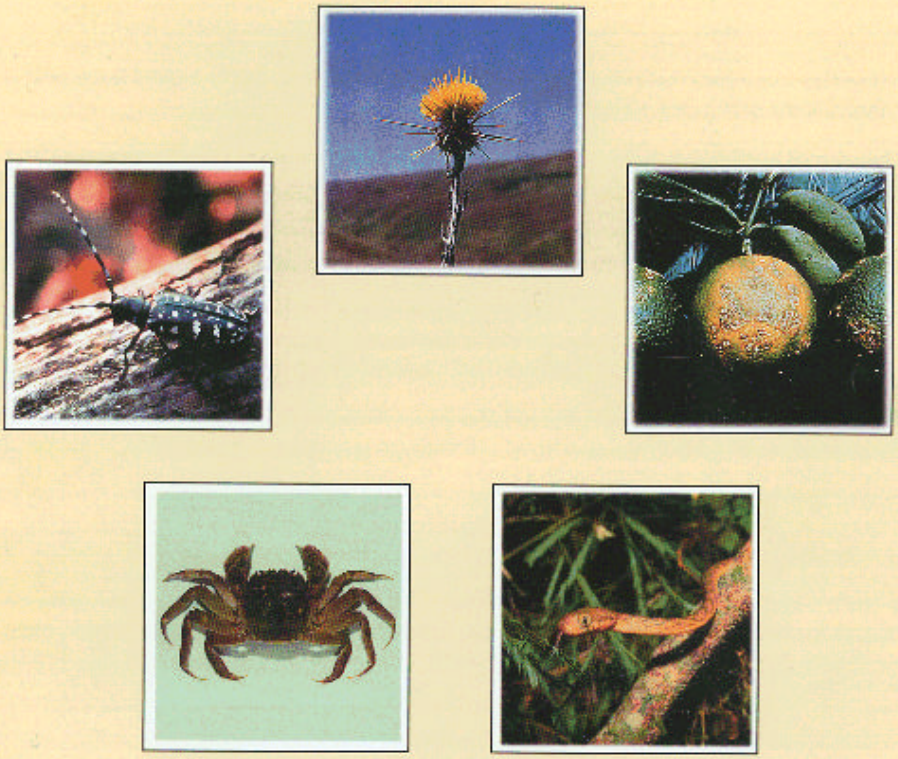
Invasive Species Databases

Proceedings of a Workshop



USDA

Charles Valentine Riley
Memorial Foundation

Cover Photos

Top center: Yellow star thistle (J. Asher, Bureau of Land Management, DOI).
Left center: Asian longhorned beetle (Animal and Plant Inspection Service, USDA).
Right center: Orange infested with citrus canker (Animal and Plant Inspection Service, USDA).
Bottom left: Chinese mitten crab (Lee Mecum, California Department of Fish and Game).
Bottom right: brown tree snake (T. Fritts, U.S.Geological Survey, DOI).

A brief description of each photo follows:

Yellow star thistle—*Centaurea solstitialis*, was introduced from southern Europe and the Mediterranean region in the mid-1800s. It has become a serious weed pest throughout the western United States (U.S.). This thistle now infests more than 10 million acres of rangeland in the western U.S. where it has greatly reduced forage production for livestock and disrupted natural ecosystems.

Asian longhorned beetle—*Anoplophora glabripennis*, is native to China where it is a serious pest of hardwood trees and has been introduced into the U.S. in infested wood in packing crates. If this insect becomes established in the environment, it could destroy millions of acres of treasured hardwoods.

Citrus canker—is a plant disease caused by the bacterium, *Xanthomonous axonopodius* pathovar *citri*, which infests fruit, twigs, and stems. The disease was first reported in the U.S. in 1910 and, although contained by an aggressive prevention and management program, has reoccurred periodically. Only a continued state and federal program consisting of surveys to detect infested trees, removal and destruction of infected and adjacent trees, and prevention through regulatory actions have prevented citrus canker from devastating the U.S. citrus industry.

Chinese mitten crab—*Eriocheir sinensis*, was initially reported in the San Francisco Bay in 1992 and its populations have expanded rapidly and are adversely affecting fish populations in selected areas. In addition, its burrowing activities are undermining stream banks and levees, leading to increased erosion and flooding, and disruption of agricultural irrigation systems.

Brown tree snake—*Boiga irregularis*, has become a serious pest in Guam where it has virtually eliminated the native forest birds. The snakes feed on a wide variety of animals including lizards, birds, and small mammals as well as bird and reptile eggs. Snakes frequently invade poultry houses, homes, and yards to consume domestic poultry, eggs, pet birds, and small mammals. The species is mildly venomous and a possible health risk, especially to small children. Several specimens have been intercepted in cargo arriving in other parts of the U.S. from Guam. The establishment of the snake elsewhere in the U.S. could have very adverse consequences.

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INVASIVE SPECIES DATABASES

Proceedings of a Workshop

Las Vegas, Nevada
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Foreword

America is under siege by invaders from planet earth. Species alien to our ecosystems—introduced from their natural range by both intentional and unintentional human activity—are spreading at ever-increasing rates throughout our lands and waters. Future ecosystem health and productivity are at risk from these alien invasions unless we move swiftly. Key to our success will be to share critical information about the prevention and control of invasive species before the damage is irreversible.

For those of us engaged in protecting the health and productivity of our nation's lands and water resources, biological invasions represent both an ecological and an economic nightmare. The costs of controlling alien species are rapidly increasing to the detriment of the nation's productive capacity at a time when increasing efficiencies are needed to remain competitive in world markets. Moreover, alien biological invaders are radically transforming familiar marine and aquatic communities by out competing, killing or infecting native species, and dominating important ecosystems.

Preventing and controlling biological invasions is a formidable task. Our success will depend upon vastly improving our understanding of invading species and pathways of introduction and upon the development of new technologies to combat them. Both will require improving information sharing among affected groups: governmental resource management agencies, commercial interests, private entities, and academia. Underlying much of the policy debate is a simple fact: information sharing between countries involved in international trade and between institutions such as natural resource management agencies and private ranchers and farmers is too rudimentary. Resource managers and scientists are calling for more and better data to improve risk assessments and screening and to help develop effective and efficient on-the-ground management programs. By sharing information with other government professionals and nongovernmental organizations and the private sector, decision making and action will be greatly enhanced and the tide may be turned against biological invaders.

That is the purpose underlying a recent workshop convened on behalf of the Departments of the Interior, Agriculture, and Commerce in collaboration with the Charles Valentine Riley Memorial Foundation. On-line demonstrations and expert panels provided an opportunity for professionals in widely diverse fields of science and management to meet for the first time to apply their skills to the problem of invasive species. By exchanging information on how various database systems have been developed in the past, these federal, state, and non-governmental participants agreed on the need for linking and exploring applied uses of databases. Future demonstrations will focus on the economic and scientific value of shared data directed at specific practical uses.

The recently signed Executive Order on Invasive Species offers new opportunities for stakeholder involvement in crafting a national invasive species management plan for the future. The results of this workshop represent a significant step toward that lofty goal. With decisive and cooperative actions, we can both raise public awareness of the need for improved data sharing and begin to share the information needed to arrest the damage caused by these biological invasions.

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Executive Summary

The Problem. Nonindigenous invasive species are adversely impacting America's landscape. Foreign animal, plant, and microbial species are displacing and killing native wildlife and plants and wreaking enormous financial and ecological damage. Alien species invasions are second only to habitat destruction in causing species to be endangered and costs are almost certainly in the tens of billions of dollars annually and may exceed $120 billion. Among other things, invasive alien species crowd out nutritious native forage, create fire hazards, limit recreation, clog lakes and waterways, destroy fisheries, and foul water pipes.

Information Needs. Resource managers and scientists in the United States (U.S). and abroad are increasingly calling for more information to help assess risks associated with invasive species and to help develop effective management strategies to minimize their impacts. Specific needs include: (1) characterizing patterns of invasion in space and time by species and transport mechanism, (2) identifying ecological and economic impacts, (3) predicting invasive species pathways and patterns and which species will be invasive, (4) establishing best management practices for prevention, eradication, and control, and (5) assessing effectiveness by monitoring how well invasions are being limited and curtailed. By sharing information with state and local governmental agencies, nongovernmental organizations, and sources from other nations, the body of knowledge increases and local on-the-ground management activities are encouraged and enhanced. Finally, information contained in databases can directly improve decision making, especially if it addresses costs and risks of available management approaches.

The Workshop. The database workshop held in Las Vegas, Nevada, on November 12–13, 1998, brought together more than 60 participants, most of whom had not met before. Also, the workshop marked the first time managers of databases covering all major taxonomic groups have joined forces to identify gaps in coverage, to discuss new strategies for linking databases, and to extend the value of nonindigenous species database resources. Abstracts from 34 databases were presented for discussion and analysis. Of these databases, 29 are actively providing data to users with 28 of these having a website on the Internet; 21 focus primarily or exclusively on nonindigenous species while the others, which do not deal directly with nonindigenous species, provide related information. References for another 28 databases, most with websites, are also included in these proceedings. The on-line demonstrations during the workshop generated lively debate, exchange of ideas, and commitments for future collaboration. Overview panels provided an opportunity for analysis and constructive criticism among the representatives from federal and state agencies, nongovernmental organizations, and academic institutions.

Issues. Workshop participants identified the need to resolve several data-related issues: (1) standardization of criteria for inclusion in databases; (2) standardization of naming, information content and quality, and compatibility needed for sharing between databases; (3) commitment to long-term support and continuity of funding, especially for national-scale databases; (4) sustainability of taxonomic expertise and reference material collections; (5) improvements to fill data gaps for baseline assessments of threat and risk of invasion; (6) data ownership and public access that complement agricultural, forestry, environmental and trade interests; (7) metadata standards and linkages to other databases; and (8) improvement of public understanding of, and support for, the role databases play in prevention, eradication, and control of biological invaders.

Short-Term Database Needs. State and local needs often drive data acquisition. With rapidly increasing access to the World Wide Web, state and local agency staff are demanding web-based sources of information. Hardware devices at affordable prices are now available. However, access via multiple search engines still requires diligence and persistence. Clearly, specialized search tools are necessary for such specialized topics as invasive species. There is an immediate need for concise and intelligent access to the information contained in multiple, linked databases. Databases must be designed to support risk assessments which can be used to prioritize efforts to exclude, eradicate, and control biological invaders. Also, needed are substantial biological,

ecological, and economic (or health) impact data as well as information on effectiveness, costs, and risks of various possible management procedures. Thus, new efforts will be needed to predict pathways and likely modes of dispersal; to document impacts at various ecological and economic levels, from ecosystems (regions) to individual species (local markets); and to support the plan of action most likely to succeed, given the need to control significant invaders. Also, databases with quarantine and trade implications should be designed to promote openness and sharing, rather than being restrictive.

The problems with biological invaders are international. Different countries can learn from one another's experiences. Sharing information through databases among agencies and countries can greatly reduce costs of control. Identification of high-risk species, vectors, and pathways to prevent the introduction and spread to new locations is the key to safeguarding both agriculture and native biodiversity. Data sharing on an international scale affords both warning and assistance once an invasion has begun. Participants agreed on the need to engage international colleagues and establish collaborative linkages among their databases.

Long-Term Database and Knowledge Needs. As interfaces improve and as it becomes known that one site links several databases in the easiest-to-use fashion, consolidation will increasingly occur. But concomitant evolution in standards for data entry and verification will take place only if those involved actively manage coordinated efforts with a clear vision of the integrated needs. Mature databases such as the Natural Heritage Network have already evolved through several generations of design and evaluation, but do not necessarily address invasive species *per se*. Only with cooperative efforts among interested groups can databases provide the basis for decisions on invasive species management strategies.

Other long-term needs include: (1) filling data gaps in taxonomic coverage, (2) documentation of pathways for transportation of biological invaders, (3) increased academic support for training in systematics to allow continued and improved identification of bioinvaders, and (4) continued basic research in the interactive effects of invaders and their biological competitors, predators, pollinators, vectors, and dispersal agents. Access to diverse databases linked across numerous common elements will aid researchers in investigating these interactions in a timely fashion and can lead to "one-stop" shopping.

Immediate Actions Indicated. The needs associated with dealing with the invasive species problem are extensive. The Executive Order on Invasive Species which was signed on February 3, 1999, should facilitate coordinated efforts to address those needs. However, in relation to databases some immediate action is suggested to take advantage of what has been learned. A *follow-up workshop* is recommended in which three to five groups of *related databases* would be reviewed and *small clusters* designed that would be *linked through a common search interface*. The objectives would include standardizing terminology and methodology in a linked array at multiple levels. This development of a limited number of integrated clusters of databases should *demonstrate the economic and scientific value* of shared information directed toward *specific practical uses* and should provide useful guidance for substantial expansion of database development. Clusters of databases to be considered include those dealing with rangeland weeds in the western U.S., aquatic weeds in the southeastern U.S., insects, diseases, and weeds in forests, and federally and/or state-regulated plant pests.

Although the workshop was organized primarily to inventory databases and to explore ways of improving them, the importance of *expanding the knowledge base* in the broadest context was so often reflected in the workshop presentations and discussions that this issue should receive special emphasis. The coordinating and planning mechanisms associated with the Executive Order on Invasive Species should, over time, address the needs for increased knowledge. However, databases provide a unique opportunity for linking the interests and achievements of a diverse array of stakeholders and there are some short-term opportunities to *enhance understanding* and to *move toward consensus* on some issues. Therefore, the *immediate conduct* of some sharply focused *facilitated activities* involving *stakeholders* as defined in the Executive Order should be pursued as soon as possible.

Introduction

Many harmful exotic species entered the U.S. as early as the 17th century but they were not recognized as injurious at the time. These species included a large number of plants that were recognized as noxious weeds decades and even centuries later. Perhaps the most dramatic adverse effects of invasive species in the U.S. was first demonstrated by insects such as the gypsy moth which escaped confinement in Massachusetts in 1869 and defoliated oak trees. Another injurious insect, the cotton boll weevil, entered the U.S. from Mexico prior to 1892 and destroyed much of the Texas cotton crop. As agriculture flourished, so did invasive species. The first federal legislation to deal with the agricultural-related problems was passed in 1912. Still, during the rest of the 20th century the numbers of accidental and intentional introductions of insect and other agricultural and forest pests increased many fold. In more recent years, large increases in worldwide travel and trade, have rapidly increased the rate of new introductions.

Beginning in the 1980s, exotic invasive species were recognized as having much broader adverse impacts, and in 1990, the U.S. Congress passed legislation that created the interagency Aquatic Nuisance Species Task Force (ANSTF) to deal with the introduction and spread of invasive species in the nations waterways. In 1993, the report of a study on harmful nonindigenous species requested by the U.S. Congress and prepared by the Office of Technology Assessment was published. This report clearly documented that invasive species had become a major national problem by adversely affecting not only agriculture and forestry, but aquatic resources, natural ecosystems, biodiversity, and commerce. In 1994, the Executive Branch of the U.S. government established, through a memorandum of understanding, the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW) to assist in coordinating federal activities and fostering partnerships with state and local governments and the private sector. In May, 1997, Vice President Al Gore, in response to a request from congressional leaders and a letter signed by more than 500 concerned scientists and managers, directed key federal agencies to make recommendations for a coordinated attack on the problem. As a follow-up to Vice President Gore's actions, an Executive Order on Invasive Species was signed by President Bill Clinton on February 3, 1999.

On the international level, the first major conference on alien species was convened by the Norwegian government and various United Nations (UN) agencies in 1996. The conference highlighted the implications of invasive species in conservation, sustainable development, and world trade and led to the development of the Global Invasive Species Program (GISP). Although this was the first widely attended international meeting, a number of specific related activities have been underway for some time. For example, the Office International des Epizooties (OIE) which deals primarily with animal diseases has been in operation at the international level for several years. Also, the International Plant Protection Convention (IPPC) was established in 1952 in association with the Food and Agricultural Organization of the UN and strengthened considerably in 1997 when the Convention was amended to accommodate the Agreement on the Application of Sanitary Measures that resulted from the Uruguay round of trade agreements under the World Trade Organization.

Recent efforts to broadly examine databases on invasive species began with a workshop on nonindigenous plant databases convened at the request of FICMNEW by the U.S. Geological Survey's (USGS) Florida Caribbean Science Center in Gainesville, Florida, on September 23–24, 1997. This workshop covered 17 databases dealing primarily with plants. Plant species comprise the largest single group of documented alien invasive species and represent about one-half of the known total. For example, a preliminary literature search by the National Agricultural Library, in which some 500 titles could be readily categorized, indicated that about 50 percent of the citations dealt with plants, 30 percent with invertebrates, 10 percent with vertebrates, and 10 percent with microorganisms. Similarly, among the 12 most unwanted organisms named by The Nature Conservancy, 50 percent are plants, 33 percent invertebrates, and 17 percent vertebrates. Thus, the U.S. Department of Agriculture (USDA) and the Department of Interior (DOI) invited the Charles Valentine Riley Memorial Foundation (RMF) to coordinate a workshop under the primary sponsorship of federal agencies from

USDA and DOI. The workshop was conducted to accomplish the following objectives:

- Provide an *inventory* of invasive species databases with emphasis on organisms other than plants, summarizing important properties including program purpose, focus and specialty, database software and format, data elements, biological and geographical coverage, accessibility of data sets, and sharing of databases.
- Strengthen *interpersonal relationships* among individuals developing and maintaining databases.
- Encourage additional *collaborative efforts.*
- Assemble information that can be used to bring *recognition* to current and planned programs that manage invasive species databases or monitor invasive organisms.

