



A M E R I C A N I N S T I T U T E O F B I O L O G I C A L S C I E N C E S

March 3, 2004

TO: NEON Invasive Species Workshop Participants

FROM: Rina Aviram and Jeff Goldman, American Institute of Biological Sciences

RE: Advance Packet for the March 18th Workshop: Designing NEON Initiatives for invasive species

We are looking forward to seeing you at the upcoming NEON workshop, "Designing NEON Initiatives for invasive species. The meeting is being convened by the American Institute of Biological Sciences with support from the National Science Foundation. As you know, the goal



for this meeting is to begin developing the scientific and technological requirements for NEON's invasive species initiatives. During the pre-workshop interviews we collected valuable ideas on the potential NEON has for addressing invasive species problems. We are looking forward to developing these ideas further and beginning the process of designing NEON's research agenda and infrastructure.

The workshop will take place on Thursday, March 18, 2004 at the **Westin Grand Hotel, 2350 M St. NW, Washington DC, 20037, (202) 429-0100**. It will begin at 10 am and continue through 6 pm. If you are not already at the AIBS annual meeting please arrive at the Washington Ballroom at 10 am for the plenary panel. The remainder of the workshop will take place in the Scott Room. A subset of participants will stay through 4:00 PM Friday, March 19th to write the workshop report. If you are interested in staying for the report writing session please let me know. If arriving by

Metrorail, exit at the Foggy Bottom station, which is a short walk to the hotel. See <http://www.wmata.com/> for more information on Metrorail. If driving, directions to the hotel can be found at: http://www.starwood.com/westin/search/hotel_detail.html?propertyID=1013. Attire for the meeting is business casual.



Attached please find materials for your review prior to the meeting. The documents include:

1. **Draft workshop agenda**

2. **Participant list**

3. **Relevant reports:** The documents that are included in this packet were chosen to provide you with background and current events information on NEON that reflects the evolution of the concept, insights into existing invasive species programs, examples of reference designs from another Major Research Equipment (MRE) Project, and guidelines that the National Science Foundation will use in prioritizing



MRE projects. Excerpts were selected from the documents listed below, however websites are shown where you can find the documents in their entirety.

- i. IBRCS White Paper: Rationale, Blueprint, and Expectations for the national Ecological Observatory Network. 2003.
http://ibr.cs.aibs.org/reports/pdf/IBRCSWhitePaper_NEON.pdf
- ii. National Research Council. NEON: Addressing the nation's environmental challenges. 2004. <http://www.nap.edu/catalog/10807.html>
- iii. National Invasive Species Council (NISC) Management Plan: Meeting the Invasive Species Challenge. 2001
<http://www.invasivespecies.gov/council/mpfinal.pdf>
- iv. National Research Council. Setting priorities for large facilities projects. 2004.
http://books.nap.edu/html/lrf_projects/0309090849.pdf
- v. Earthscope: Scientific targets for the world's largest observatory pointed at the solid earth. Workshop report. 2001.
http://www.earthscope.org/assets/es_wksp_mar2002.pdf
- vi. NSF solicitation for the NEON Coordinating Consortium (NCC), 2004.
<http://www.nsf.gov/pubs/2004/nsf04549/nsf04549.pdf>



4. **Synthesis of pre-workshop interviews.** Interviews were conducted with a subset of the workshop participants between January and February, 2004
5. **Synthesis of submitted research questions.** Potential research questions for NEON to explore within the field of invasive species research were submitted by a subset of the workshop participants.
6. **Summary of some existing invasive species programs.** Results from a survey of existing federal, state, professional and non-profit, and international invasive species programs. Programs were reviewed for their geographic scope, focal groups (weeds, pests and/or pathogens), and initiatives.
7. **Operational Dictionary**

Please review this packet in advance and also bring it with you to the meeting.

If you have any questions about the meeting or the materials within this packet please feel free to contact Rina, at 202-628-1500 ext 231, or at raviram@aibs.org.

We are looking forward to it!



Draft Workshop Agenda
Designing NEON Initiatives for Invasive Species Workshop
March 18, 2004

Westin Grand Hotel
Scott Room
2350 M St. NW, Washington DC, 20037
(202) 429-0100

Meeting Objectives: To describe the scientific and technological requirements for NEON's invasive species initiatives.

Thursday, March 18th, 2004

- 10:00 – 11:00 am Plenary Panel (Washington Ballroom):
Background on NEON and two talks on the potential NEON holds for the problem of invasive species
Elizabeth Blood, NSF, **Mark Hunter**, University of Georgia, **A. Townsend Peterson**, Kansas University
- 11:00 -11:15 am Break
- 11:15 – 12:15 pm Introductions, Expectations, Etc. (Scott Room)
Jeffrey Goldman, AIBS
- 12:15 – 1:00 pm Discussion of criteria to be used when choosing research questions
- 1:00 – 1:45 pm Lunch (provided)
- 1:45 – 2:30 pm Discussion of potential research questions
- 2:30 – 5:00 pm Breakout groups: Developing the scientific and technological requirements for NEON's invasive species initiatives
(Break from 4:15 – 4:30 pm)
- 5:00 – 6:00 pm Reports from breakout groups, discussion and conclusions
- 6:00 pm Adjourn

Friday, March 19th, 2004

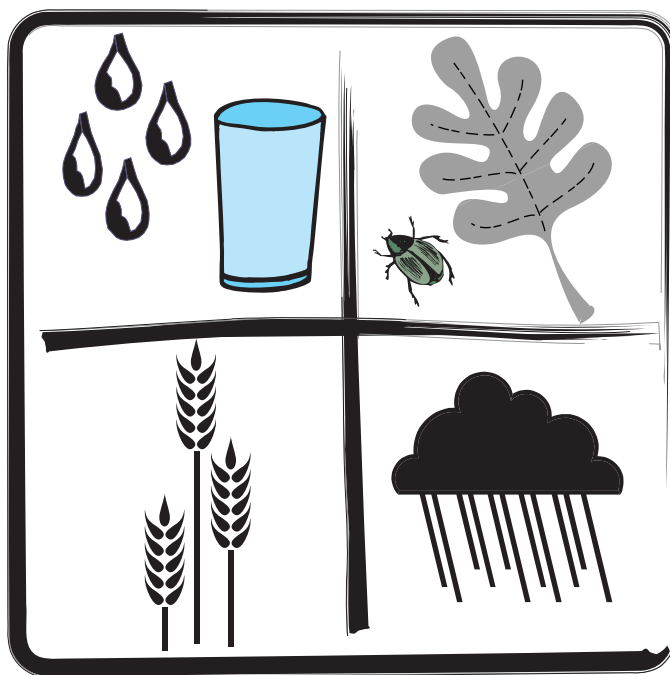
- 9:00 am Report writing
- 4:00 pm Adjourn

Participant List
Designing NEON Initiatives for Invasive Species Workshop
March 18, 2004

1. Ann Bartuska, USDA Forest Service
2. Faith Campbell, The Nature Conservancy
3. Julie Coonrod, University of New Mexico
4. Chris Dionigi, National Invasive Species Council
5. Dave Duffy, University of Hawaii
6. Clifford Duke, Ecological Society of America
7. Virginia Ferris, Perdue University
8. Deborah Goldberg, University of Michigan
9. Andrea Grosse, US Geological Survey/International Biological Informatics
10. Mark Hunter, University of Georgia
11. Alan K. Knapp, Colorado State University
12. Laura Meyerson, The Heinz Center
13. Rachel Muir, Natureserve/US Geological Survey
14. Pam O'Neil, University of New Orleans
15. Richard Orr, National Invasive Species Council
16. Townsend Peterson, Kansas University
17. George Roderick, UC Berkeley
18. Tim Seastedt, University of Colorado
19. Dave Shaw, University of Washington
20. John Silander, University of Connecticut
21. Melinda Smith, Yale University
22. Bruce Stein, NatureServe
23. Kristina Stinson, Harvard University
24. Geraldine Twitty, Howard University
25. Fernando Vega, USDA/Agricultural Research Service
26. Betsy Von Holle, Harvard Forest
27. Randy Westbrooks, US Geological Survey

IBRCS White Paper

Rationale, Blueprint, and Expectations for the National Ecological Observatory Network



**Infrastructure for Biology at Regional to Continental Scales
(IBRCS) Working Group**

American Institute of Biological Sciences



Executive Summary

This white paper was developed by the Infrastructure for Biology at Regional to Continental Scales (IBRCS) Working Group as part of an American Institute of Biological Science's IBRCS project. The aim was to further advance the National Ecological Observatory Network (NEON) initiative by explaining the scientific rationale behind the need for NEON, how NEON will operate to meet that need, and the results that NEON is expected to produce. The IBRCS Working Group was aided by input from other scientists and organizations. As a result, this white paper represents the views of a broad segment of the scientific community.

NEON Mission

In the past century we learned an enormous amount about individual species and about ecological processes at the scale of watersheds and landscapes, but there is much we do not understand. In this century we must further our understanding of ecological processes and learn how local processes can be scaled up to biomes or continents if we are to accurately predict changes in the composition, structure, and dynamics of the nation's ecosystems and understand how those changes are likely to affect us. To develop that understanding, a new type of scientific infrastructure is needed—an infrastructure that enables the simultaneous collection of compatible data on fundamental ecological and evolutionary processes over broad geographical and temporal scales. NEON is a National Science Foundation (NSF) research platform that will apply experimental, observational, analytical, communication, and information technologies to investigate the structure, dynamics, and evolution of ecosystems in the United States, to measure the pace of biological change resulting from natural and human influences at local to continental scales, and to forecast the consequences of that change. The mission of NEON is to establish and sustain the scientific infrastructure and develop the intellectual capital needed to address critical questions about changes in ecological systems and to evaluate the impacts of those changes.

Scientific Rationale

Studies of the processes that affect our nation's ecosystems have been limited mostly to small geographic areas because they were conducted by small teams at single sites. While such studies have generated critical insights into ecological and evolutionary processes, many of the most challenging questions in the ecological, evolutionary, and biodiversity sciences require us to understand processes that operate over larger spatial and temporal scales and at all scales of

biological organization, from molecules to biomes. Recent advances in analytical instrumentation, computer networking, information management, experimental methods, and computational analysis have set the stage for national, coordinated observations of our biological, physical, and chemical world. NEON will provide the infrastructure that allows scientists to investigate the suite of challenging and significant scientific problems requiring coordinated observations over large spatial and temporal scales. In addition to enabling groundbreaking research in the ecological, evolutionary, and biodiversity sciences, NEON will foster research in engineering and technology, information technology, and statistics and mathematics. From the ecological perspective, NEON will help us to understand the present composition and functioning of contemporary ecosystems, to elucidate how contemporary ecosystems have been shaped by historical natural and anthropogenic processes, and to forecast how contemporary ecosystems may respond to changes in key drivers.

NEON Design

NEON will be a common science facility open to all qualified users. Each regional observatory in the network will itself be a network of facilities, such as biological field stations; LTER sites; national parks; college or university campuses; marine laboratories; federal, state, and local agency field stations; or nature preserves. To ensure that NEON encompasses a broad range of ecosystem types, a minimum of 17 observatories is needed, 16 in the United States and 1 in Antarctica. Each observatory will include both a core site that is extensively instrumented and a number of satellite observatories that are less extensively instrumented. Highly specialized research infrastructure, including field-based sensor arrays, flux towers, stable isotope analyzers, microarray analyzers, and automated DNA sequencers, will be part of the NEON infrastructure.

The process of creating NEON involves building observatories sequentially through a process involving competitive peer review of observatory proposals, which allows the final structure of NEON to capitalize on the most creative ideas from a broad spectrum of the environmental science community.

A NEON Coordinating Organization (NCO) is envisioned to handle the national-level organization and administration. The NCO should be an open membership-based organization, broader than the institutions that operate and manage the regional observatories. A representative governing body with appropriate officers will formulate procedures, and a professional staff will see to administrative matters and work with the regional observatories to implement procedures.

A standard suite of instruments will be deployed and standardized measurements taken at NEON observatories to provide compatible data sets and analytical capability. These comprehensive measurements of (1) climate and hydrology, (2) biodiversity dynamics, (3) biogeochemistry, (4) biosphere–atmosphere coupling, and (5) spatial analysis and remote sensing, combined with manipulative experiments, provide the foundation for addressing questions about biodiversity and ecosystem function, carbon dynamics, invasive species, coupling of human and natural systems, ecology of infectious diseases, and biogeochemical imbalances.

Information technology (IT) is a key infrastructural component of NEON. It must bind together the core and satellite sites of an observatory with those of other observatories across the nation and integrate these distributed sites into a single, functional research tool. An important IT challenge lies in seamlessly integrating massive volumes of data into useful products. Such integration requires the adoption or, when necessary, development of standard protocols for data specification, data storage and dissemination, metadata specification, and data accessibility. Strong and continuous collaborations among individual observatories, the NCO, and other relevant experts and organizations will generate the cyber-infrastructure that overcomes this challenge. An important goal for NEON is to provide timely and broad access to all data; thus, NEON data policies will promulgate a cultural change that values data sharing.

In addition to observational data, and syntheses from these data, NEON activities will result in acquisition of objects within the physical, chemical, and biological domains. Curation of objects for current and future use requires a variety of appropriate repositories. In turn, efficient use of the collected objects requires comprehensive tracking and inventory information.

NEON will promote scientific cooperation and partnerships as a way to leverage resources, expertise, and information among research universities; federal, state, and tribal agencies; and for-profit and nonprofit organizations. NEON proposals for individual observatories and the NCO must clearly indicate that significant partnerships have been developed and that others will be sought.

Scientific Results and Products

A well-executed NEON program will result in many difficult-to-anticipate advances in ecological science. One general advance from NEON will doubtless be the explosive development of regional ecology, involving integrated understanding of flows of material, energy, nutrients, biological entities, and information through regional landscapes and watersheds. In addition to

such general theoretical advances, we can identify the specific types of data and other products that NEON will provide.

NEON will produce data on climate and hydrology, biodiversity and population assessment, biogeochemistry, and spatial analysis and remote sensing, in addition to the data generated by manipulative experiments. Other products include new instruments and technologies; ecological models; data processing, summarization, and communication technology; and specimens and samples.

Education and Public Outreach

To be effective over its life span, NEON must engage and involve students, scientific and nonscientific groups, and the general public at all levels. NEON's dynamic and user-ready knowledge base, comprising real-time and continuous network data, will be a considerable asset for the teaching community and other public and private organizations. NEON will serve as a model of true integration of research and education.

