

FINAL REPORT
NEON-V: CRIPTON Workshop
Collections, Research, Inventories, and People for Taxonomic Opportunities in NEON
(Field Museum of Natural History, Chicago, June 14-16, 2002)

Workshop organizers: Petra Sierwald & Rudiger Bieler

Writing Committee: Petra Sierwald, Rudiger Bieler, James Hanken and Robert Magill

NEON-V Workshop—Executive Summary

The *NEON-V* Workshop was held at the Field Museum, Chicago, 14–16 June 2002. It was organized to provide advice to the National Science Foundation regarding the possible involvement, interactions, opportunities, and needs of the biological collections institutions (BCI) community within the *NEON* program. A *NEON*-BCI collaboration would present significant and unique opportunities to combine ecological data with specimen/collections data and systematic research, thus bringing vital phylogeographic context to ecological studies. Such a collaboration would both enhance the success and impact of the *NEON* program overall and address the urgent need for expanded biodiversity research mandated by increasingly accelerating changes in the global environment.

The Workshop urgently requests that the *NEON* Mission and Objectives statement be amended to include elements of biodiversity relevant to the BCI community before publication of the first *NEON* program competition announcement. The Workshop also strongly encourages meaningful BCI community participation on *NEON* review panels.

NEON research will evaluate changes in organismal diversity and community composition, research fields that are of critical importance to the BCI community. The Workshop stressed that the existing intellectual division between phylogenetic research and ecological research represents an impediment to biological research as a whole. The Workshop outlined several areas of mutual benefit to both communities that would result from *NEON*-BCI collaboration. These include new patterns of personal and institutional collaborations; verification and documentation of collections-based research; integration of systematic-ecological research; and improved quality and accessibility of biodiversity data, and therefore better environmental policy and management decisions.

The Workshop explored seven topics critical to *NEON*-BCI collaboration, including ways to approach and foster collaboration between the two research communities as well as areas of possible concern. The topics were 1) *NEON* mission vs. BCI missions; 2) essential BCI contributions for full realization of the *NEON* mission; 3) *NEON*'s impact on BCIs; 4) meeting the needs of sustained *NEON* site research; 5) bioinformatics; 6) shared instrumentation; and 7) BCI involvement in *NEON*'s educational mission. The discussions to each topic focused on the benefits to missions of both partners and to the resulting scientific research.

The BCI community welcomes the establishment of *NEON* and looks forward to becoming an active participant in it. Such involvement will enhance both field-based

research in systematics and collections-based research in ecology. Comparable educational benefits at all levels are certain to follow as well. Appropriate and balanced funding will be required to achieve each of these objectives.

(1) INTRODUCTION

National Ecological Observatory Network (NEON)

NEON is “a continent-wide research network consisting of geographically distributed observatories, linked via state of the art communications. Each observatory will consist of a consortium of instrumented field sites and support institutions creating a regional ‘footprint.’ Collectively: a virtual lab accessed by hundreds of scientists for research to obtain a predictive understanding of the environment.” (From the most recent NSF brochure, see also NSF’s website: <http://www.nsf.gov/bio/neon/start.htm>)

The *NEON* concept offers a unique opportunity for integrated research and provides a dynamic portal for non-collections-based scientists to utilize collections in their research. The traditional funding structure may have contributed to the insularity of both ecological and systematic research. An example for integrated research development is the urgently required advancement of theoretical and practical aspects of inventory science. Integrated research will result in increased breadth of student training, both in standard of expertise and their ability to work in teams. *NEON*-BCI collaboration presents the opportunity to combine the collection of ecological data with specimen and collection data and systematic research in a way that can provide reciprocal insight by bringing phylogeographic context to ecological studies.

NEON-V: CRIPTON Workshop

The *NEON-V: CRIPTON* Workshop was organized to provide advice to the National Science Foundation regarding the involvement, interaction, opportunities, and needs of the biological collections institution (BCI) community within the *NEON* network. It follows three earlier workshops, which addressed largely separate issues: *NEON* I, Archbold Biological Station, Lake Placid, Florida, January 2000 (<http://www.sdsc.edu/NEON/jan2000/final.htm>); *NEON* II, San Diego Supercomputer Center, La Jolla, California, March 2000 (<http://NEON/mar2000/index.html>); and *NEON* III, Santa Fe Institute, Santa Fe, New Mexico (<http://www.sdsc.edu/NEON/may2000/index.htm>). An additional workshop, concerning *NEON* standards, was held shortly before *NEON-V*, but results from it were not available at the time of the Chicago meeting.