The workshop, which was held in Las Vegas, Nevada, on November 12–13, 1998, in association with the American Phytopathological Society and Entomological Society of America, served as the basis for these proceedings. The introductory section for these proceedings which contains an international perspective, a discussion of the problem and of the U.S. Executive Order on Invasive Species, and an agricultural and forestry perspective is followed by a section which includes a description of the workshop process, the abstracts of 34 databases, and a listing of over 25 additional databases. The final section addresses different perspectives on the status of databases, needs, and opportunities.

An International Perspective

Jeff Waage, Director, Biological Pest Management
CABI Bioscience

Invasive species are an international problem. This is an easy statement to accept, indeed it is almost a truism. But to say that invasive species are a shared problem between countries would not be as accurate. To the limited extent that nations have now reacted to the invasive species, they have done so in a largely unilateral manner, with national surveys, identification and closing of pathways of entry, local eradication, and control. There are some good reasons for this approach. The international threats posed by invasive species are often highly asymmetrical, and an invasive species is usually not a problem in its country of origin. In the agricultural sector, where most of our experience of invasive species problems currently resides, a strongly national focus is further encouraged by competition in international trade.

So why should countries like the U.S. make it a priority to work with other countries to address invasive species problems? One answer is that increasing trade is rapidly turning local invasive problems into global ones. For instance, in recent decades, once-restricted agricultural pests like white flies and leaf miners have become established in most countries. For these problems, new international research cooperations return to each participating country the benefits of global level of investment. For many countries facing new invasive species problems, successful programs of prevention or management elsewhere may be easily transferred. In this way, the Philippines, Sri Lanka, and Kenya have recently benefited from the Australian experience in managing the salvinia water weed. Finally, where an understanding of an invasive species in its area of origin helps prevention or management; e.g., through discovery of specific biological control agents, countries stand to gain from reciprocal research arrangements which acknowledge that each will eventually be a source of invasive species problems for the other.

On a broader scale, the benefits of international cooperation reflect the extent to which invasive species now affect cooperation in other key areas, such as trade, development and environmental conservation. International cooperation to meet growing world fuel and food needs through reclamation of degraded lands, reforestation, and irrigation now recognizes alien invasive species such as pasture and water weeds as threats to this process. With respect to conservation, invasive species are now recognized as a major threat to species survival, perhaps second only to habitat destruction in many countries.

The important role of international cooperation in invasive species problems was flagged in Article 8h of the Convention on Biological Diversity, which calls on parties to the Convention to "prevent the introduction of and control or eradicate those invasive species which threaten ecosystems, habitats, or species." Little international progress was made in this area, however, until the Norway/UN Conference on Alien Species in 1996, at which representatives of over 80 countries assessed the global magnitude of the problem and its implication for the first time. At this meeting, the Global Invasive Species Programme (GISP) was born with its objectives:

- To assemble and make available best practices for the prevention and management of alien invasive species.
- To stimulate development of new tools in science, policy, information, and education for addressing these problems.

GISP comprises an international team of biologists, natural resource managers, economists, lawyers, and policy makers, many from American institutions. They manage and contribute to a number of projects, including assessing the current knowledge base (distribution of invasive species, pathways of introduction, human dimensions of the invasive species problem), early warning systems, economic analysis, legal instruments, management of invasive species, and educational programs. Work in these projects takes various forms, from international meetings to development of practical toolkits and databases. GISP operates as a component of an international program on the science of biodiversity, DIVERSITAS, and is coordinated by the Scientific Committee on Problems of the Environment

(SCOPE) in conjunction with three international bodies which share a commitment and capacity in invasive species problems, the World Conservation Union (IUCN—formerly known as the International Union for Conservation of Nature and Natural Resources), CAB International (CABI) and the United Nations Environment Program (UNEP). In addition to the contributions of participants and coordinators, GISP receives financial support from the Global Environmental Facility (GEF), International Council of Scientific Unions (ICSU), and National Aeronautics and Space Administration (NASA).

While many aspects of GISP are relevant to the subject of this workshop on invasive species databases, two projects are of particular importance: Early Warning Systems led by the Invasive Species Specialist Group (ISSG) of IUCN; and Management of Invasive Species led by CABI Biosciences of CABI. The Early Warning Systems project has two elements:

- A review of invasive databases worldwide with a plan to publish in 1999.
- Development of pilot international invasive species databases at a regional level with an emphasis on small island developing states (SIDS) in the Pacific and Indian Oceans. Plans are to complete this activity in 2000.

In parallel to these GISP-related activities, ISSG is developing a pilot database called "World's Worst 100." Its objective is to create and test useful format and content for awareness-raising and publicity on invasive species. It will focus arbitrarily on just 100 invasive species selected across all taxonomic groups as global threats to biodiversity. This database will be published in early 2000 and made available on the Internet. The project is financed by Foundation Total.

Other ISSG activities relevant to databases on invasive species are its operation of an Internet listserver on aliens (Aliens-1) and publication of a biannual newsletter, *Aliens*. Through ISSG's network of volunteers (currently 95 participants in 26 countries), these activities are given distinctly global perspective.

The GISP project on Management of Invasive Species is developing guidelines or "toolkits" for invasive species prevention and management for national and regional programs with a particular emphasis on the needs of developing countries. Databases and early warning systems will be important elements of these toolkits. Together with the Early Warning Systems project of GISP, CABI Bioscience will convene an expert consultation in early 1999 in Malaysia to design these systems. Inputs will come from invasive species experts, from groups which have implemented national and regional invasive species programs, and from developing country agencies which will be involved in validating and using toolkits. An effort will be made to link the interest of environmental groups and agencies in invasive species problems with the experience of agricultural groups and agencies in this same area. Again, are identified as a focal point for validation of toolkits because of the severity of their invasive species problems and the particular benefits to very small, isolated countries of collective effort and international cooperation.

GISP is a small effort in proportion to the magnitude of its task, and it will benefit greatly from strong national initiatives on invasive species which are prepared to share their outputs with other nations and to enter into international efforts to prevent and manage invasive species problems. Also, there are opportunities to link the GISP initiative with other international activities on invasive species such as those associated with IPPC and the OIE. The national return on such international cooperation should be substantial, and I hope therefore that the U.S. national efforts presented in this workshop on databases will make a major contribution to GISP and to other future initiatives in global invasive species prevention and management.

Status and Plans in the United States

A. Gordon Brown, Invasive Species Coordinator, Office of the Secretary
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The Problem

Invasive alien species are transforming America's landscape. Foreign animal and plant species are replacing native wildlife and wreaking enormous financial and ecological damage. Alien species invasions are second only to habitat destruction in causing species to be endangered and costs are almost certainly in the tens of billions of dollars annually and may exceed $120 billion. Among other things, invasive alien species crowd out nutritious native forage, cause serious losses of valuable crops and trees, create fire hazards, limit recreation, clog lakes and waterways, undermine fisheries, and foul water pipes.

Alien species causing harm include weeds like thistles and leafy spurge, which cattle cannot eat; purple loosestrife, which chokes wetlands; miconia, which may destroy the Hawaiian rainforest; and melaleuca trees now expanding across the Everglades. Animals are also problems. The zebra mussel is clogging water supply facilities. The brown tree snake has extirpated forests birds on Guam and the Asian tiger mosquito is causing serious human health problems in some areas.

Diverse stakeholders such as agricultural commodity groups and environmental organizations have common needs to address the invasive species problem. Those affected recognize that the problem is bad and getting worse. Global pathways for invasion are multiplying rapidly, while federal authorities and programs have significant gaps. Immediate action is needed.

United States at Risk

The threat of biological invasions is urgent, pervasive, and growing. Alien species first established years ago are emerging from obscurity to invade our farms, rangelands, marshes, waterways, and wild lands. Many widespread invaders are expanding their ranges into new areas. The number of alien species arriving in the U.S. is increasing, both through intentional importation and inadvertent introductions as travel and trade continue to expand.

The U.S. is at particular risk. With the largest national economy and the highest volume of imports, the 50 U.S. states encompass a remarkable range of life zones, which means that somewhere within our borders suitable habitat may exist for new invaders from virtually anywhere in the world. Recently expanding trade with Russia, China, and South Africa has opened new biological connections with numerous ecological regions similar to those in the U.S.

Biological invasions are a defining environmental and economic issue. As harmful invaders continue to spread, public awareness builds and demands increase for action at home and abroad. The concerns of farmers, ranchers, commercial fishing interests, and public health officials have spurred U.S. measures to prevent and control economic pests and agents of disease. Now others are joining the campaign: wild land managers, recreationists, gardeners, and others concerned about the rapidly increasing impacts of invasions on ecosystems and native species.

Addressing these concerns will require accurate information on hundreds of free-living species that pose known or potential risks to natural and managed ecosystems in the U.S.

Once introduced in the U.S., commercial and noncommercial pathways, such as horticulture, the pet trade, and hobby collectors can spread potential invaders rapidly nationwide; or they can be spread inadvertently as hitchhikers in shipments or vehicles. Only a small proportion of alien species establish free-living populations, and only a small proportion of these become highly invasive and cause severe harm. However, the huge economic and biological impacts of aggressive invaders, and the enormous costs of achieving control once invasions have become widespread, underscore the need for additional investment and increased cooperation to

develop the information needed for effective prevention policies and coordinated action.

The Executive Order on Invasive Species

The Administration issued an Executive Order on Invasive Species on February 3, 1999, to place increased emphasis on efforts to prevent the introduction of invasive species and to provide for their control, and to minimize the economic, ecological, and human health impacts which invasive species cause. The Executive Order outlines federal agency duties, creates a new Invasive Species Council and defines its duties, and directs creation of an Invasive Species Management Plan:

Federal Agency Duties. Each agency whose actions may affect the status of invasive species will have to identify such actions. To the extent practicable, each federal agency will be required to use its programs and authorities (1) to prevent the introduction of invasive species, (2) to detect and respond rapidly and to control populations of such species in a cost-effective and environmentally sound manner, (3) to monitor invasive species populations accurately and reliably, (4) to provide for restoration of native species and habitat conditions in ecosystems that have been invaded, (5) to conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species, and (6) to promote public education on invasive species and the means to address them.

Agencies will not authorize, fund, or carry out actions believed likely to cause or promote the introduction or spread of invasive species unless a determination is made that the benefits outweigh the potential harm and that all prudent measures to minimize harm will be taken concurrently.

Invasive Species Council. An Invasive Species Council will be established and co-chaired by the Secretary of the Interior, the Secretary of Agriculture, and the Secretary of Commerce and will include the Secretaries of Defense, State, Treasury, Transportation, and the Administrator of the Environmental Protection Agency. The Secretary of the Interior will establish an advisory committee to provide information and advice for consideration by the Council including recommended plans and actions at local, state, regional, and ecosystem-based levels to achieve the goals of the Management Plan in cooperation with stakeholders and existing organizations.

Duties of the Council. The Council will provide national leadership and: (1) oversee implementation of the Executive Order and see that federal agency activities concerning invasive species are coordinated, complementary, cost-efficient, and effective; (2) encourage planning and action in cooperation with stakeholders; (3) develop recommendations for international cooperation in addressing invasive species; (4) develop, in consultation with the Council on Environmental Quality, guidance to federal agencies under the National Environmental Policy Act on prevention and control of invasive species, including the procurement, use, and maintenance of native species; (5) facilitate development of a coordinated network among agencies to document, evaluate, and monitor impacts from invasive species on the economy, the environment, and human health; (6) facilitate establishment of a coordinated, up-to-date Internet-based network facilitating access to and exchange of invasive species information, and (7) prepare and issue a national Invasive Species Management Plan.

Invasive Species Management Plan. The Invasive Species Management Plan will be developed through a public process and issued in 18 months and include (1) a review of existing and prospective approaches and authorities for preventing introductions, including those for identifying pathways, (2) research needs, and (3) recommend measures to minimize the risk that introductions will occur utilizing a science-based process to evaluate risks. If recommended measures are not authorized by current law, the Council will develop and recommend to the agencies legislative proposals for necessary changes.

The Invasive Species Council will update the Management Plan biennially and concurrently evaluate and report publicly on success in achieving its goals and objectives. The Management Plan will identify the personnel and other resources and additional levels of coordination needed and be submitted to the Office of Management and Budget (OMB) for consideration in the budget process. Within 18 months after measures have been recommended in any edition of the Management Plan,

federal agencies will be expected to take the actions recommended. No less than once every five years, the Council will report to OMB on the effectiveness of the order and whether it should be revised.

The Information Needs

Alien species data exist in myriad files and databases. However, the integration and sharing of information to improve decisions and provoke on-the-ground actions have not kept pace with the rapidly growing threats from invasive alien species to our economy, our ecosystems, and our native biological heritage. This workshop represents an unprecedented forum: the first time managers of databases representing all major taxonomic groups have joined in common cause to identify gaps in coverage and propose new strategies for linking and extending the use and usability of existing alien species database resources. This complements a key component of the Invasive Species Council: to make accessible an information network on impacts and actions to be taken for prevention and control of spread and restoration of production and natural systems injured by invasive alien species. The system could be an important component of the National Biological Information Infrastructure (NBII), which provides a cooperative framework for locating, documenting, and integrating biological information using consistent standards developed by interagency consensus.

New support is building: the President's Council of Advisors on Science and Technology has recently identified invasive species and the development of a "new generation of NBII" as priority issues of concern. The Committee on Environment and Natural Resources (CENR), within the White House Office of Science and Technology Policy, has proposed a multiyear interagency research initiative on the effects of interacting stresses on U.S. ecosystems. The initiative recognizes invasive species, along with land use change, extreme natural events, climate change, and chemical pollution, as major drivers of ecosystem change, and calls for increased efforts to document the establishment and spread of invasive species.

The proceedings of this workshop will help implement the CENR recommendations and support the work of the new Invasive Species Council by systematically documenting existing knowledge designed to serve the missions of many agencies and organizations. They will provide invaluable information for identifying taxonomic gaps, opportunities for linking databases, and ultimately for integration and synthesis of data from many sources through a distributed national information system.

Protecting Our Natural Resources: Agriculture and Forestry

Charles P. Schwalbe, Plant Protection and Quarantine, Animal and Plant Health Inspection Service
Ann M. Bartuska, Forest Management, Forest Service
U.S. Department of Agriculture

Introductions of exotic pests and diseases are a steadily increasing threat to the productivity and functioning of agriculture, forests, and natural ecosystems, and the extensive economic and social interfaces with these resources. Increasing trade and travel bring concomitant increases in exposure to invasions of exotic species, taxing the safeguards in place to prevent such occurrences. While inspection, early detection, rapid response systems and other regulatory activities combine into effective means for mitigating the risk of invasions, the enormous diversity of the world's potentially damaging flora and fauna and the scale of trade and travel challenge the effectiveness of prevention systems. Thus, a much clearer understanding of risks and a sharper focus on managing those risks identified as most critical is fundamental to protecting the nation's resources. Equally fundamental is the need to have accurate databases available to adequately assess ecological and biological risks posed by invasive species.

The single greatest threat to the long-term sustainability of forest ecosystems is represented by introduced, nonnative invasive species. The ecological consequences of these introductions has been demonstrated in the past. The region-wide loss of the American chestnut to the chestnut blight was socially and economically devastating and continues to affect today's forests. Oaks, to a large extent, replaced chestnuts in the eastern forests; but these very oaks are now at risk from gypsy moth—another introduction. Large numbers of nonnative species are displacing naturally occurring species in a wide array of ecosystems. In some ecosystems, the nonnative species are a hindrance to effective management, protection, and recovery of threatened and endangered species; e.g., bull trout. These organisms often have no natural controls and thus their populations can grow unchecked. One only has to consider the degradation of southern forests covered by kudzu to understand the detrimental effects of these species.

In addition to ecological consequences, invaders can bring about economic consequences, especially in the agricultural sector where dramatic visual evidence of invasion is sometimes not as apparent as in unmanaged ecosystems. Agricultural products contribute about $60 billion to U.S. exports annually. Many of these commodities gain access to foreign markets because they are certified free of pests of concern to our trading partners. Thus, in addition to the added production costs, pesticide usage and environmental damage brought about by new invaders, agricultural exports are threatened. Just in the past few years some of our most valuable export commodities—wheat, citrus and a wide variety of fruits and vegetables—have lost markets abroad because of karnal bunt, a fungus infecting wheat; citrus canker, a bacterium; and various tephritid fruit fly outbreaks.

In the southern U.S. especially, the impacts of invasive species on commercial timber production can result in millions of dollars in lost productivity. Thus, risk assessment must take the economics of trade into account as well as increased production costs and environmental consequences. An economic model for invasive plants is currently being developed by scientists at the University of Maryland in cooperation with several USDA agencies with technical oversight by the Economic Research Service.

