Report to the National Science Foundation

From the

Fourth Workshop on the Development of a National Ecological Observatory Network (NEON): Standard Measurements and Infrastructure Needs

Held at
The Millennium Hotel
Boulder, Colorado
4-5 June 2002

Introduction

From 4-5 June 2002 a group of 22 participants and 3 observers (See appendix) gathered in Boulder, Colorado to develop a plan for standardized equipment needs and measurements for all NEON observatories. As in previous workshops, the group enthusiastically endorsed the proposed development of a national network of ecological observatories. This report provides examples of how NEON will expand research capabilities beyond anything current available, which will greatly advance ecological research and our understanding of the environment. It also provides examples of how such a network can be of service to the Nation's, including the development and training of future generations of the Nation's technological workforce.

I. Overview: What will we be able to do with NEON that we cannot do now?

At present we cannot track biological or ecological events in time and space because we do not have a synoptic observation system at the regional and national scales. These deficiencies leave us ill equipped to trace backward in time the cause, origin and expansion of biological and ecological events because we do not systematically archive environmental and ecological samples for future analyses. NEON will provide the research platform to track dynamics in ecology, climate and biodiversity, to archive biological specimens and records for scientific analysis in the face of future technological and analytical developments, and in general, to quantify the dynamics of the nations ecosystems. Our capacity to predict ecological futures is severely limited to site and local scale predictive capability. The proposed national system of NEON observatories will put in place the science infrastructure to build the knowledge base needed to forecast the status and trends of regional and national ecological systems.

Disease and the risk of disease exposure are closely linked to the dynamics of ecological systems. While we track nationally the epidemiology of diseases, we are not able to track in similar fashion changes in the ecological components of disease systems and, thereby foster mitigation. NEON will provide a research platform from which to accomplish this surveillance.

Abrupt and catastrophic changes in ecological systems induce economic and cultural and dislocations of national significance that may on the one hand arise from natural process or on the other hand from intentional actions designed to damage regional and national ecosystems and human well-being. NEON will provide a base of understanding and to contribute to the mitigation of these damages.

II. Climate and Hydrology

NEON will provide opportunities to develop instrumentation at the Core Observatory and within satellite networks capable of regional assessment and analysis of climate and water dynamics at scales ranging from near instantaneous to decadal. Complete characterization of regional climate and hydrological systems, and evaluation of future changes in these systems, will require broad coverage using distributed networks of weather-sensing stations, surface and subsurface water flows, and near-real time processing of data. Individual NEON observatories are recommended to include the following key features:

(1) A spatially distributed network of weather-monitoring stations (hereafter called the climate mesonet) connected in near-real time to the Core Observatory and to an internet interface capable of rapid distribution to the community at large. The climate mesonet should support two fundamental aims: (a) the development and deployment of weather and ecological forecasting using current and future generations of coupled biosphere-atmosphere models, and (b) the evaluation of climate and ecological variability at numerous time scales, including decadal trends. The use of near-real time weather data with coupled biosphere-atmosphere models can provide powerful new capabilities, not only in the area of weather forecasting, but also in relation to forecasting fire danger and movement, the dispersion of pollutants and toxic/ pathogenic plumes and other environmental hazards. The exact number of individual weather stations to be included in the climate mesonet is expected to vary depending on the nature and size of the proposed observatory footprint; however, the network should be capable of characterizing variability in the dominant length and time scales. As an example, in mountainous terrain, stations should be spaced to detect relevant topographic forcings at the diurnal scale. On the Central Plains, stations may need to be more closely spaced, and measurements may need to be collected more frequently, in order to pick up relevant features of the dominant convective motions that drive extreme weather phenomena. It is recommended that each weather station in the climate mesonet include measurements of:

a. radiation (including incoming solar radiation, net radiation and photosynthetically-active radiation),
b. precipitation,
c. soil temperature and soil heat flux,
d. barometric pressure,
e. wind speed and direction (at minimum of two heights),
f. air temperature (at minimum of two heights),
g. humidity (at minimum of two heights).

The measurement of wind speed, air temperature and humidity is intended to provide at least a rudimentary vertical profile capable of being used to estimate sensible and latent heat fluxes according to the "flux-gradient" approach. To accomplish this, humidity sensors will have to be high quality with outstanding accuracy. The estimated cost of each weather station is estimated to be $25 K.