NEON-V was funded as a supplement to DEB Grant 97-12438, PI P. Sierwald and Co-PI W. A. Shear; with P. Sierwald and R. Bieler serving as PI and Co-PI of the supplemental award, respectively. Twenty-eight participants representing 15 biological collections institutions (BCI) and the National Science Collection Alliance discussed the opportunities and likely impacts of *NEON* for BCIs. Several officers of the National Science Foundation attended as observers (see participant list, Appendix A). The workshop took place at the Field Museum, 14–16 June 2002. Several formal presentations were made: Scott Collins, leader of NSF’s BIO/DEB ecology cluster, reviewed the *NEON* concept, its history and the anticipated research focus. Jonathan Coddington (National Museum of Natural History, Smithsonian Institution) offered an overview of current conceptual and technical issues and problems of biological inventory execution and analyses of results. Darlene Judd (Oregon State University) summarized the history, relationship and collaboration between the Oregon State Arthropod Collection (OSAC) and the Long-term

Ecological Research (LTER) program at H. J. Andrews Experimental Forest (<http://www.lternet.edu/sites/and/>). The remainder of the workshop concentrated on small-group sessions, with each group discussing selected topics concerning opportunities and issues arising from NEON-BCI collaboration. In joint sessions of all participants, the results were reported and discussed. Results of these sessions are reported in detail below (item 6).

(2) BACKGROUND: First BON, then NEON

NEON in part grew out of previous discussions by NSF of a proposed Biodiversity Observation Network (BON). NEON, however, “would represent a broader, more interdisciplinary enterprise involving ecological, evolutionary and systematic issues far beyond biodiversity” (Introduction to NEON I report). Reports of the four BON workshops (1998–99) are available at <http://www.sdsc.edu/BON>. Key issues to be explored in BON included taxonomic and phylogenetic features, as well as temporal and spatial patterns of biodiversity (BON I). BON III recommended “that each Biological Observatory be structured as a concrete linkage between at least one Biological Collections Institution (BCI) and at least one Biological Field Station (BFS)” (executive summary of workshop report). It concluded that “lack of sufficient taxonomic expertise for many groups of organisms, along with infrastructural limitations of existing biological collections institutions, will compromise the success of BON. We recommend that these impediments be addressed through specific training efforts and assistance to the collections in the network.” BON III offered the following specific recommendations for each BCI element in the network:

- a demonstrated dedication to long-term collection care through staffing that includes curatorial and collection-support personnel, and through its commitment of resources;
- appropriate infrastructure for the repository of voucher specimens, tissues, and other biological material associated with BON activities;
- a commitment to online databasing of collections and an open-access policy to biodiversity information; and
- institutional programs and capabilities for training, including formal and informal science education and for public outreach.

The subsequent NEON I workshop incorporated BON into a broader program: “NEON should address broad-scale scientific themes in environmental biology and international importance such as loss of biodiversity, invasive species, global change and anthropogenic influences” (executive summary of workshop report). NEON “serves a much broader range of disciplines in environmental biology, rather than just the ecological community as is the case for LTER” (p. 9) and will include “Comprehensive collection and archiving of data and biological samples, including molecular and genomic information and efficient data sharing and integration” (p. 5). Collecting and archiving of biological materials (as well as associated BCI activities) were given “high priority,” but details were referred to future discussions and the available documentation provided by the BON workshops (see above). Participants agreed that “biodiversity will be a fundamental component of NEON,” but did not reach a conclusion concerning BON-NEON relationship. They saw the possible development of “two partially overlapping networks over time” (p. 18).

NEON II focused on the technical infrastructure of both individual NEON observatories and the entire NEON network. It saw research museums as important NEON facilities (report p. 2) and saw BON (again referring to earlier BON workshop reports) as part of the “NET elements,” with “teams of collectors” and “‘smart’ vouchering and archiving equipment” (p. 7).

NEON III sought to devise the optimal configuration of a NEON observatory. It recommends that “NEON 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” (report, p. 3).

This was the background against which the participants of NEON-V: CRIPTON began to deliberate issues pertaining to BCI involvement within the NEON concept.

(3) FUNDING NEON

As currently envisaged, NEON will be funded through three different areas, all three of which are independent from regular NSF funding programs such as Systematic Biology, Cluster for Instrument-Related Activities, Informal Science Education, etc. The proposed three NEON budget lines consist of (1) Instrumentation (\$10–20 million), (2) Maintenance and Operations (\$5 million), and (3) Research funding (\$10 million). In addition, the research and education communities will be able to apply for activities’ funding through regular competitive NSF programs such as the ones offered through NSF’s Division of Environmental Biology. This proposed funding model provided an important backdrop for the workshop’s deliberations and offers the necessary context for many of the results presented below.

(4) IMMEDIATE RESOLUTIONS FROM THE NEON-V: CRIPTON WORKSHOP

Revised NEON Mission and Objectives Statement

The draft NEON Mission and Objectives statement distributed by NSF observers at the CRIPTON Workshop makes no explicit reference to biodiversity or biological collections issues. Instead, it employs a broad usage of the term “ecological” to indirectly include these issues. Participants expressed an urgent need to communicate to NSF the strong wish of the BCI community to include elements of biodiversity explicitly in the NEON Mission and Objectives statement, before publication of the first NEON program competition announcement, expected in July 2002. Workshop participants drafted, approved, and submitted a revised statement to Dr. Quentin Wheeler, director of DEB at NSF, before the end of the workshop. The revised statement *explicitly* identifies biodiversity issues as part of NEON’s Mission and Objectives (Appendix B).

