Report of the Third Workshop on the Biodiversity Observatory Network

May 6-7, 1999

California Academy of Sciences
San Francisco, California

Sponsored by the National Science Foundation

Report Submitted August 20, 1999

EXECUTIVE SUMMARY

A third workshop on the Biodiversity Observatory Network (BON) took place at the California Academy of Sciences, May 6-7, 1999. The aim of this meeting was to review and refine the recommendations of the first two workshops, focusing specifically on the role of systematic biology in the program.

- Understanding and managing the Nation's biological resources requires enhanced integration across existing disciplines and institutions. We strongly endorse BON as a mechanism to accomplish this integration and thereby to provide deep and urgently needed knowledge of biological diversity.

- We recommend 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). This organization leverages and combines the strengths of existing institutions that are critical to the BON mission, and insures from the outset a new level of interaction across biodiversity disciplines.

- We recommend the establishment of a National Center for the Analysis of Biodiversity (NCAB), which would serve as the hub of BON activities. NCAB would facilitate the integration and synthesis of biodiversity information arising from the Observatories, and through its activities would advance the utilization and value of the BON.

- BON research will explore, document, and monitor biodiversity across an array of sites representing the Nation's major biotic provinces. This will provide new understanding of spatial and temporal patterns and the processes that maintain or change biodiversity across environmental gradients.

- BON research will put the biological diversity of the Unites States in global context, and for this purpose will require research outside of the BON per se. Without such knowledge BON would fail in its mission to fully understand the factors that account for our Nation's biological diversity.

- The lack of sufficient taxonomic expertise for many groups of organisms, along with infrastructural limitations of existing biological collections institutions, will compromise the success of the BON. We recommend that these impediments be addressed through specific training efforts and assistance to collections in the network.

- The goal of BON to create, and to use, a network that will integrate biodiversity knowledge across disciplines is distinct from, yet complimentary to, existing NSF programs.

- We recommend that the BON program be structured to accommodate the variety of projects that will be necessary to achieve the goals of the network. In addition to a competition to initiate NCAB, we recommend the establishment of two panels to consider proposals focused on infrastructure and research.

- Without a substantial and sustained financial commitment to this new endeavor, the benefits of the BON identified in this report will not be realized. We recommend a budget to initiate at least 20 observatories within the first three to five years of the program, to fund research projects making use the BON, and for the establishment of NCAB.

I. Introduction

Biological diversity, or biodiversity for short, includes all the major lineages of life, their component species, populations, and individual organisms, the habitats and ecosystems they comprise, as well as the genetic diversity they contain. This biological, or natural, capital is an essential foundation for the nation's wealth and prosperity. The ecological services provided by biodiversity (clean water and air; soil production and protection; pollination; and climate control) when coupled with the economic benefits derived from the use of biodiversity (including food; medicines; agricultural, forestry and fisheries products; and recreation, among others), contribute immeasurably to the well-being of our citizenry, as well as many hundreds of billions of dollars to the United States economy. And yet these natural resources are being degraded or lost to human activities at an alarming rate. A recent report by the President's Committee of Advisors on Science and Technology concluded that increased scientific knowledge is essential if we are to mitigate these changes and sustain the benefits provided by the nation's biological capital (PCAST 1998).

Unfortunately, organizational connections and scientific integration among different disciplines, institutions, and the scientists studying biodiversity are currently inadequate to achieve the degree of scientific understanding that will be required to address all the complex issues surrounding the conservation and sustainable use of biodiversity. Narrowly focussed research, along with current discipline-based funding patterns, although in many ways responsible for major scientific advances in the biodiversity sciences, often make it difficult to connect patterns and processes across the different spatial and temporal scales at which biodiversity exists.

In order to address these challenges and to make recommendations regarding improving the nation's infrastructure for biodiversity science, two workshops were convened– the first held 10-11 September 1998 at Blandy Experimental Farm, Virginia, and the second held 14-16 January 1999 at the National Center for Ecological Analysis and Synthesis (NCEAS), Santa Barbara, California. The reports from these workshops strongly endorsed the proposal that the National Science Foundation establish a new national research program in the form of a system of biological observatories, called the Biodiversity Observatory Network (BON). This network, a web of strategic linkages that capitalize on the nation's existing biodiversity research infrastructure, is seen as a key step toward providing the environmental science necessary to understand, and therefore more effectively manage, our nation's natural resources.

Emerging from these two workshops was the recognition of the critical role that collections-based institutions, and systematic biology generally, play in understanding the nation's biodiversity. Accordingly, a third workshop designed

to solicit the input of the systematic biology community was organized. This report summarizes the deliberations of 33 biologists held 6-7 May 1999 at the California Academy of Sciences. The purpose of this workshop was to refine and synthesize the recommendations of the previous workshops on the structure and operations of the BON.

II. BON and its Mission

The Biodiversity Observatory Network will be a new approach to environmental research and problem solving. It will consist of a series of Observatories distributed across the nation that will take advantage of existing natural history collections, biological field stations and laboratories, as well as universities and other research institutions concerned with discovering, documenting, measuring, and analyzing biological diversity and its spatial and temporal components and dynamics. These Observatories will then be linked together operationally and intellectually as a network through the use of state-of-the-art bioinformatics. This infrastructural platform will provide a framework for developing a more comprehensive and integrative approach to biodiversity science than exists through ongoing programs. An infrastructure such as BON is a key requirement for addressing a number of broad research themes that depend on a large-scale approach to analyzing patterns and processes of the North American biota (all of these themes were identified as critical areas of research by the PCAST Report and by the previous BON workshops), including:

1. The composition of biodiversity– what are the lineages of plants, animals, and microbes that constitute the nation's natural biological capital?

2. The patterns of biodiversity– what are the taxonomic, ecological, and evolutionary patterns revealed by biodiversity across space and over time?

3. The processes of biodiversity– what are the ecological and evolutionary processes and mechanisms that govern biodiversity phenomena across space and through time?

4. The function of biodiversity– what are the relationships between biodiversity and the structure and functioning of ecosystems and what are their benefits to society and how are they to be measured?

5. The human dimensions of biodiversity– what are the relationship between biodiversity and human social, cultural, and economic dynamics?

BON's mission will be to advance our knowledge of biological diversity, its environmental consequences, and its role in determining biocomplexity in general. The San Francisco Workshop also sees BON as an unprecedented opportunity to

promote interdisciplinary research and to develop a more integrated research approach to environmental science having implications nationwide.

III. The Rationale for BON

The San Francisco Workshop echoes the conclusions of the NCEAS Workshop that establishing BON will be a new and significant step toward increasing our understanding of the nation's biological diversity and, furthermore, that it will have an immediate and major impact on U. S. science, first by improving our scientific infrastructure dedicated to biodiversity science, and second by providing a framework for enhancing and integrating biodiversity science to a greater degree than is possible with current programs. To understand biodiversity and the processes that generate and sustain it, a set of permanently protected, relatively undisturbed, and carefully studied sites need to be located in each of the major ecological regions across the United States. The BON program will establish and support these representative samples of our nation's landscape as locations for long-term, stable, interdisciplinary research and teaching.