(2) A subnetwork of sun photometers to be co-located at some of the weather stations in the climate mesonet. This network is intended to resolve the length scale of atmospheric transmissivity (primarily affected by water vapor) for the purpose of rigorous atmospheric correction of satellite data. The presence of this subnetwork will greatly improve the ability for observatories to analyze remotely-sensed images that are expected to be a critical part of the regional data archive. The estimated cost of each photometer is $20 K.

(3) A subnetwork of ecohydrologic sensors to be co-located at some of the weather stations in the climate mesonet. The purpose of this subnetwork is to evaluate water and nutrient transport and transformation, and the role of surface and

subsurface water in the regional energy budget. Examples of components of this subnetwork are soil moisture profiles, shallow ground water wells, lysimeters for measurement of evaporation, and soil moisture lysimeters for nutrient content analysis. The estimated cost of each ecohydrologic station is estimated to be $4 K.

(4) A broader-scale ecohydrologic network, not necessarily co-located with the weather station of the climate mesonet. The purpose of this network is to characterize the dominant surface and subsurface components of the regional hydrologic cycle, which will permit the understanding of aquatic-terrestrial interactions, hydrologic flow paths and aquatic biogeochemical dynamics. Examples of components of this broader network include stream and river gauges, subsurface gauges (hyporheic gauges), snow surveys and/or remote sensing. At coastal sites, components may also include high frequency and low-frequency tidal gauges, bathymetric surveys, optical current meters and salinity and temperature measurements. Part of this network may already exist in observatory footprints due to activities from other agencies (e.g., USGS, CUAHSI). Groups are encouraged to work with agencies to integrate new components of the NEON ecohydrologic network with existing components. The estimated cost of each ecohydrologic station is estimated to range from $3-50 K.

(5) An intensively instrumented "super-site" should be located at the Core Observatory for the purpose of more intensive and extensive measurements than those taken at the distributed stations of the climate mesonet. Groups are encouraged to refer to the DOE Atmospheric Radiation Measurements (ARM) sites in Alaska and the Southern Great Plains (Oklahoma) for an example of the super-site. Measurements that should be included at the Core Observatory super-site, in addition to those of the mesonet stations, are:

a. UV radiation,
b. aerosol optical depth,
c. diffuse versus direct radiation,
d. boundary-layer profiling,
e. high frequency — high accuracy atmospheric pressure (for use in atmospheric turbulence modeling),
f. eddy flux measurements of energy and water.

Data streams from the climate and hydrology satellite networks must be made available in near-real time (15 min — 1 hour) for use in environmental forecast and analysis models. It is expected that groups will be integrally involved in the development of regional wireless networks and other developments in telecommunications. Groups are encouraged to work with existing regional telecommunications networks to facilitate data transmission from the satellite sites to the Core Observatory and ultimately onto the Internet.

Groups need to propose strategies for management of the immense amount of weather and hydrologic data including, quality assurance and quality control, metadata collection and integration, the development of searchable databases, and long-term archiving. As an indication of the magnitude of this task, the Oklahoma Mesonet (115 weather stations) generates 1 million observations per day. Standards for this type of data management already exist in agencies and institutions that conduct weather forecasting and simulation, and groups are encouraged to learn about these standards as an initial step.

The overall maintenance and operations budget that will be required to maintain all of the climate and hydrology networks, including maintenance, replacement and calibration is estimated to be 10% of the overall instrument costs.

III. Biodiversity

Biological monitoring at the broadest phylogenetic level is one of the core functions, and one of the unique opportunities of the NEON program. Monitoring distributions and abundances across the Tree of Life, including microbes, plants and metazoans has never been accomplished, yet understanding how natural and anthropogenic environmental change affects organisms is a key goal in understanding ecosystem function through time. NEON offers the physical sites and the instrumentation to conduct phylogenetically-complete monitoring across the Tree of Life.

The research and public service components of biodiversity surveys at this phylogenetic level are enormous. To take one example, the emerging field of Community Phylogenetics requires phylogenetic trees of all taxa from a given community, with the goal of discovering the phylogenetic assembly rules that govern community ecology. Attempts at this novel research strategy have thus far been restricted to a small collection of vascular plants, but the research is grounded in using a phylogenetic perspective to understand how complex food webs, mutualisms, predator/prey and competitive interactions are assembled into communities across all taxa. Bringing microbes, plants and metazoans together with the molecular resources provided by NEON will enable Community Phylogenetics to emerge as a distinct discipline.