Efficiently and effectively contending with these threats requires accurate and meaningful risk assessments. The validity and credibility of these assessments are dependent on reliable data on pest occurrence and distribution, biology, and behavior, and the potential impact on U.S forest and agricultural ecosystems. This need has been well-served by the development of extensive electronic databases housing information potentially useful to risk assessors. Further steps need to be taken to preserve the integrity, accuracy, and accessibility of this information. Equally important is the establishment of monitoring systems for the U.S. that provide early detection and sustained monitoring of nonnative species occurrence and impact. The Forest Health Monitoring program, a federal/state partnership, has been in place since 1989 and provides an analysis of forest ecosystem health on an annual basis. A similar

system for broad scale early detection does not exist, but the implementation of such an effort is clearly needed.

Predicting the invasiveness potential of exotic species is a highly undeveloped science. While existing databases can yield insight into distribution patterns and spread dynamics, necessary data and scientific procedures are only rarely available for characterizing invasiveness. This stands as our principal challenge: to identify the biological and behavioral characteristics or traits relevant to invasiveness and develop reliable models for predicting the degree of invasive behavior in ecological niches of concern. This workshop to inventory and review databases and the resulting documentation should provide valuable information as efforts are made to improve existing and develop new invasive species programs for prevention, management, and/or restoration.

Workshop Process

William Gregg
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U.S. Geological Survey

A workshop on nonindigenous plant databases convened on September 23–24, 1997, by the U.S. Geological Survey (USGS) in cooperation with the Federal Interagency Committee for Management of Noxious and Exotic Weeds (FICMNEW) provided valuable experience for planning the subsequent workshop on databases for other groups of non-indigenous organisms. In mid-1998, the Riley Memorial Foundation coordinated the establishment of a Program Advisory Committee to help plan the second workshop. The Committee included individuals familiar with invasive species issues and databases from the U.S. Department of Agriculture (Agricultural Research Service, Animal and Plant Health Inspection Service, and the Forest Service), the Department of Commerce, the Department of the Interior (Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and USGS), the Smithsonian Institution, and specialists from academia, industry, and nongovernmental organizations (see Appendix A—Participants). The advisory committee agreed to utilize the general structure and reporting formats used in the first workshop. The structure included presentations by specialists familiar with important databases containing, at the minimum, information on the occurrence of one or more major groups of organisms containing some proportion of invasive nonindigenous species. These presentations provided the basis for discussions on information gaps and other data issues, as well as opportunities for improving the documentation, availability, and integration of data and information needed to address the increasing threats from nonindigenous invasive species. The plant database workshop demonstrated that, although relevant databases had been developed by various agencies to serve their particular goals and objectives, there was a clear need to share experience and to focus attention on how these efforts could be better coordinated to deal with invasive species. The Committee, therefore, agreed that the workshop would provide abundant opportunity for hands-on database demonstrations and informal discussion.

Relevant databases and potential participants in the workshop were identified based on the personal knowledge of advisory committee members and solicitations through their respective organizations, review of previous documentation of potential data sources such as inventories of sources biological information coordinated by USGS in planning the National Biological Information Infrastructure (NBII) and on-line distribution of a database survey information form through an Internet homepage for the workshop. Professional societies also distributed requests through their websites and newsletters. The advisory committees decision to convene the workshop in Las Vegas, Nevada, concurrently with the annual meetings of the American Phytopathological Society and the Entomological Society of America helped facilitate contributions from specialists representing key groups of invasive organisms. The staff of the USGS Nonindigenous Aquatic Nuisance Species Program provided invaluable support by revising the survey form used in a previous workshop and assisting in the collection of information. Also, NBII staff helped ensure conformity with National Metadata Standards in documenting the databases. Subsequently, the information was transferred to the NSF (National Science Foundation) Center for Integrated Pest Management at North Carolina State University in Raleigh, North Carolina, for processing which included editing and organizing the survey forms and preparing them for placement on the NBII website on invasive species at **http://www.nbii.gov/invasive/ workshops/dbsurveys.html.**

Prior to the convening of the workshop, respondents provided information on 34 databases covering all major taxonomic groups of nonindigenous organisms, including several plant databases not identified for the first workshop. Of these databases, 29 are actively providing data to users (versus 5 in the planning stage), and 28 have a website on the Internet; 21 focus primarily or exclusively on nonindigenous species, with the remaining 13 not focused specifically on nonindigenous species but providing useful data. Databases range in scale from state-level to global, in taxonomic scope from a

single species to thousands of species in numerous taxonomic groups, and in content from taxonomic lists to broad information systems with scores of data fields. Over 60 workshop participants represented the many sectors concerned with invasive species, and included policy officials from key federal agencies and organizations, and specialists from many professional disciplines representing the majority of the databases identified in the survey (see Appendix A—Participants). Most were meeting together for the first time, and perhaps realizing more fully their shared concerns and potential contributions in addressing ecological and economic threats from invasive species. Specialists representing the important databases participated in panels for databases on terrestrial vertebrates, animal and plant diseases, plant pests and other arthropods, marine and aquatic organisms, and databases with broad taxonomic coverage focusing on nonindigenous species in particular tribal lands, states, and regions. These were followed by a concluding panel on cross-cutting issues, which brought together specialists from government and academia with broad experience in the design and implementation of biological data systems. The format facilitated productive communication, both in documented question and answer sessions following each panel, and especially in informal discussions associated with the informal database demonstrations which both preceded and followed the panel sessions on the first day (see Appendix B—Workshop Program).

Databases

Because of the diverse coverage of some of the databases, any grouping of the databases is somewhat arbitrary. However, an attempt was made to arrange the abstracts in groups that reflect the interests of potential users. Within each group, closely related databases are placed together, and databases with the broadest taxonomic and geographic coverage are listed first. Also, added to some of the groupings is information on websites and/or contacts for over 25 other related databases for which abstracts were not submitted for consideration at the workshop. The databases are placed in the following groups: (1) plants, (2) terrestrial vertebrates, (3) arthropods, (4) microbial databases with broad coverage, (5) plant pests and disease agents, (6) animal diseases, (7) introduced beneficial organisms, (8) aquatic organisms, and (9) global and regional databases with broad taxonomic coverage.

Plants

The Federal Noxious Weeds (FNW) database contains taxonomic lists of plants listed as Federal Noxious Weeds under the Federal Noxious Weed Act of 1975. Listing is made by the U.S. Department of Agriculture (USDA) based on the recommendations of a technical committee of USDA scientists. Since 1976, 88 individual species have been listed, plus all species within the parasitic genera *Aeginetia, Alectra,* and *Striga* and nonindigenous species in the genera *Cuscuta* and *Orobanche*. The database is accessible by the Internet and is maintained by the Plant Protection and Quarantine Division of the USDA's Animal and Plant Health Inspection Service (APHIS) and the NSF Center for IPM at North Carolina State University. It is derived from the "Federal Noxious Weed Inspection Guide—Noxious Weed Inspection System," prepared in 1991 by Randy G. Westbrooks. Data fields include:

- Scientific name
- Common name
- Synonym
- Family
- Characteristics
- Reason(s) for listing as FNW
- Habitat
- Distribution
- Likely entry pathway
- References
- Photographs
- Plant
- Reproductive structures
- Distribution map
- Line drawing
- Life forms most likely to be intercepted at ports

Website: http://www.InvasiveSpecies.org
Respondent: Kenneth R. Lakin
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Fax: 919-513-1995
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Alien Plant Invaders of Natural Areas: Weeds Gone Wild is a web-based, public education project aimed at informing the general public, natural resource managers and others about the serious threat and impact of invasive alien (exotic-nonnative) plants to the native flora, fauna, and ecosystems in the U.S. The site provides: (1) a comprehensive national listing of alien invasive species of natural areas in the U.S. (currently around 500 species); (2) a referenced invasive database "USA Weeds" (to be posted by the summer of 1999); (3) illustrated fact sheets; (4) background information on the problem, including terminology; (5) links to species management experts and other people and organizations in the U.S. and worldwide who can provide extra expertise and assistance; and (6) invasive species policy, press releases, and selected publications.

The national list of invasive trees, scrubs, woody vines, herbs, and aquatic plants includes species that have been identified as serious ecosystem invaders by The Nature Conservancy, the U.S. National Park Service, Exotic Pest Plant Councils (California, Florida, Tennessee, Pacific Northwest), native plant societies, universities, and other people and organizations. The list continues to grow as new plants are identified and it is updated as needed.

The USA weeds database includes the following information: genus, species, plant type (e.g., herb),

family, native range, U.S. distribution, and reference citations for each plant listed.

Illustrated fact sheets are written in a consistent format, take a national perspective, and provide information on: identification, native range, habitat and distribution in the U.S., ecological threat, biology and mechanism of spread, management options, links to management experts, and suggested alternative plants. Fact sheets are available for 40 plant invaders as of March, 1999, an additional 80 are in preparation, and 200 are planned.

Alien Plant Invaders of Natural Areas is a project of the Alien Plant Working Group (APWG) which is a subcommittee of the Native Plant Conservation Initiative. The project is supported by volunteers from government, nongovernment organizations, universities, private firms, and other affiliations. Participation is open to anyone interested in helping. Fact sheet authors are needed: please contact the chair through the website.

Website: http://www.nps.gov/plants/alien
Respondent: Jil M. Swearingen
Agency/Organization: National Park Service, DOI
Phone: 202-342-1443, ext. 218
Fax: 202-282-1031
E-mail: jil_swearingen@nps.gov

***Pacific Island Ecosystems at Risk* (PIER).** The project is compiling a database and synthesis of available information on plants that are known or potential threats to Pacific island ecosystems, particularly the present and former U.S. territories. Master files will be maintained on the websites of the United Nations Food and Agriculture Organization's Global Plant Pest Information System (FAO-GPPIS) and the World Conservation Union's Invasive Species Specialist Group (IUCN-ISSG). This will facilitate worldwide access via the Internet, continuous updating, cross-referencing, use of computer search functions, links to references on the Web, and interaction with Pacific Rim and island collaborators. A loose-leaf manual will be published using the information on the website for use by quarantine officers and other field personnel who may not have ready access to the Internet. Information being compiled for each plant species includes:

- Identity (scientific/common names, botanical description, and photographs sufficient to positively identify)
- Growth form
- Area of origin
- Known/likely methods of introduction and spread
- Other countries or regions in which the weed is a pest
- Community types affected or potentially affected
- Risk of introduction and potential for spread
- Control methods
- Methods of eradication (if feasible)
- References

Website: www.hear.org/pier
Respondent: James C. Space
Agency/Organization: Institute of Pacific Islands Forestry, Forest Service, USDA
Phone: 602-802-6576
E-mail: Jim_Space@rocketmail.com

***Southwest Exotic Plant Mapping Database* (SWEMP)**. The Colorado Plateau Field Station of the U.S. Geological Survey's Biological Resources Division is developing a database on invasive exotic plants of Arizona and New Mexico and adjacent areas of Colorado and Utah using data collected by collaborating land managers. The database provides federal, tribal, state, and private land managers an important tool for inventorying, monitoring, and sharing data on exotic species invasions in the region.

SWEMP utilizes standards for database development and documentation developed by the Federal Geographical Data Committee, and is distributed on the World Wide Web using conventional file transfer protocol (ftp). Using the new Internet map server, database users may generate and query maps of exotic species locations on the Internet in the fashion of a geographic information system.

Website: http://www.usgs.nau.edu/swemp/
Respondent: Kathryn Thomas
Agency/Organization: Colorado Plateau Field Station, Biological Resources Division, USGS, DOI
Phone: 520-556-7466, ext. 235
Fax: 520-556-7500
E-mail: kat@usgs.nau.edu

Connecticut Invasive Plant Database. The Education Subcommittee of the Connecticut Invasive Plant Working Group is compiling a database to document websites, videos, brochures, books, and magazine articles on invasive species that are directed at the general public. The database, in Microsoft Access format, includes information on both aquatic and terrestrial species in the New England region. The objective is to develop a clearinghouse for information on multimedia educational materials for use by local conservation organizations and other interested parties with interests in invasive plants. The Connecticut Invasive Plant Working Group includes specialists from academia, government agencies, garden clubs, the green industry, and nongovernmental organizations; environmental educators, and other individuals concerned with the impacts of invasive species on native biodiversity in Connecticut. The mission of the Connecticut Invasive Plant Working Group is: to gather and convey information on the presence, distribution, ecological impacts, and management of invasive plant species; to promote uses of native plants or non-invasive ornamental alternatives throughout Connecticut; and to work cooperatively with researchers, conservation organizations, government agencies, the green industry, and the general public to identify and manage invasive species proactively and effectively.

Website: N/A
Respondent: Elizabeth Farnsworth
Agency/Organization: Connecticut Invasive Plant Task Force
Phone: 413-534-6572
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E-mail: efarnswo@mtholyoke.edu

Witchweed Management Database. Witchweed, *Striga asiatica*, is an introduced parasitic weed capable of substantially reducing yields in corn and other grass crops. The species was detected in North Carolina and South Carolina in the late 1950s and is listed as a federal and state noxious weed. In cooperation with the affected states, the Animal and Plant Health Inspection Service initiated an effective eradication effort that has reduced the infested acreage to approximately 6,600 acres. In 1995, the USDA delegated responsibility for completion of the project in North Carolina to the North Carolina Department of Agriculture and Consumer Services (NCDA&CS). Through a cooperative agreement, USDA provides funds to the state for survey, control, and regulatory activities. To manage the project, NCDA&CS developed a database to track the progress of the eradication effort on the infested fields. The database includes information on survey, treatment, field status, and regulatory components.

Website: N/A
Respondent: Gene B. Cross
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Fax: 919-733-1041
E-mail: gene_cross@mail.agr.state.nc.us

Plant Databases Reviewed in a Previous Workshop. The following additional databases were reviewed in a previous workshop in addition to some of those described in abstracts that appear elsewhere in these proceedings and also contain information on nonindigenous plants. Database descriptions may be found in Jacono, C. C., and C. P. Boydstun. 1998. Proceedings of the workshop on databases for nonindigenous plants, Gainesville, FL, September 24–25, 1997, U.S. Geological Survey, Biological Resources Division, Gainesville, FL. 27 pp. The reference is available on the Internet at: http://nas.er.usgs.gov/publications/plant_workshop/npwrkshp/

Army Lands Inventory
Website: N/A. Data are available in hard copy.
Contact: Al Cofrancesco
Agency/Organization: U.S. Army Corps of Engineers, Waterways Experiment Station
Phone: 601-634-3182
E-mail: cofrana@ex1.wes.army.mil

Aquatic and Wetland Plant Information Retrieval System
Website: http://aquat1.ifas.ufl.edu
Contact: Victor Ramey
Agency/Organization: Center for Aquatic Plants, Information Center, University of Florida
Phone: 352-392-1799
E-mail: varamey@nervm.nerdc.ufl.edu

Biota of North America Program
Website: http:// trident.ftc.nrcs.usda.gov/plants/
Contact: John Kartesz
Agency/Organization: Department of Biology, University of North Carolina
Phone: 919-962-0578
E-mail: jkartesz@jkartesz.bio.unc.edu

Florida Exotic Pest Plant Council (FLEPPC) Invasive Plant Database
Website: N/A. Data are available in hard copy.
Contact: Greg Jubinsky
Agency/Organization: Florida Exotic Pest Plant Council
Phone: 850-539-9681
E-mail: jubinsky_g@epic6.dep.state.fl.us

Forest Health Monitoring Program
Website: N/A. Data are available in hard copy.
Contact: Ken Stolte
Agency/Organization: Forest Service, USDA
Phone: 919-549-4020
E-mail: kstolte@rtpmail.emapfhm.gov

Forest Service Noxious/Invasive Database
Website: N/A. Data are available in digital media and hard copy.
Contact: Rita Beard
Agency/Organization: Forest Service, USDA
Phone: 970-498-1715
E-mail: rbeard/woftcol@fs.fed.us

INVADERS Database Project
Website: http://invader.dbs.umt.edu
Contact: Peter M. Rice
Agency/Organization: Biology Division, University of Montana
Phone: 406-243-2671
E-mail: biopmr@selway.umt.edu

Man and the Biosphere Flora (MABFlora)
Website: http://ice.ucdavis.edu/MAB
Contact: James F. Quinn
Agency/Organization: Division of Environmental Studies, University of California at Davis
Phone: 530-752-1768
E-mail: jfquinn@ucdavis.edu

Natural Resources Management and Assessment Program (NRMAP) and National Park Service (NPS) Exotic Plants
Website: N/A. Data are available in digital media.
Contact: Bill Commins
Agency/Organization: National Park Service, DOI
Phone: 202-208-4631
E-mail: Bill_Commins@nps.gov

NPS Species List Database (NPSpecies), a subset of NRMAP
Website: N/A. Data are available in digital media.
Contact: Joe Gregson
Agency/Organization: National Park Service, DOI
Phone: 970-225-3559
E-mail: Joe_Gregson@nps.gov

Noxious Weed Information System (NWIS)
Website: http://endeavor.des.ucdavis.edu/weeds/
Contact: Patrick Akers
Agency/Organization: California Department of Food and Agriculture
Phone: 916-654-0768
E-mail: pakers@cdfa.ca.gov

ROADVEG
Website: N/A. Data are available in digital media.
Contact: Ira Bickford
Agency/Organization: Utah Department of Transportation
Phone: 801-965-4119
E-mail: srdomain.src0f01.ibickfor@state.ut.us

The Plants Database
Website: http://plants.usda.gov/plantproj/plants/index.html
Contact: Mark Skinner
Agency/Organization: Natural Resources Conservation Service, USDA
Phone: 504-775-6280
E-mail: mskinner@npdc.nrcs.usda.gov

Wildland Weeds Management and Research—"Weeds on the Web"
Website: http://tncweeds.ucdavis.edu
Contact: Barry Meyers-Rice
Agency/Organization: The Nature Conservancy and the University of California at Davis
Phone: 530-754-8891
E-mail: bazza@ucdavis.edu

Other Plant Databases

Calweed Database
Website: http://endeavor.des.ucdavis.edu/weeds/
Contact: Patrick Akers
Agency/Organization: California Department of Food and Agriculture
Phone: 916-654-0768
Fax: 916-654-2403
E-mail: pakers@cdfa.ca.gov

Terrestrial Vertebrates

North American Breeding Bird Survey. The North American Breeding Bird Survey (BBS) database contains data from roadside surveys for more than 500 species of birds, of which approximately 250 to 300 species are considered to be well sampled. The BBS monitors the status and trends in bird populations using approximately 4,000 randomly located routes scattered across the continental United States, Canada, and Alaska. Surveys were initiated east of the Mississippi River in 1966, in central North America in 1967, across the continental U.S. and Canada by 1968, and in Alaska and northern Canada in the early 1980s. Surveys are conducted by skilled volunteers able to identify all of the breeding birds on the survey route by sight and sound. Each route is 24.5 miles long, and the observer conducts 3-minute point counts at 0.5-mile intervals. Routes are surveyed once during the breeding season, usually in June, but sometimes earlier in desert regions and in the southern states. The BBS database, which is accessible on the Internet, may be used to estimate population trends for native and exotic species at various geographic scales including states, provinces, physiographic regions, and larger regions. It may also be used to display temporal trends and geographic patterns in distribution and relative abundance. For most species of breeding birds, the BBS is the only source of data on status and trends at large geographic scales.