An infrastructure such as BON is a key requirement for addressing a number of the broad research themes that depend on a large-scale approach to environmental science. Indeed, the primary rationale for BON is that it will significantly advance and expand the science of biodiversity. Because BON will establish a coordinated program of research across Observatories, and because of the influx of resources that will inevitable result, it can be expected that scientific activity across the biodiversity sciences will increase dramatically, but in ways not realized by current patterns of funding. As noted by the Santa Barbara Workshop, the BON research program will demand and foster a new synergism among disciplines. Such interdisciplinary research efforts will be needed if we are to achieve a synthetic understanding of biodiversity that will measurably improve our response to environmental challenges.

There are many tangible outcomes in scientific knowledge that will emerge from the BON. Some of these will include:

1. Biological inventories. BON will be seen as a great achievement in the discovery and documentation of our biological capital. Systematic inventories across BON Observatories will significantly expand our discovery effort of the nation's biodiversity, thereby enhancing opportunities for discovering new species useful to science and society. Thus, concerted efforts to inventory little known groups (bacteria, fungi, and so forth) in poorly sampled habitats such as soils will provide new insights into the structure and function of soil or other poorly understood communities. At the same time, these inventories will provide the nation with a much improved baseline against which to measure and document environmental change and ecosystem health.

2. Phylogenetic relationships and comparative biology. BON will result in an improved understanding of the evolutionary history of the United States biota. Studies of phylogenetic relationships of taxa acquired through inventories across Observatories will provide new information on the historical assembly of the biota as well as on the morphological and genetic traits of these taxa. These results will also provide essential background for many investigations on the comparative biology of the U. S. biota.

3. Biological databases and informatics. BON will lead to improvements in the science of bioinformatics. The assembly of large cross-disciplinary datasets – which will facilitate the discovery and analysis of novel biological patterns and processes, and foster the formulation of predictions such as how the biota will be influenced by changes in climate or invasive species– will require new ways of thinking about bioinformatics and how biological data are to be synthesized.

4. Long-term ecological research. The Observatories will provide a broad platform for new initiatives on ecosystem structure and function across large spatial scales that are well-grounded in an understanding of the taxa that constitute those ecosystems. Comparative approaches to synthetic questions, across the many different ecosystems encompassed by the BON, will lead to new insights about ecological patterns and processes.

5. Environmental problem-solving. The BON will also establish a site-based organization of networked research that has the potential to greatly improve our scientific basis for environmental problem-solving. As one example, integrated systematic and ecological studies of invasive species across Observatories will provide us with much improved scientific picture with which to address this serious environmental threat. The Observatories might also serve as the locus for critically important research on the spatial dynamics of biotic and climatic change within the United States. Finally, we lack an adequate historical picture of the nation's biotic landscape, its original composition and distribution, and how it has changed, and is changing, as the result of human activities; a BON could make an important contribution toward gathering this information.

In addition to launching a dramatic expansion of the science of biodiversity across the United States, BON will have a number of other key benefits, including:

1. The BON will leverage current institutions and will reinvent scientific relationships among them. A key rationale for a BON, as conceived in the deliberations of the workshops, is that it will utilize current institutions already having some relevant infrastructure and staff with scientific capabilities in the biodiversity sciences. Thus, a BON can be built around sets of institutions with established associations but at the same time will have the capability to expand

by adding institutions that create novel linkages among themselves. Thus, we see the BON as establishing a milieu within which "emergent" benefits will arise as the network grows and becomes richer in its scientific programs.

There are many obvious ways the creation of the BON will improve the capabilities and infrastructure of existing Biological Collections Institutions (BCIs) and their associated Biological Field Stations (BFSs), but perhaps most importantly, we believe it will reinvent the scientific relationships they have with one another. The BON will expand the scientific role and importance of BFSs across the nation and put them to work to gather critical scientific information necessary to understand patterns and processes of biological diversity.

2. A BON will enhance the scientific infrastructure needed to study the nation's biodiversity. All three workshops agreed that BON will significantly improve the infrastructure of all institutions involved in the network. For example, a very large amount of information about the biodiversity of the United States already exists in collections-based institutions, yet much of this information is not readily available to the user community because it is not in digital form. The BON would support databasing and informatics activities, which are critical for understanding what we know about biodiversity, how it is distributed, and how it has changed over time.

   At the same time, inventory results across BON Observatories will demand enhancing collection management and care that can only be realized by improvements in infrastructure and human resources. These improvements will give collections-based institutions a greater capacity to meet the urgent national need of improving biodiversity science.

   Currently, the scientific potential of many biological field stations is unrealized. Many of these institutions focus their programs on education, a critically important objective as we will discuss below, with scientific research being undertaken by a small number of investigators who usually choose a single site for that research. Seen from a national, large-scale perspective, much of that research is idiosyncratic. BON will change this, and the result will benefit the nation as a whole. First, BON will improve the scientific infrastructure of these stations, positioning them for a stronger contribution to document and understand biodiversity. Second, BON will engender increased research on these sites. And finally, BON will result in many research efforts at multiple sites, thus producing comparative data not now emerging from the single-site emphasis currently in place.

3. A BON will enhance the human resources dedicated to studying biodiversity and will provide numerous opportunities for training at all levels of the

educational spectrum. In particular, the inventory activities arising from the BON will require increases in the professional training of the next generation of biodiversity scientists, including most importantly, professional systematists and support staff dedicated to collection care and maintenance. Importantly also, BON will have a major role in expanding training for ecologists, population biologists, and other environmental biologists.

4. A BON will provide the backbone for new programs in informal science education. Many of the institutions that will be involved in the BON – museums, botanical gardens, field stations and other laboratories, universities– already have successful programs in formal and informal science education. In addition to the increased opportunities for the professional training of the next generation of biodiversity scientists that BON will create, the Observatories also have immense potential to engage the public and enhance informal science education about biodiversity. The BON program will provide new opportunities for innovative public programs through classes, internships, Internet and WWW outreach, and student mentoring, to name but a few. Observatories will necessarily have a local and regional impact on educating the public about biodiversity and, because of the nature of the network, can extend that education to the national level. It is easy to envision a program of public science information initiatives that parallel the coordinated scientific programs taking place across the Network.

IV. Organization of the BON

The San Francisco Workshop considered a number of models for the BON including those discussed at previous workshops. We recommend a BON organization that expands on the design envisioned at the Santa Barbara Workshop by emphasizing that biological collections are an essential element of any effort to document and comprehend the biodiversity upon which our society depends. The organization outlined here achieves all the goals considered important by the three workshops. We recommend that a BON be established, to consist of a series of **National Biodiversity Observatories** that are linked among themselves as well as to a new **National Center for the Analysis of Biodiversity (NCAB)**. We recommend further that these National Biodiversity Observatories be structured as a linkage, or formal association, between multiple institutions dedicated to biodiversity research. Minimally, Observatories will consist of at least one **Biological-Collections Institution** (BCI) and one **Biological Field Station** (BFS). NCAB will have the responsibility to coordinate common scientific activities across the BON, to synthesize biological knowledge derived from scientific research across the Observatories, to promote public outreach regarding BON activities and knowledge about biodiversity, to promote and undertake research necessary to foster the network as a whole, and to promote the study and integration of the biodiversity

sciences through workshops, symposia, research,. and other activities. A schematic description of the BON and its component elements is shown in Figure 1.

