and Mexican volunteer networks have been successful in slowing the spread westward along the Gulf of Mexico coast and in eradicating it on Isla Mujeres, Yucatan Peninsula, Mexico (NAPPO 2009).



Figures 7-9. 7, Beach Vitex runners on DeBordieu Colony Beach, Georgetown, South Carolina. (Photo by Randy G. Westbrooks, USGS, Whiteville, North Carolina); 8, Beach Vitex and dune erosion, DeBordieu Colony Beach, Georgetown, South Carolina. (Photo by Randy G. Westbrooks, USGS, Whiteville, North Carolina); 9, Dr. Victor Maddox, Mississippi State University, removing cactus moth-infested plants from Petit Bois Island. (Photo by Geosystems Research Institute; used with permission).

SUMMARY

To develop better responses to IAS locally, we need open sharing of regional and global information on which species have become invasive, where they are from, where they occur at the present time, how they are being introduced and dispersed, the threat they pose to biodiversity and livelihoods, and what response options are available and prove effective. Efforts to develop local, national, and international IAS databases, and to link them via GISIN, are beginning to address those needs. IAS data sharing has obvious benefits for global-scale IAS monitoring and analysis of trends, and this is needed to provide focus for international responses, but there are also benefits for the broader conservation community. By extending existing biodiversity data standards to manage IAS data and information, IAS data can be integrated with other biodiversity data, such as that served by GBIF, and with important conservation databases such as the IUCN Red List of Endangered Species and the World Protected Areas Database, both of which need access to data about the IAS threats they face. The IAS networks described here represent the beginning of a global collaboration in IAS information management to overcome barriers related to data interoperability, accessibility, funding, expertise, and coordination.

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Figure 10. Witchweed, *Striga asiatica* (L.) Kuntze, a parasite of corn, has virtually been exterminated in the United States. (Photo by Rebecca S. Norris, USDA APHIS PPQ, Whiteville, North Carolina).

REFERENCES

CBD. 2006. Eighth Ordinary Meeting of the Conference of the Parties to the Convention on Biological Diversity, *Decision VIII/ 1, appendix – Goal 6, activity: 6.1.1.3.* Accessed online June 2009 at http://www.cbd.int/decision/cop/?id=11013

Crall, A.W., L.A. Meyerson, T.J. Stohlgren, C.S. Jarnevich, G.J. Newman, and J. Graham. 2006. Show me the numbers: what data currently exist for non-native species in the USA? *Frontiers in Ecology and the Environment* 4(8): 414–418

Ervin, G.N. 2008. Applying the state-of-the-art to advance the state of our understanding in integrated hydrophyte ecology. *Verhandlungen Internationale Vereinigung für theoretische und angewandte Limnologie (Proceedings of the International Society of Theoretical and Applied Limnology)* 30: 128-132.

Ervin, G.N. 2009a. Distribution, habitat characteristics, and new county-level records of *Baccharis halimifolia* L. on a portion of its present US range boundary. *Southeastern Naturalist* - in press.

Ervin, G. N. 2009b. Using GAP data in invasive plant ecology and management. *US Geological Survey Gap Analysis Bulletin* 16: Accepted.

Graham, J., G. Newman, C. Jarnevich, R. Shory, and T.J. Stohlgren. 2007. A global organism detection and monitoring system for non-native species. *Ecological Informatics* 2:177-183.

Graham, J., A. Simpson, A. Crall, C. Jarnevich, G. Newman, T.J. Stohlgren. 2008. Vision of a Cyberinfrastructure for Non-native, Invasive Species Management. *BioScience* 58(3):263-268.

Holly, D.C., G.N. Ervin, C.R. Jackson, S.V. Diehl, G.T. Kirker. 2008. Effect of an invasive grass on ambient rates of decomposition and microbial community structure: A search for causality. *Biological Invasions* Accepted – DOI: 10.1007/s10530-008-9364-5.

Iverson, R. 2009. *USDA-Carolinas Witchweed Annual Report.* North Carolina Department of Agriculture, Plant Protection Division, Raleigh, North Carolina.

Iverson, R., R. Westbrooks, R. Eplee, and A. Tasker. 2009. (In Press). Overview and Status of the Witchweed (*Striga asiatica*) Eradication Program in the Carolinas. *Proceedings, Invasive Plant Symposium, American Chemical Society.* Washington, August 2005.

Jarnevich, C.S. and T.J. Stohlgren. 2009. Near term climate projections for invasive species distributions. *Biological Invasions* (In Press).

Lee, S.M. and R.L. Brown. 2006. A new method for preparing slide mounts of whole bodies of microlepidoptera. *Journal of Asia-Pacific Entomology* 9: 249-253.

