PROJECT SUMMARY

Biodiversity informatics is an interdisciplinary research and infrastructure development activity. It thrives on collaborations among environmental biologists, computer scientists, and network and software engineers. The field brings together leading information processing technologies such as semantic frameworks, information models, data integration engines, network communications protocols, standards, software applications and web services, to enable wholly new kinds of analytical and synthetic research in environmental biology.

Biodiversity research is inherently a global enterprise. Systematists and ecologists in the western hemisphere for over a century have collaborated across political borders to document the distribution of species and of biological diversity. And in recent decades much work has been focused on understanding the dynamics of ecological processes responsible for the creation and maintenance of diverse systems.

Prior to the availability of ubiquitous data network connectivity, biodiversity research collaborations required face-to-face professional interactions in the form of field work, in-residence stays, or other kinds of visits, and relied mainly on paper documents and mail for remote coordination and communication. The deployment of the non-commercial research and education networks in the last 25 years has virtualized some of that togetherness and allowed researchers to interact with international collaborators through e-mail, file and document transfers, and more recently thorough web portals and applications.

Today many research communities, including systematics, phylogenetics and ecology, are on the cusp of transformative change as a consequence of network capacity that will enable a new class of research collaboration based on instant interaction with networked information servers and computational services, in a paradigm known as "Grid Computing." High-throughput international backbones linking desktops of scientists around the world will help launch a new class of research collaboration methods with scientists "wired together" in a virtual, global, biodiversity collaboration environment.

To visualize and prepare for this transformation in research communications among North and Central American countries, a 2.5 day workshop is proposed, to be jointly sponsored by government science agencies of Mexico, Panama, Costa Rica and the United States. The meeting will explore opportunities and breakthrough activities that will carry biodiversity informatics and research to the next, grid-enabled, plateau. The meeting will include 40-50 invited biology researchers, cyberinfrastructure technologists and funding agency representatives. It will be focused on identifying activities that will enable North and Central American partnerships, with an eye toward a more inclusive western hemisphere approach. Outcomes will include recommendations for follow-on activities and suggestions for investments to promote international informatics collaboration.

The **intellectual merit** of this activity will be to identify opportunities to build and sustain the technology infrastructure needed for international biodiversity research collaborations utilizing the high-bandwidth research and education network. The **broader impacts** of the meeting will ultimately be technology to support biodiversity research analysis for policy and planning, to mitigate the ecological and societal impacts of the global biodiversity crisis.

PROJECT DESCRIPTION

Introduction

Biological diversity, or simply *biodiversity,* is the sum of life on Earth—plants, animals and microbes—encompassing all levels of biological organization from genomes to species to ecosystems. Approximately 1.8 million species are known as a result of 300 years of the biological exploration of the planet. Astonishingly, an estimated 15–50 million species await discovery and basic description.

A grand challenge for the 21st century science is to harness knowledge of Earth's biological diversity and how it shapes the global environmental systems on which all of life depends. This knowledge is critical to science and society for rational policy for managing natural systems, sustaining human health, maintaining economic stability, and improving the quality of human life. The urgency for this knowledge increases daily as the conversion of natural systems to human-managed systems accelerates the decline of biological diversity.

The importance of biodiversity research and education has been established by a series of landmark reports: U.S. NSF's *Task Force on Global Biodiversity* (Black et al., 1989), the systematics and biological collections community's *Systematics Agenda 2000* (1994), the Australian government's *The Darwin Declaration* (Environment Australia, 1998), and the U. S. President's Committee on Science and Technology's *Teaming with Life* (Lane, 1998).

Global research resources to minimally identify and characterize the species which comprise earth's biodiversity are inadequate. With the current number of scientists and research activity levels, the vast majority of earth's species will be extinct before anything is known about them (Wheeler, et al., 2004). Scientists must look to advances in technology to catalyze more efficient field research, data utilization, and synthesis (Causey, et al., 2004)

Research in ecology, systematics, biogeography and phylogenetics have long been appreciated as global activity that transcends regional or national boundaries. In the western hemisphere, studies of biological diversity have been international exercises since the great naturalists from Europe explored the new world in the 18th century. Today, much international collaboration exists among North and Central American researchers in the form of surveys and inventories, floras, faunas, and with taxonomic monographic and revisionary studies.

Biodiversity informatics attempts to accurately acquire, represent, communicate, integrate, analyze and apply information extracted from natural systems. The field can be modeled as a process or 'value chain' of activities beginning with the methods and activities associated data collection, and ending in the application of derived knowledge for science and society.