Education and public outreach committees created by the NCO will guide the NEON education and public outreach missions and formulate strategic plans. Professional staff in the NCO education and public outreach offices will implement these strategic plans and coordinate programs with regional observatories. The education committee will explore all areas of formal and informal education, specifically focusing on the K–12 and undergraduate levels, but also including continuing education and special programs targeting underrepresented groups.

The public outreach office will coordinate closely with the education office and enact relevant recommendations from the public outreach committee. Public participation at NEON observatories will be fostered, and special efforts will be made to reach sectors of society traditionally underrepresented in science and environmental programs. The public outreach office will actively promote NEON resources and opportunities to the public, interface with print and broadcast media, publish newsletters, and disseminate press releases about items of popular, scientific, or agency interest.

Benefits and Applications

This synergy of new tools and approaches will benefit scientists by advancing the frontiers of knowledge and research capacity in ecology and will produce new perspectives in ecosystem science. NEON will provide critical infrastructure to support NSF research programs, such as

Biocomplexity in the Environment. In addition, NEON will provide the platform for performing research in coupled human and natural systems research, coupled biological and physical systems, and people and technology, three priority areas designated by the NSF Advisory Committee for Environmental Research and Education. The NEON program can also fill a significant gap in infrastructure for researchers from smaller institutions who want to conduct large-scale ecosystem research.

The NEON infrastructure will encourage collaboration between the research community, environmental monitoring programs, and the natural resource management community. Data emerging from NEON research sites will help inform decisions regarding management of the nation's natural resources. For example, the location and design of the NEON sites will help establish regional reference points for biological and ecological indicators of ecosystem function, something that will help state and federal agencies in setting goals for environmental management and protection. NEON observatories will also support extensive research on molecular phylogenetics and phylogeography, tools that federal and state agencies are increasingly using to establish conservation priorities.

NEON will benefit society by improving our understanding of the implications of ecosystem change for human welfare. Healthy ecosystems provide many goods and services that are essential underpinnings of our nation's economy. Ecosystem services include drought and flood control, pollination of crops, purification of air and water, pest and weed control, carbon storage, and decomposition of wastes, while goods include food, fiber, and pharmaceuticals. Furthermore, data from NEON can be used to predict the ecosystem responses to major meteorological and geological events such as hurricanes and volcanic eruptions. In addition to forecasting the ecological and environmental effects of extreme natural events, the NEON program will allow us to assess ecosystem response to human-induced stresses such as acid rain and global warming. NEON is a powerful research tool for discovering and identifying new introductions of non-native species, whose cost to the economy can total \$137 billion annually, and investigating their ecological impacts.

Conclusion

The forefront of ecological research is headed evermore toward a focus on questions and concepts that are relevant over large geographical regions, and this highlights the need for coordinated scientific infrastructure that is itself spread over large regions. Ongoing advances in our technical capability permit the development of networks of people and tools that can meet that need.

NEON has been designed by the scientific community to capitalize on such capabilities and to enable discoveries about our nation's ecosystems that until now have been impossible to address. By fostering collaboration, the development of new tools and technologies, and the study of regional- and continental-scale questions, NEON will produce new perspectives in ecosystem science and thus public benefits, both anticipated and unforeseeable.

NEON

ADDRESSING THE NATION'S ENVIRONMENTAL CHALLENGES

COMMITTEE ON THE NATIONAL ECOLOGICAL OBSERVATORY NETWORK

BOARD ON LIFE SCIENCES

DIVISION ON EARTH AND LIFE STUDIES

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS

Washington, D.C.

www.nap.edu

(NSF 2000 a,b,c, 2002 a,b,c), an American Institute for Biological Sciences report on NEON, and a variety of documents on NEON prepared by NSF, including its 2004 budget request to Congress. Information from all those sources was the basis of the committee's deliberations, which resulted in the conclusions summarized below.

CONCEPT AND POTENTIAL CONTRIBUTION OF THE NATIONAL ECOLOGICAL OBSERVATORY NETWORK

The committee felt that the vision of NEON, as developed by the scientific community in six workshops, was best articulated in two NSF statements: "collectively, the network of observatories will allow comprehensive, continental-scale experiments on ecological systems and will represent a virtual laboratory for research to obtain a predictive understanding of the environment" and "NEON will be focused around a very broadly based, general research question—what is the pace and nature of biological change. Individual observatories would have a broadly defined observatory-specific theme that would be consistent with this overarching NEON question."

The committee strongly endorses that vision as the central focus of NEON. In addition, the committee found strong support for NEON in other federal agencies, ecological scientific societies and organizations, and members of the scientific community. The committee did not address many of the minor differences and ambiguities that unavoidably arose when seven separate groups considered the diverse issues related to a potential NEON network

If NEON is implemented to fulfill that vision, the committee believes that it would be pivotal in addressing regional and continental questions of great scientific and social importance. NEON would facilitate coordinated research efforts by providing nationwide facilities for environmental biology that transcend the budget of a single university or consortium. The central goal of NEON should be to perform comprehensive, regional- to continental-scale experimental and observational research on the nation's natural and managed ecosystems to obtain an in-

depth understanding of the environment in order to assess vulnerability and resilience of ecosystems to environmental changes. The resulting knowledge would allow the identification of how various alternative societal actions and policies would affect species and ecosystems, and would suggest remedies and solutions to environmental problems.

The major environmental challenges facing the nation that must be addressed by NEON result mostly from human actions that have regional, national, or global causes or effects. In the committee's view, the major ecological and environmental challenges that need to be addressed on a substantially expanded scale include the following:

- *Biodiversity, species composition, and ecosystem functioning.* Decreases in biodiversity and changes in species composition accompany most human uses of the biosphere. The loss of biodiversity can affect ecosystem functioning and ecosystem services of value to society. The loss of biodiversity and shifts in ecosystem composition range from local to continental scales, and thus must be studied on their natural scale if their national implications are to be understood.

- *Ecological aspects of biogeochemical cycle.* Humans are dominating natural processes as the major suppliers of the basic elements of life (carbon, nitrogen, phosphorus, and sulfur). The redistribution of those chemical elements, and human-produced toxins, on regional and continental scales may have profound effects on human health and on ecosystem function and stoichiometry, which may result in shifts in biodiversity, toxin accumulation, and concentration through the food chain.

- *Ecological implications of climate change.* Human-induced climate warming and variability strongly affect individual species, community structure and ecosystem functioning. Changes in vegetation in turn affect climate through their role in partitioning radiation and precipitation at the land surface. Climate-driven biological impacts are often only discernable at a regional-continental scale. Regional changes in ecosystem processes affect global water and carbon cycles. Therefore, a national approach to understanding biological response to climate variability and change is required.

- *Ecology and evolution of infectious diseases.* Exposure to and the dynamics, spread and control of emerging diseases and their effects on humans, crops, livestock, and wildlife require a new level of understanding. The majority of emerging infectious diseases in humans either utilize vectors such as mosquitoes or ticks, or are zoonotic diseases that are transmitted from wildlife. That will require knowledge of spatial variations in exposure, of the population dynamics of disease reservoirs, of the effects of pathogens on individual behavior, of the molecular basis of host-parasite interactions, and of the interactions with other pathogens and environmental threats.
- *Invasive species.* Invasive species affect virtually every ecosystem in the United States, and can cause substantial economic and biological damage. The identification of potentially harmful invasive species, the early detection of new species as invasion begins, and the knowledge base needed to prevent their spread require a comprehensive monitoring and experimental network and a mechanistic understanding of the interplay of invader, ecosystem traits and other factors including climate and land use that determine invasiveness.
- *Land use and habitat alteration.* Deforestation, suburbanization, road construction, agriculture, and other human land-use activities cause changes in ecosystems. Those changes modify water, energy and material balances and the ability of the biotic community to respond to and recover from stress and disturbance. Actions in one location, such as farming practices in the upper Midwest, can affect areas 1,000 or more miles away because areas are joined by water and nutrient flow in rivers and by atmospheric transport of agrochemicals.

The committee listed the six issues in alphabetical order and did not attempt to prioritize them in any way. These ecological and environmental issues have been studied on a local scale, but results from those studies are confined by their spatial scale and cannot be extrapolated to address national concerns. The committee concluded that a comprehensive understanding of those environmental issues can only be achieved through regional to continental scale research using a national network of

experimental and observational research infrastructure. Although the committee acknowledges that there are other ecological and environmental issues that can be addressed only on an expanded spatial scale, it suggests those six issues because of their immediate importance. Because the six issues presented above are interrelated at many levels, they present many opportunities for research integration and for sharing resources.

The 20th century saw many threats to the environmental health of the nation, such as decreasing water availability and deteriorating water quality, spread of invasive species and emerging infectious diseases (for example, West Nile virus), and extinction of valued species, some of which are new and emerging while others have been persisting for a long time. Current responses to environmental problems are mostly attempts to reverse the adverse trends because we lack a comprehensive understanding of the source of problems. Such an understanding can only be achieved through multiscale research that combines experimentation and observation replicated at numerous sites across the nation. A network of nationwide infrastructure, such as NEON, would enable local to regional to continental scale environmental research that would otherwise be impractical or impossible due to logistical constraints. Thus, studies at NEON would allow environmental scientists and biologists to be active in mitigating large-scale adverse impacts before they become severe threats to society. The scientific advances made possible by NEON would allow forecasting of the effects of alternative environmental policies and actions. Environmental forecasting is crucial for determining the net costs and benefits of alternative policies and thereby helping society to choose policies that provide the greatest long-term net benefits.

The committee strongly supports the creation of a NEON-like program and commends NSF's overall vision for NEON. However, it feels that the proposed implementation plans need modification and refinement to ensure that NEON would focus on the most important scientific issues, efficiently provide the national network of infrastructure essential for each challenge, encourage creative research, and meet the requirements of MREFC funding. First, in NSF's current plan, a NEON network would be built gradually via funding of one or two

regional observatories at a time. Thus, NEON would not be a truly national network of sites until all the observatories are funded and built, which could take more than a decade. Second, the formulation and implementation of each regional observatory would be driven mostly by responses to requests for proposals. Institutions or consortia would submit proposals with their ideas of design and implementation to compete for a contract to build and operate a NEON observatory with a proposed budget of \$20 million for construction and \$3 million for maintenance. That approach has the great advantage of encouraging creativity and investigator dedication, but it would decrease the ability of NEON to address major environmental challenges in a coordinated regional to national manner. Moreover, NSF's current approach does not provide the committee or Congress with a clear idea of what each NEON observatory would look like or do. Detailed design and implementation plan is often required to obtain MREFC funding.

To establish a coordinated, efficient, and truly nationwide network, the committee suggests that NSF structure NEON according to the environmental challenges to be addressed rather than by locating one site in each ecosystem type represented in the United States. Thus, NEON would consist of a total of six "observatories" (rather than 17), one for each of the six environmental challenges. Each observatory would consist of multiple sites chosen simultaneously and located strategically across the nation to ensure adequate regional and national coverage for addressing the challenge. The funding needed to set up and maintain each of the six observatories would depend on its specific focus and plans, and the costs for an observatory might substantially exceed the \$20 million for construction and \$3 million for annual maintenance that NSF estimated for its original concept of a network of 17 regional observatories. The total costs for six national rather than 17 regional observatories might, however, be comparable with or less than costs for the original concept, particularly because infrastructure for research on more than one of the six themes could be colocated at many sites. Most important, sufficient funds should be allocated to ensure that each observatory is a truly nationwide network. Specific research projects conducted at

individual sites within a NEON observatory should be funded through other NSF research, rather than infrastructure, programs.

Second, the committee believes that NEON observatories could contribute to and potentially unify relevant environmental data that are being gathered by other federal, state and local agencies. Moreover, particular NEON observatories could build on existing NSF research sites (LTER sites), the Department of Energy's programs (Free-Air Carbon Dioxide Enrichment experiments and AmeriFlux eddy flux towers), and other projects. The committee supports NSF's effort to have NEON observatories form partnerships with other federal, state, and local agencies and suggests formulation of plans to address such issues as standardization of protocols and data and coordination of research.

NEON programs would be ideal location for undergraduate and graduate interdisciplinary training and for K-12 students and teachers to study science on the basis of observation and experimental inquiry. The integration of research, education, and public outreach should be a central feature of NEON, and educational and outreach plans should be included from the inception of each observatory.

FINDINGS AND RECOMMENDATIONS

On the basis of its analyses, many of which were summarized above, the committee strongly endorses a NEON-like endeavor and the broad vision of NEON's mission that NSF articulated in the opening sentences of its 2004 congressional budget request. We offer the following findings and broad recommendations to help NEON to achieve its goals.

Finding 1

The committee identified six critical environmental challenges that are regional, continental, or global in their extent—biodiversity, species composition, and ecosystem functioning; ecological aspects of biogeochemical cycles; ecological implications of climate change; ecology and evolution of infectious diseases; invasive species; and land use and

MEETING THE INVASIVE SPECIES CHALLENGE



Management Plan
National Invasive Species Council
2001

Survey of Federal Roles and Responsibilities

Invasive species and the problems they create are far from new. The River and Harbors Act of 1899 directed the Department of Defense's Army Corps of Engineers to manage aquatic invasive plants. State laws requiring the eradication or control of invasive weeds have been on the books for more than 100 years. Many Federal laws, authorities, and programs, as well as international agreements and treaties, have been established as part of efforts to prevent, control, and manage the many different types of invasive species and their impacts. More than 20 Federal agencies now have responsibilities, authorities, and programs that address some aspect of the invasive species issue. Some of these programs are significant in their breadth and scope [e.g., the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS)] and some focus on specific, high-profile aspects of the overall problem (e.g., the Department of the Interior's Office of Insular Affairs oversees a program to control and contain the brown tree snake).

The major Federal invasive species efforts currently in place are outlined in this section. Further detail is provided in Appendix 2. A list of legal authorities can be found in Appendix 3. Although many Federal programs and responsibilities cut across several aspects of the invasive species issue, they have been grouped under the headings of prevention; early detection and rapid response; control, management, and restoration; research and monitoring; international measures; public outreach and partnership efforts; other interagency efforts; and related issues. More complete reports describing Federal authorities are available elsewhere (e.g., U.S. Congress, OTA 1993; National Plant Board 1999; U.S. General Accounting Office 2000).