Intensive biological monitoring affords the opportunity to track key taxa of societal and economic importance as well. Invasive species, human, livestock and agricultural diseases, endangered species, as well as indicator taxa including amphibians, songbirds and butterflies will provide information that is critical to monitoring ecosystem health of natural and human-modified landscapes. In some cases, existing databases in museums and herbaria collections can provide a historical context that will allow NEON monitoring to provide immediate results of societal importance. In other cases, trends and patterns of species turnover and invasion will be generated over the decades-long time scale by the NEON site itself. Both will provide invaluable, completely novel levels of information that are critical in managing landscapes now and in the future.

Biodiversity Surveys

Much of the sampling of biodiversity will require traditional techniques; however, the development and implementation of novel approaches to monitoring biodiversity are encouraged, where possible. Each NEON observatory should monitor all major phylogenetic groups of life, using accepted approaches for each group. These surveys should involve both permanent plots and observatory-wide sampling. In addition to this baseline information for all groups, specific types of organism should be monitored, as appropriate to the observatory, such as indicators of environmental change (e.g., amphibians, lichens, aquatic organisms), invasive species, sensitive, threatened, and endangered species, species of social relevance (e.g., disease organisms, organisms of bioterrorism, viruses). Surveys of all organisms will involve collections, and these collections should be archived in appropriate facilities (e.g., museums and herbaria, a centralized NEON facility for soil and water samples, or at the core site). In addition, museums are moving toward the incorporation of digital images, perhaps of the entire collection, in their archives. Thus, provision should be made for acquisition, storage, and curation of both digital and real collections. We anticipate that an observatory would make use of the collections and check lists compiled in its region (from universities, state and other agencies); ideally, collection information would be databased and archived for use by the observatory.

Molecular Monitoring

A major focus of biodiversity sampling at NEON observatories will be groups of organisms or dispersal units that are not easily sampled by traditional techniques, such as insects, arthropods, pollen and spores, plus microbial communities, with samples representing Bacteria, Archaea, Fungi, and other microbial eukaryotes. For microbial sampling, novel approaches, initially involving gene sequence identifications and ultimately microarrays, will prove most useful. Soil samples should be obtained from permanent plots, with replication, from multiple habitats within an observatory. Phyloinformatics, using existing RNA gene databases, will be used to match sequences obtained from these soil samples to known samples. We envision that soil samples will be processed at the core site labs and sent to a centralized NEON molecular laboratory for further analysis (initially DNA extraction, sequencing, and informatics). Ultimately, the centralized facility will use the information gathered through these analyses to develop microarray approaches for more rapid and efficient monitoring of microbial organisms. Ideally, the microarrays will incorporate information on microbial function as well as diversity. Similar approaches will be beneficial for groups with large numbers of unidentified and undescribed species and for dispersal units such as pollen and spores.

IV. Biogeochemistry Group Report

The cycles of carbon, nitrogen, phosphorus, many other major biological nutrients, as well as trace elements and pollutants are all changing due to human activity. The dynamics of major biogeochemical cycles have direct implications for human health and well-being, both directly, and indirectly via effects on ecosystem goods and services. The pace and scale of biogeochemical changes is beyond both the time and space scales of many traditional scientific studies, and therefore requires coordinated networks that can effectively document such changes for decades, with high spatial resolution at continental scales. The observational capability of a NEON network can provide such data, thereby greatly improving our capability to predict and respond to biogeochemical changes that affect human and ecosystem welfare.

Requirements for Biogeochemical Data

At a minimum, all NEON sites must address the inputs, internal dynamics and outputs of carbon, nitrogen, phosphorus and biologically important base cations across the landscape. Analyses of other elements are encouraged as appropriate for a given site. A biogeochemical strategy should also extend beyond the major element cycles, in particular to consider the characterization of fluxes and accumulation of both organic and inorganic ecologically important pollutants. As well, a regional NEON approach must take into account the full range of landscape heterogeneity, including land use strategies, across both terrestrial and aquatic systems.

Each NEON site should include a continuous documentation of biosphere-atmosphere exchanges of CO_2, H_2O, carbonaceous trace gases, and nitrogen gases using eddy flux techniques in which standards used are consistent with the current Ameriflux network. These measurements should include isotopic characterization as much as possible, and effective landscape-scale estimates of biosphere-atmosphere exchange must also include data on the vertical structure of the lower atmosphere (e.g. lidar; see climate and hydrology section).

Core site documentation of biosphere-atmosphere exchange via the use of eddy flux techniques should be coupled with a landscape-scale strategy for documenting key components of such exchange, notably net primary production, net ecosystem production, plant and heterotrophic respiration, and the soil flux of important chemically and radiatively active trace gases. In addition, significant efforts must be aimed at documenting belowground production. We recommend the formation of a rhizotron network that is coordinated at the national level, including the development of new software that can ensure a consistent and effective strategy for cross-site comparison of belowground root dynamics. Documentation of landscape-scale carbon dynamics should also include regular measurements of litter fall (where appropriate), decomposition rates and above and belowground pools of carbon.