Figure (1) illustrates graphically the steps in the process chain. International collaboration can occur at every step, and network and computational technologies impact research protocols at many points on the chain.

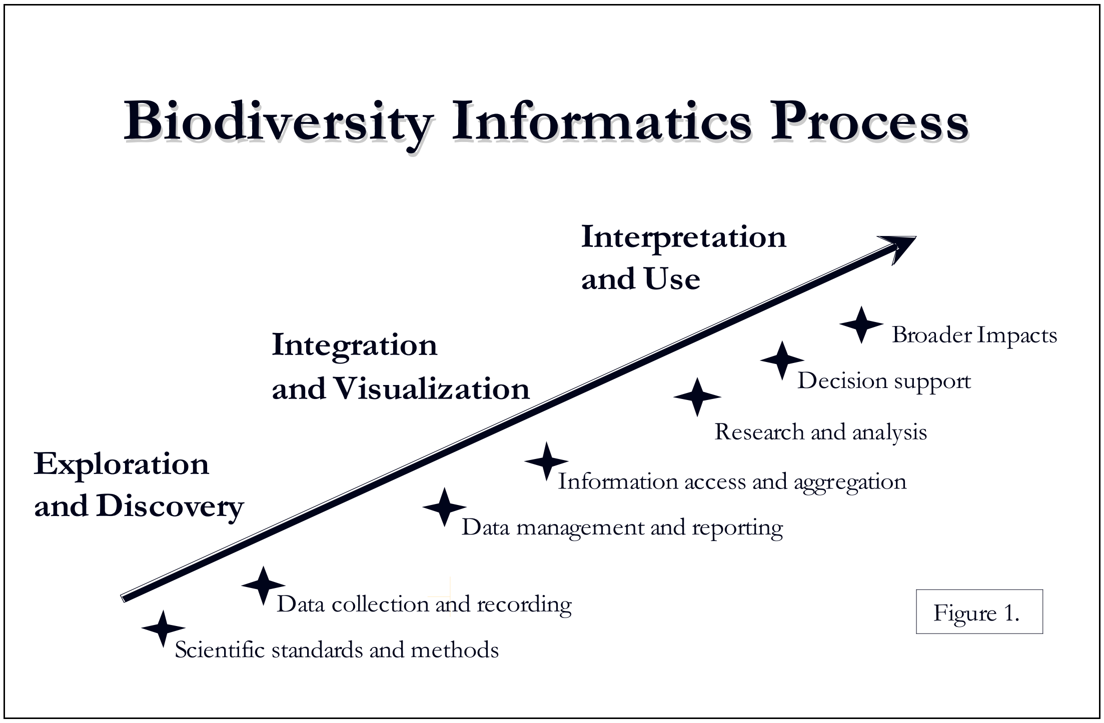

Figure 1.

Networking Biodiversity Research

As environmental biology become increasingly data-driven, the nature of international collaborations in biodiversity will evolve to include more network-based interactions and communications. The Internet continues to create expectations for more effective access to research data sets, analysis tools, visualization applications, etc. and for more remote interaction with collaborators scattered around the globe. Expectations for essentially instantaneous access to data sets and to computational tools and services, will change the timing and logistics of collaborative work. Scheduling field work in seasons will change to requiring access in milliseconds to archived museum records, ecological research data, geospatial and climate data archives, molecular barcode identifiers, etc.

Several trends likely to drive change in biodiversity research and informatics in the next decade.

Trends likely to effect biodiversity research informatics

1. There will be an increasing need for basic biological inventory and systematics research.

The need for documenting the species and patterns of biologically diverse systems will become more acute as more pressing conservation and resource management options need to be evaluated. Baseline, benchmark data on the identity and distribution of species, and patterns and hot spots of biological diversity in remaining wild area's will become increasingly important for analysis and prediction models about the value and sustainability of conservation decisions. With inadequate numbers of scientists to undertake even a small fraction of the needed monographic and survey work, new research techniques, from rapid field assessment, to rapid labeling of organisms with DNA bar codes, to more reliance on predictive models, will be needed to complement traditional descriptive taxonomy and inventory approaches (Herbert 2003, Wilson, 2000, 2003; Godfray, 2002).

2. Web technologies for accessing remote databases and data repositories will continue to transform research protocols and priorities.