Website: http://www.mp2-pwrc.usgs.gov/bbs/bbs.cfm
Respondent: Bruce Peterjohn
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Iowa Department of Natural Resources Annual Roadside Surveys. Since 1962, the Iowa Department of Natural resources has conducted annual roadside surveys to monitor the abundance of gray partridge and ring-necked pheasant. Data are obtained from 210, 30-mile routes, and counts are conducted on sunny, cool mornings with heavy dew. The data are analyzed for nine geographic regions and statewide. Since 1963, additional data regarding the size and distribution of the harvest of these birds have been obtained from a random mail survey of small game hunters.

Website: Contact respondent for current address.
Respondent: Steven D. Roberts
Agency/Organization: Iowa Department of Natural Resources
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Fax: 515-432-2835
E-mail: robertssd@netscape.net

Arthropods

North American Nonindigenous Arthropod Database (NANIAD). NANIAD is a database in Microsoft Access format, on North American nonindigenous insects and arachnids. The database contains information on more than 2,441 species in two orders of Arachnida (Pseudoscorpiones, Acari) and 18 orders of Insecta, within which names of taxa are alphabetically arranged by family, genus, and species. The development of NANIAD was initiated as part of a project U.S. Congress' Office of Technology Assessment (OTA) on nonindigenous insects and arachnids, for which the final report, "Pathways and Consequences of the Introduction of Nonindigenous Insects and Arachnids in the United States" by K. C. Kim and A. G. Wheeler was submitted to OTA in 1991. The report examined the current status of nonindigenous species of U.S. insects and arachnids, major entry factors and pathways, impacts, case studies, and analysis of information gaps. The NANIAD project was continued through a grant in 1993 from the National Biological Control Institute (NBCI) of USDA's Animal and Plant Health Inspection Service (APHIS), and the initial development of the database was completed in 1995. Preparation of the database utilized an extensive literature search, contributions from 123 taxonomists, various reports, and several databases including the USDA Biological Control

Documentation Center's database on importation of biological control organisms, the USDA Agricultural Research Service's North American Immigrant Arthropod Database and Western Hemisphere Immigrant Arthropod Database. NANIAD includes information on:

- Species name and classification
- Natural distribution
- Immigrant distribution
- Economic/ environmental impacts
- Habitat/host
- Status
- Date and location of first entry
- Date and location of reentries
- Type and pathway of entry
- Biology/ecology
- Literature citation

A mechanism is needed for continuous integration of new records as they become available from publications and taxonomists. The database requires updating to include records of new entries and pathways that have accumulated during the last decade. Basic information is currently available on a website. However, development of search capabilities is needed to enable analysis of patterns of interactions involving points of origin, introduction, and establishment of nonindigenous arthropods to support future pest management policies.

Website: http://www.InvasiveSpecies.org
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Agency/Organization: Frost Entomological Museum, The Pennsylvania State University
Phone: 814-863-2863
Fax: 814-865-3048
E-mail: kck@psu.edu

Systematic Entomology Laboratory Databases. The Systematic Entomology Laboratory of the USDA Agricultural Research Service (ARS) has various databases and expert systems which are currently being made available on the Internet and on CD-ROM. The databases include (1) species inventories of the holdings of the Smithsonian Institution's National Entomological Collection, (2) catalogs of insects important to agriculture, and (3) information on how to identify various insects of agricultural importance. Projects for specific insect groups include:

Diptera—The ARS leads an international effort to develop a biosystematic database of world Diptera (flies) parts of which are being disseminated as they are completed. Currently, this database includes all the family-group names (4,296 records), genus-group names (18,000 records), and some species-group names (78,742 records). The final database, to be completed by the year 2000, will probably include more than 250,000 records. Completed databases include a catalog of the family-group names, the Systematic Database of Nearctic Diptera providing basic nomenclatural data for all flies found in North America, and the first fascicle of World Diptera covering the Tephritidae (fruit flies). An expert system for the identification of fruit flies of importance to agriculture is also complete and available on CD-ROM. In addition, the ARS Diptera staff is building an inventory of the Diptera in the National Entomological Collection (about 18,000 records are already available on the Smithsonian Institution's website).

Lepidoptera—ARS is developing and maintaining various databases on Lepidoptera (butterflies and moths). A large database on world Noctuidae (noctuid moths) and its associated bibliography, already published, are continuously updated. Specimen label databases for Chionodes (Gelechiidae—gelichiid moths. about 18,000 entries) and North American cuculliine and simpistine Noctuidae (30,000 to 40,000 entries) are active and growing. Mapping programs are also in use. A pilot project to test the feasibility of developing a computerized library of colored photographs of lepidopterous larvae (with data on hosts and distribution) has been started with the digitizing of about 200 slides. The computerized library archives these valuable photographs so that they are protected from deterioration and yet are easy to reference for making taxonomic determinations, for publishing, and for creating prints and CD-ROMs.
Homoptera—The ARS Homoptera staff has developed collection databases for Aphididae (aphids), Aleyrodidae (whiteflies), and Psyllidae (psyllids). An inventory database for species in the Coccoidea (scale insect) collection, including information on species names, synonymy, distribution, host associations, pest status, etc. Data on

several major families of scale insects have been completed and are accessible on the Internet at http://www.sel.barc.usda.gov/scalenet.htm. This database is already being used to provide information to action agencies and state departments of agriculture in tracking invasive species, such as the pink hibiscus mealybug.

Hymenoptera—The ARS Hymenoptera staff has developed collection databases Eulophidae, Aphelindae, Tanaostigmatidae, and Toryminae. These families include important larval parasites of insects.

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Hymenoptera On-Line provides access to literature and specimen-based data for the order Hymenoptera (ants, wasps, bees, sawflies, chalcids, ichneumons, etc.). The database is developed and maintained by Ohio State University. The scope is worldwide. The database structure is based upon the information model of the Association of Systematic Collections. The database contains information on species taxonomy and classification, geographic distribution, seasonal phenology, biological associations, and systematic literature. The website also facilitates connections to other relevant Internet accessible databases.

Website: http://iris.biosci.ohio-state.edu/hymenoptera/ hym_db.html
Respondent: Norman F. Johnson
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Phone: 614-292-2730
Fax: 614-292-7774
E-mail: Johnson.2@osu.edu

Exotic Bees of North America. The Bee Biology and Systematics Laboratory maintains a database on exotic bee species. Since the 17th century, 21 species of foreign bees are known to have joined the 3,800 native North America species, or 0.5 percent of the overall continental fauna. Of the six deliberately introduced bee species, all but the honey bee were released to pollinate agricultural crops. Most other species were accidentally introduced from Europe in trans-Atlantic cargoes. Most remain restricted to limited areas of the eastern United States and adjacent Canada. Four species have spread transcontinentally.

Website: http://www.LoganBeeLab.usu.edu
Respondent: James Cane
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Fax: 435-797-0461
E-mail: jcane@biology.usu.edu

Microbial Databases with Broad Coverage

Microbial Germplasm Database (MGD). MGD lists, in varying degrees of detail, organisms held in research oriented stock collections held at universities and research stations. Most collections are maintained by individual researchers, primarily plant pathologists, and reflect their particular research interests. Collections often span many years and contain organisms from habitats that no longer exist. In some cases, the collection manager has provided data to fully characterize the individual strains. In other cases, only very general information has been provided.

Website: http://mgd.nacse.org/cgi-bin/mgd
Respondent: Joe Hanus
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Phone: 541-737-6606
Fax: 541-737-3573
E-mail: hanusj@nacse.org

U.S. National Fungus Collections Databases. Databases developed at the U.S. National Fungus Collections are continuously updated by the Systematic Botany and Mycology Laboratory of USDA's Agricultural Research Service. They provide access to information about fungi, primarily those associated with plants of agricultural importance. The following databases may be selected individually on the website, or searched together for information on a particular fungus or host.

Nomenclature—About 32,000 scientific names of fungi have so far been reviewed and listed, along with accurate authorities, synonyms, alternate states, notes on worldwide distribution, and important literature references. This database enables the user to select data from various databases about a particular fungal species or host.

Specimens—The database enables the user to access the database of fungal specimens in the herbarium of the U.S. National Fungus Collections. This is the world's largest fungal collection, and includes more than one-million specimens from around the world. Information associated with these specimens constitutes an enormous data resource, especially about plant-associated fungi. All groups of importance to agriculture have been completed including the Uredinales (rusts), Ustilaginales (smuts), Polyporales (polypores) Deuteromycetes (imperfect fungi), and Ascomycetes.

Host-Fungus Distribution—Reports of fungi on vascular plant hosts from both inside and outside the U.S. are continuously entered as new publications are received. The database includes over 340,000 reports of about 62,000 fungal species on 14,500 plant hosts from 408 localities throughout the world. A reference is cited for each entry and all references are found in the literature database listed below.

Literature—The database includes all important references on the systematics of fungi of agricultural importance. More than 25,000 references have been entered. References may be retrieved by author's name, scientific names of the fungi (genus and species) and hosts (often limited to plant genus name), or separately entered keywords.

The newest addition to the databases is an interactive identification system for species of *Tilletia* (bunt fungi) in the U.S. based primarily on plant host data and the characteristics of fungal teliospores. The database includes photomicrographs and illustrations of descriptive terminology to aid in teliospore identification. For example, the system enables the user to distinguish the teliospores of Karnal bunt of wheat from the teliospores of a new species of *Tilletia* on ryegrass (*Lolium perenne*) with which Karnal bunt has been confused.

Website: http://nt.ars-grin.gov
Respondents: David F. Farr and Amy Y. Rossman
Agency/Organization: Systematic Botany and Mycology Laboratory, ARS, USDA
Phone: 301-504-5364, 301-504-5274
Fax: 301-504-5810
E-mail: dave@nt.ars-grin.gov, amy@nt.ars-grin.gov

Other Microbial Databases

Association of Applied Biologists Description of Plant Viruses
Website: http://www.res.bbsrc.ac.uk/dpv/index.htm for information to obtain CD-ROM
Contact: Carol Millman
Agency/Organization: Horticulture Research International
Phone: +44 (0)1789 470-382, ext.191 (United Kingdom)
Fax: +44 (0)1789 470-234

Virus Identification Data Exchange (VIDE)
Website: http://biology.anu.edu.au/research-groups/MES/vide/refs.htm
Contact: Michael Dallwitz
Agency/Organization: CSIRO Division of Entomology
Phone: +61 (0)6 246 4075 (Australia)
Fax: +61 (0)6 246 4000

Plant Pests and Disease Agents

Identified Plant Pests Regulated by APHIS is an interactive database of plant pests (insects and other arthropods, mollusks, plant pathogens, etc., but not weeds), listed by name in the regulations of the USDA Animal and Plant Health Inspection Service (APHIS). However, it is not a comprehensive list of all pests for which APHIS may take action upon inspection of commodities or conveyances at ports of entry. The focus is at the species level; however, some records are provided at the family level; e.g., Tephritidae (fruit flies). The regulatory information has been obtained from the Code of Federal Regulations, Title 7, Volume 5, Parts 300 to 399. The database is updated quarterly. Information in the database is useful to commercial importers and/or exporters, port inspection officers, risk assessment specialists, and other parties interested in international trade and associated pest organisms. Data fields include:

- Pest scientific name
- Pest common name
- Pest phylum
- Pest class
- Pest order
- Pest family
- Pest type
- Host scientific name
- Host common name
- Pest location
- Code of Federal Regulation Number

Website: http://www.InvasiveSpecies.org
Respondent: Kenneth Lakin
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Fax: 919-513-1995
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***Port Information Network*–309 (PIN-309).** The USDA Plant Protection and Quarantine (PPG) unit of the Animal and Plant Health Inspection Service conducts quarantine inspection as a primary defense against entry of foreign insects, mites, snails, nematodes, plant pathogens, and federal noxious weeds. Approximately 1,300 PPQ officers serve at international airports, seaports, and border stations to inspect passengers, baggage, agricultural commodities, general cargo, and ship's stores. Officers inspect these introduction pathways for pests, pathogens, and federal noxious weeds. PIN-309 is a centralized database system that records and tracks all quarantine significant pests detected by officers. USDA uses this information to support risk assessments, international phytosanitary discussions, port resource allocation, local program analysis, customer inquiries, and other types of analysis. Upon request, customized reports from PIN-309 are available to researchers outside PPQ for analysis regarding movement of certain potentially invasive alien species.

Website: N/A
Respondent: Joyce E. Cousins
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***National Agricultural Pest Information System* (NAPIS)**. NAPIS provides plant pest survey data in conjunction with the Cooperative Agricultural Pest Survey (CAPS). It describes the results of a wide range of plant pest surveys conducted throughout the U.S., and serves as the official U.S. phytosanitary database under the standards of International Plant Protection Convention. Emphasis is on surveys for exotic pests, pests which may impact export of U.S. agricultural products, cooperative program pests, and biological control agents. CAPS projects facilitate the collection and management of data on these subjects.

NAPIS data are referenced to a state and county, and each record may have point-location referencing. Access to NAPIS has been provided to the State Land Grant University, the State Department of Agriculture, and the headquarters for the USDA-APHIS-PPG unit in each state and in Puerto Rico. Other USDA agencies also have access to NAPIS. CAPS members and other users may access NAPIS via direct dial telephone service or the Internet. CAPS members may use NAPIS for managing data on any nonvertebrate plant pest, and may enter individual records, summary records, presence/absence data, or quantified data. In addition to formatted data, NAPIS contains graphic and textual information in a World Wide Web link format.

NAPIS has replaced hard copy publications which formerly reported the results of various USDA pest surveys (i.e., the Cooperative Plant Pest Report, the Cooperative Economic Insect Report, and the Plant Disease Report). Data previously reported to these publications is now entered into NAPIS, which can download data in coded or plain-language forms and generate a variety of reports, including specialized reports tailored for particular projects or needs. Used with standard geographic information system (GIS) software, NAPIS data can also be downloaded to create maps and analytical reports.

Website: http://ceris.purdue.edu/napis
Respondent: Dave McNeal
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E-mail: dave.mcneal@usda.gov

Exotic Forest Pest Information System for North America (EFPISNA). The database, being developed by the USDA Forest Service and maintained by the NSF Center for Integrated Pest Management, identifies exotic insects, mites, and pathogenic organisms with potential to cause significant damage to North American forest resources. It contains valuable background information on each identified pest and serves as a resource for regulatory and forest protection agencies in North America. The database indicates the relative importance of each pest based on the ability to maintain a free-living population and to cause either economic or environmental damage in its new range. The pest risk assessment model developed for this project emphasizes potential for establishment and impact. Information on pathways for introduction and means of dispersal is provided in Pest Fact Sheets. The online database, initially deployed with minimal records in November 1998, should prove useful for the assessment and management of introduced pests, wood products and other commodities from foreign sources. The number of pest records in the database is expected to increase greatly in 1999.

EFPISNA is being developed under the sponsorship of the North American Forest Commission and involves, Canada, the U.S., and Mexico. The database will be available in French, English, and Spanish.