These ground-based strategies for documenting the carbon cycle should be coupled to the use of remote sensing data that can provide annual, spatially resolved estimates of vegetation structure and dynamics. In addition, C fluxes and storage should be documented in aquatic as well as terrestrial systems; for the former, aquatic production should be analyzed using a network of datasondes. As with the eddy-flux measurements, landscape-scale data on the abundance of biogeochemical species should be complemented by isotopic characterization of such species to the maximum extent possible.

A strategy for documenting not only land cover change, but temporal and spatial variation in land use strategies (e.g. management type and intensity) is also essential to regional-scale estimates of biogeochemical dynamics. This strategy should merge remote sensing data with ground-based information. We suggest that each NEON site invest resources in becoming a core validation sites for the EOS platform, thereby providing access to imagery. This investment is relatively modest, and consistent with needs outlined in the climate and hydrology section, as it includes documentation of albedo, diffuse and direct radiation, sun photometers for atmospheric correction, and meteorological data.

We recommend a coordinated strategy where ground-based measurements of plant biomass, tissue chemistry and water content can be coupled to analyses of satellite imagery and aircraft hyperspectral data to allow large-scale, spatially resolved estimates of such variables. The NEON program should strongly consider leasing or purchasing a light aircraft on which at least an imaging spectrometer is mounted, thereby allowing the acquisition of the spectral data at ecologically important times.

Each NEON region should document atmospheric inputs of biogeochemically important species in both wet and dry forms. Where possible, it is expected that some of this information can come from existing networks, but these networks will likely need to be augmented, most notably for dry deposition where aerosol chemical and physical properties should be analyzed. Losses of biogeochemical species should also be documented by coupling to the hydrological and climate instrumentation, and should include lysimetry, watershed-scale measurements, and groundwater analyses. Use of in-situ automated sensors that can provide real-time data on water chemistry is strongly encouraged.

In general, strategies that make NEON sites compliant and consistent with other major national networks, including NASA satellite missions, USGS water quality networks (e.g. NAWQA), NADP, and EPA air quality measurements are strongly encouraged.

Each NEON site should propose a strategy for documenting key microbial functional variables, such as nutrient mineralization and microbial biomass, at the relevant spatial and temporal scales. As sites develop in the network, common techniques for such data should be agreed upon, facilitated by the coordinating committee.

In general, data should be collected using real-time, in situ techniques to the maximum extent possible. Where this is not possible, we recommend that NEON-wide laboratory facilities be developed that are responsible for major classes of analyses, such as isotopic analyses and biogeochemical analyses that cannot be done in situ. A single, central site is desirable both for economies of scale and to ensure consistent data across sites that allow robust comparisons (see below). Such central facilities should be designed to allow rapid turn-around of samples, so that data can be as close to "real-time" as possible. More generally, the ability to acquire and process information and make it available on-line rapidly is an essential component of all NEON sites. Thus, a strategy for routine, rapid automated data posting should be proposed.

Finally, each NEON program should devote significant resources and attention to the archival of soils, biota and water samples, stored in such a way that reconstructions of changes over time can be done in the future. A good archive strategy can allow the future production of a broad range of data that is either beyond the financial or analytical capabilities of the current program, or that is not recognized as ecologically important today.

National Analytical Centers

As the NEON effort develops, there will be a series of continuous and essential core samples, where analyses of those ecological materials are more feasibly conducted at a core national facility than at individual NEON sites. With respect to biogeochemistry, it is likely that analyses of stable isotopes and water quality chemistry are examples of such national needs. Justification for national centers with rapid analytical turnaround includes uniformity of analytical methods, consistency in standard across time for comparative consistency across data sets, and reduction in costs though large-scale sample processing. In addition, a national center serves additional critical roles, including: training for sample collection and analysis, education to train broadly in ecologically important areas, such as stable isotope analyses and water chemistry, where these sample approaches provide an integrated assessment (often at the molecular level), that can be applied to a variety of ecological questions. Having them concentrated on a single facility, rather than on multiple upgrades across individual sites also reduces the costs of future upgrades in analytical capacity. As an example of one such facility, we estimate that the cost of a central isotopic facility (light, stable isotopes only) would be approximately $1-2 million in capital equipment, with an annual O&M cost of roughly 300K.