Organizations that curate voucher collections and ecological data sets have been embraced structured databases and web data exchange technologies for providing access to information for remote researchers. The biological museum community and ecological researchers have adopted mainstream relational database technologies and Internet protocols such as HTTP/XML/XSL/SOAP/WSDL/WMS/WFS/ to interface data stores with web and software application interfaces. Internet-based capabilities of environmental research and data projects are evolving from read-only, human readable HTML interfaces, to machine-readable data transfer formats, capable of being used by online analysis services, data integration servers, network-based research toolkits, etc. It is clear that researchers are only beginning to capture the power of the Internet for biodiversity analysis (Bisby, 2002; Krishtalka, 2002; Soberon and Peterson, 2004, Edwards et al., 2000; Bisby, 2000). A major paradigm and technology shift, which will transform all of research computing, is the emergence of networked, computational grids. Internet-based Grid computing, which is being architected and implemented by many leading international laboratories and university research labs, will bring, massive, internet-wide computing services to research applications (Foster and Kesselman, 1999)

3. An internet-based, global, biodiversity and ecological informatics infrastructure is emerging.

The Global Biodiversity Information Facility (www.gbif.org) has multi-national government backing to support the development of standards and tools for the global biodiversity information infrastructure. GBIF has extended research community technology innovations to harden communications protocols, models and web portals for biodiversity information. There continues to be considerable leading-edge, network protocol and applications development throughout North and Central America. Examples include the Mexican REMIB network (http://www.conabio.gob.mx/remib/doctos/remib_esp.html), the DiGIR distributed network architecture (http://digir.sourceforge.net/); tools and services being developed with U.S. NSF funding for taxonomic discipline networked collaboratories: MANIS (http://elib.cs.berkeley.edu/manis/), ORNIS (http://ornisnet.org/), Herpnet (http://www.herpnet.org/), and FishNet, (http://habanero.nhm.ku.edu/fishnet/). The Instituto Nacional de Biodiversidad (INBIO) in Costa Rica is also an active developer of innovative biodiversity software tools and services (http://www.inbio.ac.cr/en/default.html).

The Inter-American Biodiversity Information Network, IABIN, with its mandate from the Organization of American States, has an aggressive plan to support a decentralized, Internet-based, western hemisphere network to provide access to biodiversity information resources, including the development of software tools, training, and other services (www.iabin.net; IABIN, 2004). Additionally, the Taxonomic Databases Working Group (www.tdwg.org), an operating arm of GBIF, recently received funding from the Gordon and Betty Moore Foundation (http://www.moore.org/grantees/grant_summaries_content.asp?Grantee=gbif_tax_db) to formalize and structure the processes of standards development and standards maintenance for networked biodiversity information.

4. High-bandwidth, low latency, international networks, and networked environmental sensor arrays will enable new kinds of ecological and biodiversity monitoring and experimentation.

The last decade of research in embedded networked sensor systems (Pottie et al. 2000, Estrin et al. 2001) has produced technology solutions that now enable a new class of research "portal" into natural environments utilizing distributed, *in situ* sensors and instruments. New observational and experimental methods are available for the first time enabling scientists to address challenging questions using dense spatiotemporal phenomena sampling.

Environmental sensor networks are becoming increasingly relevant to ecological and biodiversity research and with the international deployment of high bandwidth research and education network backbones, they are likely to become a significant part of multi-national collaboration efforts. Test deployments have shown that it is now feasible for sensors deployed for long-term monitoring or short-term experimental observation, to stream video, sound, measurement data into remote databases and through web portals. Real-time, remote interaction with sensor arrays and sensor platforms, will also open up opportunities for education and training uses (Estrin, et al. 2003; Broad, 2005; Withey, et al. 2001).

5. Synthesis and predictive modeling activities will become easier and increasingly relevant outputs of biodiversity research.

A global infrastructure for data access through web protocols and services, is bringing biodiversity data into computational environments where information can be integrated across disciplines, e.g. species occurrence data from museums can be used with geospatial data sets of climate, habitat, land use, etc. Bird observation data can be merged with specimen voucher data, with radar or satellite tracking data, with bird identifications from vocalizations from audio sensor networks. DNA barcoding will bring the capability to analyze and model genetic diversity across spatial domains.

Using online data sources, predictive modeling and simulation research will continue to add tremendous value to the baseline information collected by biodiversity researchers. These analysis and synthesis activities generate important deliverables for policy makers and resource managers at the end of the biodiversity informatics value chain. Data integration activities that will allow scaling of local observations to regional or continental scale landscape analysis will be an essential part of the proposed U.S. National Ecological Observation Network (NEON, http://www.neoninc.org/documents/ IBRCSWhitePaper_NEON.pdf). The U.S. NSF-funded Long-term Ecological Research Network sees regional scaling and cross-site synthesis as a research priority for the organization (http://www.lternet.edu/collaborations/).