The States have numerous programs relating to the wide variety of invasive species issues and also play a critical role in preventing and controlling the spread of invasive species. Generally, the States, except on Federal lands and where specifically provided by Federal law or international treaty, have jurisdiction over resident fish and wildlife. Nothing in this Plan alters or modifies existing State or Federal jurisdiction in any way. A description or analysis of the wide variety of State policies and programs is beyond the scope of this Plan. However, coordination and joint action with State partners is an important element of many of the Plan's action items (next section). State, tribal, local, and foreign government participation will be critical to addressing the U.S.'s invasive species problems.

Overview

The Council's member Departments spent approximately \$631.5 million in Fiscal Year (FY) 2000 on invasive species issues (U.S. General Accounting Office 2000). The Department of Agriculture (USDA), a Council co-chair, has by far the largest budget to address invasive species, with USDA agencies accounting for almost 90 percent of the spending. USDA has jurisdiction over the importation and exportation of plant species, plant pests, biological control organisms, and animals

considered to be plant pests or a threat to livestock or poultry health. It also has authority over forest pests and management of invasive species in the U.S. 190-million-acre National Forest and Grasslands System.

The Department of the Interior (Interior) has a much smaller program – approximately \$31 million in FY 2000 – accounting for about 5 percent of the total Federal invasive species expenditures (U.S. General Accounting Office 2000). Interior regulates the importation of animals found to be injurious, enforces laws and regulations governing the import and export of all wildlife into the U.S., plays a key role in implementing actions to address aquatic invasive species and has responsibility for management of invasive species on the lands managed by its agencies.

The Department of Commerce, through the National Oceanic and Atmospheric Administration (NOAA), is trustee for the Nation's marine resources and has programs to deal with aquatic invasive species. NOAA's primary focus has been on research and outreach regarding aquatic invasive species. In FY 2000, NOAA spent a total of \$5.5 million on these programs.

The Department of Defense (Defense) spent a total of \$14.5 million in FY 2000 controlling invasive species on its installations and ensuring that invasive species are not transferred into the United States or to other nations during its operations (U.S. General Accounting Office 2000). Most of these funds (\$9.1 million) were spent to control aquatic plant growth (most of which are invasive species) and support research on zebra mussels.

Other Federal Departments play limited but important roles. For example, U.S. Customs Service (USCS), works with USDA and Interior to enforce laws prohibiting or limiting the entry of invasive species. The Environmental Protection Agency (EPA) regulates chemical pesticides and biopesticides. It also reviews environmental impact statements.

Prevention

The protection of agriculture has been, and continues to be, the primary focus of Federal efforts to prevent invasions of non-native species, but damage to natural areas is increasing in priority. About half of the total Federal expenditures on invasive species are for prevention activities. The new Plant Protection Act (PPA), which consolidated the authorities in the Plant Quarantine Act, Federal Plant Pest Act, Federal Noxious Weed Act, and other plant-related statutes, authorizes USDA to prohibit or restrict the importation or interstate movement of any plant, plant product, biological control organism, or plant pest. "Plant pest" is defined very broadly to include almost any living organism (other than humans) that damages or causes disease to any plant. The PPA specifically authorizes USDA to hold, seize, quarantine, treat, or destroy any plant or plant pest moving in interstate commerce if necessary to prevent the movement of a plant pest or federally

listed noxious weed into a new area. In addition, USDA “preclears” some shipments before they can be exported from foreign countries to the United States to ensure that they are free of certain invasive species. It has long been recognized that the resources for USDA’s exclusion activities have not kept pace with the increased volume of trade and tourism.

USDA also has authority to regulate the importation and interstate movement of certain invasive animal species under a number of statutes collectively referred to as the animal quarantine laws. These laws authorize USDA to prevent the introduction and dissemination of communicable diseases and pests of livestock and poultry. The USDA also regulates the importation or exportation of veterinary biological products and prohibits the importation or shipment of any veterinary products that are contaminated, dangerous, or harmful.

The movement of seed is regulated under the Federal Seed Act, which prohibits the importation of any agricultural or vegetable seed containing high-risk weed seeds. The Federal Seed Act also allows the interstate transport of seed containing other specifically listed weed seeds, as long as the shipment is accurately labeled and the density of those weed seeds does not exceed the tolerance levels for the State in which it is offered.

Interior regulates the importation of animals found to be injurious under the Lacey Act. The species that have been specifically listed as injurious include 12 genera of mammals, 4 species of birds, 1 reptile, 1 mollusk, and 1 crustacean. Interior’s port inspection program is relatively small – in FY 1999, the budget was just over \$3 million. Several provisions within the Lacey Act limit Interior’s ability to comprehensively address invasive species introductions. Most notably, the Act is limited to only vertebrates, mollusks, and crustaceans.

A number of Departmental agencies are charged with preventing and controlling the introduction of aquatic nuisance species under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990. The Fish and Wildlife Service (FWS), NOAA, the EPA, USDA, Defense, and the Departments of Transportation (Transportation) and State (State) are all represented on the Aquatic Nuisance Species Task Force (ANSTF), which coordinates Federal activities to implement the Act. Transportation is charged with issuing regulations to prevent introductions through the ballast water of vessels. Specifically, they have issued regulations requiring management of ballast water in the Great Lakes and Hudson River, and issued voluntary guidelines to prevent the introduction and spread of non-native species from ballast water in ships entering other U.S. waters from outside the exclusive economic zone.

Defense transports large shipments of equipment into the U.S. that could harbor invasive species. These shipments are inspected by USDA agents. In addition, Defense and other departments ship a great number of items to other countries

and take actions to ensure they do not cause problems in other countries. The U.S. Customs Service assists USDA and Interior in the enforcement of plant and animal regulations by detaining, where applicable, imported or exported products pending their clearance by agency inspectors.

The Federal land management agencies in both USDA and Interior have internal prevention strategies as well as interagency programs such as Noxious Weed-Seed Free Forage and Mulch program and the Slow the Spread program (which is intended to prevent the further spread of gypsy moth in the eastern forests).

Early Detection and Rapid Response

A number of Federal Departments have programs to detect, assess, and respond to invasions by non-native species. This section specifically addresses Departments that have special or emergency authority to identify and address new or incipient invasions rapidly - before invasive species can become established or widespread, while eradication is still cost effective and possible. Only USDA has emergency authority to deal with an incipient invasion. Both the PPA and the animal quarantine laws described above provide authority to seize, quarantine, destroy, hold, and treat prohibited species that are imported into the United States or moved between States. These authorities also authorize the USDA to declare an extraordinary emergency in order to address a situation in which the prohibited species has not been moved but a State is unable or unwilling to take appropriate action to prevent dissemination of a plant pest or a communicable disease of livestock or poultry.

In addition, Interior has established four exotic plant management teams to identify, eradicate, or control small, localized infestations on lands managed by the National Park Service. Many departments have interagency and interdepartmental rapid response teams. All Federal rapid response actions must comply with the National Environmental Policy Act (NEPA).

Control, Management, and Restoration

All Federal land and water management agencies within Interior, NOAA, and Defense have authority to control and manage invasive species as well as restore affected areas on their lands and waters. This authority arises from the various agency organic acts and other statutes that govern management, uses, and planning on the lands and waters under their jurisdiction. The level of effort and budgetary resources for management, control, and restoration vary with each Department. None of them has the resources to control every invasive species present on Federal lands and waters. Departments and their agencies also work in partnership with States and private landowners to control invasive species on public lands. These efforts are summarized below in the section on Partnership Efforts.

The Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) enables the Federal members of the ANSTF to undertake control actions in addition to prevention and monitoring activities. NANPCA also provides regulatory authority to FWS, NOAA, and Transportation for control activities. To date, this regulatory authority has not been used because it is only applicable to unintentional introductions, and there is uncertainty as to the extent of the authority.

The EPA has authority under three statutes that can be used to control and manage invasive species. The EPA may have authority under the Clean Water Act to control and manage invasive species through permits or other requirements and programs and is currently reviewing its authorities under the Clean Water Act relative to invasive species. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requires manufacturers and importers who produce or sell a pest control product to register the compound with the EPA. FIFRA is a critical statute for invasive species whenever pesticides are used to control or reduce the impact of invasive species. Examples include the use of a pesticide to control lamprey populations in the Great Lakes and the use of herbicides to control noxious weeds. FIFRA also gives EPA review authority for biopesticides when they are used to control invasive pests. Finally, EPA reviews all environmental impact statements under NEPA. This review, conducted in EPA's regional offices, now includes an explicit consideration of the proposed action with regard to invasive species.

A number of Departments are involved in control and management efforts. USDA has authority under the PPA and other statutes for the control and management of invasive species. The PPA specifically authorizes USDA to develop integrated management plans for noxious weeds for the geographic region where the weed is found. The Emergency Watershed Program gives the Natural Resources Conservation Service (NRCS) authority to provide technical and financial assistance to carry out restoration following declaration of a disaster. Defense manages aquatic plants and other invasive species in 562 reservoirs, 237 navigation locks, 962 harbors, 75 hydropower projects, and 25,000 miles of inland and coastal waterways through its operations and maintenance activities.

Research and Monitoring

Almost all the Departments with major responsibilities in the areas of prevention and control of invasive species also have research and monitoring programs to support their efforts. For several agencies with USDA, Interior, and NOAA, research and monitoring are very significant activities. USDA regularly monitors its emergency programs to determine efficacy and potential environmental impacts, and through the Cooperative Agriculture Pest Survey program has developed a database system to store information collected in the surveys of agricultural pests, which is called the National Agriculture Pest Information System (NAPIS). USDA also conducts significant research efforts on invasive species under its various authorities. It provides leadership in developing

biological control technologies, as well as research on invasive insects and pathogens of concern to forest, rangelands, and wetlands. It also establishes partnerships for the integrated management of invasive species. Defense has a number of research programs focused on aquatic plant problems and zebra mussels. In addition, EPA conducts research on the risks associated with invasive species and monitors the extent of invasive species spread by ecosystem type as part of its research and development authority. Interior coordinates important information systems on non-native aquatic species in ecosystems.

Information Management

Departments engaged in invasive species prevention and control activities have developed a variety of databases and decision support tools to increase predictive capacity for preventing introduction of new invasives and to improve control efforts in both agricultural production and conservation areas. The Smithsonian Institution and various research and development bureaus and agencies of the Council (especially USDA, Interior, and NOAA) have incorporated computer-assisted digital photography and rapid dissemination to taxonomic experts via the World Wide Web to speed identification of pests and noxious weeds in trade. Databases at USDA record and analyze information on pests intercepted at ports of entry. Research and informatics programs at the USDA Forest Service and the Interior's U.S. Geological Survey document and analyze the spread of invasive species such as forest pathogens and aquatic nuisance species. These structured databases and other new technologies under development for locating and treating aquatic and terrestrial invasive species have greatly enhanced the ability of land and water managers to stop the spread of some of the most invasive species. Interior and USDA have joined efforts to combine components of the National Biological Information Infrastructure (NBII) and various research and bibliographic databases at the National Agricultural Library (NAL) to assist the Council in its charge to implement a web-based network capability for information sharing among professionals and the public at large.

International Measures

The global dimensions of the invasive species problem increase as trade, tourism, and transport expand. Any realistic strategy to prevent the spread of invasive species must be built upon international agreements, cooperation, and capacity building. The U.S. Government plays an active role and provides leadership in efforts to prevent and control invasions of non-native species internationally. For example: USDA leads U.S. negotiations under the International Plant Protection Convention (IPPC) and works with the World Trade Organization to facilitate regulations concerning imports to prevent invasions under the Application of Sanitary and Phytosanitary Measures. The Office of the U.S. Trade Representative (USTR) leads or directs U.S. negotiations with other countries through meetings of the World Trade Organization (WTO) and the North American Free Trade Agreement (NAFTA). Interior leads the United States in negotiations on invasive species in the Convention on International Trade in Endangered Species of Wild Fauna

and Flora (CITES). State leads negotiations under the Convention on Biological Diversity (CBD) and is providing financial support to several international meetings of policy makers. Transportation has led U.S. efforts to address the issue of ballast water management within the International Maritime Organization (IMO). It has also sponsored the resolution adopted by the International Civil Aviation Organization (ICAO) that calls for participation by ICAO and national aviation authorities in the prevention and control of invasive species transported by air. Defense undertakes agreements on the management of invasive species with the defense departments of other nations and supports the development and implementation of regional programs of cooperation on invasive species, such as the South Pacific Regional Environment Programme (SPREP). The EPA leads U.S. activities under the North American Agreement for Environmental Cooperation (NAAEC). In the Great Lakes region, the EPA and NOAA work on invasive species issues in close association with the governments of Canada and the Baltic region, the U.S.-Great Lakes Fisheries Commission, and the U.S.-Canada International Joint Commission (IJC). The U.S. Agency for International Development (USAID) supports projects to control invasive species in developing countries, especially when food, water, or health security are at risk. The National Science Foundation (NSF) promotes exchanges of scientists and research collaborations with other countries.

Public Outreach and Partnership Efforts

Given the scope and pervasiveness of the invasive species problem, outreach and partnership efforts play a center stage role in many Federal efforts. Prevention efforts will not be fully successful without the participation of an informed public. Control efforts in many cases cannot be successful unless all affected landowners — including State, local, tribal, and private — cooperate and coordinate the control action. A number of Federal Departments have special projects and programs that provide information to the public or assistance to State, local, and private landowners for control efforts, especially agencies within the Departments of the Interior, Agriculture, and Commerce. Commerce conducts outreach efforts on aquatic invasive species. USDA conducts public information campaigns directed at travelers and their extension specialists provide information to the public. (See Appendix 3, Public Outreach and Partnership Efforts.)

Other Interagency Efforts

There are a number of Federal entities that provide coordination among Federal agencies regarding different aspects of the invasive species problem. The Executive Order on Invasive Species specifically directs the Council to work with three of these, the:

- 1) Aquatic Nuisance Species Task Force (ANSTF), which coordinates activities relating to aquatic invasive species;
- 2) Federal Interagency Committee on the Management of Noxious and Exotic Weeds (FICMNEW), which coordinates weed management efforts on Federal lands; and
- 3) Committee on Environment and Natural Resources (CENR) of the National Science and Technology Council (NSTC), which coordinates research efforts.