Website: http://www.ExoticForestPests.org
Respondent: Joseph G. O'Brien
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Phone: 651-649-5266
Fax: 651-649-5238
E-mail: obrie031@tc.umn.edu

Slow-the-Spread Gypsy Moth Database. The database is part of a cooperative pilot project of the USDA Forest Service, Animal and Plant Health Inspection Service, and state governments to delay the damage and management costs associated with the spread of the exotic gypsy moth to new forest areas. Since its introduction to North America near Boston in 1869, the gypsy moth has slowly expanded its range and, in 1998, infested somewhat less than one-third of the potentially susceptible U.S. forests. Spread rates have increased during the last 30 years and projections indicate that the species could infest most of the remaining susceptible forests in the South and Midwest during the next 30 years. The database contains monitoring data, collected and reported using standardized procedures, from the Slow-the-Spread (STS) pilot project conducted from 1992 to 1998 in portions of Michigan, North Carolina, Virginia, and West Virginia. STS deploys grids of pheromone traps to intensively monitor transition areas where numerous distinct, low-density populations have recently become established ahead of the expanding population front. Detected populations are treated. Without treatment these populations would continue to expand, coalesce, and contribute to increased spread. Analyses using the database have shown that the rate of gypsy moth spread could be slowed by at least 60 percent through comprehensive implementation of these management practices throughout the transition area.

The distributed database currently has nodes in four (soon to be five) states. All nodes run Oracle-E27 either on Sun SPARC stations or on PCs with Windows NT operating systems. The Virginia Gypsy Moth Information Management System in the Department of Entomology at Virginia Polytechnic Institute and State University (Virginia Tech) maintains the master database with approximately 600 megabytes of data stored online, as well as the primary STS web server (on a Sun workstation). Web pages are the major means for disseminating STS information at all project levels. Their primary functions are to introduce the project, distribute survey reports and maps, facilitate access from the field to the STS FTP server, provide a repository of historical data, and facilitate evaluation and analysis of information. Efforts have been made to have all servers present data in an identical or similar format to provide a seamless interface among the different servers. As the STS program expands, the distributed design of the database and Web server will allow for a seamless expansion of the information system toward the goal of an operational, national STS program.

Website: http://www.gypsymoth.ento.vt.edu/STS
Respondent: Sally Waldon
Agency/Organization: Virginia Tech
Phone: 540-231-9119
Fax: 540-231-9131
E-mail: swaldon@vt.edu

Historical Gypsy Moth Data. The database provides data collected through several pest management programs, including the USDA Forest Service's Appalachian Integrated Pest Management (1988 to 1992) and Slow-the-Spread (1993 to present) Programs. The database consists of georeferenced data on male moth counts (1980 to 1998) of the gypsy moth *Lymantria dispar* L. and egg mass sampling (1988 to 1991). Data on male moth counts can be analyzed on-line to monitor the progression of the population front and to suggest areas for placing delimiting grids of traps and for treatment. All files are in ASCII format with three columns separated with tabs or spaces, and x y counts, where counts refer to male moth counts in a pheromone trap or counts of gypsy moth egg masses in a plot.

Website: http://www.ento.vt.edu/~sharov/stsdec/histdata.html
Respondent: Alexei Sharov
Agency/Organization: Department of Entomology, Virginia Tech
Phone: 540-231-7316
Fax: 540-231-7131
E-mail: sharov@vt.edu

Other Plant Pest and Disease Databases

CABI Crop Protection Compendium
Website: http://cabi.org. See website for information to obtain CD-ROM.
Contact: Peter R. Scott
Agency/Organization: CAB International
Phone: +44 (0)1491 832-111 (United Kingdom)
Fax: +44 (0)1491 826-090
E-mail: cabi@cabi.org

Global Plant and Pest Information System
Website: http://pppis.fao.org/Content.htm
Contact: Tonie Putter
Agency/Organization: Food and Agriculture Organization
Phone: +39 06 5705-4022 (Italy)
E-mail: Tony.Putter@fao.org

New and Emerging Plant Diseases Project
Website: http://www.ces.ncsu.edu/depts/ent/clinic/Emerging/
Contact: O.W. Barnett
Agency/Organization: Department of Plant Pathology, North Carolina State University
Phone: 919-515-2730
E-mail: ow_barnett@ncsu.edu

Animal Diseases

WILDPro Multimedia. WILDPro is being developed by the U.S. Geological Survey's National Wildlife Health Center and cooperating organizations to provide data on wildlife diseases. The project is designed from a user's perspective and organizes data in a structure unlike traditional fixed databases. The database allows users to find information through hypertext links rather than through search queries, although queries are available. When completed, WILDPro will contain data on species biology, disease agents, and disease conditions; link environmental, ecological, and habitat data; and provide source references for all data. The program allows for direct entry of new data and direct input from preexisting databases. Flowcharts offering step-by-step guidance for the identification and control of diseases are also included, with hypertext links to supporting data. Geographical data are linked to both disease agents and affected species.

Website: N/A
Respondent: Joshua Dein
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***Wildlife Health Epizootiological Database* (EPIZOO).** EPIZOO is a computerized record of wildlife mortality and morbidity events (epizootics), summarizing information gathered by personnel at the U.S. Geological Survey's National Wildlife Health Center. EPIZOO tracks events throughout the U.S. and territories, primarily in migratory birds. Data include incident, dates, species involved, history, population numbers, total sick/dead, and morbidity and mortality information. Complete data from 1975 to the present are included, as well as some data from earlier years.

Website: N/A
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***Wildlife Health Diagnostics Database* (DIAGDATA).** The diagnostics database is a computerized record of specimens (from serum samples to carcasses) sent to the U.S. Geological Survey's National Wildlife Health Center for processing and diagnostic work-up. The data file includes five 80-character lines of coded data for each specimen. Data include history and record-keeping information (identifier numbers, species, sex, submitter information, etc.); types of tests run (virology, bacteriology, parasitology, chemistry, etc.) and some test results for heavy metals, particularly lead; and diagnostic results. The diagnostic coding system is based on the terminology of the Systematized Nomenclature of Medicine (SNOMED), with certain modifications and additions to fit Center needs. SNOMED is a structured nomenclature and classification of terminology used in human and veterinary medicine.

Terms are assigned in any or all of the following five categories for each diagnosis:

1. Topography—anatomic term for the site of interest.
2. Morphology—information on the pathogenic change or process associated with the site of interest.
3. Etiology—cause or causal agent of the disease or dysfunction.
4. Disease—disease, disease entity, or syndrome.
5. Link—qualifier to link one diagnosis to another.

Historical and some procedural information is available for data from 1975 (when the Center opened) through 1983. Coding of diagnostic information on these older submissions is ongoing, but slow. Beginning in 1984, all five lines of data are provided for all cases that have been finalized.

Website: N/A
Respondent: Joshua Dein
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OIE World Animal Disease Data. The International Office of Epizootics (OIE) maintains a database on the status of selected animal diseases found throughout the world. Currently, diseases are listed by their potential for spread and the severity of damage caused. "List A" contains transmissable diseases which have the potential for very serious and rapid spread, without regard to national borders, which have serious socioeconomic or public health consequences, and which are of major importance in the international trade of animals and animal products. "List B" contains diseases which are considered to be of socioeconomic and/or public health importance within countries and which are significant in the international trade of animals and animal products. The database is available both in hard copy and in electronic form via the Internet. Searches can be conducted either by disease or by geographic location. OIE's website provides information on disease classification; disease distribution; standards for surveillance, diagnosis, and reporting; control; laboratories; experts; and other information.

Website: http://www.oie.int
Contact: Steve Weber
Agency/Organization: Veterinary Services, APHIS, USDA
Phone: 970-490-7901
Fax: 970-490-7999
E-mail: steve.weber@usda.gov

Introduced Beneficial Organisms

Releases of Beneficial Organisms (ROBO) in the U.S. and Territories. The USDA Agricultural Research Service's Biological Control Documentation Center (BCDC) manages ROBO to document the introduction, field release, and recolonization of exotic natural enemies (both invertebrate and microbial) of invertebrate pests and weeds in the U.S. (including Hawaii and U.S. Caribbean and Pacific territories), and the shipment of such organisms from the U.S. to foreign countries. Importation and release

of exotic pollinators is also recorded. ROBO is currently being reprogrammed from its origin on a Wang computer system to operate on the UNIX Sun computer of the USDA's Germplasm Resources Information Network (GRIN). The ROBO database currently includes records for only five years (1981 through 1985). Entry of historical data from the voluminous records of past importations and releases resident in the Documentation Center, as well as data on current importations and releases, are expected to be accomplished rapidly when database reprogramming is completed in 1999. ROBO is still in the process of development on the Internet in early 1999. This includes final development and testing of the data entry screens, refinement of data search capabilities, and final review of five years data (19,706 records) currently included in the database. USDA facilities (Agricultural Research Service, Animal and Plant Inspection Service, and Forest Service) and their cooperators (including many U.S. universities, state departments of agriculture, etc.) will then be able to enter current data and search the database via the Internet, allowing the Documentation Center to fill the gaps between 1986 to the present and to add data for importations and releases from 1934 to 1980. ROBO provides important information for use in efforts to address threats from invasive species, protect global biological diversity, and develop U.S. regulations relating to international trade involving exotic organisms.

Website: http://www.ars-grin.gov/nigrp/robo.html
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E-mail: jcoulson@nal.usda.gov

Aquatic Organisms

Nonindigenous Aquatic Species Database. Primarily in response to the introduction of the zebra mussel into the Great Lakes, Congress enacted the Nonindigenous Aquatic Species Prevention and Control Act of 1990. The major focus of the Act was to set a framework to monitor, control, and prevent the introduction of nonindigenous aquatic species. A core element of this framework was to create an Information Service to provide timely data on the presence and distribution of introduced aquatic species. In 1993, the Nonindigenous Aquatic Species Program was established. The program is founded on a database containing more than 39,000 geographically referenced accounts of aquatic organisms introduced to fresh and marine waters since 1850. More than 1,100 species of vertebrates, invertebrates, their diseases and parasites, as well as vascular and nonvascular plants are tracked. Nonindigenous coverage includes exotic species as well as native organisms introduced outside of their natural range. Staff scientists from the U.S. Geological Survey's Florida-Caribbean Science Center research and compile spatial data from a variety of sources including published literature, agency reports, monitoring programs, museum accessions, on-line databases, professional communications and a website reporting form. The database is composed of fields that set a protocol for extracting and referencing data. Records are normalized by georeferencing according to USGS hydrologic unit, which correlates occurrence data to drainage basin. Real time Internet access to a portion of the dataset ensures that new records are available within 24 hours to the World Wide Web. Website users can perform state or hydrologic basin queries, obtain fact sheets and distribution maps, or contact the staff for custom reports.

Website: http://nas.er.usgs.gov
Respondent: Pam Fuller
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E-mail: Pam_Fuller@usgs.gov

National Marine and Estuarine Invasions Database. The database focuses on marine and estuarine alien species in U.S. waters, including organisms that occur in tidal waters of all salinities (i.e., freshwater to full marine salinities). The database is developed and maintained by the Smithsonian Environmental Research Center (SERC) with the primary goal of describing the patterns and effects of alien species invasions in coastal communities at multiple spatial and temporal scales. For each species, the database includes detailed information about taxonomy, invasion history (e.g., mechanism and date of introduction, source region, history of spread, etc.), population biology (e.g., life-history characteristics, abundance), community ecology

(e.g., habitat utilization, environmental tolerances, interspecific interactions, and ecological effects), economic impacts, as well as associated references for each topic area. Although the database is used to synthesize available information on a species-by-species basis, it is explicitly designed as a research and management tool to test hypotheses about invasion patterns and processes. It can be queried to examine patterns and impacts of invasion by taxa, region, habitat, date of invasion, mechanism of introduction, source region, etc. The database is now complete for Chesapeake Bay and analyses of invasion patterns and effects are at various stages of completion. SERC is presently expanding the scope of this database to include other coastal sites and regions throughout the U.S. to (1) characterize invasion patterns on a national scale and (2) measure spatial variation in the extent and consequences of invasions. The database (and resulting analyses) will continue to develop and expand over many years, as part of the National Ballast Water Information Clearinghouse, and will provide a national information source on marine and estuarine invasions through SERC's website.

Website: http://www.serc.si.edu
Respondent: Gregory M. Ruiz
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Phone: 301-261-4190, ext. 227
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E-mail: ruiz@serc.si.edu

The Aquaculture Health Page is a compilation of links to aquacultural information on fish, molluscan, and crustacean diseases, nutrition, multimedia, educational programs, diagnostic services, drugs, water quality, conferences, and organizations.

Website: http://geocities.com/CapeCanaveral/Lab/7490/index.html
Respondent: Bill Lussier
Agency/Organization: Spencer Institute of Training and Further Education
Phone: +61 (0)8 8688-3639 (Australia)
Fax: +61 (0)8 8688-3675
E-mail: billluss@sp.tafe.sa.edu.au

Indian River Lagoon Species Inventory. The high biodiversity of the Indian River Lagoon (IRL), located on Florida's central East Coast, is a valuable coastal resource which is increasingly impacted by anthropogeneic activities. A taxonomic listing of over 2,400 plants and animals, compiled initially by Hilary Swain, provides an important basis for disseminating and updating information on the status of IRL's biodiversity. The Smithsonian Marine Station is converting the IRL Species Inventory into an Internet-accessible database, using a format that will allow for updating and revising the initial data and for expanding the database to include available information on species life history, habitat requirements, ecology, economic importance, special status (exotic, threatened, endangered), and geographic range, including distribution within the IRL. The expanded database is scheduled to be accessible at http://www.sms.si.edu by May 1, 1999.

Website: N/A
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E-mail: dineen@hboi.edu

Other Databases on Aquatic Organisms

Aquatic, Wetland, and Invasive Plant Information Retrieval System. Database provides access to numerous sources of information and services relating to aquatic and wetland invasive plants in Florida.

Website: http://aquatl.ifas.ufl.edu/
Contact: Karen Brown
Agency/Organization: Center for Aquatic and Invasive Plants, University of Florida
Phone: 352-392-1799
Fax: 352-392-3492
E-mail: kpb@gnv.ifas.ufl.edu

Directory of Nonnative Marine Species in British Waters.
Website: http://www.jncc.gov.uk/advisors/marine/dns/
Contact: N. C. Eno
Agency/Organization: Joint Nature Conservation Committee
Phone: +44 (0)1733 562-626 (United Kingdom)
Fax: +44 (0)1733 555-948
E-mail: Feedback@jncc.gov.uK

Florida Department of Environmental Protection Biological Database. Taxonomic database for aquatic organisms in Florida. Majority of data for freshwater invertebrates; considerable information on marine invertebrates; and 400,000 records from 1950 to present.

Website: http://www.flmnh.ufl.edu/fbic/dep.html
Contact: Landon Ross
Agency/Organization: Florida Department of Environmental Protection
Phone: 904-487-2248
Fax: 904-922-5368
E-mail: ross_l@dep.state.fl.us

Introduced Marine Species in Australian Waters. Provides lists of introduced marine species for Australia as a whole and for the seven Australian states.

Website: http://www.ml.csiro.au/~hewitt/CRIMP/isppfram.html
Contact: Castray Esplanade
Agency/Organization: National Center for Research on Introduced Marine Pests
Phone: +61 (0)3 323-452 (Australia)
Fax: +61 (0)3 323-485
E-mail: crimp@marine.csiro.au

Introductions of Aquatic Species (DIAS)
Website: http://www.fao.org/waicent/faoinfo/fishery/statist/fisoft/dias/mainpage.htm
Contact: D. Bartley
Agency/Organization: Fisheries Department, Food and Agriculture Organization
Phone: +39 06 5705-4376 (Italy)
E-mail: devin.bartley@fao.org

Seaweed Database includes scientific names, distribution, and other information on benthic marine green, brown, and red algae, and the genus *Vaucheria*, for more than 6,500 species, subspecies, varieties, and formae.

Website: http://140.203.14.29/Tango/species.qry/function-form
Contact: Michael D. Guiry
Agency/Organization: Martin Ryan Marine Science Institute
Phone: + 353 (0)91 750 410 (Ireland)
Fax: +353 (0)87 251 9917
E-mail: mike.guiry@seaweed.nuigalway.ie

Global and Regional Databases with Broad Taxonomic Coverage

***World's 100 Worst Invasive Species*.** The World's 100 Worst Invasive Species is a database funded by the total Foundation and making up a part of the Global Invasive Species Programme (GISP) "Early Warning" section. This database will focus on invasive species that threaten conservation and biodiversity values, rather than agricultural, economic or other interests. It is intended to serve as a tool for public awareness and education and thus is limited (artificially, but usefully so) to 100 species only. Species will be included if they are deemed to be amongst the top 100 of those high-risk species (e.g., the brown tree snake being developed by the World Conservation Union's Invasive Species Specialist Group and cooperating organizations, for elucidation and testing of database design and content for two larger-scale regional databases. World's 100 Worst will focus on species that threaten conservation and biodiversity, rather than agriculture or other values. The database is intended to serve as a tool for public awareness and education, and is thus limited to 100 species. Species will be included if they are deemed to be amongst the top 100 of those presenting a high global risk to biodiversity; e.g., the brown trees snake, a small, nocturnal, generalist predator which has devastated the native land birds of Guam, and is easily transported worldwide after self-concealment in aircraft undercarriages and packaging.