Although biodiversity and ecological data are heterogeneous and complex, computational infrastructure initiatives such as the U.S. NSF-funded Science Environment for Ecological Knowledge project ("SEEK"; http://seek.ecoinformatics.org) are building computational frameworks and web-based, work-flow platforms, for ad hoc information discovery, semantic integration, modeling and analysis. Similar, spatially-extended, grid-based, data integration and knowledge discovery environment development projects are underway in other earth and biological science research communities, e.g. GEON (http://www.geongrid.org) and ROADNet (http://roadnet.ucsd.edu/).

6. Web-based biodiversity decision support systems by facilitating ad hoc analysis and interpretation of short- and long-term biodiversity trends.

Decision support systems (DSS) represent a terminal link of the biodiversity informatics value chain, as automated analysis techniques to facilitated analysis, interpretation and decision-making for policy makers and planners. Their potential utility has led a number of research groups, federal agencies and NGOs to develop them, Johnson and Lachman (2001) provide a survey of biodiversity decision support systems. Natureserve has recently developed one DSS system "Vista" (http://www.natureserve.org/prodServices/vista.jsp) to add value to its information resources for its clients. Collaborative development of an information infrastructure that would support and open, international architecture for decision support systems would do much to ensure a strong impact of biodiversity research.

Summary. Technology will continue to be an important driver in the evolution of biodiversity research methods and protocols. Efficiency gains will be sought to optimize the distributed expertise of a very limited number of researchers. Web technologies and network software will become increasingly critical foundations for collaborative interactions and research progress. These services, protocols, applications and standards will emerge and be supported in a global architecture for biodiversity research computing. High-bandwidth network connections will enable new classes of remote interaction including environmental sensor networks which will play an increasingly important role in long-term environmental monitoring. Analytical and synthetic activities at the tail end of the biodiversity informatics value chain will become more important pieces, applying value and relevance through modeling and environmental predictions. Decision support systems will facilitate the conversion of models and analyses into biologically-meaningful natural resource policies.

The Role of Cyberinfrastructure in Biodiversity Research

Continuing advances in computation and communication are transforming the scientific process. Science is increasingly being conducted in virtual laboratory environments; it is increasingly collaborative, and increasingly global. Large data sets with hundreds of gigabytes of data (e.g., genome sequences), available online, which means that for a growing number of biologists, "data" is now found on the Web, not in the field (Foster, 2005). Biodiversity research, like the disciplines of molecular, structural and proteomic biology, is re-inventing itself with new technology applications, and is evolving into an increasingly predictive and integrative science focused on important research and policy issues. Advances in information technologies such as computational tools, data communication networks and environmental sensors will continue to improve the ability of scientists to address research challenges by enabling integrative, multidisciplinary analyses of inherently complex environmental phenomena (Michener et al. 2001). Many recent meetings and workshops have analyzed the potential impact of applications of new information technologies for the study of natural systems (e.g. Estrin et al. 2003, Withey et al. 2002, and <http://research.calit2.net/cibio/report.htm>).

Environmental data is being collected in greater volumes with the use of sensors. The integration of sensors and cyberinfrastructure has started to change the practice of ecological science. Having the ability to measure in real-time, scientists envision being able to understand how different processes in the environment operate at different frequencies, learn more about soil contaminants, land changes, water flow, invasive species, etc. (Broad, 2005). These data are being stored in large distributed databases compiled from many unrelated and independent projects. There is effort in coordination and standardization; however, the full potential of this data has not yet been reached. As it is doing for other science disciplines, cyberinfrastructure technologies will enable environmental biologists to reap the full potential of their data and resources by which they can collaborate to create and share knowledge. The following list identifies relevant cyberinfrastructure that apply to environmental biology:

- Wireline Networks (optical and electrical)
- Sensor Networks
- Wireless
- Distributed and cluster computing
- Grids
- Grid services and Web services
- Semantic web
- Databases, in particular distributed databases
- Real-time remote observations and experiment participation using video conferencing technology
- Autonomous agents
- Virtual observatories
- Tools that allow biologists to define workflows that integrate information from multiple sources, including both biological databases and bioinformatics applications.