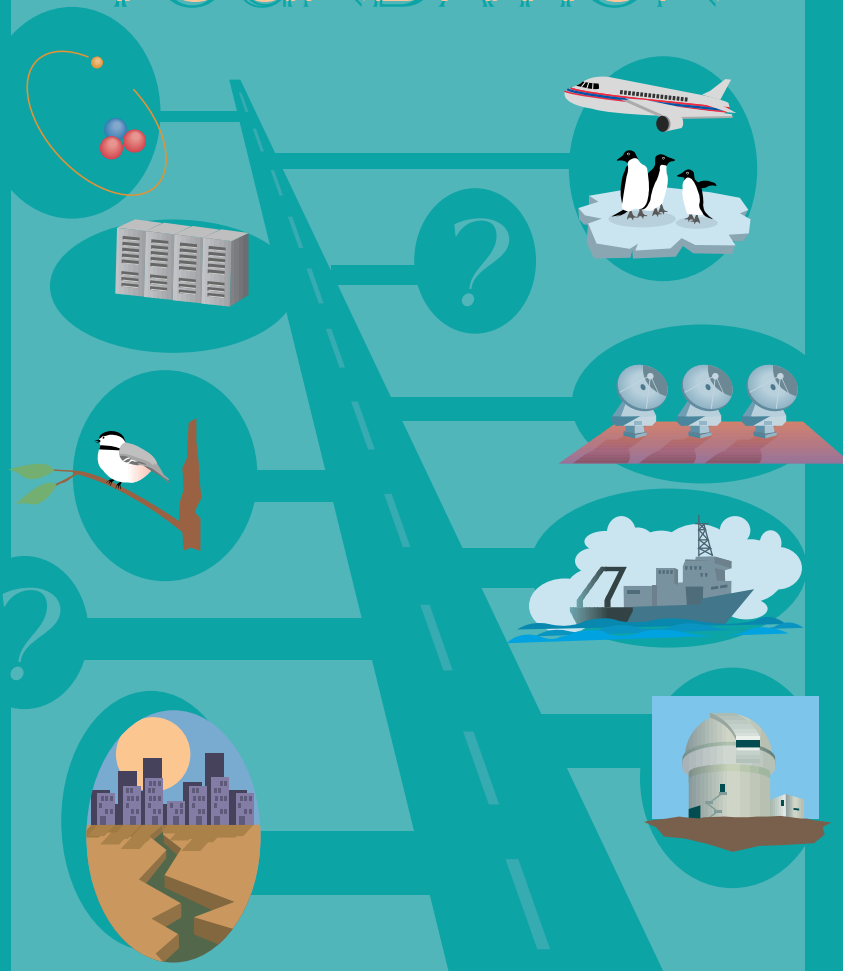
There are many other important organizations and interagency efforts that Council members have and will continue to work with on invasive species issues.

Related Issues

A number of related issues repeatedly emerged during the development of information on Federal roles and responsibilities. The first issue is whether existing legal authorities are sufficient and whether and how they can be better utilized. The second issue is whether existing legal and regulatory authorities are being adequately enforced. These issues will be addressed in the analysis required under the leadership and coordination section of the plan. The third issue is whether human and financial resources are adequate to address the problem. A number of action items in the Plan highlight the need for additional resources.

SETTING PRIORITIES for LARGE RESEARCH FACILITY PROJECTS

supported by the
NATIONAL SCIENCE
FOUNDATION



Criteria for Developing Large-Facilities Roadmaps and Budgets

Overlapping categories of criteria should guide the preparation of the large-facilities roadmap and NSF's annual budget submissions. Scientific and technical quality must be at the core of these criteria. Because these are large-facility projects, they must have the potential to have a major impact on the science involved; otherwise, they should not reach the next step.

The rankings show what we would expect to happen first within a field, then within a directorate of NSF, and then across NSF. The criteria from earlier stages must continue to be used as the ranking proceeds from one stage to the next.

· **First Ranking: Scientific and Technical Criteria Assessed by Researchers in a Field or Interdisciplinary Area**

- Which projects have the most scientific merit, potential, and opportunities within a field or interdisciplinary area?
- Which projects are the most technologically ready?
- Are the scientific credentials of the proposers of the highest rank?
- Are the project-management capabilities of the proposal team of the highest quality?

· **Second Ranking: Agency Strategic Criteria Assessed Across Related Fields by Using the Advice of Directorate Advisory Committees**

- Which projects will have the greatest impact on scientific advances in this set of related fields taking into account the importance of balance among fields for NSF's portfolio management in the nation's interest?
- Which projects include opportunities to serve the needs of researchers from multiple disciplines or the ability to facilitate interdisciplinary research?
- Which projects have major commitments from other agencies or countries that should be considered?
- Which projects have the greatest potential for education and workforce development?
- Which projects have the most readiness for further development and construction?

· **Third Ranking: National Criteria Assessed Across All Fields by the National Science Board**

- Which projects are in new and emerging fields that have the most potential to be transformative? Which projects have the most potential to change how research is conducted or to expand fundamental science and engineering frontiers?
- Which projects have the greatest potential for maintaining US leadership in key science and engineering fields?
- Which projects produce the greatest benefits in numbers of researchers, educators, and students enabled?
- Which projects most need to be undertaken in the near term? Which ones have the most current windows of opportunity, pressing needs, and international or interagency commitments that must be met?
- Which projects will have the greatest impact on current national priorities and needs?
- Which projects have the greatest degree of community support?
- Which projects will have the greatest impact on scientific advances across fields taking into account the importance of balance among fields for NSF's portfolio management in the nation's interest?

Ranking projects across disciplines is inherently not an exact science; nevertheless, these criteria, as illustrated by the questions, provide a framework for a discussion of why one project was accorded a higher priority than another and a mechanism for the discussion to be as objective as possible in ranking projects across fields.

Within the ranking categories, the questions might change as governmentwide initiatives and unexpected occurrences shift priorities. Similarly some questions might have greater weight than others at certain times in the judgment of the NSB. The key element is for the questions and weighting to be identified before the ranking process begins and for a clear rationalization to be provided when proposed large-research-facility projects are ranked.

earth scope



SCIENTIFIC TARGETS
FOR THE WORLD'S LARGEST
OBSERVATORY POINTED
AT THE SOLID EARTH

WORKSHOP
REPORT

SNOWBIRD, UT
OCTOBER 10-12, 2001

Introduction

Many fundamental aspects of continental structure and dynamics, including those responsible for earthquakes and volcanic eruptions, are not yet well understood. This is, in part, because of the difficulty of piecing together the results of many focused, regional studies carried out by a single investigator or a small team of investigators. Most major Earth processes act, and interact, on much larger and longer time scales than can be resolved by such isolated studies. These processes drive geological events at Earth's surface that affect humankind. To understand how these large-scale systems respond to internal and external forcing requires linking detailed information about surface geology with its underlying crustal structure and extending and linking these observations to interactions between the crust and the underlying mantle.

EarthScope will provide the first detailed, integrated examination of North America's structure and will monitor plate deformation at the continental scale. The seismic and magnetotelluric component of EarthScope (USArray) will map the structure of the continent and underlying mantle at high resolution. EarthScope's geodetic components, the Plate Boundary Observatory (PBO) and Interferometric Synthetic Aperture Radar (InSAR), will measure surface motions at a variety of spatial and temporal scales. Deep drilling across the San Andreas fault by the San Andreas Fault Observatory at Depth (SAFOD) will directly determine stress conditions and rock properties in the seismogenic zone of a major fault. Combining these direct measurements with associated geological, geochronological, geochemical, experimental, and theoretical studies will provide the clearest picture yet of our continent's

dynamics. EarthScope's decade-long effort thus offers the potential for unprecedented discovery and a model for a future of truly integrative, multidisciplinary research in the solid Earth sciences.

EarthScope is an interdisciplinary experiment of unprecedented resolution that will identify links between the surface geology of North America and the forces at work in Earth's interior.

To further develop ways to fully exploit the measurements provided by EarthScope's observational components, approximately 200 Earth scientists assembled in Snowbird, Utah for the first "pan-EarthScope" workshop. This report summarizes the workshop discussions, divided according to the broad scientific themes around which working groups were formed. These themes blend into a broad-ranging examination of the major issues of continent formation and the factors controlling its current dynamic behavior. This report first lists some of the key scientific questions identified at the workshop as a means of capturing our current understanding of this broad topic. With this background, we then explore the many ways in which EarthScope can contribute to answering these fundamental questions. Working groups also discussed what additional data sets, modeling efforts, and education and outreach are necessary to maximize the scientific return from EarthScope.

EarthScope offers the first opportunity to measure plate tectonic movements while they are happening, and at the continental

EarthScope's facilities include the following four coupled components:



USArray (United States Seismic Array): A combination of permanent, transportable broadband, and flexible seismic arrays will map the structure of the continent and the underlying mantle at high resolution.



InSAR (Interferometric Synthetic Aperture Radar): A remote-sensing technique will provide spatially continuous strain measurements over wide geographic areas with decimeter to centimeter resolution.



PBO (Plate Boundary Observatory): A fixed array of GPS receivers and strainmeters will map ongoing deformation of the western half of the continent, from Baja California to the Bering Sea, with a resolution of one millimeter or better over regional baselines.



SAFOD (San Andreas Fault Observatory at Depth): A borehole observatory across the San Andreas fault will measure subsurface conditions that give rise to slip on faults and deformation in the crust.

spatial scale, so that the cause and effect of these movements finally can be deciphered. The combination of instrument, technique, and computational developments, the existence of a collaborative, multi-institutional, multi-agency infrastructure capable of managing an experiment of this size, and the maturity of the scientific field to which the EarthScope instrument will be directed combine to make this the perfect time to create the EarthScope facility.

The next major advance in our understanding of how the dynamic Earth works, and how humankind can best deal with both the beneficial resources and the dramatic hazards Earth provides, must come by expansion of our observational network to the scale of Earth activity. EarthScope will provide this step for the United States.

Scientific Targets for EarthScope

Fault Properties and the Earthquake Process

Key Questions

Over the last few decades, considerable research into earthquake sources and the hazards they pose have greatly improved our understanding of both. Increases in the quality and quantity of data recorded, combined with the development of new analysis techniques, have resulted in significantly better models of the earthquake rupture process. These in turn have permitted more reliable statistical seismic hazard predictions. Despite this progress, many fundamental questions concerning earthquake rupture and fault processes remain unanswered, and others have been identified as we learn more about them.

At the workshop, five outstanding, fundamental scientific questions were identified that any large-scale initiative in earthquake science needs to address:

1. **How does strain accumulate and release at plate boundaries and within the North American plate?** Where is slip along a fault aseismic versus seismic? What are the structure and other properties of active fault zones? How do they affect the manner in which faults slip? How can we explain the observed space-time pattern of seismicity? How do earthquakes interact with and trigger one another?

2. **How do earthquakes start, rupture, and stop?** Do all earthquakes start from similar beginnings, or does the nucleation process determine the final size of the earthquake? How do fault properties and rupture dynamics combine to control rupture propagation and extent? What causes the rupture to stop?

EarthScope will help develop predictive models for earthquakes by unraveling the dynamic processes along faults, from stress build-up to catastrophic rock failure.

How are earthquake ruptures on subduction zones different from those on crustal faults? What are the causes of intermediate depth earthquakes (such as the one under Seattle in January 2001), and do they vary with depth?

3. **What is the absolute strength of faults and the surrounding lithosphere?** Where are plate driving forces carried? Are faults relatively low-strength features? How do faults in different tectonic settings compare?

4. **What structural and geological factors give rise to intraplate regions of seismic hazard and seismicity, such as the New Madrid zone?**

5. **How can we accurately predict earthquake-induced ground motions over a wide frequency range?** For example, what is the geometry and response of large sedimentary basins? How nonlinear is site response?

These five questions largely reflect the frustration of the Earth science community in their attempts to solve problems that 25 years ago appeared to be nearly solved. For instance, the Parkfield reach of the San Andreas fault was thought to be sufficiently well understood in terms of earthquake recurrence that a magnitude 6 event was forecast to occur there in January 1988, plus

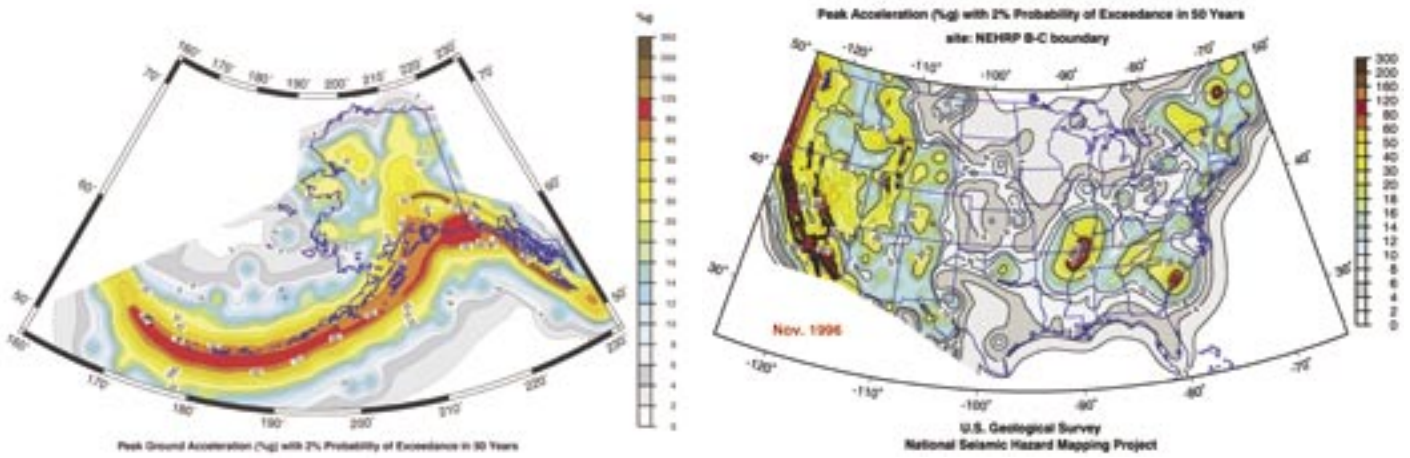


Figure 1. Current seismic hazard maps of the United States demonstrate clearly that California is not the only state to experience or expect large earthquakes. PBO and USArray will greatly improve our understanding of earthquake processes along the Cascadia and Alaskan subduction zones. USArray and InSAR will provide us with unprecedented resolution and information about the eastern half of the United States, where large damaging earthquakes can occur. Figures courtesy of the USGS.

or minus five years, at the 95% confidence level. In 2001, we are much humbler regarding our understanding of the San Andreas fault and, needless to say, are still waiting for the next Parkfield earthquake. Similarly, we do not know, within a factor of three or four, the magnitude of the stresses acting on the San Andreas fault needed to cause slip despite substantial research on this issue beginning in the 1960s. Solving these, and other, fundamental problems of earthquake occurrence and fault dynamics clearly requires a substantially augmented effort to acquire the key, but elusive, data sets that bear on these issues.