A) National Biodiversity Observatories

The focal elements of the BON will be the National Biodiversity Observatories. The minimum standard observatory should consist of a formal linkage, or association, between a Biological Collections Institution (BCI), such as a natural history museum, botanical garden / herbarium, or university-based collection, on the one hand, and a Biological Field Station (BFS), on the other. This minimum standard Observatory is shown in Figure 1A. We emphasize, however, that other similar arrangements would be suitable (Fig. 1C-D), including a connection between one BCI and several BSF's, or between one BSF and several BCI's.

The rationale for inclusion of a BCI in this organizational framework is that, collectively, natural history collections house a permanent record of the nation's biological diversity. As such, they can best provide both an historical perspective to BON research, as well as a long-term and secure repository for vouchers and biodiversity information associated with the scientific activities of the observatories. Furthermore, BCIs undertake the research that establishes the systematic relationships that function as a primary linkage between disparate biodiversity research programs. Because of these considerations, it is also desirable that some formal agreement or association exist between the BCI and the BFS in order to ensure a long-term commitment of both elements to the BON, to collection care, and to the coordination and administration of scientific activities between the BCI and BFS as well as with the BON as a whole.

The Workshop realized that this model of a minimum standard observatory required flexibility if the BON were to achieve its potential. At present, some BCIs have responsibility for multiple BFSs (Figure 1B), and in a few cases several BCIs may already share administrative responsibility for one or more BFSs (Figure 1C). In addition, some institutions, here termed for convenience an Affiliated Biodiversity Research Institution (ABRI), such as many universities, may have a Biological Field Station but no biological collections. In the latter case, we propose that an Observatory might be formed by a formal agreement between the ABRI and a BCI (Figure 1D). It is also possible that an ABRI may itself be an independent Biological Field Station, in which case a formal linkage with a BCI would make them eligible to become an Observatory. Finally, some BCIs may not currently be linked to a BFS but, because of the extent and importance of their collections, may be in a unique position to contribute to the BON. For example, institutions such as botanical gardens / herbaria might have extensive collections that could provide important comparative data across many BON Observatories, and their participation in BON could be accommodated in a number of ways.

We endorse the conclusions of the Santa Barbara Workshop that if the BON is to serve science and society effectively, its Observatories should be distributed broadly across the biological and geographic diversity of the United States. This means that at least one, and ideally multiple, observatories should be situated in each of the nation's major habitats and ecosystems. BFSs should be sited so as to represent broad-scale variation in the taxonomic composition and complexity of natural communities, broad-scale gradients in relevant geophysical and environmental characteristics, unique or endangered biotas, areas of diversification or radiation, or to expand our understanding of ecosystem structure and function.

We recommend that the BCI and BFS elements of each observatory have the following characteristics:

Biological Collections Institution (BCI)

The Santa Barbara and San Francisco Workshops concluded that the BON research mission requires that each BCI within an Observatory meet certain minimum standards and be equipped with specific capabilities and infrastructure. In order to support the goals of the BON, each BCI element of an observatory should have:

- administrative linkages to, or formal agreement with, one or more Biological Field Stations

- 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

- institutional programs and capabilities for training, including formal and informal science education and for public outreach

- a willingness to undertake core scientific activities on the BFSs, such as inventory, monitoring, and to support infrastructural requirements, such as bioinformatics, of the BON

Biological Field Station (BFS)

The Santa Barbara Workshop concluded that the BON research mission requires that each Biological Field Station within an Observatory meet certain minimum standards and be equipped with specific capabilities and infrastructure. We endorse this position and recommend that each BFS element of an Observatory:

- must establish appropriate formal agreements with one or more BCIs that will serve as permanent repositories for biological materials

- must be managed and protected to ensure that long-term studies of biodiversity can be undertaken

- should be sufficiently large in area to allow for resolution of questions concerning its biota across multiple spatial scales

- must have the capability, infrastructure, and commitment to undertake activities such as systematic inventories, long-term monitoring, physical observations, and bioinformatics, all of which will be required to support the BON. This would also include appropriate geographic information systems, climatic and biogeochemical instrumentation, bioinformatics infrastructure, appropriate temporary collections facilities, and so forth.

- must have the facilities and capabilities to house and support a broad range of biodiversity research from both internal and external investigators undertaking BON-supported investigations, including systematic inventories and the collecting of voucher specimens if required by the research. This would include laboratories, lodging quarters, vehicles, and so forth.

B) National Center for the Analysis of Biodiversity (NCAB)

Both the Santa Barbara and San Francisco workshops strongly endorsed the idea of a BON core facility, here referred to as the National Center for the Analysis of Biodiversity, or NCAB. We agree with the Santa Barbara workshop that NCAB would play a critical role in facilitating integration, networking, informatics, interoperability, some forms of training, and in conducting some research that is relevant for the BON (such as in bioinformatics). The central theme of the NCAB's intellectual activities will be biodiversity, including but not limited to systematics, comparative biology, phylogenetics, biogeography, ecological patterns and correlates of diversity. In short, such a facility will serve as a hub around which the intellectual content of biodiversity science can be advanced.

We believe a strong need exists for a center devoted specifically to biodiversity science, which to be successful will require active participation by the systematics

community. Furthermore, the NCAB's focus on the BON per se will entail major activities and responsibilities that are unique with respect to current National centers and facilities. The San Francisco Workshop is of the opinion that the undeniable success of NCEAS comes from its programmatic concentration on the ecological sciences. We see a similar programmatic focus of a NCAB to be essential for the success of the BON. It is our opinion that to combine the functions of the proposed NCAB with those ongoing at any other center will result in a very large bureaucratic facility that will lose current advantages and not gain new ones. Moreover, such an arrangement would not serve BON well; BON's programmatic activities and intellectual agenda will require its own central facility in order to be successful. At the same time, we believe NCAB will be synergistic with, complimentary to, NCEAS, and we see great potential for collaborative activities that will increase the value of both facilities.

Although the San Francisco workshop endorses the position of the Blandy Farm and Santa Barbara Workshops as to the critical importance of a central facility, the San Francisco Workshop had a different point of view about how it would best function. We agree, as noted above, that NCAB will provide the framework for coordinating activities across the BON; indeed it must if BON is to be successful. The San Francisco Workshop sees this happening, however, not from centralized decision-making at NCAB but through mutually agreed upon principles that can be adapted to the particular circumstances of each observatory. Thus, we prefer greater decentralization of informatics and training efforts throughout the network, as opposed to "top-down" strong central coordination discussed by previous workshops. Moreover, in contrast to previous reports, we do not see NCAB as a facility that will undertake scientific services such as taxonomic survey and support, DNA analysis, or even data analysis for individual BONs. We envision these activities as being distributed across the Network.