Future NEON-Panel Composition

The recently published NSF NEON brochure, under the heading “Why is NEON needed?” refers to the difficult questions confronting our society “*in areas such as loss of biodiversity, global change, invasive species, and bioterrorism.*” At least two of these areas fall into the realm of collections-based biodiversity research, which underscores the fundamental contribution and role of the collections-based research community within the NEON model. The workshop participants strongly encouraged NSF to include sufficient BCI and collections-based systematics presentation on the upcoming and on future NEON-panels.

(5) SPECIFIC WORKSHOP RESULTS AND RECOMMENDATIONS

NEON research will address changes in organismal diversity and community composition. This is the key element of *NEON*'s mission. The BCI community is enthusiastic about the focus on biodiversity research, and deeply appreciates the opportunity of new research avenues, particularly for interdisciplinary research bridging the fields of ecology and systematics. The workshop participants stressed that the existing division between phylogenetic research and ecological research represents an impediment to biological research as a whole. BCI representatives discussed how the large-scale instrumentation and new networking/collaborative opportunities provided through *NEON* might best be utilized for collections-based systematic research. Workshop participants were also aware of *NEON*'s need for particular "service functions" and associated issues likely to be requested from the BCI community.

Benefits of *NEON*-BCI joint research

Workshop participants identified the following issues as key benefits:

- Establishment of new patterns of collaboration among scientists and institutions.
- Enhancement of the theoretical and empirical foundation of collections-based research.
- Advancement of integrated systematic-ecological research.
- Enhancement of quality and accessibility of biodiversity data (baseline data and changes), thereby improving environmental policy and management decisions.

Realization of *NEON* benefits

The BCI community emphasizes that full realization of the scientific and societal benefits of *NEON* depends on several core requirements that need to be implemented in the *NEON* concept.

- Collection of baseline diversity inventory data at each *NEON*-site.
- Establishment of long-term specimen and data management strategies.
- Adherence to curatorial and data standards best practices before specimen/data collecting begins, including establishment of standards required for voucher specimens deemed as 'high quality' specimens: best state of preservation, full complement of collecting and ecological data.
- Assessment of scope and accessibility of existing BCI data relevant to *NEON*'s mission such as data-mining in collections and collections' databases.
- Realistic budgets and funding models for BCI needs regarding specimen handling, sorting, reliable taxonomic identification, vouchering and data management.

Identification of BCIs- and systematics needs with regard to the *NEON* mission

Workshop participants agreed that meeting the BCI-needs listed below are essential for a fully collaborative partnership between BCIs missions and the realization of *NEON*'s mission.

- Collection management support.
- Retrospective collection data entry.
- Parataxonomists training and mid-level collection staff positions.
- Dedicated and substantial support for the generation of identification-keys; identification-key software development.

(6) SUMMARY OF TOPICAL DISCUSSIONS

Break-out sessions were dedicated to particular topics. Some of these topics were pre-selected by the workshop organizers; other topics were chosen by the participants. Up to four individual groups discussed each issue, with joint sessions following in which the discussion points were summarized.

NEON Mission vs BCI Missions

NEON's mission includes the study of the pace and nature of biological change, and BCIs' mission, at its core, is to document biodiversity. The missions are logically intertwined and BCIs are fundamental to *NEON*'s operation and success.

BCI missions vary in scope, from large freestanding museums with worldwide collection focus, to regional and specialized collections. The ability and willingness of BCIs to interact with (and provide service) within *NEON* will vary accordingly. Some university museums may have difficulty participating, since their missions may not be aligned closely enough with those of *NEON*.

NEON-BCI interaction will fall into two broad categories, a **research track** (BCI-initiated or collaborative activities, including affiliated educational projects) and a **service track** (e.g., taxonomic identifications, specimen vouchering and affiliated training efforts). *NEON* research may be site-based and focus on selected core taxa, whereas systematics is clade-based. Also, while vouchering of selected specimens to document biodiversity is of intrinsic value to BCIs, large-scale storage of ecological samples and the routine provision of taxonomic expertise are not. New capacity for such functions must be developed, either in conjunction with existing BCI facilities or elsewhere.

Essential BCI contributions for full realization of the NEON mission

BCIs can and will make valuable contributions to the *NEON* mission. The list of contributions is long and the contributions cover a wide range of topics. This demonstrates how closely BCIs and *NEON*-sites must work together to accomplish *NEON*'s mission.