To date, most earthquake research has been focused in California, but other parts of the United States also have significant seismic hazards (Figure 1). Earthquakes have been recorded in all but one of the 50 United States, and the country includes a wide range of tectonic environments for

studying earthquakes and deformation in many different conditions. EarthScope will improve our resolution of the earthquake rupture process in regions where we currently have the most detailed knowledge, such as California, but will also enable us to study regions that have received relatively little attention to date, such as the subduction zones of Cascadia and Alaska, and the more stable eastern parts of the country where seismicity is rarer, but still significant, and potentially damaging.

The EarthScope Contribution

Recent work has demonstrated that only an order of magnitude improvement in data quality and quantity will permit us to address the outstanding scientific questions about earthquake processes with any realistic hope of success. The combined EarthScope components will provide much of the data required to significantly increase our understanding of the entire earthquake rupture process. For example, previous work has demonstrated that large earthquakes nucleate as a result of processes acting at a very small scale that currently cannot be resolved. Measurements and observations from SAFOD, USArray,

EarthScope will provide a comprehensive suite of geophysical data sets that are critically needed to advance understanding of earthquake processes and related hazards.

and PBO instrumentation will enable us to resolve earthquake nucleation processes at the smallest scale, but also capture critical information at longer temporal and larger spatial scales.

Adding a time dependence to statistical forecasts of seismic hazard is becoming possible as we begin to understand how one earthquake may affect or trigger another event. Data on earthquake interactions, detailed crustal structure, and the state of stress in the crust exist in too few parts of the country, however, for us to produce reliable forecasts. USArray will provide the needed information about crustal structure and ongoing seismicity that will greatly extend our ability to forecast hazards (Figure 2). The USGS-sponsored Advanced Na-

tional Seismic System (ANSS) is also important, providing the long-term seismicity coverage needed to address seismic hazard problems. PBO and InSAR will enable us to identify where strain is building up and where it is being released on longer time scales. Detectable earthquakes may not be produced at such locations, but the crustal stress fields may be modified in ways that can accelerate or retard the likelihood of a future earthquake. The proposed paleoseismic component of PBO also is needed to provide an even longer-term perspective on crustal strain build-up and release.

More specifically, each EarthScope component will contribute to answering the five questions posed in the following ways:

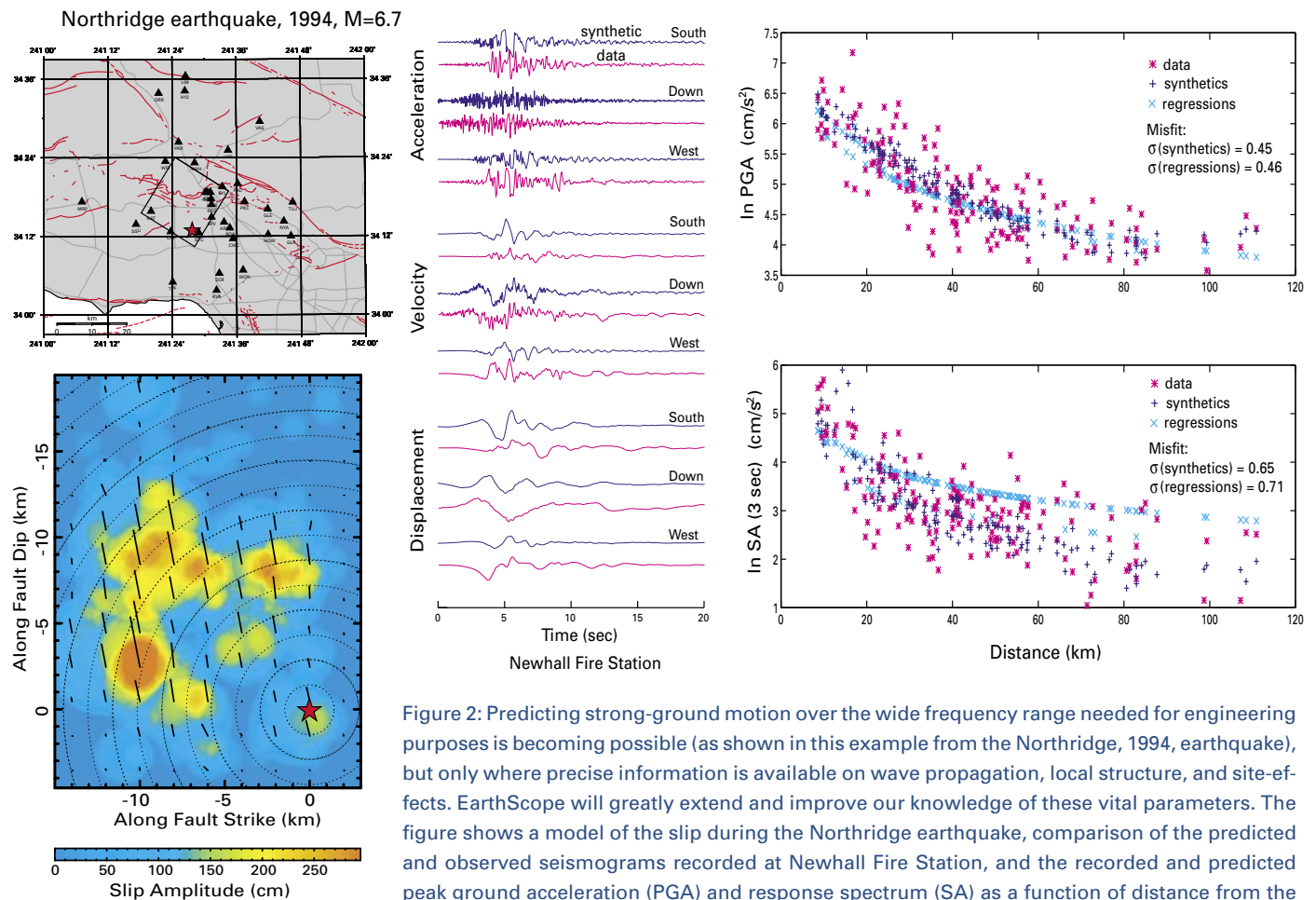


Figure 2: Predicting strong-ground motion over the wide frequency range needed for engineering purposes is becoming possible (as shown in this example from the Northridge, 1994, earthquake), but only where precise information is available on wave propagation, local structure, and site-effects. EarthScope will greatly extend and improve our knowledge of these vital parameters. The figure shows a model of the slip during the Northridge earthquake, comparison of the predicted and observed seismograms recorded at Newhall Fire Station, and the recorded and predicted peak ground acceleration (PGA) and response spectrum (SA) as a function of distance from the earthquake. Courtesy of J. Anderson and Y. Zeng, UNR.

SAFOD will provide direct observations of the structure and properties of an active fault zone at seismogenic depths. Seismic and strain observations over a number of years will provide close-in records of earthquake nucleation, rupture, and termination that are needed to address fundamental questions about the earthquake process. (Questions 1 and 2).

USArray includes the main Bigfoot transportable array, which will provide a significant improvement in our ability to locate earthquakes, and the flexible component, which can be used for higher-resolution studies of more limited areas such as detailed examination of individual faults. Crustal velocity structure and fault orientations are needed to help answer all five questions. USArray's flexible array also will be invaluable for earthquake studies by enabling dense deployment in regions where there is swarm activity or an aftershock sequence, greatly increasing the resolution of the lithosphere structure in those regions. In addition, USArray will permit detailed studies of the nature of earthquake sources in regions far from the plate boundary, and so investigate how different conditions affect the earthquake generation process.

EarthScope will enable us to observe the processes and properties of faults that drive the earthquake machine.

PBO and InSAR will provide much-needed measurements of the integrated strain field, forming the basis for resolving aseismic processes of permanent and transient deformation, as well as seismic strain recharge and release. At the detailed scale of the PBO dense clusters, observations of strain changes before and after earthquakes will be invaluable for understanding how dynamic rupture begins and ends, and what triggers it (e.g., Question 2). The larger scale PBO network and InSAR will enable us to map the distribution of aseismic strain over the continent, which is needed to understand seismicity distributions and larger-scale triggering (Question 1). InSAR and GPS also provide valuable information about the distribution of seismic slip in an earthquake (Question 2).

ANSS will play an important role in addressing these questions. The new stations will provide the long-term monitoring component essential to improve seismic-hazard modeling, as well as adding to the data available to study the earthquake source and crustal structure.

Necessary EarthScope Data Sets

At present, there is a severe lack of reliable high-resolution data on earthquake and fault properties. Thus, workshop attendees spent considerable time discussing the data sets necessary to make headway in answering the five questions mentioned above. Table 1 summarizes the discussion on: (1) which data sets are required to address the five key questions, (2) whether the data sets are currently available, (3) whether EarthScope will provide the required data, and (4) what else is needed to obtain the data.

Table 1: Data Sets Needed for a Better Understanding of the Earthquake Process

Data Set	Relevant to Questions	Available?	Will EarthScope Provide?	What Else?
Instrumental seismicity catalogues	1,2	ANSS	Not enough	Regional networks with local densifications.
Pre-instrumental catalogues	1-5	Partial	No	Additional data (especially at PBO sites). Compile existing data in usable form ¹ .
3D active fault map (location, strike, dip)	1-5	Partial	Partial (PBO)	Flexible array (P.I. driven).
Internal fault zone architecture in 4D: geometry (e.g., width, depth, continuity), material properties (e.g., seismic velocities, attenuation, anisotropy, viscosity), and geology (e.g., fabrics, microstructures)	1-3,5	A little	SAFOD	Flexible array (P.I. driven). Compile existing data in usable form ¹ .
Transitions between: (1) fault segments, (2) an entire fault system and surrounding rock, and (3) brittle and ductile depth sections	1-5	A little	SAFOD	Flexible array (P.I. driven). Compile existing data in usable form ¹ .
Crustal and upper mantle structure in 4D	1-5	Partial	Partial	Flexible array (P.I. driven).
Strain-rate field in 4D	1-4	Partial	PBO and INSAR	Additional geodesy.
Finite strain (geology: total fault slip, pressure solution in bulk)	1,2	Partial	No	Additional geology. Compile existing data in usable form ¹ .
Heat flow	1,3,4	Partial	SAFOD	At PBO and other sites. Compile existing data in usable form ¹ .
Electromagnetic/MT	1,2	A little	USArray	Additional measurements. Compile existing data in usable form ¹ .
Seismic waveforms (broadband with high dynamic range)	1-3,5	Partial	USArray, ANSS, SAFOD	Flexible array (P.I.-driven). Add broadband and strong motion to PBO sites ² .
Site response at all new and temporary sites	2,5	No	Partial	Geotechnical measurements.
Lab data of rheological and geophysical rock properties	1-4	Very little	No	New EarthScope observations will require complementary lab studies to interpret. Compile existing data in usable form ¹ .
Ground water and other environmental effects	1,3,5	Partial	No	Monitor ground water etc. at PBO sites.

(1) Compilation of existing data in usable form should provide best values and uncertainties for two data sets: raw measurements and interpretation. (2) The current instrumentation plan for the PBO borehole sites does not include broadband and strong ground motion seismometers. This is a major short shortcoming because the PBO sites are close to major faults, and thus are likely to experience moderate and large earthquakes. The sites may also record microearthquake data (e.g., with $M < -1$). Near-fault seismic data over broad magnitude and frequency ranges are critically needed to test different hypotheses on the physics of earthquakes and faults (e.g., existence of strong dynamic variation of normal stress during rupture propagation; scaling of earthquake properties; sources of high-frequency seismic radiation; slip histories). On-scale recording of moderate and large earthquakes over a broad frequency range will require broadband and strong ground motion seismometers at or near the borehole sites. These seismometers should be augmented at selected sites by tight 2D arrays around the fault, or at least by pairs of instruments on the different sides of the fault, to allow imaging of key rupture and fault properties (e.g., symmetry characteristics of particle motion). Detection and recording of microearthquakes may perhaps be done with the geophones currently planned at the borehole sites.

National Ecological Observatory Network (NEON): Development of NEON Coordinating Consortium (NCC) and Project Office

Program Solicitation

NSF 04-549



National Science Foundation
Directorate for Biological Sciences
Division of Biological Infrastructure

A prospective Principal Investigator meeting will be held Feb 6, 2004 in Washington, DC to discuss this solicitation as well as the National Ecological Observatory Network (NEON), NSF's Facilities Management and Oversight Guide, and Large Facilities Project Management. For details contact Dr. Elizabeth Blood, Program Director, Directorate for Biological Sciences, Division of Biological Infrastructure, 615 N, telephone: (703) 292-8470, email: eblood@nsf.gov.

Letter of Intent Due Date(s) (required):

March 08, 2004

Full Proposal Deadline(s) (due by 5 p.m. proposer's local time):

April 26, 2004

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

National Ecological Observatory Network (NEON): Development of NEON Coordinating Consortium (NCC) and Project Office

Synopsis of Program:

The most pressing challenges facing the nation's biosphere result from complex interactions between human, natural and physical systems, which operate over large spatial and temporal scales and transcend all levels of biological organization. To better understand these interactions requires a new tool to investigate the structure, dynamics, and evolution of ecosystems in the United States and to forecast biological change. Through a series of workshops, reports, and planning activities the research community determined that the National Ecological Observatory Network (NEON) should be the new tool: a continent-wide research platform, composed of networked state-of-the-art analytical and communication technologies. NEON will create new collaborative environments, support multi-and inter-disciplinary research, stimulate innovative approaches to information management, develop human capital, and

I. INTRODUCTION

The Directorate for Biological Sciences (BIO) of the National Science Foundation (NSF) announces its intention to support the establishment of a national coordinating organization for the National Ecological Observatory Network (NEON). The NEON Coordinating Consortium (NCC) will provide the scientific leadership, administration, community participation, and overall governance of NEON. The NCC will establish a NEON Project Office that will formulate and implement a management plan to define the science requirements, technical requirements, and draft the preliminary project execution plan for NEON.

Human actions have become a dominant force in environmental change. Ongoing land alterations, climate change, and altered biogeochemical processes have resulted in changes in biodiversity and ecosystem functioning and the goods and services they provide. Globalization has led to the introduction and spread of invasive species and infectious diseases with little understanding of the consequences to biodiversity or ecosystems functioning. Achieving a mechanistic and predictive understanding of environmental change will require comprehensive and interdisciplinary studies that span large spatial and temporal scales and transcend levels of biological complexity.