Proposed Workshop Plan

Introduction

This multinational-sponsored workshop is being proposed to benchmark current biodiversity and ecological informatics activities and to explore opportunities for international informatics collaboration. The workshop would focus on the following areas: (1) Understanding the challenges and issues of conducting collaborative biological-ecological sciences research and practice in the Americas; (2) creating an environment that will stimulate discussion on the application of cyber-based tools to biodiversity and ecological issues; (3) to share knowledge of the practices and tools that are being applied, in particular for data management; (4) engaging NSF and other funding agency representatives on developing a roadmap of programs for increasing U.S. – Central American collaborations; and (5) discovering opportunities to collaborate and coordinate towards helping each other improve, innovate and expand the biodiversity and ecology domain practices mediated through cyberinfrastructure technologies.

Jim Beach, University of Kansas, and Julio Ibarra, Florida International University, are the principals of the workshop. Beach, Director of Informatics at the KU Biodiversity Research Center and an active biodiversity informatics researcher, is the lead for organizing the biodiversity-ecology component of the workshop. Ibarra is the recipient of the NSF International Research Connections (IRNC) grant award for Latin America, and is the lead for organizing the cyberinfrastructure component of the workshop. Beach and Ibarra have identified scientists and subject matter experts in their respective fields to participate in the workshop and to satisfy the goals of the workshop. They will coordinate and collaborate closely to select participants from the U.S., Mexico and Central America that have the experience or the readiness to work on collaborative proposals with the potential to lead to collaborative projects in biodiversity that apply cyberinfrastructure in programs of research, education and outreach.

Understanding the issues and challenges of conducting collaborative e-Science research. The workshop program is tailored to create opportunities to engage the experts and participants to share their experiences increase awareness and understanding of these issues and challenges. The workshop will provide the opportunity to discuss and understand how collaborative biodiversity research is being done today and what is possible in the region with the application of cyberinfrastructure tools.

Creating an environment to stimulate discussion. The workshop organizers intend to stimulate a rich discussion on the science, the practices, the requirements for cyberinfrastructure towards the identification and/or development of appropriate environments and tools by bringing together representatives from the communities of biodiversity, cyberinfrastructure, funding agencies, policy makers and stakeholders. Known issues, such as data management (Pennisi, 2005), and how they impact the ability to conduct effective research in this region in a collaborative non-collocated manner, will be emphasized.

Engaging the NSF and other funding agencies to discuss priorities and opportunities to stimulate collaborative programs in biodiversity cyberinfrastructure-enabled research, education and outreach. During the course of the workshop, the organizers will facilitate structured and unstructured discussions on existing and new collaborative programs, and to get a sense of the opportunities for unsolicited proposals that target specific problems/challenges of interest to the funding agencies. A roadmap should emerge from these discussions that will stimulate existing and new of collaborations.

Discovering opportunities to collaborate will be an important activity before the start of the workshop, through the course of the workshop, and afterwards. Semi-structured surveys and focus group discussions will provide data that will be used to help frame where there are issues and challenges, then to discover opportunities to collaborate. Survey data will also provide essential information towards the development of the workshop report. Beach and Ibarra will organize a Report Committee, consisting of workshop participants, which will contribute to the writing of a workshop report. This report will be submitted to the NSF and to the participating funding agencies and workshop stakeholders. The report will describe a vision and make recommendations of how the cyberinfrastructure and the biological and ecological sciences communities in the U.S., Mexico and Central America should collaborate to fully exploit the benefits of cyberinfrastructure innovation to benefit the biological and ecological sciences domains.

Workshop Themes

These questions will be used to focus discussions and to direct ideas to generating useful, approachable, implementable suggestions.

- How to transform ‘manual’ collaboration environments into international ones.
- How to identify the issues of access and infrastructure in Latin America.
- Identifying the key network capabilities, and key, catalytic projects that address the biological research and conservation needs in Latin America.
- How to use it to best impact the integration of education and research.

- How to best train students in a global infrastructure for biodiversity informatics.
- Role of universities, biodiversity agencies, NGOs, international network organizations like IABIN, GBIF, MANIS, the ILTER model.