- BCIs will provide essential contributions to the scientific challenges of *NEON* research. Biotic inventories have been identified as a major *NEON* activity. However, the actual methods for conducting successful inventories of truly diverse taxa are still poorly known. BCIs have extensive experience with the current state-of-art inventories, but further theoretical advancements need to be made (see under **(7) Unresolved Issues and Recommendations** below) to develop efficient sustainable methods of reliable inventories. BCIs and *NEON*-researchers will benefit from collaborative development, implementation and evaluation of Rapid Assessment protocols.
- BCIs can provide taxonomic guidance for inventories and monitoring, assist in the selection of bioindicator species and in the development of core taxa to be monitored at all *NEON* sites to allow comparisons of habitats and conditions. Such efforts will broaden the list of standard model organisms for all types of biological studies, since detailed spatial and temporal data for many more species will be generated through joint BCI-*NEON* inventorying and monitoring efforts.
- BCIs will assist *NEON* research in basic practical terms such as the implementation of proper collecting (e.g., extraction techniques) and preservation methods, resulting in high quality specimens, established through well over 200 years of collection experience.
- BCIs have developed extensive protocols for standards and best practice in management and maintenance of specimen, tissue, bulk sample, and other special collections, including archival-quality housing and durable labeling techniques. These protocols will guarantee long-term vouchering of *NEON*-specimens, tissues and samples and thus contribute directly to one of *NEON*'s basic missions, the documentation of biotic change. Supporting and maintaining extensive collections of voucher material, however, will require substantial support to the collections facilities of existing BCIs, from glassware to compactorized storage systems.
- BCIs have developed detailed protocols for standards and best practice for managing and maintaining collection and specimen data, notably through collection databases. These

databases will facilitate tracking of *NEON*-site specimens across taxonomic boundaries for biogeographic and ecological research. Also, these databases will assist with loan management and facilitate exchange of specimens among *NEON*-sites.

- BCIs are well suited to provide planning support for appropriate specimen acquisition with regard to type and scope of specimen acquisition, e.g.; few specimens through qualitative target collecting or large volume acquisition through bulk collecting. BCIs are ideally suited to provide detailed advice for sorting of specimens and samples: required equipment and space for sorting activities; sorting training through BCI staff. Work-up of high volumes of specimen material is labor extensive and requires a rigorously structured work flow and a recording practice structure. In particular cases, the establishment of regional, *NEON*-site specific sorting centers may be advised.
- BCIs staff are uniquely enabled to provide guidance of proper specimen identification and follow-up quality control of identifications. It is in the interest of the BCI/systematics community to exert quality control over published taxonomic statements. BCI taxon-centered systematists can provide identifications themselves, provide identification training, generate identification tools, and locate specific taxon-expertise world-wide. Accomplishing these tasks will require substantial support for BCI staff, especially in the form of research assistants, and training of a cadre of parataxonomists to perform routine species identifications. The development of easy-to-use, richly illustrated identification tools would provide the most efficient form of support to *NEON*'s mission and would be welcomed by a wide range of users world wide. However, currently no particular funding support structure is in place for these most needed tools in biodiversity research (see under **(7) Unresolved Issues and Recommendations**).
- BCI libraries and archives, but in particular the existing collections, contain an abundance of background data important to particular *NEON*-sites. BCIs can provide guidance to access these data. Data contained in the existing collections can be mined through databases, in cases where collections are fully computerized. This is rarely the case for the most species- and specimen-rich groups – invertebrates and other small-bodied organisms. Retrospective data capture is absolutely necessary, but also extremely labor intensive and represents the predominant challenge facing BCIs and their collections. It appears advisable that this challenge be explored in a dedicated forum or workshop (see under **(7) Unresolved Issues and Recommendations** below)
- If coordinated through a *NEON*-funded initiative, BCIs can provide additional support:
(a) Formation of Biological Swat teams: teams of specialists on selected groups who would inventory sites within a *NEON* region and/or between *NEON* sites; (b) Development of *NEON*-site specific specimen reference collections designated exclusively for identification training and on-site identification quality control.

***NEON* impact on BCIs**

Potential impact of *NEON* on BCIs' research and collections was discussed in detail at the workshop. While there are numerous opportunities that will enhance collections and research at BCIs, there are also issues of concern which will need to be addressed by each *NEON* and the *NEON* funding structure.

- By providing improved infrastructure for field-based, specimen-based research *NEON* research will foster advancements of basic alpha- and beta-taxonomic work. Here it is of special concern to the BCI/systematics community that guaranteed attention is given to rare species as well as 'standard' exemplars. In some cases, revisions will be underway on groups of interest to *NEON*. Funding through *NEON* should be available for completion of these revisions and monographs through dedicated grants for systematics in the three budget areas of the *NEON* system.

- *NEON* will generate large quantities of detailed data on spatial and temporal distribution of organisms which are of interest to both systematists and ecologists. Such data will permit answering questions such as how and why species richness in different groups varies across latitudinal and climatic gradients.
- *NEON* will support advancement of evolutionary biology by combining ecological species attributes from comprehensively sampled populations with state-of-the-art phylogenetics, leading to collaborative and integrative research opportunities between taxon specialists and ecologists.
- BCIs' collections growth opportunities through *NEON* activities: (a) Periodic and regularly repeated sampling will build more comprehensive collections, capturing all life stages of a wide variety of groups, thereby contributing to life history studies, developmental biology and evolutionary biology. (b) Extensive sampling will provide quantities of fresh material for molecular research. (c) Extensive sampling will also increase collection holdings of poorly collected, rare groups.
- Participation in a *NEON* may lead to revitalization of neglected university collections and small museums.
- *NEON* funding for retrospective data capture could be a tremendous contribution to BCIs, the *NEONs* and society in general (suitably connected with NBII [National Biological Information Infrastructure; <http://www.nbio.gov/>] and GBIF [Global Biodiversity Information Facility; <http://192.38.112.110/welcome.htm>]).
- Recruitment and training of future generations of taxon specialists will be enhanced through *NEON*-BCI collaboration.
- Development of parataxonomist training and multiplication of sorting and identification expertise will benefit both BCIs' and *NEON*'s research productivity.