The system will be structured as a *Paradox* database with web-page front end. It will be a globally accessible, free, and a user-friendly information source. The project is being managed by Sarah Lowe from the World Conservation Union's (IUCN) Invasive Species Specialist Group, in collaboration with many partners. Technical expertise is supplied by the Hawaiian Ecosystem at Risk (HEAR) Project,

and specifically Phillip Thomas. A publication will be available for parties without access to Internet.

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Integrated Taxonomic Information System **(ITIS).** ITIS is the first comprehensive, standardized reference for the scientific names, as well as synonyms and common names, of all the plants and animals of North America and surrounding oceans. The goal of ITIS is to create an authoritative, easily accessible, well-documented database with scientifically credible integrated information on species names and authors, their taxonomic classification, commonly used synonyms, common names, species nativity (native or introduced), and general distribution. The ability to refer to an authoritative taxonomic nomenclature or dictionary of accepted biological names is a prerequisite to biological data sharing and effective communication about flora and fauna. ITIS is a cooperative effort of several U.S. federal agencies including the U.S. Geological Survey, Environmental Protection Agency, Agricultural Research Service and Natural Resource Conservation Service, National Oceanic and Atmospheric Administration, and the National Museum of Natural History, Smithsonian Institution. Within the past year, Agriculture-Canada has joined the ITIS effort. ITIS is also a partner in the global Species 2000 program to index the world's biological diversity. ITIS partner agencies collaborate with taxonomic specialists throughout the world who serve as "stewards" to develop, review, and verify the reliability and quality of the taxonomic data represented. ITIS data are periodically reviewed to ensure current information is being presented. The database can be directly accessed from the World Wide Web.

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Invasive Species of Indian Ocean Islands. The database is currently being developed to disseminate information about invasive species, and specifically those which threaten biodiversity and conservation values. The geographical focal area, at least for the first phase of database development, is the small islands of the Pacific and Indian Oceans. Small isolated ecosystems are particularly vulnerable to invasion by more cosmopolitan species, and as a result, suffer huge losses of native biodiversity. The database is part of the "Early Warning" section of the Global Invasive Species Programme (GISP); this section aims to put in place systems that will either prevent new invasions or provide expertise to control or stop invasions detected in their early stages, before too much damage is done. The system under development is a *Paradox* database with web-page front end. The project is being managed by Sarah Lowe from the World Conservation Union's (IUCN) Invasive Species Specialist Group, in collaboration with many partners. Technical expertise is supplied by the Hawaiian Ecosystem at Risk (HEAR) Project, and specifically Phillip Thomas. An updateable hard-copy handbook will be produced, in conjunction with the database, for users without Internet access.

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Harmful Nonindigenous Species in Hawaii. The database is a loosely-bound collection of databases and electronic information sources containing information about alien species which are or could be detrimental to the economy, quality of life, and/or natural resources of the state of Hawaii. The U.S. Geological Survey's Biological Resources Division, in cooperation with partner agencies and organizations, is developing the database as a component of

the Hawaii Ecosystems at Risk (HEAR) Project. The purpose of the HEAR database is to provide access to information about nonindigenous species to land managers, decision makers, and the general public. The individual data sets comprising the database are maintained by HEAR as well as federal, state, and private sector organizations. Data sets include information such as: detailed harmful nonindigenous species write-ups; one-page public education flyers on particular species; permanent-plot/transect-based data from protected areas; island- and area-specific distribution and "controllability" data; plant pathogen data; herbicide-treated areas (national park data); information on alien threats to endangered/ threatened species; and information on other data sets relevant to alien species in Hawaii. Most information in the HEAR database currently focuses on plants, although some information on vertebrates and invertebrates is included. However, any harmful or potentially harmful nonindigenous species is eligible for inclusion. The individual data sets comprising the HEAR database codify species information based on statewide de facto standard "taxon codes," developed by HEAR, which in turn are based on standard nomenclature maintained by Bishop Museum (the State Museum of Natural and Cultural History). Using these data sets, HEAR has developed a prototype modeling system for predicting the potential range of alien species in Hawaii based on species-specific climatic tolerance information. HEAR's goal is to eventually put all HEAR-maintained data on the World Wide Web; and much of the HEAR database is already available on-line in various formats. More detailed descriptions of all components of the database are available through HEAR's website.

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Illinois Natural History Survey Collections. The database provides computerized specimen label data from the extensive collections of the Illinois Natural History Survey (INHS). It includes data for the entire INHS collections of vascular plants, fish, mammals, reptiles and amphibians, mollusks, and crustacea, plus a few selected orders of insects. However, some assemblages containing a large number of non-indigenous species, mostly within the insects, have not yet been entered. All completed databases, except vascular plants, are available on the Internet at the INHS homepage under "On-Line INHS Databases." Georeferencing of specimens, at whatever level permitted by the label data, is included in some of the insect databases. Coordinates associated with specimens are plotted as point locations, place names, or county records using unique symbols. These maps are currently served to the Internet in a somewhat static form. Interactive mapping using the Internet may soon be possible, and will further encourage applications of the data in mapping, modeling, and prediction of species occurrence. This system is envisioned for all INHS data in the future.

Currently, only the mollusk database indicates whether a species is indigenous or not. Other INHS databases could be linked through taxon names to such resources as the USDA's North American Nonindigenous Arthropod Database. This would permit coding of species origins, at least at the continental level. Difficulty arises in coding species origins when smaller political and geographic units are considered. This more specific coding must be accomplished on a state-by-state basis.

INHS, founded in 1858, is the second oldest and largest of the state biological surveys in the U.S. INHS maintains major collections of aquatic and terrestrial organisms from middle North America, including more than 6 million insect specimens (ninth largest collection in North America) and 712,000 fish. As many INHS-supported state and regional surveys of fauna and flora occurred prior to pervasive degradation of natural habitats, the collections have exceptional value for documenting geographic and temporal distributions of indigenous and nonindigenous taxa.

Illinois is a hub for commerce and transportation. It retains very little of its natural habitat, and is especially vulnerable to the establishment and spread of nonindigenous, invasive species. The Asian longhorn beetle outbreak in suburban Chicago is a startling example of just how fast an invader can become problematic. To encourage an integrated approach to the study and management of non-indigenous species, a consortium of Illinois natural

resource agencies recently proposed to state government a new Illinois Exotic Species Invasion Management Strategy for fiscal year 2000. The objectives of this initiative include (1) identification and assessment of nonindigenous species threats in Illinois, (2) development of an educational program for young Illinoians, and (3) development and implementation of exclusion and control technologies for invasive, nonindigenous species. The INHS database provides essential information for implementing the proposed strategy.

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Other Databases with Broad Taxonomic Coverage

Fish and Wildlife Information Exchange
Website: http://fwie.fw.vt.edu/www/nframes/species.htm
Contact: Jeff Waldon
Agency/Organization: Department of Fisheries and Wildlife Sciences, Virginia Tech
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E-mail: fwiexchg@vt.edu

MABFlora/MABFauna Database. On-line database documenting occurrence of vascular plant and animal species (primarily vertebrates) in biosphere reserves and other significant protected areas, and various available metadata on reported species (including identification of nonindigenous species). Database includes country, regional, and global species checklists for plant and animal groups. Current coverage includes 379 biosphere reserves in 75 countries.

Website: http://ice.ucdavis.edu/MAB
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Hawaii Biological Survey Databases
Website: http://www.bishop.hawaii.org/bishop/HBS/hbsdb.html
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Overview of Databases

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The preceding abstracts provide a description of many of the databases discussed at the workshop, and additional detail on most of the databases described can be obtained by reviewing the completed data survey information forms on the National Biological Information Infrastructure (NBII) website on invasive species at **http://www.nbii.gov/invasive/workshops/dbsurveys.html.**

Any database on biodiversity should be considered as containing potentially important information for enumerating invasive species and their attributes. The databases reviewed at the workshop represent a small but important fraction of those developed and available. These databases do, however, provide examples of the spectrum of information needed in studying and documenting invasive species.

Regulated and Invasive Species

Among those databases specific to invasive species are several maintained by the USDA's Animal and Plant Health Inspection Service (APHIS): Federal Noxious Weeds, the North American Nonindigenous Arthropod Database, Identified Plant Pests Regulated by APHIS, and the Port Information Network. The latter two databases include only regulated and excluded pests and the information is limited to taxonomic and geographic data. More detailed biological information, together with risk analysis results, can be found in the Exotic Forest Pest Information System for North America being developed by the North American Forestry Commission and available in English, French and Spanish.

Other invasive species databases, such as the Invasive Species of Indian Ocean Islands and the Invasive Species of Pacific Islands, are relatively new efforts and focus on species that threaten biodiversity and conservation values. The World's 100 Worst Invasive Species is a pilot database being developed by the same Global Invasive Species Programme as the previous databases, again with those species threatening to biodiversity as the targets. On a more local basis, the Connecticut Invasive Plant Task Force is developing a database of brochures, websites, and other literature for the lay public.

Single Species Spread

There are a number of databases that provide detailed information on single species with a history of invasiveness. These databases provide more in-depth information, usually with current status of the species spread. Examples here include the Slow-the-Spread Gypsy Moth database and the Witchweed Management database. Such databases typically also contain historical information allowing analysis of long-term invasions and other distributional data.

Biodiversity/Taxonomy

Almost every museum and taxonomic research unit maintains taxon-specific databases with a focus on biodiversity. Of particular use are survey databases such as the Illinois Natural History Survey Collections and the North American Breeding Bird Survey. One of the most important efforts in this area is IABIN (Inter-American Biodiversity Information Network, see website www.nbii.gov/iabin), a collaborative effort of a number of museums working in biodiversity. This network uses a Z39.50 compliant client and Z servers to allow access to cooperating distributed databases.

Pest/Economic

Because of their economic importance, many taxa have databases detailing their biology, distribution, and life histories. Examples here include the Microbial Germplasm Database, the ROBO Database, and Hymenoptera-Online.

Database Considerations

Many of the above databases do not contain information on invasiveness specifically, but rather data on distributions, biology, and historical movement. The sheer number of databases available force us to

consider issues of database access, integrity, and continuity. Present technology allows us to share information, but compatibility, ownership and database security present formidable challenges.

Compatibility is a complex question incorporating both philosophical problems (naming conventions) and new technologies. The need for vocabulary standards and dictionaries represent only the first steps in dealing with compatibility issues.

New technologies such as XML, thin-clients, and COBRA-compliant software greatly increase our abilities to interact. These technologies are even changing our fundamental definition of databases. The World Wide Web has already done that. The largest databases ever to exist, by far, are the indexed searches of the major Web search engines. They are relatively disorganized and dumb, but XML and the next generations of Web languages and software could well make present day database efforts obsolete.

It is a simple matter today to embed searches (queries) to almost any Web database in another database or Web page. For data on the public Internet, trained experts can access that data and manipulate the resulting query output prior to presentation. At least among government and university workers, we must move to develop protocols to guide decisions on ownership designation and output configuration.

Database Coordination

There needs to be a significant effort to identify what key databases are presently available and which are needed, as well as an analysis of critical information which may be lacking in those databases already available. This need not be an exhaustive search, but rather the identification of those of greatest significance. Many of the databases available are taxonomic in nature. They contain little biological information and do not separate invasive from noninvasive species. However, they are critical in determining species distributions and need to be analyzed through time to present information on invasiveness propensities and pathways.

What is clearly lacking is a blueprint for coordination and use of these myriad databases. The key to prevention and control of invasive species lies in our ability to concurrently access the major invasive species databases. By creating on-demand documents containing all of the current and critical information on a given species, regulatory agencies can prepare management plans for interception, containment, or control within scientifically acceptable time constraints. This same information is also crucial in the development of predictive models for invasive species.

Many of the present databases are housed at land-grant universities on servers with high-speed, Internet access and highly trained information technology experts. The continued and expanded use of such facilities/expertise for database development and maintenance would enable continued access to these databases at modest costs.

All critical databases must be made available on-line. There must be an international effort to develop and maintain on-line database search tools capable of intelligent queries of key databases. Increasing global trade and resultant increasing threat of invasive species require quick and informed actions. Present technology allows this capability, but requires database coordination and cooperation at the highest level to provide funding for both the databases, their integration, and concurrent access to that information.

Such a program should involve not only U.S. government agencies, but should seek partnerships with state and foreign governments, universities, nonprofit organizations, and companies with a stake in preventing the ingress of invasive species. Understanding and managing invasive species requires all stakeholders to commit to the establishment and use of invasive species databases which can be used and interpreted quickly and accurately. We must all agree that *"information is not power; the sharing of information is."*

Models for Database Integration and Use

As we look to the future, we must develop processes that will enable us to share information much more effectively. However, in view of the large number of highly diverse databases and the many different perspectives that the developers of those databases have, it is probably unrealistic to attempt to develop a national plan that would deal with all of the integration, ownership, and use issues. Therefore, efforts to

deal with some of these key issues can best be directed towards efforts to work with small clusters of databases whose developers have close common interests to develop one or more models. One or more such models could then serve as a basis for developing protocols for more extensive integration of databases useful in dealing with invasive species. In view of the large resources being devoted to databases and the relative lack of coordination among them, action should soon be undertaken to develop models for the integration and use of databases. Databases provide a unique opportunity to link diverse interests and achievements, to enhance understanding, and to build consensus. Therefore, the conduct of some sharply focused facilitated activities involving stakeholders and public agency representatives should be organized as soon as possible.

State and Tribal Perspectives

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This session was devoted to databases that cover a particular state, tribal area, or smaller region. Databases of this type may have a vital role to play in addressing invasive species issues because the actual prevention and management of many invasive species is likely to be undertaken at the state, tribal, or site scales. Ironically, less than one-fifth of the 34 databases for which detailed information was submitted at the workshop were focused on a state, tribal area, or more local scale. To date, the invasive species databases that are most widely known and accessible tend to be regional or national in scope.

The panel for this session included three state agency representatives, a tribal agency representative, a representative from a federal agency that is encouraging the development of state-level databases, and a representative from one of the state Natural Heritage programs knowledgeable about how the different Natural Heritage databases are coordinated and are able to interact.

North Carolina Department of Agriculture and Consumer Services

The North Carolina Department of Agriculture and Consumer Services (NCDA&CS) maintains a database on the distribution of the federally designated noxious *Striga asiatica* (witchweed) as part of a project to eradicate this nonnative species. Witchweed was first detected in North Carolina in the late 1950s and at its greatest extent it infested 400,000 acres in North Carolina and South Carolina. Witchweed causes severe crop losses and is extremely difficult to control so the USDA set out to contain and then eradicate it from the United States. Several years ago, NCDA&CS assumed the lead responsibility for the effort. As part of the eradication effort infested land is quarantined to prevent the species from spreading, so accurate field data are essential. The project also determines when quarantines of these farmlands are lifted, so accuracy and up-to-date information are very important.

NCDA&CS staff members conduct on-the-ground surveys and collect location data for witchweed. They record field data on scantron-type sheets which are quickly shipped back to the office, error checked and uploaded to the database. Monitoring continues at sites even after they have been released from quarantine to ensure that new outbreaks are quickly detected. The witchweed database is used to track the history of infested acreage and to pinpoint areas that require inspection. Mapping classifications for the database will be refined in the future. The database is an integral part of the eradication program which has thus far reduced the witchweed infestation to approximately 6,600 acres. A distinguishing feature of this database is its narrow and clearly defined purpose, and its integration into a highly responsive witchweed eradication program. See the database abstract in these proceedings.

Illinois Natural History Survey

The Illinois Natural History Survey (INHS) collection of databases are dedicated to the understanding of Illinois' biotic resources. They contain information on more than 8 million plant and animal specimens housed in the state's herbaria and museum collections. Because they contain information on when and where each specimen was collected, they allow species to be tracked through time and space across the state. The location data on each specimen is also assigned a spatial accuracy code, which allows the accuracy of species distribution maps generated from the databases to be assessed. Of the total number of specimens in the databases, about 75 percent are arthropods, 9 percent fish, 3 percent plants, 2 percent mollusks and crustaceans, and 11 percent other taxa. Most of the information in the databases is on a website, although insects and various other arthropods are underrepresented. The INHS also maintains ecological databases on insect pathogens and viral diseases. INHS is the largest state natural history survey in the nation and has maintained this status and a relatively high level of staffing, mainly because of its long-standing university relationships.

See the database abstract in these proceedings and the website given there for additional information.

Hawaiian Ecosystems At Risk Program

The Hawaiian islands are faced with tremendous threats to their biological diversity that differ in kind and degree from that seen on the mainland. The Hawaiian biota has a higher rate of endemism than any other state or region in the U.S.; in fact, it is one of the highest in the world. The biota developed in isolation had no native land mammals, reptiles or amphibians, ants, and species from many of the families that dominate continental tropical and subtropical areas. These factors appear to have made the islands especially susceptible to disruption by invaders from these and other taxa. In addition, the islands have been a shipping and trade center for the entire Pacific Basin for the past 200 years and they contain almost all of the worlds' climatic zones or biomes, and the islands provide appropriate climatic conditions for a vast number of species. Today, nearly 50 percent of the flowering plant species growing wild in the islands are nonnative species introduced directly or indirectly by humans.