Given the organizational structure of BON that we recommend, we believe NCAB will not function effectively or economically if it has a centralized decision-making role. Instead, the San Francisco Workshop recommends that consideration be given to creating a decision-making body within NCAB composed of representatives from the institutions comprising the BON Observatories. This committee would have responsibility for setting policy and common programmatic activities that affect the BON as a whole. As one of their obligations, the staff of NCAB would be charged with facilitating these decisions.

The San Francisco Workshop recommends that a competition to establish NCAB should be among the first formal activities of the BON program. We suggest that an NCEAS-like organizational framework will serve NCAB best. Because the success of the BON hinges on coordinated and collaborative activities among sites, attention of the NCAB facility and leadership should be focused on stimulating and nurturing the ideas and the teams of scientists who will carry out such activities.

Consequently, we urge that NCAB develop a proactive "think-tank" and research support role. This Center would support the work of a small permanent staff, as well as provide space and resources for post-doctoral fellows and visiting scientists (perhaps on sabbatical leave). A primary function would be to facilitate BON project- and/or issue-focused working groups.

We also strongly recommend that a NCAB facility be physically and programmatically independent of its home institution and that its staff be chosen by representatives of the BON institutions. It is clear from NCEAS, as well as from the centers of the U.S. National Academy of Science, that having a comfortable, spacious facility in pleasant surroundings facilitates the work of the center. We urge that the NCAB site be chosen and developed with this in mind. Because of the expected role NCAB will play in hosting meetings, workshops, and visiting scientists some attention should also be given to easy year-round access as well as cost effective housing and travel conditions.

C) *Nature of the BON Network*

The BON network will be both a physical network of observatories and a virtual network of scientists and students involved in biodiversity research throughout the U.S., with support and leadership provided by NCAB. The observatories will be networked in an organic and dynamic way by virtue of shared goals and projects. As detailed below, we envision that network research projects will develop in two ways. First, a number will be implemented as part of the initial infrastructure grants that establish observatories. Second, others will be proposed for observatories (and elsewhere) as part of "stand-alone" research proposals to be funded by BON. As BON matures, we anticipate that projects will be over-lapping among sites and distributed among them in a non-hierarchical way (e.g., scientists at observatory X may be collaborating on a project on migratory song birds with scientists at observatory Y, and with scientists at observatory Z on microbes in soils derived from ultramafic rocks). As data accumulate, the data themselves will provide a solid platform for networking among sites as synthesis, analysis and manuscript preparation take place (we see a central role for the NCAB in facilitating this phase of BON research).

All of the observatories will be linked as a result of the informatics component of the comprehensive goals of the BON. Scientists and technicians working at each site on this component of the project will likely have as much contact with their colleagues at other observatories as with others on-site.

BON will also be a virtual network composed of biodiversity scientists whose projects take place at several sites, whether they be site-based, clade-oriented, community-based, or methods-oriented projects (e.g., how best to inventory spiders across the entire range of vegetation substrates accommodated by the

observatories). This virtual network will also include biodiversity scientists who are based in the U.S. but conduct research elsewhere. We specifically urge that the NCAB develop activities to incorporate these biodiversity scientists into the BON web.

V. Nature of BON Research

The San Francisco workshop was convened by NSF specifically to incorporate the perspectives of the community of systematists in the U.S. into BON. This group agreed that the overarching goal of the BON program is the integration of biodiversity research across disciplines, and sought to speak directly to the systematic research and support activities necessary to achieve this overarching goal. Previous reports have emphasized other kinds of biodiversity research and we direct readers to those reports for detailed presentations of BON research beyond systematics.

Workshop participants agreed that the establishment of the BON and the results of research conducted both on-site at observatories and elsewhere should enable biodiversity scientists and policy makers in the U.S. to address the following sorts of objectives:

- Monitoring the well-being of the nation's biota
- Documenting changes in the biota in response to abiotic (e.g., climate change) and biotic (e.g., the arrival of alien invasives) impacts
- Understanding how the idiosyncratic ranges of individual species merge together to give us the plant and animal communities that characterize regions of the country
- Understanding how the US biota is related to that of other regions and what biotic (e.g., dispersal) and abiotic (e.g., continental drift) processes are responsible for these patterns of relationship
- Documenting the evolutionary history of ecological interactions (e.g., plant-pollinator relationships, host-parasite relationships)

The systematic research that will be necessary to achieve these sorts of goals is of two modal classes. First, it is the role of systematics to document by survey and inventory the elements of biodiversity that exist today (species and lineages). Second, we must also understand how these elements fit within a global evolutionary and ecological context.

Although we present these in distinct subtitled sections below, we emphasize that they are in fact not distinct. Ideally (and in practice for many groups of organisms), systematists undertake both phases simultaneously (i.e., clarifying the nature of species entities while documenting evolutionary relationships among them). However, as discussed below, in some groups, the species discovery phase is not sufficiently advanced to permit such a research strategy whereas in others, the species discovery phase is essentially complete. Further, the results of these kinds of systematic research provide the basis for addressing different kinds of ecological and evolutionary questions. For example, survey and inventory work provides the basis for monitoring the well-being of our nation's biodiversity whereas phylogenetic research is necessary to understand the evolutionary history of mutualisms.

A) Survey and Inventory: What biodiversity exists today?

The status of our knowledge varies remarkably among groups of living organisms. For some groups of organisms (e.g., many invertebrates, almost all groups of microbes), there are giant lacunae in our species-level knowledge. That is, survey of these groups at any one BON site is likely to yield both species that are newly recorded for the site, as well as those that are entirely new to science. For these organisms, basic survey and inventory research is required simply to document diversity of these groups in the U.S. We urge that each observatory undertake survey of one or more such poorly known groups, with the specific identity of those groups to be identified based on two criteria: first, the specific location and ecological context of the observatory and second, the existence of parallel survey projects at one or more other observatories such that the overarching goals of the BON can be addressed.

We recognize that, all too often, such poorly known groups are the research focus of only a few trained systematists such that it may be difficult for a given BON site to find appropriate scientists who are able to undertake such an inventory (see section VI, impediments). On the positive side, such groups provide an opportunity to realize the potential of the BON network to provide training of future systematists. Through the NSF-funded PEET project, there are already opportunities to collaborate in such training efforts in place. We urge scientists developing BON proposals to learn of PEET projects (and of other NSF funded, taxon-oriented projects) and to develop collaborations with PIs of such grants.

The San Francisco workshop also stressed that survey and inventory projects dealing with poorly known organisms will yield large numbers of specimens that must be handled by institutions housing collections. It is in part for that reason that we urge adoption of the fundamental structure of observatories as presented above (i.e., at least one site plus at least one collections institution). It is also vital for the success of the BON that the resources that will be required to handle these

specimens be provided as part of the BON. That is, the existing collections institutions in the U.S. cannot accept the major responsibilities that an active BON will demand of them without provision of new resources.