Workshop participants urge *NEON* project developers to have reasonable expectations, specifically:

- avoid overwhelming BCIs with specimens;
- avoid overwhelming the taxonomic community through identification requests;
- allow realistic time-frame for taxonomic work to proceed.

Workshop participants also recommend that *NEON* project developers consider the following long-term concerns:

- Long-term care strategy for residues after specialists 'high-graded' them, possibly in a designated all *NEON* sites serving storage facility.
- Site-based *NEON* research must not lead to decrease in essential clade-based systematics research; *NEON* projects must not become the driver of the BCI/systematics agenda.
- Permitting procedures are increasingly complex and time-consuming. Permitting issues must be resolved. Combined systematic and ecological work within a *NEON* may streamline permitting procedures and thus serve all aspects of field-based research.
- Ownership of data and specimens must be clarified

Meeting the needs of sustained *NEON* site research

The main characteristic of the *NEON*-system is sustained research at selected sites over a period of one or two decades. Such long-term perspective will require close coordination between *NEON* and BCIs with regard to collections growth of the BCIs. Long-term *NEON* research will require:

- Long-term monitoring protocols for selected core taxa and bioindicators.
- Managing scarce taxonomic expertise efficiently. Taxon experts may be involved with several *NEONs*, coordinating some or all *NEON* research on a particular taxon group. Training of parataxonomists, who will sort and identify samples and specimens of their

particular taxon group from several *NEON*-sites represents a high priority. Subsequent identification quality control through primary taxon experts on selected samples will be required.

- Development of efficient, environmentally low-impact monitoring protocols. Increase of efficiency and accuracy as well as reduction of environmental impact through repeated inventory surveys are crucial.
- Development of multiple and *NEON*-site specific reference collections of common species, targeted taxa, and bioindicators supporting student and parataxonomist training and identification quality control.
- Database development and maintenance for tracking of *NEON* site specimens across taxonomic boundaries for biogeographic and ecological research (may include bar-coding) as well as for loan management and exchange of specimens.

BioInformatics

NEON research will require major advances in data management, data storage and integration of existing data pools. Advances in bioinformatics infrastructure will be required and are anticipated in the *NEON* funding model. While *NEON*-related ecological research will have its own computing needs (see previous BON/*NEON* workshops), there are several bioinformatics issues that are of importance to BCIs and *NEON*. The *NEON*-V: CRIPTON workshop identified the following issues:

- Opportunities for improvement of collection management at BCIs, specifically database development, including tracking special *NEON* voucher specimens and associated ecological data, generating and maintaining new data types such as associated specimen images for development of keys and identification guides, field guides for different educational and research purposes,
- Establishment of single, central *NEON* information repository for specimen data.
- Unified specimen data creation and modification procedures, including automatic location generation (e.g., GPS) and integration with field recording technologies.
- Adherence to international data description (metadata) and technology standards.
- Survey of BCI specimen data resources to determine what type of *NEON*-relevant data already exist in BCIs and of best practices to identify digital library structures to house *NEON* data.
- Retrospective mining of existing identified collections and collection databases for *NEON* research relevant data (e.g., change in distribution ranges) and tools for synchronizing central *NEON* repository with taxonomic databases to insure ongoing data integrity.
- GIS and specimen visualization development through *NEON*-BCI joint research.
- Development of combined collection databases from different BCI-*NEON* sites, with identified authorities at BCIs or other institutions for taxonomic information. BCIs should have contracting authority for taxonomy services.
- New data types and tools (ecological data, core taxonomic information, identification keys, shared instrumentation data) linked to specimen data in collections databases.

Shared Instrumentation

BCI-based research programs will certainly benefit from the collecting of environmental data through shared *NEON* instrumentation. In addition, there is need for state-of-the-art facilities and laboratories for conducting inventories and systematic research (appropriate space and tools for dealing with extracting, sorting and handling of specimens). Efficient specimen imaging is the most critical factor causing time delays in taxonomic research of many species-rich organism groups. The imaging encompasses a much wider range today that it did in the past, where line drawings were the then state-of-the-art. Electronic image capture from light and

electron microscopy allows much faster image generation, but images still need to be cleaned-up and labeled. Furthermore, image capture directly from the specimen requires a larger number of images than a line drawing which combines several focal planes in a single illustration. Shared BCI-NEON imaging equipment and expertise could significantly alleviate such problems. Among special pieces of shared equipment for the BCI community are CTC scanners (including “cave” CTC viewing rooms and micro-CTC scanners for section analysis), sequencers, and advanced histological, SEM and TEM equipment.

At the collection management end, appropriate storage facilities for biological specimens (including liquid nitrogen storage facilities for molecular samples) are needed. In addition, the field needs software development (e.g., 3D section reconstructions, GIS implementation for freshwater systems) and would greatly benefit from advanced DNA-identification systems. Staffing for these facilities, as well as mechanisms that maximize facility use, must also be in place.