Mack, R.M., S.C.H. Barrett, P.L. Defur, W.L. MacDonald, L.V. Madden, D.S. Marshall, D.G. McCullough, P.B. McEvoy, J.P. Nyrop, S.E. Hayden Reichard, K.J. Rice, and S.A. Tolin. 2002. *Predicting Invasions of Nonindigenous Plants and Plant Pests.* National Academy Press, Washington DC. 194p.

Madsen, J.D. and G.N. Ervin. 2007. Integrating effects of land use change on the invasive plant species distribution into an invasive plant atlas for the Mid-South (IPAMS). *Proceedings of the Southern Weed Science Society* 60:197.

Madsen, J.D. and R.M. Wersal. 2008. Growth regulation of *Salvinia molesta* by pH and available water column nutrients. *Journal of Freshwater Ecology* 23:305-313.

Majure, L.C. and G.N. Ervin. 2008. The *Opuntia* (Cactaceae) of the state of Mississippi, United States. *Haseltonia* 14:1-16.

NAPPO. 2009. Detection and eradication of a cactus moth (*Cactoblastis cactorum* Berg) outbreak in Isla Contoy, municipality of Isla Mujeres, Quintana Roo, Mexico. *North American Plant Pest Organization Phytosanitary Alert System*. Accessed: 01 July 2009 online at http://www.pestalert.org/oprDetail.cfm?oprID=376

Pimentel, D., Zuniga, R., and D. Morrison. 2005. Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States. *Ecological Economics* 52:273-288.

Randall, R.P. 2002. *A Global Compendium of Weeds.* R.G. and F.J. Richardson, Meredith, Victoria 3333, Australia. 905p.

Ricciardi A, W.W.M. Steiner, R.N. Mack, and D. Simberloff. 2000. Toward a global information system for invasive species. *BioScience* 50:239–244.

Sand, P.F., R.E. Eplee, and R.G. Westbrooks. 1990. Witchweed Research and Control in the United States. *Monograph series of the Weed Science Society of America.* 5:99-106.

Sellers, E., A. Simpson, and S. Curd-Hetrick. 2004. Draft List of Invasive Alien Species (IAS) Online Databases and Databases Containing IAS Information. Appendix C. *In*: Sellers, E., Simpson, A., Fisher, J.P., S. Curd-Hetrick, (*Eds*). Experts Meeting on Implementation of a Global Invasive Species Information Network (GISIN), Proceedings of a Workshop. 6-8 April, 2004. Baltimore, Maryland, USA. Accessed: 01 July 2009 online at http://www.gisinetwork.org/Documents/ProceedingsPDF/GISIN%20Proceedings%202004.pdf

Simonsen, T.J., R.L. Brown, and F.A.H. Sperling. 2008. Tracing an invasion: Phylogeography of *Cactoblastis cactorum* (Lepidoptera: Pyralidae) in the United States based on mitochondrial DNA. *Annals of the Entomological Society of America* 101(5):899-905.

Simpson A. 2004. The global invasive species information network: What's in it for you? *BioScience* 54:613–614.

Simpson A., E. Sellers, A. Grosse, and Y. Xie. 2006. Essential elements of online information networks on invasive alien species. *Biological Invasions* 8:1579–1587.

Solis, M.A., S.D. Hight, and D.R. Gordon. 2004. Tracking the Cactus Moth, *Cactoblastis cactorum* Berg., as it Flies and Eats its Way Westwards in the US. *News of the Lepidopterists Society* 46:3-4, 7.

Stiling, P. 2002. Potential non-target effects of a biological control agent, prickly pear moth, *Cactoblastis cactorum* (Berg) (Lepidoptera: Pyralidae), in North America, and possible management actions. *Biological Invasions* 4:273-281.

***Web*er, E. 2003.** *Invasive Plant Species of the World.* CABI Publishing, London. 548p.

Westbrooks, R. and E. Brabson. 2009. (In Press). Overview and History of the Carolinas Beach Vitex Task Force – An Interagency Partnership in Action. *Proceedings, Invasive Plant Symposium, American Chemical Society.* Washington. August 2005.

Wilson, E. O. 1997. Foreward, *In* Simberloff, D., D.C. Schmitz, and T.C. Brown, (*Eds*) *Strangers in Paradise: Impact and Management of Nonindigenous Species in Florida.* Island Press, Washington DC. 453p.

Zimmerman, H.G., V.C. Moran, and J.H. Hoffman. 2000. The renowned cactus moth, *Cactoblastis cactorum:* its natural history and threat to native *Opuntia* floras in Mexico and the United States of America. *Diversity and Distributions* 6:259-269.