For other groups of organisms (e.g., butterflies, birds, amphibians, reptiles, some lineages of plants [conifers, Magnoliaceae]), species level survey is for all intents and purposes complete such that most sites that are likely to compete successfully for BON status in the U.S. will already have or can easily assemble complete check-lists of species for these groups. In such cases, appropriate BON research would involve survey and inventory research at a very different level including such research goals as: How many individuals are present and at what times of year?; What habitats or micro-sites do they occupy?; Does successful reproduction depend on one or more particular habitats?; Where do they go when not actively in residence?; If there is a dormant season, on what particular habitats do they depend during this dormant period?; If the organisms are migratory, where do they go and on what habitats do they depend there?

This kind of information will be most valuable when synthesized across BON sites (and with extensions beyond BON sites) to provide a very sophisticated understanding of the spatial and temporal distribution of these organisms. This understanding will provide the basis for an equally sophisticated level of monitoring of the status of these organisms for the future. Thus monitoring projects, on a time-scale appropriate for the organisms in question, are very appropriate BON activities.

We thus anticipate a wide range of projects at BON sites that will fit under a "survey and inventory" umbrella. Projects ranging from the determination of the number of pairs of summer-resident trogons in each canyon in the mountains of southern Arizona and New Mexico, to those determining the species of soil microbes in a cubic centimeter of soil from three habitats in BONs across a latitudinal gradient will all be necessary to document biodiversity as it exists today in the U.S.

There was consensus among workshop participants that the very nature of the BON requires that essentially all such survey and inventory projects take place at more than one observatory. A minority of participants argued for a series of “core taxa” that would be surveyed at all BON sites. Most participants instead urged a more flexible approach, with research questions driving both choice of taxa to be inventoried and the appropriate sites in the BON network for those inventory projects. Even in the absence of “core taxa,” it is clear that large, comparable datasets for a number of groups of organisms can and must emerge from the BON. We therefore urge that BON guidelines stipulate that prospective observatories must collaborate with others such that survey and inventory projects contribute broadly and comparably to our understanding of biodiversity

in the U.S. The NCAB can immediately work to stimulate cross-observatory survey and inventory projects by hosting workshops to design such projects. It will be absolutely key that such workshops include not only the nation's experts on birds or mammals or angiosperms, but also a number of scientists actively involved in the BON (i.e., at the outset, individuals participating in proposal preparation, further down the line, individuals who seek to develop research projects sited at least in part at several existing observatories).

Further, although our workshop focused on systematics, it is clear that survey and inventory projects that are inclusive of the range of biodiversity scientists are to be strongly encouraged and, in fact, required. Thus systematists, ecologists, and geoscientists might work together both to document the ranges of a set of taxa and to understand the biotic and abiotic basis for those ranges.

The survey and inventory component of BON research is also likely to yield a number of projects that are methodologically oriented: which methods work best to sample group X, with and without constraints imposed by budget and time. These are highly appropriate BON activities especially if they either involve multiple observatories or are specifically designed to address network level issues and problems.

B) Putting the U.S. Biota into Global Context

Even if we had complete lists of species for all groups of living organisms that occur in the U.S., we would not be able to attain many of the goals set forth by the PCAST report and identified by these workshops. The U.S. is not an independent biological universe. Understanding the U.S. biota requires understanding evolutionary links between that biota and the rest of the world. Thus, to achieve the goals of the BON, we must also understand the context in which the biota of the U.S. exists, that is, its relationships to the world's biota at large. Which groups are endemic to the U.S. and which have very close relatives elsewhere? What portion of the flora/fauna has evolutionary "roots" in the tropics to the south? What portion of the flora/fauna arrived via dispersal over the Beringian land bridge or over the isthmus of Panama? Which groups have been in this region for millions of years and which have arrived more recently? These questions are addressed in the context of phylogenetic relationships: by developing explicit hypotheses regarding the relationships among species and higher level lineages and then using these phylogenies in the context of other kinds of data (e.g., geographic range, habitats, pollinators, parasites) to explore questions of the sort raised above.

For some groups, traditional sites, as here proposed for BON, and especially a carefully sited series of them, will support both kinds of systematic research. However, for other groups (e.g., vertebrates, angiosperms), a site-based approach is not sufficient for this second sort of systematic research (and even

survey and inventory work on these groups will be interesting only if it adds textural detail to our understanding of these organisms [e.g., detailed information on ranges, life histories, associated species as alluded to above]). This is true also of other kinds of biodiversity research: some projects that seek to understand the ecological context of biodiversity can be accommodated at BON sites whereas others are larger or broader in scale.

Indeed, workshop participants emphasized that one of the most serious challenges that faces successful implementation of BON is the need to strike an appropriate balance between local and global perspectives. The vision of BON is to increase our knowledge of biodiversity in the U.S. and to promote integrative research in part by providing a geographic focus. However, BON will fail to produce the desired outcome if that focus is so restrictive that research occurs only at the designated BFSs. BON programs must actively include research that strives to put these local sites into a broader national and international perspective.

With this in mind, the BON must expand the concept of site to include facilities from which travel is possible and supported logistically. The observatories should have field vehicles that are available to researchers working both on and off-site. Especially critically, observatories should be prepared to help researchers with research and collecting permits and other bureaucratic hurdles that can thwart research. That is, there is a component to the functioning of the observatories that will be like that of the central offices of the Organization for Tropical Studies and the Smithsonian Tropical Research Institute in Costa Rica and Panama, respectively.

From the perspective of systematics, we anticipate that BON will support a number of projects for large-scale, clade-based phylogenetic research. Our vision of these is not redundant with what is currently funded by NSF Systematics panel. Specifically, to qualify for full or partial support from BON, a project must:

- Treat a major element of biodiversity (the particular group of organisms involved will dictate what constitutes major)

- Conduct research on a group with significant representation in the U.S. (significant might mean numbers of species or it might mean taxa of special interest)

- Treat the species belonging to the group that occur in the U.S., including but not limited to BON sites

- Involve multiple investigators, ideally some of whom will be sited at the collections institutions associated with observatories

- Build phylogenies based on multiple sources of data

- Intend multiple research approaches involving and linking to BON sites (e.g., study of phenology, life history, biotic relationships; gathering of detailed information on ranges)

- As appropriate, commit to provision of user-friendly, illustrated, soft and hard identification guides to the organisms that occur at observatories and ideally that occur in the U.S. as a whole

VI. Impediments and Possible Solutions

Workshop participants were excited by the opportunities that the BON would provide, but also recognized possible impediments to its success. We were especially concerned to identify potential impediments related most directly to the activities of systematists and collections-based institutions. These fall in two broad categories: the availability of taxonomic expertise, and the ability of museums to accommodate the increased demands that the BON would inevitably create. We believe that without careful attention to these impediments, the BON would fail to realize its potential, and we offer several suggestions as to how these problems might be solved. Some problems can be addressed directly within BON; others, we believe, will require the allocation of funds to existing programs within NSF. Recognizing both the seriousness and the complexity of these issues, we further recommend that they be addressed on a continuing basis by a BON Steering Committee (see below).