BCI involvement in NEON's educational mission, BCI opportunities

Workshop participants were enthusiastic regarding prospective educational cooperation. The BCI and systematics community envisaged significant beneficial opportunities from the NEON system, with regard to:

- Increased training the next generation of taxon specialists.
- Establishment of a training-program for parataxonomists.
- Joint teaching opportunities with consortium members, e.g., taxonomy/systematic and various “-ology” courses.
- Establishing a training program for collecting methods and collection management similar to the scientific technician training program proposed in the 2nd NEON workshop (2000. Report to the National Science Foundation from the Second Workshop on the Development of a National Ecological Observatory Network (NEON) San Diego).
- Using databases, associated ecological data and specimen images to develop on-line identification tools and monitoring guidelines for a wide variety of educational levels and community activities.
- Development of a joint BCI-NEON education mission.

Funding BCI contributions to NEON

Workshop participants discussed various funding models to support NEON-BCI research; (a) BCI-specific funding as integrated part within a NEON-budget, (b) BCIs charging NEON consortiums for particular efforts, e.g., vouchering, archiving, databasing of collections; and (c) grants specifically requested by and applied to distinct projects within a NEON which are given to individual researchers or small groups of collaborating researchers with their students. Funding models (a) and (b) would be an integral part of one of the three NEON- funding sources (Instrumentation, Maintenance & Operations, and Research, see above under (3)). Funds for model (c), individual researcher grants, could come from one of two sources, NEON research funds or regular NSF programs such as those under the Division of Environmental Biology (DEB), the Division of Biological Infrastructure (DBI) and others. NEON-V workshop participants clearly expressed a number of concerns:

- Shortage of funds in existing NSF programs, specifically in DEB's **Biodiversity Surveys & Inventories** and DBI's **Biological Research Collections** programs. Since every one of the ten anticipated NEONs will go through an initial inventorying phase and continue to require funds to conduct ongoing monitoring projects, the relatively small budgets of both will require a massive funding increase.
- Expenses for specimen acquisition, sorting, care and maintenance of collections (from glassware to compactorized cabinetry), and databasing efforts may be severely

underestimated and become seriously underfunded, as this occurs currently under the relative small budgets of DEB's Biodiversity Surveys & Inventories and DBI's Biological Research Collections. Perpetual care costs (space, curation, upkeep, databasing, access) could be addressed through a reasonable deposition fee to endow and/or cover the care. Models for such deposition fees exist, e.g., at the Smithsonian Institution.

- Production of urgently needed **taxonomic tools**, especially identification keys and diagnostic software development, but also species lists and catalogues, are currently not part of any specific program within NSF. Such taxonomic tools, currently funded as part of individual research grants, must be provided with a funding base, either in form of an extended existing NSF program such as Systematic Biology or Biodiversity Surveys & Inventories, or through a new dedicated program, and certainly must be part of the *NEON*-budget for the fauna and flora of *NEON*-sites.
- Shortage of taxon-centered systematic expertise remains a critical problem, despite some recent relief through NSF's PEET program (1997 PEET, Program Announcement). *NEON* research may require designated funds for PEET-like programs dealing with the Nearctic fauna and flora, and the training of new taxon-centered systematists and a **cadre of well-trained parataxonomists stabilized through reasonably long-term positions**.

(7) UNRESOLVED ISSUES AND RECOMMENDATIONS

Participants identified the following issues as being of significant importance and complexity, and recommend further investigations and debate, possibly in workshops and/or symposia:

- Establishment of a *NEON* Coordinating Center. Dedicated staff monitors regular data collection of standard set of environmental measurements to be performed at all *NEON* sites; monitors ongoing specimen collection activities to avoid duplications of effort. Functioning as a centralized sorting center (participants pointed to problems at the now defunct Smithsonian Institution Sorting Center), centralized bulk-residue sample storage, and dedicated storage for non-traditional sample collections, e.g., water, soil, blood samples.
- The Art of the Inventory. The actual methods for conducting successful inventories of truly diverse taxa are still poorly known, and even more poorly documented. Very few actual examples of inventories of speciose and taxonomically difficult taxa that can be documented to be 90% complete have ever been conducted. Outside the depauperate fauna of Great Britain, they are virtually nonexistent. Until such projects have been conducted and can serve as laboratories to test the most effective methods of discovering the extent of a local flora and/or fauna, inventory science will be held back.
- Details of specimen-, voucher- and data-standards.
- Collections facility needs: details need to be identified, particularly expenses.
- BCIs, *NEONs*, environmental and conservation efforts, as well as society in general will greatly benefit from the development of a cadre of well-qualified parataxonomists to combat the lack of taxonomic expertise. The *NEON* system offers a unique opportunity to generate such parataxonomist, since BCIs can contribute all required training expertise. The overarching concern however is the development of a sustainable, reliably funded mid-level position structure to ensure permanent job placement for parataxonomists. The need for them is undisputed; funding such positions at BCIs through endowments may lead to permanent improvements of 'taxonomic service' to a wide range of users.
- Development of an electronic virtual imaged type collection (E-type collection). Benefits: increasing speed of basic taxonomic work and increasing quality of identification,

reduction of stress on types through loan traffic; reduces researcher travel to type collections.