The databases that the Hawaiian Ecosystems at Risk (HEAR) Project maintain are designed to disseminate information to land managers, policy makers, the Maui Invasive Species Committee, and the general public. This is done through websites, e-mail lists, technical support, etc. HEAR uses its normalized relational databases to provide range maps, species information sheets, and species-island matrices. Most recently, work is being done with landscapers to provide horticultural alternatives to invasive species. See the database abstract in these proceedings and the website given there for additional information.

A View of Databases from the Bureau of Land Management

The Bureau of Land Management (BLM) has the responsibility for managing millions of acres of public lands and is concerned primarily about invasive weeds. BLM is working primarily at the state level to encourage the development of databases that will be useful in managing noxious weeds. At the present time, there is a need to move towards some standardization of record keeping and of database design, but the methodology needs to be practical and user friendly. In this regard, BLM is encouraging the development of state-level databases modeled after one in Idaho using MS Access software. BLM is also encouraging further development of a similar database in Montana. In Colorado, state-level efforts to deal with noxious weeds are fairly recent since the first state weed law was passed in 1991. A more recent initiative by the Governor of Colorado has resulted in the employment of a full-time state noxious weeds coordinator, the development of a memorandum of understanding involving about 14 state and federal agencies, and the establishment of a noxious weed management team. The team meets regularly and sponsors an annual "Weeds Awareness Week." As efforts in Colorado continue to increase, databases are certain to receive more attention.

Experiences by personnel in the Colorado BLM Office indicate that the development of state-level databases is likely to be the most effective approach, at least in the short term, for BLM to use computerized databases in managing invasive plants.

The Tulalip Tribe

The Tulalip Tribe has retained its rights to harvest 50 percent of the finfish and shellfish in certain waters of Washington state under treaties signed in the 1800s. These treaties have been upheld by recent court rulings. The tribe's natural resources program co-manages finfish and shellfish populations with Washington state agencies. It has developed, through the Bureau of Indian Affairs, Geographical Information Systems (GIS) projects that map shellfish distributions, especially for application in litigation proceedings. The U.S. Environmental Protection Agency is also supporting a related GIS project. Data from these projects have application for Endangered Species Act issues, cultural and enthnobotanical databases, finfish/shellfish databases, and exotic species monitoring. The tribe is monitoring the status of such invasive species as purple loosestrife, eurasian milfoil, spartina, zebra mussels, green crabs, and mitten crabs in waters it harvests. Plans are being made to design a database to accommodate the monitoring data being collected and to use it for management purposes.

The Nature Conservancy and Colorado Natural Heritage Program

There are Natural Heritage programs with conservation databases in each of the 50 United States as well as similar programs in several Canadian provinces, Mexican states, and Latin American nations. There are a total of 135 programs worldwide. Each of these programs has a distinct history and operates as a separate unit, but they share a common methodology that allows for exchange of information. The first Natural Heritage programs were initiated by or with assistance from The Nature Conservancy (TNC), a private, nonprofit conservation organization. Natural Heritage programs are now administered and funded by state agencies in most states but in a few states these programs are still fully or partially funded and administered by TNC. TNC also continues to fund and administer staff who help maintain and update national, indeed international, database platforms and who assist with data collection and database methodology. TNC's role at this level is undergoing a rapid change, however, and a separate nonprofit organization, Association for Biodiversity Information, will assume many of these functions for the Natural Heritage network over the next few years.

Originally, TNC was one of the main users of the detailed information on the location and status of plants and animals provided by the Natural Heritage programs. As time has passed more and more federal, state, and local agencies, private organizations, and corporations have become "customers" of the Heritage programs. All the Heritage programs operate with a uniform methodology, and track the same sort of data; i.e., what are the "elements" (species and biological communities) in the state and where are they located, how rare are they at the state and global level (rated with numerical state/global indices known as S-ranks and G-ranks), and how healthy or viable is each population or occurrence. Together the Heritage networks house the largest, most comprehensive set of location and condition data on native flora and fauna in the world. To date, however, only a few of the individual programs have collected data on nonnative species although some have recently accelerated their compilation.

Common Issues

Common issues arose frequently. The need to ensure data quality, and not just data quantity, is important and often under managed. There is a common interest to make data available on the Internet, although usually only subsets of the information contained in each database are appropriate to post. In some cases combining databases would be useful, but it was unanimously agreed that specific benefits of combining information from two or more databases should be identified before the time-consuming and expensive work to make this possible is undertaken. Fusing different data sets is usually nontrivial, and should only be done if real benefits will result. Often the best results come from smaller databases—bigger is not always better.

Underlying Problems Of Databases: Concerns And Needs

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Review of the various databases at the workshop identified a number of problems inherent with databases targeted to alien invasive species. Of those reviewed, the databases were in various stages of development, utilized different data entry and management systems, and the means for maintaining the information in a current and accessible form was not always clear. A comprehensive database for all invasive species does not exist and is not likely to be developed because of the diversity of the various species and the diversity of users. Relevant information may be imbedded into larger databases designed for other purposes, and specific information on invasiveness is difficult to identify. The ideal solution is to create a single portal of entry to a multitude of databases, each of which is maintained in a scientifically accurate, timely, and accessible manner.

Organism Information and Verification

Databases will be of greater value for communicating information to multiple users addressing alien/invasive species only if agreement can be reached on common language, terms, and definitions across disciplines. For example, for some organisms it might be sufficient to include organism descriptions at the most common level of classification, the species. For others, such as microorganisms that are plant pathogens, subspecies, or infra subspecies, level descriptors must be included in order to record information relative to their distribution and host specificity. Further, the nomenclatural designations should include current scientific names as well as alternative and previously used names. There must be a mechanism for incorporating new descriptions and taxonomic changes, and new approaches to classification. Voucher specimens of some organisms are needed for examination to verify identity by systematists, who themselves are becoming an endangered species. In contrast, most microorganisms require comparison of characteristics with living cultures or nucleic acid from them. Systematists are increasingly using molecular genetic and genomic data for identification.

Organisms for Inclusion in Alien/Invasive Species Databases

The types or organisms most discussed were those which have been highly visible and recognized as invasive, nonindigenous species in aquatic, forest, range, and farmlands. Organisms such as “escaped” animal pets may also establish readily and became invasive, but data to support this do not seem to be available. No database information was included on the potential for invasiveness of nonindigenous species that have been introduced by, for example, botanical gardens as horticultural specimens and by others who have exchanged seeds such as agronomist/plant breeders and plant hobbyists. Such data could be valuable in addressing the ability to predict whether an introduced, nonindigenous species will become invasive and harmful. From experience, many introductions must be nurtured to survive in new habitats and are thus unlikely to become established and spread. Such negative data might be of value.

It is also known that all organisms bring with them a coterie of other organisms, both macrobial and microbial, that may be either beneficial pests or pathogens. These invisible invaders—hitchhikers—are co-travelers in the lives of organisms, but must be recognized and reconciled. A small number entering in this way are plant pathogens, recognized as alien/invasive and specific to a host; others go unnoticed. Pathogens such as viruses may not be considered invasive until a vector is introduced. It is important that databases be accessible across taxa, however, since some have a broader host range and the potential for harm is much greater. For example, the cross-kingdom affecting bacterium, *Burkholderia cepacia* (a.k.a. *Pseudomonas cepacia*), is a soil-inhabiting organism now known to have strains that cause disease in plants and animals.

Validity and Predictive Nature of Data

A database will only be as good as the data that are entered into it. A report that is from a single observation should be of questionable validity and entered with appropriate qualifications. Entries of the highest validity should be those from peer-reviewed publications, as the review should have established the quality of the identification, and the paper described the site(s) where the organism has been reported. A follow-up process is needed for updating and observation, and for providing evidence that an organism continues to exist in an area or it is no longer found. Since the amount of detail in a published report may vary, criteria that an organism must have met before it is included in a database of alien invasive species need to be agreed to. Such criteria may include the ability to colonize or establish in a site; maintain a population of individuals; spread to other sites; and have an environmental or economic impact. The process for assessing the impact of the species and judging it harmful should be stated. Differentiation must be made between ecosystem disruption and economic disruption. Past analyses have, for example, focused on economic disruption caused by pathogens and pest species rather than their impact on natural ecosystems. A database might be more useful for predicting and managing invasions if ecological studies could be done in the countries of origin with potential and known invasive species. Credibility of predictions even with the best data is, however, low because of ecosystem variability.

Sensitivity of Data

A report of the presence of an organism, particularly a pest and pathogen species, may have tremendous implications for exchange of organisms in science, trade, or for other purposes. Thus, information becomes power and its validity and accessibility are crucial. Premature disclosure is a very sensitive issue and may lead to individual censure. Accurate, truthful reporting of species distribution may thus be compromised. Quarantines have been used quite effectively in the past to limit spread of recognized undesirable species, but their effectiveness in safeguarding not only agriculture but also natural ecosystems is being questioned. Secrecy, for whatever reason, can be a double-edged sword. There needs to be transparency between what is publicly available and why some data need to be restricted. The enormous increase in global movement of people and commerce, particularly live commodities and material, makes it imperative that alien invasive species databases resolve the issue of ownership and access in order to complement, rather than conflict with, international agreements.

Cross-Cutting Issues

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This workshop provided a first step toward identifying needs and approaches to develop a national database, or network of databases, on invasive species. A primary objective was to present an overview of existing and emerging invasive species databases within the U.S., across a broad range of ecosystems and taxa. Throughout the

two-day workshop, participants also highlighted significant gaps in available information on invasive species and identified key data or functions that are critical, but now lacking, to address pressing management and policy needs in this area. Many presentations identified similar gaps and needs, underscoring the cross-cutting nature of these issues among the diverse array of databases and interests represented. Here, the cross-cutting issues which were discussed are reviewed.

Database Function and Goals

The desired function of a database is of paramount importance in guiding its design and evaluating its utility. Within the U.S. and overseas, resource managers and scientists are increasingly calling for more comprehensive databases to assess risks associated with invasive species and develop effective management strategies to minimize their impacts. More specifically, such databases can provide a powerful tool to:

- Characterize patterns of invasion in space and time according to species, taxonomic group, transport mechanism (or vector), habitat, latitude, and a suite of biological characteristics.
- Identify ecological and economic impacts of known or potential invaders.
- Develop predictions and risk analyses about patterns and effects of invasion, based upon empirical data (above).
- Establish management strategies to prevent/control invasions by particular species or vectors, using empirical analyses to set priorities with limited financial resources.
- Assess the efficacy of management strategies to abate the rate of invasive species invasions.

Although a variety of databases on invasive species presently exist within the U.S. (described herein), these include collectively a small portion of the information needed from a research and management perspective to provide the above function. Most databases focus on a relatively narrow range of taxa, leaving many taxonomic groups unexplored. Even the existing databases are incomplete for their selective taxa, including data for a subset of species, geographic regions, invasion characteristics, and biological attributes. At best, current efforts have resulted in an uneven patchwork of data on invasive species with many significant gaps.

Expanding the present databases to create more comprehensive information on invasive species, as an effective research and management tool, remains a major challenge. There are many important aspects and obstacles to evaluate in undertaking such an effort, and some of these are discussed below.

Database Design: Next Steps

To increase the value and function of existing databases, we must expand the taxonomic coverage as well as breadth of information included within taxa. This is perhaps best achieved as a network of databases by taxa and habitats, instead of a single centralized database. A decentralized model creates better opportunities to take advantage of existing expertise and develop strong relationships with end-users, who may differ among taxonomic groups.

However, it is not simply enough to gather more data on more species, as the usefulness of expanded databases will depend upon developing standards for nomenclature, information content, information quality, and compatibility among databases. Such standards should be designed to achieve a relatively high level of resolution on key information fields (e.g., spatially or temporally referenced data, biological attributes) that is often absent in current databases, limiting their utility. Importantly, standardized approaches and compatibility will permit queries across databases (taxa) that are not now possible, and enhance opportunities for linking databases for management, research, and public uses.

Commitment and Continuity

Opportunities to expand, standardize, and integrate existing databases, which together create a strong management and research tool, are contingent upon long-term commitment and continuity. To date, lack of sustained funding and support infrastructure has been a critical deterrent. Pulses of funding have certainly been available to create a wide variety of databases. However, with few exceptions, such funding is short-lived and generates a relatively streamlined, static database. Although the resulting products may be well-suited to their original purpose, these do not function as comprehensive and national-scale databases (as above). Instead, development toward this goal requires (1) funding explicitly for this purpose, (2) long-term continuity to create and sustain dynamic (i.e., current and evolving) databases, and (3) programmatic coordination to develop standards, integration, and access among databases.

Taxonomy and Reference Material

Our ability to use and improve databases of invasive species also depends in large part on the quality of taxonomic identification and information. A significant problem exists in the area of taxonomy that greatly limits our capacity to detect, describe, and control invasive species. There are now many groups for which taxonomic experts no longer exist in the U.S., as resources and expertise in taxonomy have continued to erode over the past decades. Thus, organisms now arriving to the U.S. often are not identified

appropriately, identification (if attempted) may be greatly delayed, and associated risks of colonization and impact cannot be assessed.

More broadly, taxonomy and reference collections are both integral parts of establishing more comprehensive, useful databases on invasive species. In addition to initial identifications, maintenance of voucher or reference collections for comparative analyses and confirmation is of great value. Ideally, such reference collections would include both morphological and genetic vouchers, as many recent studies have found invasiveness and the magnitude of impacts can vary greatly by genotype.

Information Sources

Although there is clearly much information available presently to develop more comprehensive databases across all taxonomic groups, it is a misconception that all needed data have been collected. For example, there are many regions and habitats within the U.S. for which we do not have contemporary surveys of biota within the past 50 years, and some areas have never been surveyed. As a result, we now have a very incomplete picture of the extent, pattern, and impact of nonindigenous species invasions. Without adequate baseline data, it is impossible to assess the threat of invasive species and develop management strategies in undersurveyed regions. More fundamentally, the lack of such baseline data also limits our ability to assess the efficacy of management strategies on the rate of invasions. Thus, as we contemplate development of more comprehensive databases as management tools, we must recognize gaps in available data and consider strategies to collect further data where needed.

Data Access and Linkage

A critical issue for access to existing and future databases remains. Ideally, information within databases can be readily accessible to a broad range of users, from agencies and managers to researchers and the public. This requires considerable forethought. Information from databases is variously available among many dispersed websites and individual/ institutional database managers. As we evolve toward expanded and integrated databases, there is a broad range of issues to resolve concerning:

- Data ownership and timetable for public access.
- Directories and metadata standards for databases.
- Technologies for access to databases.
- Degree of integration and linkage among databases.
- Technology for linkage among databases.

Interaction with the international community creates another important dimension for both access and linkage of databases. Although overseas access to U.S. databases may not present any novel problems, the overall value of our databases could be greatly enhanced by linkage and some integration with overseas databases. At minimum, the opportunities for compatibility and synergism should be explored, and directories to international databases should be developed as a potentially important resource.

Outreach

Although the importance of public access to information is well recognized, the need for public support and understanding for the value of databases has received relatively little attention. Outreach programs have certainly been effective in describing the threat associated with particular invasive species (e.g., zebra mussel, green crab, brown tree snake) and value of management activities directed at these species. A similar effort should exist to articulate clearly the value, function, and need for comprehensive databases on invasive species.

Conclusions

It is evident that comprehensive information on invasive species is required to develop effective management that minimizes the risks and impacts of alien species. As a result, databases will play a pivotal role in both creating and assessing policy actions. Careful attention should be given to the appropriate development and implementation of such databases, to maximize function and utility. Although a variety of useful databases now exist on invasive species, these do not satisfy the present national need for comprehensive databases. We presently lack sufficient programmatic support and coordination to adequately develop such databases. This should be a top priority for action under the Executive Order on Invasive Species.

Needs And Opportunities

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This workshop comes at a propitious time. Although extensive study of particular nonindigenous species (NIS) began in the 19th century, there was no synthetic science of invasion biology as recently as twenty years ago. Ten years ago, it was a new, largely arcane branch of ecology driven by the academic curiosity of a few ecologists, and its relevance to agricultural, silvicultural, and other real-world concerns was barely recognized. Ecologists did not talk much to weed scientists, Extension entomologists, and similar people dealing with problems on the ground, much less to the managers fighting invasions in the trenches. And people battling invasions like those of rangeland weeds and Russian wheat aphid did not see themselves as allies, in a larger battle, with those struggling against the zebra mussel or the rainbow trout. By five years ago, that was changing fast. Increasing publicity about introduced species problems, with tremendous costs as well as conservation and sometimes human health consequences, plus a natural evolution in the scientific and managerial communities, crystallized a growing science of invasions and began to bring together researchers and managers—this workshop is one result.

The opportunities to ratchet up the battle against invasive NIS are great. People everywhere are recognizing the problem as huge. In the United States alone, the costs are almost certainly in the tens of billions of dollars annually and may exceed $120 billion. Worldwide the costs must be staggering.