Pre-workshop Activities

- Complete invitation process, identify additional funding or sponsoring agency representatives, ongoing logistics planning.
- Identify members of a workshop steering committee, two teleconferences to identify focal areas for discussion, strategies for optimizing participation and success.
- Distribute a workshop vision document for distribution among the organizers for comments, then to all workshop participants 2-3 weeks prior to the workshop.
- Post an online questionnaire (Surveymonkey.com) of thought questions to be answered by all participants online and collated before the meeting.
- Included in these questions would be a short statement of research interest by the participants. That would be distributed before the meeting via email with paper copies available at the meeting.
- 1-day site visit by Ibarra and Beach to City of Knowledge to confirm local arrangements and meet local hosts.

Proposed Workshop Schedule

The workshop will elicit active discussion about important theme areas identified for international biodiversity informatics collaboration over the high-bandwidth networks. A half-day plenary session will welcome and inspire the participants to think about what might be possible, then breakout sessions for the afternoon and next day will attempt to focus discussions into small, productive groups. Discussion groups will be charged with identifying constraints and opportunities for international collaborations, within the context of cross-cutting workshop topical themes. Short plenary sessions will be interspersed with mini-presentations and to report findings and gauge progress. At the end of the workshop a wrap-up session will synthesize findings and discuss issues in plenary. The workshop is tentatively scheduled for January 10-13, 2006. A draft daily schedule is enumerated below.

Tuesday, January 10

Morning	Participants travel; Organizers arrive evening of Friday, October 6 to attend to local arrangements Saturday.
Afternoon	Workshop Steering Committee meets, participants arrive.
Evening	Reception, brief welcomes (Ibarra), hors d'oeuvres, drinks, perhaps a short inspirational speaker or two after dinner with coffee (Possibly at STRI offices or at STRI Marine Lab)

<u>Wednesday, January 11th</u>

Morning	Plenary session, welcome, introduction to the goals of the workshop, funding agency sponsors speak briefly, 1-2, 30 minute inspirational, energizing, visionary talks, need a brief intro to network capacity and capability to set the context on the technology side
	Coffee Break
	Return to plenary for discussion and breakout group assignments. Draft discussion leaders and scribes
Afternoon	Breakout groups meet for 1-1.5 hours for preliminary discussions centered on themes.
	Plenary reporting of initial discussion directions
	Coffee Break
	Breakout groups 1 hour discussion; scribes submit 1 page summaries to organizers
	Plenary, 2-3, 20 minute presentations on themes, citing project experiences
Evening	Dinner nearby restaurant, time appropriate to local custom Organizers meet to synthesize 1 page summaries into short PowerPoints for next day session and suggest changes or variations on the themes

<u>Thursday, January 12th</u>

Morning	Plenary, 1-2 short talks, organizers review findings from previous day, short discussion, and breakout group logistics, writing assignments
	Break
	Breakout groups, discussion writing on revised themes, 2 slides per participant group discussion and summary before lunch identify writing topics work in groups of two.
Afternoon	Breakout groups to complete slides and writing assignments
	Break
	Wrap up session, slides from breakouts, individual contributions, summary slides and recommendations, final discussion.
Evening	Panamanian Biodiversity-themed Celebration Banquet

Friday, January 13th

Morning	Organizers (Steering Committee) meet to synthesize findings into report draft, Participants depart
Afternoon	Organizers depart on afternoon flights or stay in afternoon to complete synthesis activities

Expected Workshop Outcomes

The outcome of the workshop will be a report that will describe a vision of how the cyberinfrastructure and the biological and ecological sciences communities in the U.S., Mexico, Central America and ultimately all of the countries of the western hemisphere, could collaborate to fully exploit the benefits of cyberinfrastructure innovation to benefit the biological and ecological sciences domains. The report will provide recommendations to (1) the NSF and the other national funding agencies to quantitatively and qualitatively assess the current state of biological and ecological collaborative research in the region; (2) the NSF and other agencies about how to engage this community through programs, research, education and outreach; (3) the Mexican and Central American participants to enable them to work with the NSF to develop opportunities for this research area; (4) policy makers and industry representatives to inform them of opportunities, issues and challenges in this area that can have an impact on their communities of interests.

The report will include:

- Current high-bandwidth enabled environmental research,
- Future research and research collaboration possibilities,
- A survey of collaborative programs from the NSF and the other participating funding agencies that solicit proposals involving the integration of cyberinfrastructure with biodiversity and ecology,
- A survey of existing cyber-based tools being used by the biodiversity community,
- Recommendations for support of collaborative work between biologists and cyber experts for the improvement/development of cyber tools,
- Recommendations for funding cyberinfrastructure-enabled science between the U.S., Mexico and the countries of Central America, and
- Recommendations to develop integrated programs of research, education and outreach that involving researchers, practitioners and students from biology and cyber disciplines.