Ecosystem research using traditional approaches cannot be scaled up to regional and continental scales. New collaborative environments needed to foster the necessary interdisciplinary studies, innovative training, and effective communication among scientists, students, decision makers, and the public are emerging but the biological infrastructure required to conduct studies at regional to continental scales does not exist. Therefore, to address the major environmental challenges, a new national research platform is needed.

The National Ecological Observatory Network (NEON) has been defined as just such a nationally networked and collaborative research platform that will apply current and emerging technologies to address pressing environmental questions on regional to continental scales. With common interdisciplinary research infrastructure and protocols, NEON will facilitate the measurement and forecasting of biological change across the United States. In so doing, NEON will provide critical capabilities that are currently unavailable to research and education.

II. PROGRAM DESCRIPTION

The Directorate for Biological Sciences of the National Science Foundation (NSF) requests proposals to establish a national coordinating organization for NEON. The NEON Coordinating Consortium (NCC) will provide the scientific leadership, administration, community participation, and overall governance of NEON. The NCC will establish a NEON Project Office that will formulate and implement a management plan to define the science requirements, technical requirements, and draft the preliminary project execution plan that includes the scope, budget, and schedule for the design, construction and operation of NEON as well as preliminary plans for research, networking and education infrastructure.

Proposals should consider previous workshops, reports, and planning activities that provide the research community's perspectives on NEON such as "IBRCS White Paper: Rationale, Blueprint, and Expectations for the National Ecological Observatory Network" (IBRCS 2003) [<http://ibr.cs.aibs.org/reports/index.asp>], National Research Council (NRC) Report Neon: Addressing the Nation's Environmental Challenges (NRC 2003) [<http://www.nap.edu/catalog/10807.html>], and "Coordination and Implementation of the National Ecological Observatory Network (NEON)" (<http://ibr.cs.aibs.org/reports/index.asp#NEONCoord>). The major deliverable from this award will be a preliminary Project Execution Plan (PEP) as detailed in NSF's "Facilities Management and Oversight Guide" (<http://www.nsf.gov/pubs/2003/nsf03049/nsf03049.pdf>).

NEON Coordinating Consortium (NCC)

The NCC will lead, coordinate, organize, and serve as the research community focal point for NEON. A significant task of the awardee will be to convert the *consensus within the community into an organizational structure that can define the organization, governance, planning, administration, and management of NEON*. In addition, the awardee will foster interactions between NEON and other observing systems both nationally and internationally, including other appropriate NSF research infrastructure such as Earthscope (<http://www.earthscope.org>).

The NCC, in consultation with the research community and NSF, will establish an advisory structure that provides the scientific, technical, and management leadership to define NEON infrastructure. This advisory structure will address scientific vision and technical requirements; management and governance; cyberinfrastructure and information technology; education, training, and outreach; and other technical and ecological issues related to development, construction, implementation and operation of NEON. Proposals should describe how advisory committees will be organized, led, operate, interact, reach consensus, and disseminate their discussions and findings. For guidance on these issues, proposers should familiarize themselves with the recent IBRCS report, "Coordination and Implementation of the National Ecological Observatory Network (NEON)" (<http://ibr.cs.aibs.org/reports/index.asp#NEONCoord>).

NEON Project Office

The NCC must establish a NEON Project Office. Responsibilities for the NEON Project Office are grouped in three stages. The stages include (1) the development of the Project Execution Plan, (2) the implementation of the PEP and construction of NEON, and (3) the operations and management of NEON. This solicitation addresses the first stage. With advice from the NCC and research community, and in consultation with NSF, the Project Office will formulate the scientific and technical requirements for NEON, including opportunities for education, outreach, and training unique to NEON. The Project Office will prepare a preliminary project scope, budget, and schedule for the design, construction and operation and maintenance phases of NEON, as outlined in NSF's "Facilities Management and Oversight Guide" (<http://www.nsf.gov/pubs/2003/nsf03049/nsf03049.pdf>).

In later stages, the NEON Project Office will construct and be responsible for the operations and management of NEON. After the NEON Project Office has developed the PEP, another solicitation will be released for the construction phase of NEON, pending the availability of funds.

The proposal should describe the process for establishing the office, duties and responsibilities of the office, and administrative and management structure. At a minimum the NEON Project Office should have a dedicated staff to plan and conduct its activities. The project staff credentials must demonstrate expertise and past accomplishments in ecological science, development of organizations, project management, committee organization and management, education and outreach, and interactive web site development, usage, and maintenance. Expertise must also be provided for project management software, technical report editing, web page development and maintenance and web-based publications.

A Principal Investigator (PI) must be designated with a significant time commitment to direct the day-to-day activities of the NEON Project Office. Co-PIs, administrative/clerk staff, and consultants who bring additional expertise needed to conduct the duties of the office may assist the PI. An experienced Webmaster must be budgeted for the project period. Office and meeting facilities must be available for the project, including Internet communications capabilities and institutional meeting space necessary to conduct planned activities. The PI will work closely with the cognizant NSF Program Officer to keep NSF informed of Project Office activities and also to solicit input on aspects related to program planning.

Intellectual property materials resulting from NSF funded research must be made promptly and freely available.

Time Line Requirement

The awardee is expected to achieve five major milestones:

1. establish the NEON Coordinating Consortium and NEON Project Office by March 1, 2005;
2. provide a science plan outlining the scientific requirements of NEON by October 1, 2005;
3. provide a baseline design for the networking and informatics components of NEON by October 1, 2005;
4. formally incorporate as a legal entity in the United States by January 1, 2006 in order to receive awards from the federal government (if not currently able to do so), for the construction, management, and operation of NEON, and;
5. provide a preliminary Project Execution Plan (PEP) for all of NEON by June 1, 2006.

Synthesis of Pre-workshop Interviews

Agenda

Workshop participants suggested several items for the agenda. Generally, the facilitator should state the expectations for the meeting and have a vision for how to accomplish those goals. There should also be an opportunity to approach issues collectively before the workshop begins.

Participants are interested in discussing:

- The questions that require a national scale research platform, such as NEON;
- The issue of network design and how observatories should be structured;
- How can NEON integrate issues across discrete themes;
- Priority setting;
- How to network and ensure outreach among collaborating observatories;
- Whether invasive species are fundamentally a regional issue and whether a national view can be adopted;
- The highest priority needs on invasive species threats in the US;
- The role NEON has in making policymakers more committed to protecting biodiversity and influencing their decisions, and therefore how to design NEON so as to have an impact on policy;
- How to make a NEON flexible for future changes;
- Limits to NEON's scope;
- How to emphasize hypothesis driven research versus data collection; and
- The potential for predicting invasiveness;

Anticipated challenges for the workshop organizers and participants

Several challenges were identified for a workshop of this nature. First, it will be difficult to provide sufficient background information about NEON and still forge ahead with the agenda. Participants predict that there is going to be a significant difference of opinion, which will both enrich the discussion and make consensus difficult to meet. Another challenge that was identified is whether or not we will find that there is generality between invasive species and ecosystems. It will also be challenging to maintain flexibility in the system for long term research that meets the needs of ecological research in the future.

Success for the meeting

Success from the meeting will entail the generation of new ideas, a white paper that will lead to a result that is not a watered down average of what everyone thinks but addresses the frontiers of the field. We must distill invasive species issues down to at least 5-10 broad and answerable questions and come up with a new planning paradigm on how to structure NEON with priorities and direction for invasive species research. We should make sure not to replicate existing programs and create questions that are not pushed by

policy but push policy. One participant stated that an ideal conclusion would be that we end up with a compete consensus on all the critical questions for invasive species research and the designs that would let us answer them.

Scope

The majority of the workshop participants feel that NEON's major focus should be placed on researching the causes and consequences of invasions (9 of 13 chose this category within the top 3). Their reasoning is that understanding causes and consequences has implications for prevention, mitigation, and predicting the future. Also this line of research may overlap least with agency work. It was noted however, that research on causes and consequences of invasions should be central and general to several species and regions. Early detection was given high priority by 8 of 13. Reasons given are that NEON's design is perfect for detecting spread since it will be situated throughout the country. Also, detection work was found to be essential because it is critical for effective mitigation. Predicting the future was chosen by 6 of 13 since this line of inquiry is considered the frontier of invasive species research.

Several participants remarked that prevention may not be within the scope of NEON since it is much more dependent on regulation than research. One stated that effective mitigation is also not within the scope of NEON.

Participants stated that if the research is planned well each of these categories will have impacts on the others. It was suggested that NEON should also gather baseline data, inventories and taxonomic data on biodiversity to detect invaders.

Attention should be paid to avoiding redundancy with existing programs and government agency work. Priorities may be changed in an adaptive management manner.

Applied versus basic research

Of 13 participants who were interviewed, 11 believe there is at least some need for policy applications in NEON's research agenda, however there are a variety of opinions on whether or not policy applications need to be a priority. Several feel that the research should be basic science with real world implications (9). Three feel strongly that focus should be on basic research since NEON is not a government agency. Further, solutions and policies are not generalizable since they will vary regionally, while basic research may focus on general theories. Also, basic research will be invaluable for predicting future changes in ecosystems and therefore predicting the needs for applied research in the future.

Criteria for setting priorities

The following is a list of criteria that have been recommended by workshop participants for prioritizing NEON research questions on invasive species research:

- Focus attention where solutions are possible;
- Research should have public policy implications;
- Research does not need to have immediate policy implications;
- Chose questions that will best be addressed with long term data sets at several locations;
- Questions with the broadest impacts. For example, synergistic questions that lead to general principles;
- Questions that can best be explored at regional and continental scales;
- Questions that require sophisticated instrumentation over long periods of time;
- Questions that do not reflect one researcher's agenda or that have a primarily local focus;
- Research that addresses urgent needs: What species' are threatened with now, the species that are doing the most economic damage or that are threatening pristine areas;
- Questions that predict the critical issues to come, not necessarily that exist currently;
- Research that focuses on natural areas not managed and agricultural systems,
- Research for which new methodologies can be tested and created;
- Push fields toward new questions that have not been possible to address in the past;
- Questions that are the least constraining and allow for flexibility in the future; and
- Research that takes into account existing programs, thereby not competing with existing efforts.

Concerns for NEON

Below is a list of the spectrum of concerns that workshop participants have for NEON:

- Room for flexibility in the research and data that is collected in the future;
- Regional observatories versus issue orientation and the potential for redundant data collection with a thematic approach;
- Governance will be an interesting challenge;
- Making sure there is not redundancy with existing programs and that there will be open coordination with federal agencies;
- How is NEON going to facilitate and encourage collaboration between researchers?;
- Without a mission NEON may just collect background data and become a long term monitoring system. This program should continue with a mission and strive for generality;
- Is NEON being funded with new money or limiting the pool of money that is currently available for research?
- Make NEON as open as possible for all to participate;
- NEON is perceived as a platform to inform regulation and policy-becoming almost like the EPA-and this is not ideal;
- NEON should not be LTER grown up;
- NEON is all over the board. What is it and what is funding going to do?;

- Research themes should not be predefined by one group of people (NRC);
- Will we have enough money to make it work?;
- There should be a connection between ecologists and land managers because ecologists do not think in political terms (in terms of regions and issues); and
- We need to quickly define NEON and see what it will deliver with performance measures so OMB and congress can see it as a viable entity in the ecological community.

Success of NEON

Participants feel that NEON should become a venue for data sharing and collaboration where scientists can develop a predictive understanding of natural phenomena at regional and continental scales. Ideally, it will reveal patterns and provide new insights, rather than create new places for more of the same research to take place. NEON should facilitate high quality, cutting edge science at an amount and rate that one cannot do individually. Results from the research conducted at NEON observatories should be compiled and disseminated to policymakers and stakeholders to generate action. Ultimately, success will lie in NEON pushing the frontiers of biological research.

Synthesis of Submitted Research Questions

I. Biology of Invasion

Including the natural history, genetics, characteristics of specific invasive species, or suites of species, and their interactions with the surrounding community

- Do invasive species or native species relationships across the country share similar characteristics? For example, do the invasives typically have longer germination period than the natives?
- What are the traits that make some species invasive and others not? Are there general principles so that successful invasions are predictable *a priori*? This can be separated into (a) probability of arrival at new region from native region, (b) success in local invasions (once arrived at a site, does it become dominant?) and (c) rate and extent of spread into new sites (how fast and how broadly does an invasive spread once arrived in a new region?)
- Are traits that lead to success of a recent invader in a community the same as those that lead to dominance of native species in a community? Alternatively, is success of invaders due to qualitatively different processes that are due to the lack of common evolutionary history of the invader and the rest of the community? For example, the predator escape hypothesis is clearly an example of the latter. The answer to this question bears on how much we can learn about the broader questions of community ecology from studying invasive species and *vice versa*.
- What is the evolutionary history of invasive species and populations?
- Can we develop accurate ecological classifications for types of invasive species?
- How do traits of potential invaders and characteristics of communities interact? That is, do the traits that make good invaders depend on the characteristics of the community that is being invaded? If so, are there general principles that underlie the interactions so that they are predictable? Similarly, do the consequences depend on particular combinations of the traits of invaders and community characteristics?
- There are a number of cases in which particular species may become naturalized without showing any tendency to spread. Then all of a sudden they take off. Does this reflect some change in the environment, the coinciding of several favorable ecological conditions at one time, changes in the genetics of the populations, etc?

II. Ecology of Invasion

The ecological aspects of invasion, including, the characteristics of ecosystems that make them resilient or vulnerable to invasion, and responses to disturbance

Characteristics of ecosystems

- What are the attributes of ecosystems that are less vulnerable to invasion or the consequences of invasion? Are there general principles so that easily invadible communities are predictable *a priori*?

- In diverse communities, can redundancy of functional types buffer process rates in response to species loss or gain?
- In what conditions are invasive species able to out-compete natives?
- What role does environmental stochasticity play in the establishment, naturalization and spread of invasives?
- Are there links between native diversity, productivity and invasion?
- What role do invasive mutualisms (bird-plant) have in invasion success (e.g. starlings and oriental bittersweet)?