Expertise Impediments: For many taxonomic groups, we anticipate that BON will produce a demand for expertise that far exceeds existing human resources. This so-called "taxonomic impediment" has been extensively documented in previous reports (e.g., "Systematics Agenda 2000: Charting the Biosphere," 1994; "Biodiversity: The UK Action Plan," 1994). Here we simply note that for eubacteria, archaebacteria, microscopic eukaryotes, various algal groups, fungi, many insect groups, etc, there are simply not enough trained taxonomists to accomplish the tasks of the BON, including the most basic identifications. BON will be unsuccessful if this problem is not addressed.

Possible Solutions: Funds are needed to support taxonomic training, especially in little known groups of organisms, at the undergraduate, graduate student, and postdoctoral levels. Proposals to the BON program that include such training should be strongly encouraged. In as much as training is also linked to the availability of jobs, proposal should also be encouraged which show institutional commitment to the creation of new positions for taxonomic experts. We also recommend that with the creation of BON, the allocation of funds to existing NSF programs related to taxonomic training should be re-evaluated and supplemented. In particular, we recognize the great importance of the

"Partnerships for Enhancing Expertise in Taxonomy" (PEET) program within Systematic Biology, and the role that an expanded PEET program could play in connection with the BON. Likewise, there may be opportunities to augment support for training programs through EHR, such as the IGERT program. In view of the long range nature of such training programs, we also recognize the need to support existing taxonomic experts who take on significant work in connection with BON projects, through the provision of summer-salaries, release time from other obligations, etc.

Infrastructure Impediments: New specimens produced in connection with baseline inventory work, monitoring, and other BON research projects, will exert enormous pressure on space, equipment, and personnel of collection-holding institutions. That these institutions are not adequately funded to address existing demands has been documented elsewhere (e.g., "Systematics Agenda 2000: Charting the Biosphere," 1994; "Biological Collections at Risk," 1997). Without additional support, these institutions will be unable to cope with the new demands, and the long term value of the BON will be severely compromised. Here we also specifically note that crucial information about BON sites is housed in existing collections, but that these data have not yet been captured electronically and are not network accessible. BON collection-holding institutions will likely be unable to accommodate such tasks, or the database management requirements of the BON program, with existing staff.

Possible Solutions: Resources should be included in relevant BON proposals to assist collection-holding institutions to prepare for the influx of new material, including funds for preparing, housing, and curating specimens. BON proposals should also be encouraged that include support for database management personnel, as well as personnel to enter BON-related specimen data into databases. Although funds should be funneled through BON for these purposes, we also recommend that the budgets of those programs within NSF that now provide funds to collections institutions should be augmented with the impact of the BON in mind. In particular, this should include the "Biological Research Collections" (BRC) program within BIR, and the Database Activities program.

VII. BON Proposals and Program Organization

We recommend that the BON program be substructured for purposes of soliciting and evaluating proposals (NSF is experienced with such organization, and has recently initiated programs with complex substructure, such as Knowledge and Distributed Information [KDI]). Specifically, one panel should handle infrastructure proposals, including the initial competitions for the NCAB and for observatories, as well as the subsequent addition of new observatories to the network. A second

panel should handle proposals focused on biodiversity research at BON observatories and beyond.

In evaluating all proposals and making awards, the BON program should be guided by the principle of building a functioning network, better able to fulfill its fundamental mission of obtaining, understanding, and making available crucial information on the nation's biodiversity. As emphasized above, proposal evaluation should bear clearly in mind the goal of fostering research that cuts across the standard disciplines bearing on biodiversity, and should therefore specifically favor proposals for observatories at which multidisciplinary, often long term, studies can be sited. Similarly, research proposals that include both solid disciplinary research and strong cross-disciplinary components should be favored.

A) Infrastructure Proposals

Coincident with the establishment of the program it will be necessary to carry out a special competition to select a site for the BON core facility. Thereafter, it will be necessary to maintain an operating budget for the NCAB, as well as to make special awards for activities and projects centered there. We would especially encourage the allocation of funds to the center to provide small grants to support research and planning meetings involving BON participants, postdoctoral fellowships, and a visiting fellows program (e.g., sabbatical leave projects carried out at the center, etc.).

Subsequently, this panel would be responsible for proposals to establish the biodiversity observatories, and would provide continued funding for these, including infrastructure development. In addition, this panel would consider proposals for network-wide activities: the development of analytical tools, database development and data entry, and all aspects of training.

The San Francisco workshop rejected the "build it and they will come" model of designating sites/facilities. That is, there must be an explicit intellectual basis for the selection and establishment of observatories. The participants are skeptical that the ideal BON can be created as an outcome of a single competition to create these observatories. Therefore, we believe that the best way to ensure the creation of a successful BON is for NSF to adopt a progressive implementation strategy for Observatories. Once an initial suite of Observatories has been established, proposals to establish additional Observatories can be evaluated not only on their own "independent" merits, but also on the basis of how well they complement and actively coordinate with pre-existing Observatories.

Specific proposal types envisioned at the San Francisco Workshop are presented here for guidance but are not meant to be proscriptive in any way.

- At the outset of the program, proposals will be submitted to establish observatories. These should be carefully justified in three contexts: importance of the observatory in terms of the nation's biodiversity, appropriateness of the site in terms of question-driven research that will be sited there, and existing or newly established infrastructure and linkages. Thus, these proposals should present clearly the capabilities and characteristics of the BCI(s), of the associated BFS(s), and the linkages between them. In the case of the BCI(s), it will be necessary to document infrastructure and capacities with respect to specimen management/curation. In the case of the BFS(s), it will be especially necessary to document long-term accessibility, security, and facilities for research. We anticipate that some proposals for observatories will be presented as teams of observatories centered around particular research themes. These proposals would need additionally to justify the focal theme, the appropriateness of the set of observatories with respect to this theme, the personnel involved, etc.

- Proposals to add individual observatories to the network should also be accommodated, with special emphasis placed on the addition of compelling biological phenomena or otherwise missing habitats and/or special significance in connecting to one or more existing observatory sub-networks. Again, the appropriateness with respect to BON research themes and of the existing infrastructure will need to be carefully documented and justified.

- Awards for the maintenance and development of existing observatories will be necessary to promote their functioning as the projects utilizing them develop, and as new projects are added. Here we envision proposals to develop new infrastructure at particular observatories. In addition to items such as computers and other machinery, requests for infrastructure related to the maintenance and proper curation of museum specimens related to BON projects must also be encouraged.

- Awards should also be made for database activities associated with the BON. Here we include projects focused on data obtained in connection with new inventory activities, but also the databasing of archival information. We view retrospective capture of the data associated with museum specimens as critical to the BON mission, especially as such data provide context for the diversity present at observatories and base-line information for the analysis of spatial and temporal changes in diversity. In addition to database development, it is critical that funds be made available to populate databases with the relevant data, since BON activities and products ultimately depend on the ready availability of these data.