Significance Statement

Diversity, at all levels of biological organization, transcends national boundaries, and the *study* of biodiversity cuts across myriad research disciplines. Biodiversity informatics provides communication and computational infrastructure for this global, interdisciplinary research enterprise. This workshop will explore the international issues and opportunities for collaborative infrastructure development and utilization, with a particular focus on the connectivity provided by high-bandwidth, non-commercial research and education networks. Broad participation by researchers from North and Central American countries will provide a foundation for future biodiversity informatics collaboration between those countries and ultimately among those of the entire western hemisphere.

The broader impacts of the workshop will be to support international biodiversity research itself. Natural systems have never before been under as much pressure from human populations; the sustainability and integrity of diverse ecosystems is probably the greatest challenge facing the human species. A global architecture, built through international collaboration, will provide the conduit for biodiversity research results to travel from raw data acquisition and monitoring activities in the field, to decision support systems on the desktops of policy makers and planners, to enable the well-informed, timely, biologically-meaningful decisions about biodiversity phenomena and the health of natural systems, upon which all life forms depend.

Workshop Participants

Invited U.S. Participants:

A. U.S. cyberinfrastructure researchers (10)

Peter Arzberger SDSC/UCSD PRAGMA	**Ian Foster** Argonne National Labs, Grids
Bob Chang NWU [VC only], Materials Network, Collaborations, Coordination	**Gabrielle Allen** LSU, Grids
Steve Hutter Oregon, Network Startup and Resource Center	**Steve Kelling** [TBD] Cornell Lab of Ornithology, Data Management
Gary Olson Michigan, Science of Collaboratories, Collaboration and Coordination	**Amatto Gonzalez** FIU, Access Grid and Collaboration Tools
TBD	TBD

B. U.S. biodiversity and biodiversity informatics researchers (10)

William Kaiser UCLA, Center for Embedded Network Sensing (CENS)	**John Wieczorek** UCB, MaNIS and Biogeomancer Project
Deana Pennington UNM, SEEK Project (NSF/BIO/ITR)	**Tony Fountain** SDSC, Internet-based Environmental Networks

Donald Henshaw Oregon State University, LTER Information Management Lead	**A. Townsend "Town" Peterson** Univ. of Kansas, Biodiversity modeling
Jorge Soberon Univ. of Kansas, Recent head of CONABIO, biodiversity researcher	**William Michener**, NEON and LTER Network Office
Representative from ESRI, Inc.	TBD

International Participants (tentative):

A. International biodiversity and informatics participants (about 10), to be invited by national delegation leaders

Costa Rica (suggestions from A. Sittenfeld, UCR) Gabriel Macaya (bioinformatics) Erick Mata (INBio) Ana Sittenfeld UCR	**Mexico** (suggestions) Dra. Patricia Koleff Osorio, CONABIO Dr. Enrique Martinez Meyer, UNAM Dr. Rafel Perez Pascual UNAM Dr. Alejandro Pisanty Baruch UNAM
Colombia Four bio and cyber researchers are committed to attend.	**Panama** (3 bio and cyber researchers committed, to be identified by Julio Escobar)
Nicaragua TBD	**Honduras** TBD
Guatemala TBD	**Caribbean countries** TBD

B. International cyberinfrastructure participants

Costa Rica (suggestions, from A. Sittenfeld and J. Ibarra) Guy de Teramond or Vladimir Lara (networks) Luis Diego Espinoza, CR2NET, Abel Brenes, ICE Pedro Leon,CENAT	**Mexico** (suggestions) Carlos Casasus CUDI, MX Francisco Javier Mendieta Jimenez, CICESE Dr. Raúl Gilberto Hazas Izquierdo, CICESE Boris Ramirez Luis Enrique Garcia Barrios, San Cristbal, Chiapas
Colombia See Colombia above.	**Panama** See Panama above. IABIN representative
Nicaragua TBD	**Honduras** TBD

Guatemala TBD	**Caribbean countries** TBD

Foundation Representatives to be Invited

- US, NSF (Harold Stolberg, Mande Holford, 1-2 additional program officers)
- Costa Rica, CRUSA representative
- Mexico, CONyCIT representative
- Nicaragua, possibly someone from DANIDA
- Panama, SENACYT, Julio Escobar
- JRS Foundation, John Marchioni, (Biodiversity Informatics)

REFERENCES CITED

Bisby, F.A. 2002. The quiet revolution: biodiversity informatics and the internet. *Science* 289: 2309-2312.