Effects of disturbance

- In diverse landscapes with multiple types of land use, do invasion and extinction processes accelerate?
- Are there relationships among invasive species, habitat alteration, and the dynamics of disease vectors?
- How may land-use history influence invasive species occurrences? Very little work has been done to understand the extent to which past land-use practices influence patterns of occurrence and abundance of invasive species vis-à-vis ecological or environmental variables. In the Northeast understanding the linkage between land-use and invasive species distribution patterns seems to be particularly important. For example large, old intact forest stands in the Northeast appear to resist the establishments of invasive species. This contrasts with agricultural lands that have reverted to forests, even decades ago, or smaller forest patches with many edges.
- What ecosystems are most vulnerable, what is the role of disturbance and does this change with the species that is introduced?
- What are the factors explaining the invasibility of ecosystems? This question has received substantial attention in the last decade, and reasonable and general explanations have been offered. (e.g., Davis et al. 2000; Davis 2003). However, within this framework, the relative significance of other components of global environmental change (e.g., climate, atmospheric chemistry, historical range of variability issues, fragmentation, etc) needs to be established.

III. Distribution

The current and future distribution of one or several invasive species

Current Distribution

- How can we detect rare populations of invasives before they become explosive? We need to develop new and innovative methods for the early detection of invasive, or potentially invasive, species in the landscape. The most effective methods for the eradication of invasive species is to find the small populations of establishing invasives in the landscape, and then respond rapidly to eradicate them.
- Document and map the historical and current spread of all invasive species in the U.S.. Each species should have an on-line map that traces its spread from introduction to current distribution. These maps should be linked to climatic/habitat data.
- We should have on-line bibliographies for each invasive species.
- During what period of time have invasive species spread most rapidly?

Future Distribution

- We need more and better predictive modeling of invasive species spread. The objective of this research is to allow one to predict where and how fast invasive species will spread across the landscape, and which localities are most vulnerable. These models need to be calibrated and tested to evaluate their predictions. The joint modeling of suites of invasive species will allow the identification of invasive “hotspots” as well as the site attributes associated with such hotspots or vulnerable regions.
- What are the variances associated with predicted invasive species occurrences and abundances-since modeling needs to include uncertainty?
- Characterize the tails of species dispersal functions in order to predict future spread.
- Do biomes vary in the type, spread, or consequences of invasive species?
- How frequently do invasive species spread by wavefronts or by leap-frogging and back-fill, and are these predictable based upon taxonomy or functional groups?
- What controls the rate of spread of invasions?

IV. Impacts of Invasion

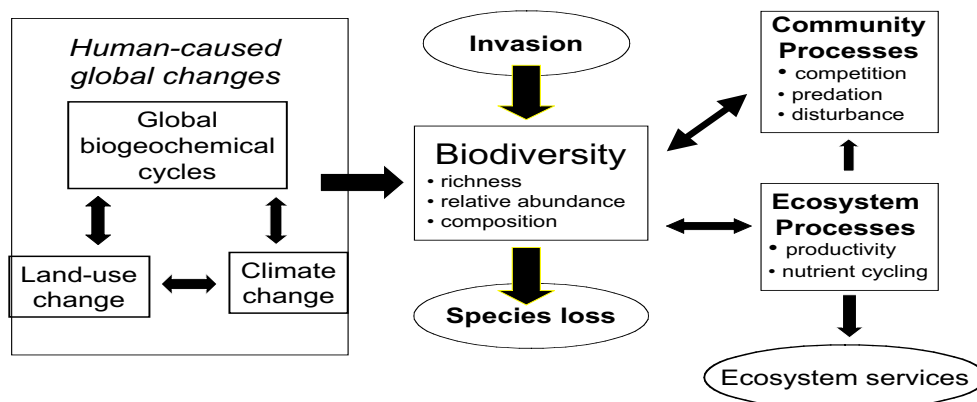
The ecological and economic impacts of invasion

- How may invasive species change ecosystem functions and services? How do invasive species alter ecosystems processes (e.g. soil nutrient status and dynamics, carbon storage, hydrology, etc.). Reversal of the drivers that facilitated invasion will not exclude the invasive species because the invader changes biogeochemical/structural of the system.

More effort should be focused on soil-plant interactions as well as feedbacks on native and invasive plant species performance.

- How does the abundance of invasive species alter the water cycle and the carbon cycle? Is evapotranspiration increased/decreased and does this feedback to the atmosphere increase/decrease precipitation?
- What are the relationships among invasive species, changes in biodiversity, and changes in ecosystem function?
- What the impacts of invasive species and how can these impacts be mitigated?
- At present, invasive species appear to have idiosyncratic impacts on biodiversity and ecosystem services. A much more thorough analysis of impacts and analysis of the mitigation of impacts is warranted.
- Do the invasives replace and provide suitable habitat for endangered species?
- What are the consequences of invasion for community structure and ecosystem processes of the invaded community? Are there general principles so that consequences (e.g., for diversity or productivity) are predictable *a priori*?
- What are the widespread impacts of invasion throughout the food chain. Comparing baseline data before an invasion with information on changes to ecosystems after an invasion will be valuable for making predictions that policy makers will take notice of.
- In the figure below, the relationship between "invasion" and each of the other components, alone and in combination, forms a research, education, and management question.

Biodiversity, invasion and ecosystem functioning



(adapted from Chapin et al. 1997)

- At what point is the damage caused by invasive species irreversible? Therefore, how much perturbation can a community withstand and recover from?

- What are the consequences of invasion by the full range of exotic species – in terms that can be understood by policymakers (usually, that means money/costs/losses!)?
- What is the economic impact of invasive species? There are a number of estimates on the economic impact invasive species, but very little of this is based on reliable data or economic models. One option is to develop standard economic models to compare with published economic costs to landowners, conservationists, and other stakeholders of invasive species in the US or regionally. An alternative approach using ecological economic models would provide costs in terms of ecosystems services valuation, system sustainability, etc. A third phase could focus on the impact on the Green Industry of state and federal regulations. It is this later unknown that has many in the Green Industry fighting regulation.

V. Responses to Invasion

Measures that can be taken to limit the effects of invasive species, and what are the consequences of those actions

- How can we define success for projects: What are the consequences and efficacy of prevention programs?
- Can current biotechnology be used to neutralize alien species? Non-reverting horticultural cultivars may be developed that lack pollen or seed production, even though fruits may formed.
- What are the ecological responses to various mitigation activities, such as herbicide response, response to biological control agents, and controls. At present, no agency or group has the mandate to organize these activities at scales appropriate for analysis and management.

Summary of some existing invasive species programs

The following table shows 50 programs that were randomly sampled from a list of federal, state, professional and non-profit, and international invasive species programs, compiled by the National Invasive Species Council (www.invasivespecies.gov). All available information on the program's websites was used to conduct this survey. If you notice any errors prior to the meeting kindly tell Rina Aviram (raviram@aibs.org) so they can be corrected prior to the meeting.

A graphical summary of this survey is also found within the pre-meeting packet. Programs were surveyed for their mission, geographical scope, focal group of concern (weed, pest and/or pathogen) and programmatic strategies. The goals and activities of the programs were organized into the following categories:

- (P) Prevention
- (C) Control
- (ED) Early detection
- (MR) Management and restoration
- (R) Research
- (M) Monitoring
- (POP) Public outreach, information exchange and partnership efforts
- (RR) Rapid Response

Invasive Species program activities: Operational definitions

Control

Any measure taken to limit the growth of an invasive species population, including mechanical, physical, chemical and biological control strategies

Early Detection

Finding invasive species before they spread to new areas, when their populations are still manageable and eradication is possible in a cost effective manner.

Management and Restoration

Managing, coordinating, authorizing and initiating measures to recover or limit the damage to biological systems and organisms impacted by invasive species

Monitoring

Recording the expansion or annihilation of invasive species populations

Outreach, Information sharing and Partnerships

Any effort to share knowledge and coordinate activities related to invasive species with managers, researchers and/or the public.

Prevention

Intercepting of the spread of invasive species. This is done in a variety of ways, e.g. regulations, public outreach, treatment, destruction or quarantine of suspected vectors.

Rapid Response

Any action taken to remove an invasive species as soon as it is detected, so as to prevent its population from expanding

Name of Project/ organization	LEAD Organization GOV/NGO/OTHER	Mission	Geographic Scope	System of primary concern
1. Exotic & Invasive Weeds Research Unit	USDA/ARS	To develop and help implement sustainable approaches to managing pests	National	Agricultural, Natural systems
2. Sustainable Agricultural Systems Lab	USDA/ARS	Research to understand fundamental agro-ecological processes underlying the functioning of sustainable systems	National	Agricultural
3. Formosan Subterranean Termite Research Unit	USDA/ARS	To determine the biology, behavior, chemical ecology and pathogens of the Formosan subterranean termite	National	Agricultural, Natural systems
4. The Ecological Areawide Management (TEAM) Leafy Spurge	USDA/ARS/APHIS	To research, develop and demonstrate ecologically based integrated pest management strategies that landowners and land managers can use to achieve effective, affordable leafy spurge control	Little Missouri River	Agricultural, Natural systems
5. GRIN (Germplasm Resources Information Network) Taxonomy	USDA/ARS-NPGS,NAGP, NMGP, NIGP	GRIN taxonomic data provide the structure and nomenclature for the accessions of the National Plant Germplasm System	National	Agricultural
6. Integrated Pest Management & Eradication	USDA/APHIS	Scientific support to regulatory program managers and decision-makers engaged in safeguarding America's crops and environment from adverse impacts caused by invasive species	National	Agricultural, Natural systems
7. Survey, Detection & Identification	USDA/APHIS	To rapidly detect and identify pest threats	National	Agricultural, Natural systems
8. Technical Advisory Group for Biological Control Agents of Weeds (TAG)	USDA/APHIS	Information and advice to researchers and those in APHIS responsible for issuing permits for importation, testing, and field release of biological control agents of weeds	National	Agricultural, Natural systems
9. Tropical/Subtropical Agricultural Research Program (T-STAR)	USDA	To strengthen the research capabilities and economy of the United States' tropical-subtropical areas in the Caribbean and Pacific Basins	Caribbean and Pacific Basin	Agricultural
10. Northeastern Area - Emerald Ash Borer	USDA/Forest Service	Information exchange and collaboration with research facilities that conduct lab and field studies and effective mitigation	National	Natural, Forestry
11. North Central Research Station	USDA/Forest Service	Research on landscape change, forest productivity, and riparian landscapes	National	Natural, Forestry
12. Bureau of Land Management (BLM) - Weeds	DOI	To promote ecosystem health and prevent the expansion of weeds across public lands	National	Natural
13. Science and Technology Program	DOI/Bureau of Reclamation	To find effective solutions to complex water management challenges	National	Natural-water systems
14. Division of Environmental Quality - Invasive Species	DOI/FWS	Provides national leadership preventing, eradicating, and controlling invasive species	National	Agriculture, Horticulture, Forestry, Natural
15. Nonindigenous Plants and Animals Program	USGS-Biological Resources Division	Tracks the status and distribution of introduced aquatic organisms and provides this information in a timely manner for research, management and education	National	Natural
16. Hawaiian Ecosystems at Risk (HEAR)	USGS-Biological Resources Division	To provide technology, methods, and information to decision-makers, resource managers, and the general public to help support effective science-based management of harmful non-native species in Hawaii and the Pacific	Hawaii	Natural
17. Upper Midwest Environmental Sciences Center (UMESC) - Invasive Species	USGS-Biological Resources Division	Finding tools for controlling pests as well as developing strategies for reestablishing native plant and animal communities	Mid-west	Natural

Name of Project/ organization	Focal Group	Program Focus [(P) Prevention; (ED) Early detection; (RR) Rapid Response; (C) Control; (MR) Management and restoration; (R) Research; (M) Monitoring; (POP) Public outreach, information exchange, and partnerships]	Strategy
1. Exotic & Invasive Weeds Research Unit	weeds and pests	R, C, MR, M	develop and implement biological,mechanical, cultural and chemical control tactics
2. Sustainable Agricultural Systems Lab	weeds and pests	R, C, P, POP	develop and implement integrated weed management and biological pest control
3. Formosan Subterranean Termite Research Unit	pests	R, C, ED	research on natural history for insight into biocontrol applications/detection
4. The Ecological Areawide Management (TEAM) Leafy Spurge	weeds	R, M, C, ED	research Integrated Pest Management for leafy spurge control/ecological assesments/detection
5. GRIN (Germplasm Resources Information Network) Taxonomy	weeds	POP	database of all germplasm (in order to maintain genetic diversity) relevant to agriculture
6. Integrated Pest Management & Eradication	pests and pathogens	R, C, P, ED	chemical treatments, quarantine technologies,developing trapping technology, etc
7. Survey, Detection & Identification	pests and pathogens	R, M, P, C, ED	mapping pest distributions, rapid ID net software,trapping
8. Technical Advisory Group for Biological Control Agents of Weeds (TAG)	weeds	POP, C	information exchange
9. Tropical/Subtropical Agricultural Research Program (T-STAR)	pests and pathogens	R, C, MR	germplasm collection, breeding, genetic engineering, restoration and maintenance of healthy agroecosystems
10. Northeastern Area - Emerald Ash Borer	pests	C, M, P	N/A
11. North Central Research Station	pests	R, C, M, ED	studies on effective mitigation/natural history/detection
12. Bureau of Land Management (BLM) Weeds	weeds	POP, MR	information exchange/management and restoration
13. Science and Technology Program	All-Aquatic	R, C, ED, P, M, MR	prevention, control and irradiation of aquatic nuisance species
14. Division of Environmental Quality - Invasive Species	All-Aquatic emphasis	POP, R, M, C, P, MR, ED, RR	varied
15. Nonindigenous Plants and Animals Program	All-aquatic	R, M, C, ED, POP	field assessments
16. Hawaiian Ecosystems at Risk (HEAR)	All	POP	information exchange
17. Upper Midwest Environmental Sciences Center (UMESC) - Invasive Species	weeds and fish	R, C, MR, M, ED	risk assessment/research on ecology and interactions with other species/control-chemical and biological/habitat improvement/distribution and monitoring