Furthermore, there is growing agreement among conservationists that NIS are the second leading cause of extinction and endangerment of species, following only habitat conversion. Often the distinction is fuzzy, because many NIS cause or even constitute habitat conversion, as when zebra mussels carpet an entire soft-bottom surface, or when melaleuca forests replace half a million acres of sawgrass and muhly prairies.

The Executive Order on Invasive Species highlights the problem and raises even further the consciousness of policy makers and the public to invasive NIS. International activity is also growing, signaled by the Convention on Biological Diversity in 1994. The initiation of the Global Invasive Species Programme, the formation of an Invasive Species Specialist Group by the IUCN, and the United Nations workshop in Trondheim, Norway, all reflect this increased concern.

The key factor that separates this issue from other environmental issues, and augurs well for real progress, is that commerce, agriculture, forestry, and conservation and environmental stakeholders are all on the same side. It is not a situation in which an industry wants to increase production and environmentalists want to stop them. Sometimes the same species are causing both production and environmental problems: the leafy spurge, balsam woolly adelgid, and zebra mussel. Usually in the NIS struggle, all sides lose together, they all want pretty much the same thing, and they are beginning to understand that cooperation and coordination can help everybody. One key focus of the Executive Order will be to improve cooperation among agencies, but this is already happening.

So how can this tremendous eagerness to solve the NIS problem help us with databases? Everyone recognizes that data are crucial to understanding the problem and that we cannot begin to solve it until we understand it. So everyone agrees we need databases; that is why there are so many of them. It is also obvious from this workshop and that convened by FICMNEW that there are more databases out there than anyone had realized. What more must be done? Needs are both short term and long term.

Short-Term Needs

Because the whole reason for the interest in invasive NIS is the problems they cause now, short-term needs must take precedence. We have to be able to provide the data that are needed, right now, to help managers in the field. A general urgent short-term need is to have sufficiently comprehensive and accessible data

that it is possible to tell quickly whether a report represents a totally new threat, a range extension of a threat that already exists, or simply just another record of something already known. We need to begin immediately to link and/or integrate some databases and to begin to move toward one-stop shopping.

State and Local Needs. Many people who have to deal on the ground with NIS, in both decision-making and managerial capacities, are not in federal agencies or international programs. In the U.S., many are in state and local agencies. For workers in federal agencies or universities, it is a trivial matter to use databases on the Web; we do this sort of thing all the time, or we have students or colleagues who can help. But many people in state and local agencies are ill-equipped to deal with anything but the most user-friendly database. Often they have marginal hardware and lack facility in dealing with something even as simple as an Access file without a lot of help. Many people dealing with NIS in third-world countries are in even worse shape and are also forced to work in a foreign language.

Even to those of us with a lot of experience with databases on the Web, especially now that we know the great number of NIS databases, it is forbidding to have to call up one after the other to see what is available. This is why we have all gravitated towards the idea of one-stop shopping. If we feel this way, imagine how important it is to someone in a state department of parks or a developing nation's resource ministry. The exact nature of the linkages that achieve one-stop shopping is not too important in the short term, so long as the resulting product is very user-friendly. The important point is that this is an immediate need, and we have to settle on a system and make sure that all relevant databases are linked to it.

Risk Assessment. Another set of short-term needs not too well addressed by many of the existing databases relates to the fact that any user has to prioritize activities. No one has enough money or time to attempt to deal with all NIS; there is a danger of management grinding to a halt if we attempt to exclude, eradicate, and control every alien species. So we have to have some way to rank them in terms of likely impact. Therefore, we need to be able to do some version of a risk assessment on each, even if it is a very cursory one, in order to know where to put our energies. And since a lot of the real use of these databases will be quite local, the assessment has to be based on information related to risks in a local setting. Since NIS often pose very different risks in different settings, this poses a burden on databases, but this variation in risk has to be taken into account or we can waste a lot of effort.

Some existing databases are directly associated with a risk assessment; e.g., the Exotic Forest Pest Information System. A number of existing risk assessment tools are very similar but lack their own database: for example, the National Park Service has a ranking system applicable to both plants and animals at both site and regional levels, and so does the Australian Weed Risk Assessment program. Also, the Aquatic Nuisance Species Task Force and USDA's Animal and Plant Health Inspection Service have developed risk assessment protocols.

To use risk assessments or other sorts of predictive tools, there has to be a fair amount of ecological and other biological information, and many of the databases do not capture this information. We need information on:

- Entry pathway and modes of dispersal.
- Likely types of impacts, at several levels. Some species affect entire ecosystems, directly or indirectly—feral pigs, European boar, and their hybrids, for example. There are effects at the community level, for example on community structure. There are a whole battery of impacts on particular species, like predation, competition, parasitism, disease, herbivory. Hybridization is also a frequent impact. And there are economic and other impacts associated with these ecological impacts.
- Biology: life history, breeding system, natural history.

Some fraction of this information is needed for even a cursory risk assessment. It will be obvious that, for many NIS, much of this information is unavailable, so some databases will be sparsely populated, a point I will return to. But some of it is available, and it is important information.

Prioritization and Decision Making. For prioritization purposes for both managers and decision makers,

a risk assessment is necessary but not sufficient. We have to make a decision based on the results of the risk assessment and information on the costs and likelihood of success of potential management procedures. No matter what the risk is, if there is zero chance that anything we do will help to control the invader, it does not pay to try. Some people say that the jellyfish-like marine animal, *Mnemiopsis leidyi* in the Black Sea and Azov Sea falls in that category. It is also possible that some procedure will probably exert economically or ecologically significant control of the invader, but the cost will be so great that there will be no resources left to fight other invaders. Or there might be a high probability of a major impact on nontarget species—as with many chemicals, for example.

So for a database to be maximally useful in decision making, it has to have available information on effectiveness, costs, and risks of various possible management procedures.

Internationalization. Another short-term need is the internationalization of whatever system we settle on to achieve one-stop shopping. The problems are international, so there is every reason to think that the different countries can learn from one another's experiences. Many of the species that rank as major pests in the Hawaiian islands, for example, crop up repeatedly in lists of the worst pests of small island nations. And the growing volume of travel and trade can only enhance this overlap. We in the U.S. would be missing a bet by not associating our distributed database system with databases of other nations. Some are very advanced technologically. Further, we are not being good global citizens if we do not try to disseminate whatever we know that might help others dealing with similar problems.

Long-Term Needs

Consolidation. As some version of a one-stop system becomes operational, there will be consolidation and evolution of the component databases over a long period. Different entities evolved different kinds of databases partly because they had different missions and needs, and these differences will remain. Furthermore, different entities will be better equipped to do the verification and housekeeping procedures required to keep parts of the database system current and accurate. Nevertheless, it is also true that there is much overlap among some of the databases, both in the kinds of data they intend to capture and the way data are organized. Furthermore, managing a database is an onerous proposition requiring resources. So attractive economies of scale will lead some people to forswear the natural proprietary sense that we all have when we have developed something that works and to consider allowing the job to devolve to someone else.

Regardless of how the system of databases is linked in a one-stop system to begin with, the components will evolve to be more similar at least in form and probably also in content. That is because different databases will be seen to have different advantages; there is more than one way to build a mousetrap, and if someone does part of it better, it will be natural to try to adopt that way of doing that part. Each of us has frustrating stories of trying to use the so-called ultimate database. Obviously these will improve as the people using them also use other databases that are much more user-friendly and want to emulate them. It will then be a still smaller leap simply to merge one or more databases.

Probably there will also be some movement towards consolidation within the system by an evolution towards similar standards for data entry and verification. Another factor leading towards consolidation is the expense and inevitability of upgrades in both software and hardware. Mature databases, like the Natural Heritage Network, have already gone through several generations, and it is expensive yet absolutely necessary to evolve as the technology evolves.

Another long-term need that would begin to be met by partial consolidation of the component databases is the ability to look at many different taxa simultaneously. We must do this for several reasons. One is again prioritization; we have to prioritize across taxa if we are going to use our resources optimally. If insects, weeds, vertebrates, and pathogens all attack some crop or reserve, we cannot focus only on one taxon when deciding what to do.

Synergy. There is another fundamental reason to look at data on many types of organisms at once. Some species facilitate actions of other species, and some groups of species act synergistically to make a greater problem than the sum of the individual

effects. An exotic pathogen can be innocuous or a scourge depending on whether or not an exotic vector is also present. Fig trees were harmless ornamentals for many decades in south Florida until their obligatory pollinator fig wasps were introduced, and then they suddenly became highly invasive. The ornamental shrub, *Lantana camara,* in Hawaii spread much faster once the myna bird was introduced. There are many other ways in which NIS become more problematic when they are together than when they are alone. So a risk assessment for many species is going to have to take account of which other species are present. This kind of data will surely be more easily captured in a consolidated database.

Data Gaps. Another long-term need is that some taxa, even important ones, are not yet well covered. NIS mammals, bacterial pathogens of plants, spiders —the data are not comprehensive or assembled. So there is much basic work to make any database system taxonomically comprehensive, and this will take time.

Systematics. This last need relates to two issues that are long-term projects, but they will have to be solved or the whole enterprise will ultimately be in trouble. First is that at the very time when we need systematists to generate the data in the database system, there is a sharp trend to reduce the training needed to produce systematists. This is also true, to a lesser extent, for the field ecologists needed to populate the database system with all the information that would be needed for a risk assessment and to help develop the various management procedures that should also be present for use in making decisions.

To the extent that systematists and ecologists can hitch their stars to conservation biology and molecular biology, there is an opportunity to help to redress this trend in academia, but certain kinds of ecology and systematics are old-fashioned, yet critical to dealing with NIS, including producing useful databases. Perhaps we should turn the problem around and ask if the burgeoning interest in introduced species can boost the fields of systematics and ecology. After all, we need to increase the knowledge base in both systematics and ecology, and in basic research in general, in order to confront the problem of NIS in every way, not just the production of sufficient databases. Even as we deal with the immediate need to get a usable system on-line quickly, we must recognize that we need to develop more scientific knowledge to deal with this problem effectively. This is probably our biggest challenge—getting a public that wants short-term results on pressing problems to see that long-term progress has no quick fix and requires basic research.

The Challenge

We *can* meet these needs! But it is up to us to capitalize on unparalleled opportunities that now face us. The climate for new and expanded initiatives to deal with NIS is propitious, as is noted above. We all sense this, and the problem is increasingly recognized every day. Obviously the data needs are great, but they are not mysterious or technically impossible. If we agree among ourselves that these *are* the needs we must satisfy to make major headway in the battle against NIS, if we can avoid battling among ourselves over turf and funds, and if the public increasingly recognizes the scope and expense of the problem, we ought to be able to present the case in a unified, understandable way to convince them to give us the wherewithal to do the job.

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Acronyms

ANSTF	Aquatic Species Nuisance Task Force
APHIS	Animal and Plant Health Inspection Service
APWG	Alien Plant Working Group
ARS	Agricultural Research Service
BBS	Breeding Bird Survey
BCDC	Biological Control Documentation Center
BRD	Biological Resources Division of the U.S. Geological Survey
BLM	Bureau of Land Management
CABI	CAB International
CAPS	Cooperative Agricultural Pest Survey
CENR	Committee on the Environment and Natural Resources
DIAGDATA	Wildlife Health Diagnostics Database
DOD	Department of Defense
DOI	Department of the Interior
EFPISNA	Exotic Forest Pest Information System for North America
EPIZOO	Wildlife Health Epizootiological Database
FAO	Food and Agriculture Organization
FICMNEW	Federal Interagency Committee for the Management of Noxious and Exotic Weeds
FNW	Federal Noxious Weeds
FS	United States Forest Service
GEF	Global Environmental Facility
GISP	Global Invasive Species Programme
GPPIS	Global Plant Pest Information System
GRIN	Germplasm Resources Information Network
HEAR	Hawaiian Ecosystems at Risk Project
IABIN	Inter-American Biodiversity Information Network
ICSU	International Council of Scientific Unions
INHS	Illinois Natural History Survey
IPPC	International Plant Protection Convention
IRL	Indian River Lagoon
ISSG	Invasive Species Specialist Group
ITIS	Integrated Taxonomic Information System
IUCN	World Conservation Union, formerly International Union for the Conservation of Nature and Natural Resources
MGD	Microbial Germplasm Database
NANIAD	North American Non-Indigenous Arthropod Database
NAPIS	National Agricultural Pest Information System of the U.S. Geological Survey
NAS	National Science Foundation

NASA	National Aeronautics and Space Administration
NBCI	National Biological Control Institute
NBII	National Biological Information Infrastructure
NCPI	Native Plant Conservation Initiative
NCDA&CS	North Carolina Department of Agriculture and Consumer Services
NIS	Nonindigenous Species
NMNH	National Museum of Natural History
NPS	National Park Service
NRCS	Natural Resources Conservation Service
OIE	Office International des Epizooties
OMB	Office of Management and Budget
OTA	Office of Technology Assessment
PPQ	Plant Protection and Quarantine
RMF	Charles Valetine Riley Memorial Foundation
ROBO	Releases of Beneficial Organisms in the U.S. and Territories
SCOPE	Scientific Committee on Problems of the Environment
SEL	Systematic Entomology Laboratory
SERC	Smithsonian Environmental Research Center
SIDS	Small Island Developing States
SNOMED	The Systematized Nomenclature of Medicine
STS	Slow-the-Spread
SWEMP	Southwest Exotic Plant Mapping Database
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UNEP	United Nations Environment Program

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Silver Spring, MD

Steve Yaninek
CSREES, USDA
Washington, DC

David Voegtlin
Illinois Natural History Survey
Champaign, IL

APENDIX B

Invasive Species Databases: Gap Identification and Use Strategies

Final Workshop Program

November 12–13, 1998, Las Vegas Hilton, Las Vegas, NV
Continental, Royal, and Grand Saloon Suites, 2nd Floor, East Tower

Thursday, November 12

8:30 am **Registration**

Electronic Communications Coordinator: Harvey Berenberg, Forest Health Program

9:00 am **On-Line Demonstrations.** Four on-line stations with PCs and color monitors and a fifth color monitor for use with laptops will be available for use in demonstrating databases. Anyone wishing to demonstrate databases is encouraged to take advantage of this opportunity. A number of individuals will be available to assist those wishing to demonstrate databases. These individuals will also be knowledgeable of databases that they will be prepared to demonstrate. The demonstration station coordinators include:

Peter Bodker, Treescapes
Ken Lakin, APHIS
Joe O'Brien, FS
Sharon Shin, USGS
Ron Stinner, NCSU

Session Co-Chairs: Denny Fenn, USGS, DOI, and Chuck Schwalbe, APHIS, USDA

1:00 pm **Introductory Remarks—**Denny Fenn

*The Global Invasive Species Programmme***—**Jeff Waage, CABI Bioscience, United Kingdom
*United States Invasive Species Programs and Plans***—**Gordon Brown, SEC, DOI

1:45 pm **Database Panel**

Terrestrial Vertebrates
Bill Gregg, USGS, DOI, Moderator
Bruce G. Peterjohn, USGS, DOI
Alfred Gardner, USGS/NMNH-SI
James Quinn, UC, Davis
Jeff Walden, Virginia Tech

2:45 pm Break

Session Chair: Anne Vidaver, University of Nebraska

3:00 pm **Database Panel**

Animal and Plant Diseases
Sue Tolin, Virginia Tech, Moderator
Jerry Freier, APHIS
Robert McLean, USGS, DOI
Norman Schaad, ARS, USDA

Thursday, November 12, continued

4:00 pm *Plant Pests and Other Arthropods*
Ann Bartuska, FS, USDA, Moderator
Nancy Lorimer, FS, USDA
K. C. Kim, Pennsylvania State University
Rebecca Bech, APHIS, USDA
Ken Lakin, APHIS, USDA

5:30 pm **Reception**; On-Line Demonstrations, continued

7:00 pm Adjourn

Friday, November 13

7:00 am **Continental Breakfast**

Session Chair: John Randall, TNC

8:00 am **Database Panel**

Marine and Aquatic Organisms
Dean Wilkinson, NMFS, NOAA, DOC, Moderator
Pam Fuller, USGS, DOI
Gregory Ruiz, Smithsonian Institution

8:45 am *Development and Use of Multiple Purpose State- and Tribal-Level Databases*
Chris Pague, TNC Moderator
Ed Dewalt, Illinois Natural History Survey
Gene Cross, NCDA&CS
Phillip Thomas, University of Hawaii
Carol Spurrier, BLM, DOI
Kelly Toy, The Tulalip Tribes
Barry Meyers-Rice, TNC, Raporteur

10:00 am Break

Session Co-Chairs: Chuck Schwalbe, APHIS, USDA, and Gordon Brown, SEC, DOI

10:15 am **Cross-Cutting Issues Panel**
Gordon Brown, SEC, DOI, Moderator
Ron Stinner, North Carolina State University
Ted Case, UC, SD and UC, SB
Gary Waggoner, USGS, DOI
Greg Ruiz, Smithsonian Institution, Raporteur

11:15 am **Needs and Opportunities—**Dan Simberloff, University of Tennessee

11:55 am **Closing Comments—**Chuck Schwalbe

12:00 n Adjourn