Bisby, F.A., Shimura, J., Ruggiero, M., Edwards, J. and C. Haeuser. 2002. Taxonomy, at the click of a mouse. *Nature* 418: 367.

Black C., et al. 1989. Loss of Biological Diversity: A Global Crisis Requiring International Solutions. National Science Foundation, National Science Board, NSB 89-171.

Broad, W.J. 2005. A Web of Sensors, Taking Earth's Pulse", *New York Times*, May 10, 2005.

Causey, D., Janzen, D. H., Peterson, A.T., Vieglais, D., Krishtalka, L., Beach, J.H. and E.O. Wiley, 2004. Museum Collections and Taxonomy. *Science*, Vol 305: 1106-1107 (Letter).

Environment Australia, 1998. The Darwin Declaration. Australian Biological Resources Study, Department of the Environment, Environment Australia, Canberra.

Edwards, J.L., Lane, M.A. and E. S. Nielsen. 2000. Interoperability of Biodiversity Databases: Biodiversity on Every Desktop. *Science* 289 (5488) 2312-2314.

Estrin, D., G.J. Pottie, and M. Srivastava. 2001. Instrumenting the world with wireless sensor networks, *ICASSP 2001*, Salt Lake City, May 7-11, (Abstract).

Estrin, D., W. Michener, G.Bonito, et al. 2003. Environmental Cyberinfrastructure Needs for Distributed Sensor Networks: A report from a National Science Foundation sponsored workshop, 12-14 August 2003, Scripps Institute of Oceanography, 64 pp.

Foster, I. 2005. Service-Oriented Science. *Science*. 308: 814-817.

Foster, I. and C. Kesselman. 1999. The Grid: Blueprint for a New Computing Infrastructure. Morgan Kaufmann Publishers, San Francisco. xxiv + 667 pp.

Godfray, C.J. 2002. Challenges for taxonomy. *Nature* 417, 17–19.

Herbert, P. D. N., Cywinska, A., Ball, S. L. and J. R. DeWaard. 2003. Biological identifications through DNA barcodes. *Proc. R. Soc. Lond. B* 270: 313-322.

IABIN (InterAmerican Biodiversity Information Network), 2004. Building the Inter-American biodiversity information network: Project implementation plan. Report. Draft 8.4, 133 pp.

Johnson, P., and B. Lachman, 2001. Rapid Scan Of Decision Support System Tools for Land-Use Related Decision Making, Report to Association for Biodiversity Information, Arlington, Virginia, 79 pp.

Krishtalka, L., Peterson, A.T., Vieglais, D., Beach, J. and E. Wiley. 2002. The green internet: a tool for conservation science. *In,* Conservation in the Internet Age: Strategic Threats and Opportunities, pp. 143-164, J. Levitt (ed.). Island Press, Washington, DC.

Lane, M. A. 1998. Teaming with Life: Investing in science to understand and use America's living capital. President's Committee of Advisors On Science and Technology: Panel on Biodiversity and Ecosystems. 86 pp.

Pennisi, E. 2005. Boom in Digital Collections Makes a Muddle of Management. *Science* 308: 187-189.

Pottie, G.J. and Kaiser, W.J. 2000. Wireless Integrated Network Sensors, *Communications of the ACM*. 43: 51-58.

Soberon, J. and A. T. Peterson, 2004. Biodiversity informatics: managing and applying primary biodiversity data. *Phil. Trans. R. Soc. Lond. B.*, 359: 689-698.

Stein, B. R. and J. Wieczorek. 2004. Mammals of the World: MaNIS as an example of data integration in a distributed network environment. *Biodiversity Informatics* 1: pp. 14-22.

Systematics Agenda 2000 (Committee). 1994. Charting the Biosphere. American Museum of Natural History, New York. 1994. 25pp. (Booklet)

Wheeler, Q.D., Raven, P.H. and E. O. Wilson. 2004. Taxonomy: Impediment or Expedient? *Science*, Vol 303: 285.

Wilson, E.O. 2000. On the future of conservation biology. *Conservation Biology*. 14, 1–3.

Wilson, E.O. 2003. The encyclopedia of life. *Trends in Ecology and Evolution.* 18 (2): 77-80.

Withey, A., Michener, W. and P. Tooby (eds.), 2002. Scalable information networks for the environment (SINE). Report of an NSF-sponsored workshop, 29-31 October 2001, San Diego Supercomputer Center, 65 pp.