- Classic taxonomic literature as PDF-files available on-line. Classic literature would not present copyright problems. Benefits as for E-type collection.

Recommendations:

Workshop participants highly recommend funding support for two important BCI-NEON tools:

- Establishing **a funding structure to generate identification tools** is immediately needed. This issue is especially urgent, since numerous taxon-centered systematists, who are best able to assist in the preparation of identification tools are retiring in the very near future.
- Retrospective collection data capture remains a major challenge, especially with regard of funding. For NEON research to prosper, this issue must be addressed.

Workshop participants also urge the National Science Foundation to review the funding structure of several of its programs with regards to the needs and concerns listed above. Funding of NEON-biodiversity research through NSF programs instead of from NEON-specific funds requires increasing funding of **Biodiversity Surveys & Inventories** program by an order of magnitude.

References

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Appendix A, Participant List, NEON-V workshop, June 15-16, 2002; Field Museum, Chicago, Page 1

Participant	email	Taxon/Special Interests	Administrative position	address	phone
Allen Allison	allison@bishopmuseum.org		Vice President for Research	Bishop Museum, 1525 Bernice Street, Honolulu, HI 96817	Phone: 808-848-4106;
William Barnett	wbarnett@fieldmuseum.org		VP for Information Services	Field Museum, Information Services, 1400 S Lake Shore, Drive Chicago, IL 60605-2496	Phone: 312-665-7959; FAX: 312-665-7416
John Bates	jbates@fieldmuseum.org	Birds	Curator	Field Museum, Zoology, Birds, 1400 S Lake Shore Drive, Chicago, IL 60605-2496	Phone: 312-665-7730; FAX: 312-665-7754
Rudiger Bieler	rbieler@fieldmuseum.org	Mollusks	Curator, Chairman Zoology	Field Museum, Zoology- Invertebrates, 1400 S Lake Shore Drive, Chicago, IL 60605-2496	Phone: 312-665-7720; FAX: 312-665-7754
Arthur Bogan	arthur.bogan@ncmail.net	Freshwater mollusks	Curator	North Carolina State Museum of Natural Sciences, Research Laboratory, 4301 Reedy Creek Road, Raleigh, NC 27607	Phone: 919-733-7450, x753
Georgie Boge	gboge@fieldmuseum.org		Assistant to the President	Field Museum, President's Office, 1400 S Lake Shore Drive, Chicago, IL 60605-2496	Phone: 312-665-7457
Barry Chernoff	bchernoff@fieldmuseum.org	Fishes	Curator	Field Museum, Zoology, Fishes, 1400 S Lake Shore Drive, Chicago, IL 60605-2496	Phone: 312-665-7733; FAX 312-665-7391
Jonathan Coddington	coddington.jon@nmnh.si.edu	Arachnids, biodiversity studies	Curator	Department of Systematic Biology, National Museum of Natural History, Smithsonian Institution, Washington, DC, 20560-0105	Phone: 202-357-4148
Scott Collins	scollins@nsf.gov		Leader of Ecology Cluster/DEB	The National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230, Room 635N	Phone: 703-292-8481
Christopher Dunn	cdunn@mortonarb.org		Director of Research	The Morton Arboretum, 4100 Illinois Rte. 53, Lisle, IL 60532	Phone: 630-719-2423; FAX: 630-719-2433
Roberta Faul-Zeitler	faulzeitler@nscalliance.org		Executive Director	Natural Science Collections Alliance, 1725 K Street NW, Suite 601, Washington, DC 20006	Phone: 202-835-9050; FAX: 202 835-7334
William L. Fink	wfink@umich.edu	Fishes	Curator, Associate Chair	Fish Division, Museum of Zoology, 1051 Museums Building, 1109 Geddes Ave., University of Michigan, Ann Arbor, MI 48109	Phone: 734-764-9928; FAX: 734-763-4080

Appendix A, Participant List, NEON-V workshop, June 15-16, 2002; Field Museum, Chicago, Page 2