Name of Project/ organization	LEAD Organization GOV/NGO/OTHER	Mission	Geographic Scope	System of primary concern
18. NatureNet: Invasive Species Management	NPS	Restoration and management of park lands	National	Natural
19. Introduced Fish Section	American Fisheries Society	Information exchange/informing decision making/coordination of efforts	National	Natural-fisheries
20. Atlantic States Marine Fisheries Commission		Healthy, self-sustaining populations for all North American fish species	Atlantic Coast	Natural-fisheries
21. Consortium for International Crop Protection (CICP)		To assist developing nations reduce food crop losses caused by pests while also safe-guarding the environment.	International	Agricultural
22. Lake George Association - Aquatic Exotics		To protect and restore the lake and its watershed	Lake George, NY	Natural
23. National Association of Counties (NACo)		To share and store information on counties	National	Natural
24. Eastern Invasives Management Network	The Nature Conservancy	Development of comprehensive strategies for adaptive management of invasive species threats at landscape-scale conservation areas	Eastern States	Natural
25. New England Chapter of NALMS (NECNALMS)	(NALMS) North American Lake Mangement Society	To promote further understanding of lakes, ponds, reservoirs and impoundments, and their watersheds; the ecosystem of which they are a part; and their protection, restoration and management	New England	Natural
26. New England Invasive Plant Group	SE-Exotic pest/plant council	An organization that networks organizations, agencies and individuals concerned about invasive plant issues in the region	New England	Natural
27. North American Plant Protection Organization (NAPPO)		Coordinates the efforts among Canada, the United States and Mexico to protect their plant resources from the entry, establishment and spread of regulated plant pests, while facilitating intra/ interregional trade	International	plants
28. Backyard Wildlife Habitat (BWH) Program	NWF	Establishing native habitat in backyards	National	Natural-backyards
29. Western Weed Coordinating Committee		Coordinate noxious weed management programs among state and federal agencies	National	Natural
30. Alabama Wildlife and Fresh Water Fisheries Division		Protecting natural resources	Alabama	Natural
31. Alaska Cooperative Extension Service	US Department of Agriculture, University of Alaska Fairbanks, College of Rural Alaska	An outreach educational system	Alaska	Natural
32. Arkansas Native Plant Society		To promote the preservation, conservation, and study of the native plants and vegetation of Arkansas	Arkansas	Natural
33. Glassy-Winged Sharpshooter Project	California-Department of Pesticide regulation	To irradicate glassy winged sharpshooter	California	Natural
34. California Interagency Noxious Weed Coordinating Committee (CINWCC)		To facilitate, promote, and coordinate the establishment of an Integrated Pest Management partnership between public and private land managers	California	Natural
35. Colorado Bureau of Land Management - Weed Management	DOI-BLM	Manage land for a multitude of uses including recreation, mining, wildlife habitat and livestock grazing	Colorado	Natural
36. Colorado Lake & Reservoir Management Association (CLRMA)	(NALMS) North American Lake Mangement Society	To promote understanding of lakes, ponds, reservoirs and impoundments, and their watersheds; the ecosystem of which they are a part; and their protection, restoration and management	Colorado	Natural

Name of Project/ organization	Focal Group	Program Focus [(P) Prevention; (ED) Early detection; (RR) Rapid Response; (C) Control; (MR) Management and restoration; (R) Research; (M) Monitoring; (POP) Public outreach, information exchange, and partnerships]	Strategy
18. NatureNet: Invasive Species Management	All	MR	sprays, manual eradication, overflights
19. Introduced Fish Section	All-aquatic	POP	information exchange
20. Atlantic States Marine Fisheries Commission	All-aquatic	POP	information exchange
21. Consortium for International Crop Protection (CICP)	Pests	POP	information exchange
22. Lake George Association - Aquatic Exotics	All-aquatic	POP, MR	information exchange/collaboration for management and control
23. National Association of Counties (NACo)	All	POP	information exchange
24. Eastern Invasives Management Network	All	POP, R, M, MR, C, ED, RR	monitoring and irradiating invasive species, control and detection, research on management strategies
25. New England Chapter of NALMS (NECNALMS)	All-Aquatic	POP	information exchange and collaboration/organizing meetings
26. New England Invasive Plant Group	weeds	POP, M, ED	inventories and on-line information/organizing conferences
27. North American Plant Protection Organization (NAPPO)	pests	POP	information exchange
28. Backyard Wildlife Habitat (BWH) Program	All	POP	information exchange
29. Western Weed Coordinating Committee	weeds and pests	POP	information exchange
30. Alabama Wildlife and Fresh Water Fisheries Division	All	MR, ED, RR	regulations/mangement
31. Alaska Cooperative Extension Service	All	POP	information exchange/outreach
32. Arkansas Native Plant Society	weeds	POP	field trips/meetings/making field guides
33. Glassy-Winged Sharpshooter Project	pests	MR, C, R	chemical applicatons by air or ground
34. California Interagency Noxious Weed Coordinating Committee (CINWCC)	Weeds	POP	information exchange/outreach/grants
35. Colorado Bureau of Land Management - Weed Management	Weeds	MR, C, P, R, M, ED, POP	prevention/detection/education/integrated weed management/coordination/monitoring/research/erradication
36. Colorado Lake & Reservoir Management Association (CLRMA)	All-aquatic	POP	information exchange and collaboration

Name of Project/ organization	LEAD Organization GOV/NGO/OTHER	Mission	Geographic Scope	System of primary concern
37. Colorado State University - Integrated Pest Management in the Western Region	National Integrated Pest Management Network	Public-private partnership making the latest information on pest management available on the World Wide Web	Western Region-Multi-State	Agriculture/Natural/Forestry
38. Florida Department of Environmental Protection-Invasive plant management	Florida EPA	Protection of Florida's natural resources	Florida	Natural
39. Florida Farm Bureau - Issues		For Florida's agricultural industry to be safe, affordable and abundant	Florida	Agricultural/Natural
40. Florida Marine Research Institute - Invasive Species	Florida Fish and Wildlife conservation commission/academic, non-profit, and private marine research institutions	Research, information exchange and guidance to protect, conserve and manage marine and coastal resources	Florida	Natural
41. Georgia Lakes Society (GLS)		A partnership to promote understanding, protection, restoration and management of lakes, reservoirs, wetlands, and their watersheds	Georgia	Natural-lakes/wetlands/streams/watersheds
42. Big Island Invasive Species Committee (BIISC)		Partnership of private citizens, community organizations, businesses, land owners, and government agencies to control, eradicate, and prevent the spread of invasive species threatening agriculture, native ecosystems, industry, human health or the quality of life	Hawaii county-Hawaii	ag/natural/natural resources
43. Native Hawaiian Plant Society		Preservation (and restoration) of Hawaiian native plants	Hawaii	Natural
44. Southern Illinois University at Carbondale, Department of Plant Biology - Parasitic Plant Connection		Information exchange	National	Natural
45. (Indiana) Invasive Plant Species Assessment Work Group (IPSAWG)		Developing assessment tools to determine which plant species may become threats	Indiana	Natural
46. Kansas Department of Health and Environment		Protection of the public health and environment	Kansas	Natural
47. Louisiana Cooperative Extension Service	Louisiana State University Agricultural Center	Informal teaching of agricultural and natural resource technology and management techniques	Louisiana	Agricultural/Natural
48. Louisiana Department of Wildlife and Fisheries	US FWS/LA Dept. Environmental Quality/LA Dept. Natural Resources/LA Dept. of Wildlife and Fisheries	Management of the state's renewable natural resources including all wildlife and all aquatic life	Louisiana	Natural
49. U.S. Fish and Wildlife Service Offices in Louisiana		To conserve, protect and enhance fish and wildlife and their habitats	Louisiana	Natural
50. Maine Department of Environmental Protection		Protection and restoration of natural resources/enforcement of environmental laws	Maine	Natural-aquatic

Name of Project/ organization	Focal Group	Program Focus [(P) Prevention; (ED) Early detection; (RR) Rapid Response; (C) Control; (MR) Management and restoration; (R) Research; (M) Monitoring; (POP) Public outreach, information exchange, and partnerships]	Strategy
37. Colorado State University - Integrated Pest Management in the Western Region	All	POP	information exchange
38. Florida Department of Environmental Protection-Invasive plant management	All-aquatic	MR, ED, RR, C, POP, M	inventories/biocontrol/public outreach and education programs/inspections
39. Florida Farm Bureau - Issues	Pests and plants	POP	advocacy and information exchange
40. Florida Marine Research Institute - Invasive Species	All-aquatic	R, M, MR, ED, RR, POP	a wide array of research from assessments of fisheries and ecosystem health/restoration
41. Georgia Lakes Society (GLS)	All-aquatic	POP, MR	information exchange/coordinated management
42. Big Island Invasive Species Committee (BIISC)	All	P, C, MR, POP, ED, RR, R	coordinate research/information exchange/develop screening methods and early detection methodology
43. Native Hawaiian Plant Society	weeds and pathogens	POP, MR, R	information exchange, native plant gardens and enclosures, restoration, research on native plants-life history
44. Southern Illinois University at Carbondale, Department of Plant Biology - Parasitic Plant Connection	parasitic plants	POP	information pages/photographs and exchange of research results
45. (Indiana) Invasive Plant Species Assessment Work Group (IPSAWG)	weeds	R, MR, POP, C, ED, R	Surveying the number of invasives/types of habitats they invade/distribution and cover in habitat/alteration to habitat
46. Kansas Department of Health and Environment	All	C, MR	N/A
47. Louisiana Cooperative Extension Service	All	POP, R, M, MR, C	research on information exchange/management techniques/monitoring/restoration/control
48. Louisiana Department of Wildlife and Fisheries	All	C, P, MR	N/A
49. U.S. Fish and Wildlife Service Offices in Louisiana	All	C, P, MR, R, M, POP	N/A
50. Maine Department of Environmental Protection	All-aquatic	P, C, ED, RR, POP, R, M, MR	boat inspections/identify vulnerable pathways and waterbodies/rapid response/detection system/research on bio and chemical control options/baseline distribution and population sizes of established invasives

Summary of some existing invasive species programs

Fifty Invasive Species programs were randomly sampled from a list of over 1000, compiled on the Invasive Species Council website (www.invasivespecies.gov). These programs include Federal, State, Professional and Non-profit, and International Organizations. Programs were surveyed for their geographic scope, the taxa they focus their efforts on, their mission, and research strategies.

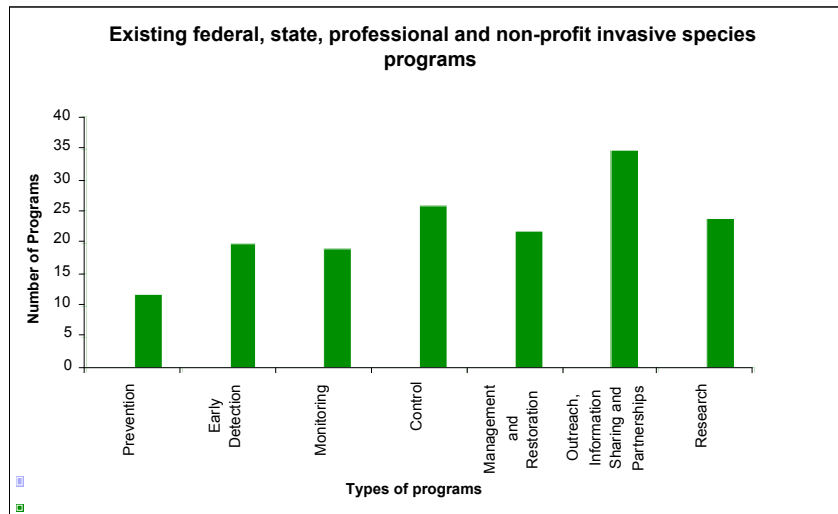


Figure 1: Existing Invasive Species programs focus attention on controlling invasive species and sharing information about research on invasive species. The majority of programs that were sampled carry out several of types of activities on invasive species. For example, a program may do research on controlling invasive species while managing populations and restoring infested sites. Within the “Prevention”, “Early Detection”, “Monitoring”, “Control”, “Management and Restoration” categories there are programs that are involved in implementation and those doing research in those areas.

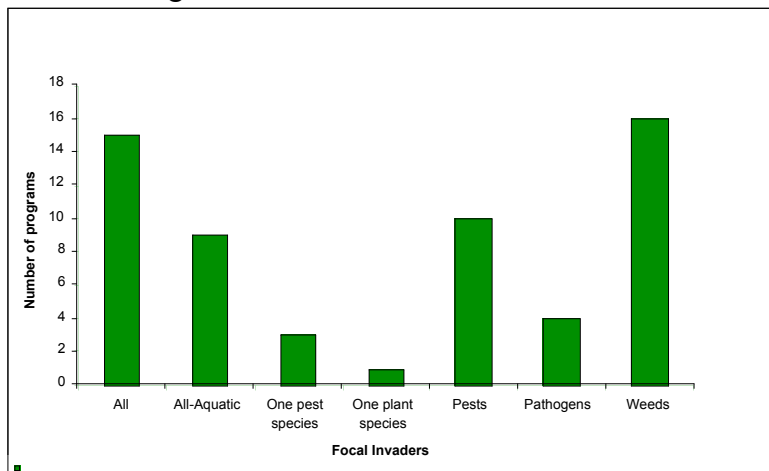


Figure 2: Most invasive species programs focus on plants, or spread their efforts among several groups of invasive species. The majority of programs are actively researching, eradicating or monitoring more than one invasive species. **All** refers to programs that do not limit their actions to invasive plants, pathogens, animals, or pests but focus on invasive species generally.

Operational Dictionary

Major Research Equipment And Facilities Construction Account

NSF budget line item: funding used for the purpose of constructing large facilities.

Pathogen

A specific causative agent (as a bacterium, fungus, virus) of disease¹

Pest

Any living organism (other than bacterium, fungus, virus) that causes damage to plants².

Reference design

A reference design is a preliminary description of the major components of a proposed large-scale facility or other infrastructure construction project. It articulates the scientific questions to be explored and details how the facility or infrastructure can be used to address the questions. It should address the project's scientific, technological, and financial requirements. Elements of a reference design may therefore include:

- Scientific themes
- Scientific questions
- Scientific requirements
- Technological requirements
- Technological options
- Required R&D
- Rough bottom-up cost estimates

A reference design should paint a sufficiently detailed picture of a project to justify support from funding agencies and the research community to be served. It has more flexibility than a baseline definition and project execution plan, which together is a precise description of what will be built, the schedule of progress, and the final estimated cost of a project. Whereas a baseline definition and project execution plan essentially represent a commitment to a funding agency about precisely what will be built and is thus subject to strict change control policy, the reference design is useful as a reference point which describes essentially what the project is and why it is worth doing.

See EarthScope Workshop Report for one example of level of detail (http://www.earthscope.org/assets/es_wksp_mar2002.pdf).

Weed

Any plant that has spread to areas beyond its range, where it is interfering with native processes

¹ Definition taken from Merriam-Webster Dictionary on-line (www.m-w.com)

² Modified definition from NISC-National Management Plan