- Proposals should be solicited that lead to the development of specific approaches and technical tools that are especially useful from the standpoint

of obtaining, synthesizing, or analyzing data that emanate from the BON. Here we would include the development and testing of new inventory and/or identification methods, new database tools, new analytical techniques to make use of BON data, etc. Special emphasis should be placed on the development of products that are broadly applicable across the entire network.

- Proposals to use the network, core facility, or particular observatories for training activities should be strongly encouraged. Here we include informal science education projects (including the creation of web access, production of field guides, etc.) , as well as the training of undergraduate, graduate, and postdoctoral students. Of special interest are proposals that involve training to fill gaps in taxonomic knowledge, as the shortage of systematists in many groups is a major impediment to fulfilling the BON mission.

B) Research Proposals

This panel would focus on hypothesis-oriented proposals submitted by individual PIs or multi-disciplinary teams of PIs who wish to make use of BON facilities and data. It would oversee research making use of the BON, including projects specifically focused at BON sites and projects that enhance the value of the network through studies that extend outside of BON. Because proper identification of organisms under study is seen as a primary means of integrating research within and between Observatories, proposals must specify the collection, preparation, accession at a BCI, and databasing of voucher specimens. Training and informal education components would be a highly-valued component of all research proposals.

The Research goals of BON are described in detail above and in earlier Workshop reports. Proposal types envisioned at the San Francisco Workshop are presented here for guidance but are not meant to be proscriptive in any way.

- Proposals to carry out biodiversity inventories at particular sites, or especially across observatories, should be strongly encouraged, as these will generate primary data upon which other BON research depends. Such proposals might focus on particular groups of organisms (e.g., weevils, basidiomycetes), or coordinate inventories for several groups in a particular habitats (e.g., soils). Awards might also be made to use BON sites in assembling collections for special purposes (e.g., DNA samples).

- Research proposals focused on the assembly and analysis of data associated with the BON should be a prime focus of the program. While it is difficult to anticipate the nature and variety of such proposals, we expect many to focus on the analysis of biodiversity (species or clades) in relation to various abiotic

or biotic environmental gradients. Studies of biodiversity in relation to ecosystem functioning and services, or in relation to human impacts, should also be strongly encouraged. Patterns of diversity through time, including the relatively recent past and the deeper history of the biota, would also be highly appropriate, along with studies of change in the biota since the establishment of BON.

- Research designed to put BON information in perspective, or otherwise add value to BON data, should be strongly encouraged. Here we specifically mean to include studies that obtain and/or analyze data from sites outside of BON itself, but which clearly bear on the interpretation of data collected at BON sites. Such proposals would include ecological studies at sites outside of BON, as well as clade-oriented studies that put elements of the BON biota in broader phylogenetic and biogeographic perspective. In such cases, funds for field and museum studies outside of BON would be highly appropriate.

Whereas many proposals would fall within the purview of one of these two broadly circumscribed panels, it is clear that some proposals will overlap them. Therefore, it will be critical to closely coordinate the activities of such panels within the program. We also anticipate the submission of proposals that will connect to the mission of other programs within NSF. For example, a proposal involving the development of taxonomic expertise in a poorly known group of organisms would relate directly to the mission of the "Partnerships for Enhancing Expertise in Taxonomy" (PEET) program within Systematic Biology in DEB. Likewise, a proposal to enhance the infrastructure of an observatory (e.g., add museum cabinets) would be relevant to the "Biological Research Collections" (BRC) program within BIR. In such cases, arrangements to share funding among programs may be most appropriate.

In view of the evident complexity of the BON program, we strongly recommend that a BON steering committee be established, including NSF officials and outside members. This committee would oversee the development of the overall organization of the program, as well as provide advice and coordination as the program develops. In view of the broad nature of the program, and the desire to create a structure that fosters truly new activities and understanding, the selection and orientation of BON panels will be especially critical.

VIII. Budget

Creation of the BON will require a NSF budgetary commitment to establish and maintain (a) the BON Observatory infrastructure required to support BON activities, most of which will be add-ons to current programs; (b) a research program to make use of the BON Observatories in order to fulfill the research goals of the program, and (c) a center, NCAB, to provide for coordination among the scientific and informatics activities of the BON Observatories. Without a substantial

financial commitment to these three budget categories, we believe that the benefits of a BON identified in this report will not be realized. It is our opinion that current programs within the Division of Environmental Biology are inadequate to meet these goals and that incremental additions to their budgets will not meet the objectives expected from the BON.

The Workshops in Santa Barbara and San Francisco are in agreement that the long-term goal of BON should be to establish multiple, geographically distributed Observatories in ecologically diverse environments across the United States. In order to build an effective network, one that will meet the scientific objectives of BON and provide input to a broad user community, we estimate the total number of Observatories in a fully functional BON should probably number between 50 and 75. Both workshops recommend that the BON be established gradually in order to establish a baseline of information and experience that will make growth efficient and effective. This will mean the costs of establishing these observatories can be spread out over many years.

The Observatories are the fundamental elements of BON. Because these will be comprised of pre-existing biodiversity research institutions (BCIs and BFSs), the investment required to prepare them to support interdisciplinary research is relatively modest. Nevertheless, most of these institutions will require additional infrastructure and staff to support the BON research and activities. Possible additional infrastructure might include installation of electronic network capabilities, improving facilities to house additional scientists, facilities to house specimens temporarily, and additional or improved laboratory space. Possible staff additions must be in the areas of informatics, collection management of care, and logistical support.

There will be, in addition, a need to acquire as soon as possible baseline scientific data at the Observatories, including the retrospective databasing of specimen information, acquisition of new baseline data and specimens in the field, and establishment of a monitoring program. These activities will be the responsibilities of the institutions forming the Observatory, or in some cases may be handled through collaborations involving other institutions.

Along with establishing the infrastructure (Observatories) of BON, resources will be required to support the research that makes use of the network. Many of the existing NSF programs do not support the kind of interdisciplinary biodiversity research for which BON is ideally suited, nor do they target many other kinds of research (large-scale inventories, ecosystem research) that most logically will utilize the BON. These research needs will require a long-term financial commitment.

Finally, all three NSF workshops concluded that a core facility, here called NCAB, is essential if BON is to achieve its scientific potential and societal relevance.

This facility will be charged with many activities and responsibilities that will be unique to BON and cannot be easily delegated to existing facilities. Resources will be required to establish the infrastructure of this facility, to properly staff it, and to initiate scientific and coordinating activities associated with the BON.

Given these considerations, we recommend the following budgetary guidelines for establishing and maintaining the BON:

BON Observatories. We recommend that a minimum of 20 Observatories be established within the first three to five years of the program, and that approximately 5 Observatories be added each year over a 10-year period. We estimate an initial input of $2- 4M per Observatory over a 3-5 year granting period; after that period, maintaining Observatory activities may require $0.5-0.75M / year. Start-up costs will, of course, depend on existing infrastructure. However, we anticipate that all Observatories will require additional bioinformatics-related infrastructure, as well as resources to undertake scientific activities, including salaries for new personnel.