Participant	email	Taxon/Special Interests	Administrative position	address	phone
Daniel L. Graf	graf@acnatsci.org	Mollusks	Curator	The Academy of Natural Sciences, 1900 Benjamin Franklin Parkway, Philadelphia, PA 19103	Phone: 215-299-1132; FAX: 215-299-1170
James Hanken	hanken@oeb.harvard.edu	Amphibians and reptiles	Professor, Curator and Director	Museum of Comparative Zoology, 26 Oxford St., Harvard University, Cambridge, MA 02138	Phone: 617-495-2496
Sabine M. Huhndorf	shuhndorf@fieldmuseum.org	Fungi	Curator	Field Museum, Botany, 1400 S Lake Shore, Drive Chicago, IL 60605-2496	Phone: 312-665-7855; FAX: 312665-7158
Michael A. Ivie	mie@montana.edu	Coleoptera	Curator and Professor	Department of Entomology, 333 Leon Johnson Hall, Montana State University, Bozeman, MT 59717-3020	Phone: 406-994-4610 office, 406 994-4943 lab; FAX: 406 994-6029
Darlene D. Judd	judd@bcc.orst.edu	Diptera	Director, OSAC	Oregon State Arthropod Collection, OSU, 2046 Cordley Hall, Corvallis, OR 97331	Phone: 541-737-8174; FAX: 541-737-3643
Lynn Kimsey	lskimsey@ucdavis.edu	Entomology	Director	Center for Biosystematics, Bohart Museum of Entomology, 1124 Academic Surge Bldg, Davis, CA 95616	Phone: 530-752-5373; FAX: 530-752-9464
Meredith Lane	meredith.a.lane@verizon.net	Biodiversity informatics/Plants	Consultant	2102 Bryn Mawr Pl., Ardmore, PA 19003-2928	Phone: 610-649-8175
Mathew Leibold,	mleibold@midway.uchicago.edu	Science Advisory Board of NCEAS	Professor	Dept. of Ecology and Evolution, Zoology 404, University of Chicago, 57th Street, Chicago, IL 60637	Phone: 773-702-0953/334; FAX: 773-702-9740
Diana Lipscomb	dlipscom@nsf.gov	Microbiology	NSF program officer BIO/DEB, George Washington University	The National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230, Room 635 N	Phone: 703-292-8481
Robert Magill	bob.magill@mobot.org		Director of Research	Missouri Botanical Garden, P.O. Box 299, St. Louis, MO 63166-0299	Phone: 314-577-5111
Robert Martin	Rmartin@fieldmuseum.org	Anthropology	VP, Academic Affairs	Field Museum, Academic Affairs, 1400 S Lake Shore Drive, Chicago, IL 60605-2496	Phone: 312-665-7809; FAX: 312-665-7806
Scott Miller	miller.scott@nmnh.si.edu	Lepidoptera	Acting Chair	Department of Systematic Biology, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560-0105	Phone: 202-357-1355

Appendix A, Participant List, *NEON-V* workshop, June 15-16, 2002; Field Museum, Chicago, Page 3

Participant	email	Taxon/Special Interests	Administrative position	address	phone
Lawrence M. Page	lpage1@ufl.edu	Fishes	Emeritus	Florida Museum of Natural History, University of Florida, Gainesville, FL 32611	
Petra Sierwald	psierwald@fieldmuseum.org	Arachnida & Myriapoda	Curator	Field Museum, Zoology - Insects, 1400 S Lake Shore Drive, Chicago, IL 60605-2496	Phone: 312-665-7744; FAX: 312-665-7754
Margaret K. Thayer	mthayer@fieldmuseum.org	Coleoptera	Curator	Field Museum, Zoology - Insects, 1400 S Lake Shore Drive, Chicago, IL 60605-2496	Phone: 312-665-7741; FAX: 312-665-7754
David L. Thomas	dthomas@inhs.uiuc.edu	Fishes, Birds, Ecosystem Restoration	CEO	Illinois Natural History Survey, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820	Phone: 217-333-6880
Laurie Vitt	vitt@ou.edu	Herpetology	Curator and Associate Director of Collections and Research	The Sam Noble Oklahoma Museum of Natural History, 2401 Chautauqua Avenue, Norman, OK 73072	Phone: 405-325-4712
Quentin Wheeler	qwheeler@nsf.gov	Beetles	Director of DEB, Cornell University	The National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230, Room 635N	Phone: 703-292-8481

Appendix B

NEON-V: CRIPTON Workshop

**Collections, Research, Inventories, and People for Taxonomic Opportunities in NEON
(The Field Museum, 15-16 July 2002)**

17 June 2002

Dr. Quentin D. Wheeler
Division Director
Division of Environmental Biology
National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230

TO WHOM IT MAY CONCERN:

The participants in the NSF-sponsored *NEON* Workshop (15-16 July 2002, Field Museum of Natural History, Chicago) suggest that the *NEON* Mission and Objectives statement be amended as attached, and request that all *NEON* Panels include a significant element from the systematics community to assure that any proposed activities involving biodiversity documentation accurately reflect the capacities and goals of that community.

The *NEON* Mission and Objective

The mission of *NEON* is to establish and sustain the scientific infrastructure and foster the development of the intellectual capital needed to establish the required observational base and address critical questions about changes in ecological systems and to evaluate the impacts of those changes.

The objective of the *NEON* program is to build a fully integrated distributed national network of environmental observatories and to provide the technical means and support personnel to achieve the mission of *NEON*.

***NEON* is designed to address fundamental questions**

What are the elements of biodiversity and dynamics of ecological change?

What are the environmental impacts of ecological change?

What are the ecological impacts of environmental change?

These questions increase in importance with increasing spatial and temporal scales, ultimately to global and generational scales (see Table A). In addressing these questions, *NEON* is designed to work across spatial scales and over the long-term. The breadth and diversity of specific research questions within the construct call for a structured and diverse intellectual community with access to common, shared resources in a distributed, nationwide configuration.

[Endorsed by unanimous vote on 16 June 2002; submitted on behalf of the Workshop participants by Petra Sierwald and Rudiger Bieler, Workshop Organizers]