BON Research. Once the initial Observatories are established, we recommend that a minimum of $10-20M / year be targeted for research, including common inventory and monitoring activities across BON Observatories and investigator-originated research using the network. This commitment should grow as Observatories are added to the network.

National Center for Analysis of Biodiversity (NCAB). Based in part on the NSF's experience in establishing NCEAS, we recommend an initial start-up budget of $8-10M for a 5-year period, with renewal at a similar level of support after that time as the center's activities expand. In addition to initial setup costs and ongoing expenses related to the informatics functions, these funds would support an NCAB staff of up to ten people, a program to support postdoctoral students and visiting researchers, and a substantial number of workshops and training activities.

IX. Participants

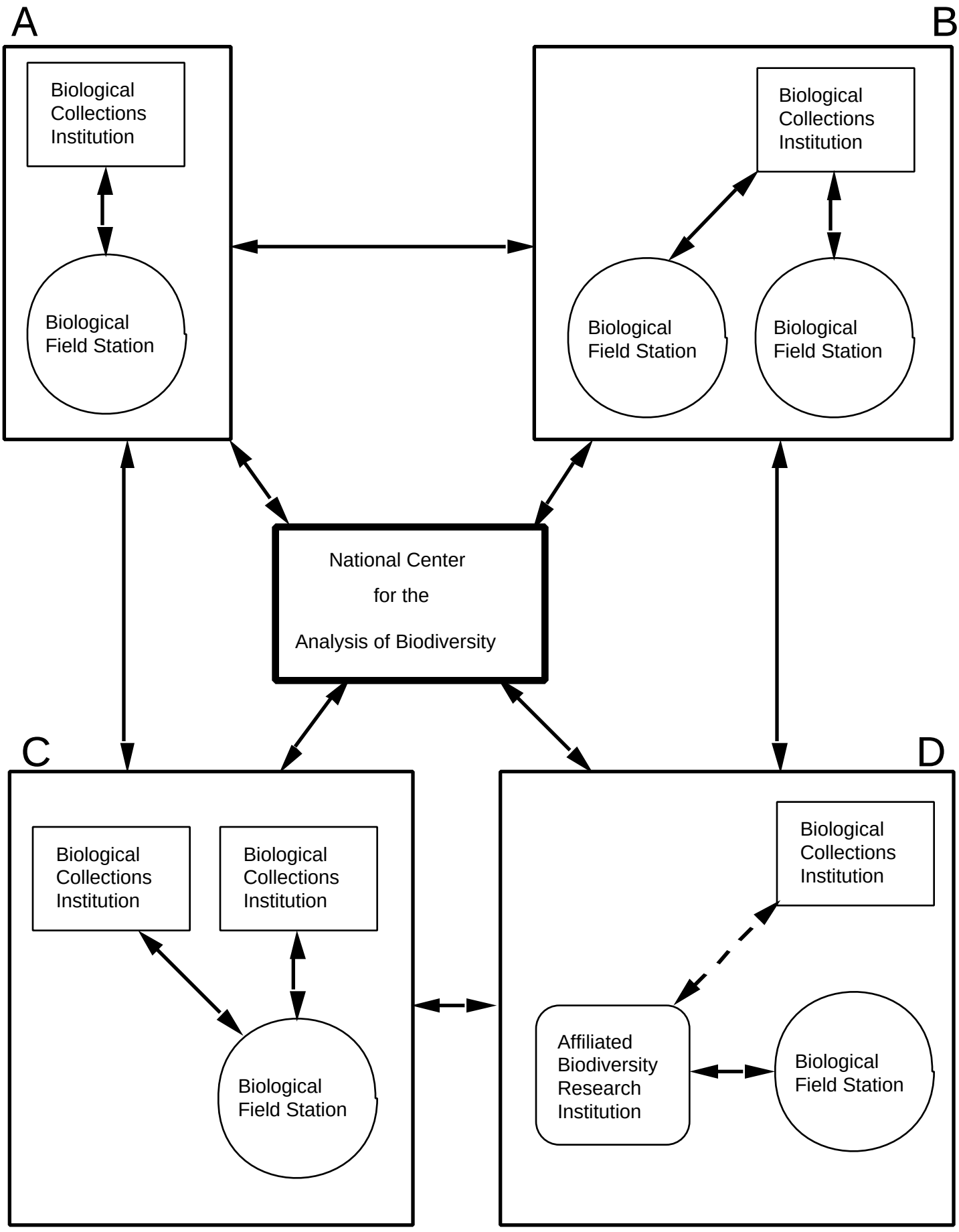
Co-Chairs: Patrick Kociolek, Michael Donoghue

Writing Committee: Joel Cracraft, Michael Donoghue, Patrick Kociolek, Scott Lanyon, Lucinda McDade, Brent Mishler

Attendees:

Stan Blum, California Academy of Sciences, CA
Richard C. Brusca, Columbia University, Biosphere 2 Center, AZ

David C. Cannatella, Texas Memorial Museum, TX
Joel L. Cracraft, American Museum of Natural History, NY
Keith A. Crandall, Brigham Young University, UT
Dennis Desjardin, San Francisco State University, CA
Michael J. Donoghue, Harvard University, MA
Terry L. Erwin, National Museum of Natural History, DC
Roberta Faul-Zeitler, Association of Systematics Collections, DC
Jud Fuhrman, University of Southern California, CA
Scott L. Gardner, University of Nebraska State Museum, NB
Terrence M. Gosliner, California Academy of Sciences, CA
Michael E. Irwin, University of Illinois, IL
Patrick Kociolek, California Academy of Sciences, CA
Scott M. Lanyon, James Ford Bell Museum of Natural History, MN
John "Jack" T. Longino, The Evergreen State College, WA
John G. Lundberg, University of Arizona, AZ
Joel W. Martin, Natural History Museum of Los Angeles County, CA
Lucinda A. McDade, University of Arizona, AZ
Brent D. Mishler, University of California, Berkeley, CA
Steven A. Nadler, University of California, Davis, CA
Barry M. O'Connor, Museum of Zoology, University of Michigan, MI
Jose Panero, University of Texas, TX
Ronald Peterson, University of Tennessee, TN
Donald H. Pfister, Harvard University, MA
Donald C. Potts, University of California, Santa Cruz, CA
Fred A. Rainey, Louisiana State University, LA
O.J. "Jim" Reichman, University of California, Santa Barbara, CA
Douglas Siegel-Causey, National Science Foundation, VA
Ellen L. Simms, University of California, Berkeley, CA
Felix A.H. Sperling, University of California, Berkeley, CA
Melanie L.J. Stiassny, American Museum of Natural History, NY
Eugene F. Stoermer, University of Michigan, MI
David Wake, University of California, Berkeley, CA


A
B
Biological Collections Institution
Biological Field Station
Biological Collections Institution
Biological Field Station
Biological Field Station
National Center for the Analysis of Biodiversity
C
D
Biological Collections Institution
Biological Collections Institution
Biological Field Station
Biological Collections Institution
Affiliated Biodiversity Research Institution
Biological Field Station