V. Ecological Dynamics

A key component of NEON activities will be to sense (assess) fundamental change in integrated ecosystem structure and function. Specifically, the NEON observatory will facilitate the collection and analysis of data that can be used to address questions about what organisms are present in the nation's ecosystems, and how they interact to form the complex ecological dynamics that form the foundation for ecosystem health, and the ability of ecosystems to provide goods and services to citizens. It is recommended that each NEON Observatory site include the following attributes in the area of ecological dynamics:

(1) Regional landscape structure needs to be characterized for both the core and satellite sites. This will entail a combination of remote sensing and extensive ground truth data collection. Remote sensing measurements should be conducted according to protocols established by the proposed, central NEON Coordinating Unit. Landscape structure includes overall watershed structure, community types, and mosaic (patch) structure.

(2) Establish an extensive, permanent grid of sampling sites in order to systematically inventory all major and minor taxa. A complex of sites, representing characteristic landscape units, should be established at the Core Observatory and at all

satellite sites. At each site, species composition and community structure should be determined; these data sets should be thoroughly and accurately GIS-referenced.

(3) Phenology of the major landscape units and species should be measured at the core and satellite sites. Ice cover of lakes and snowpack (if applicable) will be determined, as will the time of budbreak for the major (or characteristic) perennial plant species, germination of annual plants, flowering of "indicator" plant species, emergence of insects and other key taxa, and arrival and nesting of birds. NDVI, which effectively integrates leaf area and chlorophyll content of vegetation, should be determined on a regular basis for the major sites via remote sensing. For aquatic systems, timing of phytoplankton blooms and fish spawning need to be determined.

(4) Ecosystem metabolism (production) needs to be measured in each Observatory. It is recommended that the quantification of NEP (net ecosystem production) be prioritized, with real-time data if possible. In terrestrial systems, this is best done with flux tower data; in aquatic systems with sonde data. At several intensive sites, NEP needs to be partitioned into aboveground and belowground components with harvest-biomass type data. A rhizotron network for belowground production needs to be established at intensive study sites, that represent major vegetation types; although this will require additional technical advances and national data coordination before mandating the network nationwide. Litter production should also be quantified as a proxy for aboveground NPP. Finally, it should be noted that production assessment techniques will differ across growth forms and ecosystem types, so although there is a mandate to quantify NEP/NPP within each Observatory, the actual techniques used to do so may be specific to regional ecosystem types.

(5) Invasive species should be monitored in two ways. First, the extensive grid of monitoring sites should be used as a permanent monitoring network to detect new invasive species. Second, each Observatory should establish a specific monitoring network to assess the distribution, abundance, and population structure of existing invasive species that are deemed to be important in that ecosystem type.

(6) Food web structure should be quantified in two ways. First, abundance of various taxa, by guild, should be determined in the extensive network of monitoring sites. Second, trophic relationships should be assessed through stable isotope analyses at the intensive production sites using multiple isotopes if necessary.

(7) Microbial dynamics should be assessed by linking microbial community composition and ecosystem function. Microbial biomass should be quantified at the intensive production sites and partitioned by bacteria, fungi, and microarthropods.

National Facilities

Within the framework of Ecological Dynamics, two primary national support facilities are encouraged for development:

- A remote sensing national interface; and
- A national rhizotron network with centralized data imaging support.

Rough Estimates of Costs

Given the potentially disparate techniques utilized in different ecosystem types to assess Ecological Dynamics, it is difficult to assess costs for any individual region or for the national network. However, the following "main ticket" items would potentially include:

- Towers and support infrastructure for the NEE/NEP measurement networks;
- Aquatic sonde networks, which could approach $2 million for an Observatory with extensive aquatic habitats;
- Remote sensing of landscape structure, NDVI, etc.;
- Rhizotron network.

VI. Spatial analysis and remote sensing

Spatial analysis needs to be augmented through remote sensing analysis utilizing a variety spectral and spatial scale observations. Analysis of spatial-temporal dynamics of landscape and land use units can be evaluated at the regional scale with a combination of current satellite (MODIS) and aircraft observations. NEON needs to strongly collaborate with NASA and other satellite-operating entities to provide regional information of seasonal and spatial data of various ecological features. Seasonal dynamics of land and aquatic systems (TERRA and AQUA) can be captured through moderate spatial resolution high temporal observations to capture events such as leaf out, algal blooms, plowing events, although these relatively simple sensors provide access to only a small number of biological variables (light utilization, phenology). Land use and land cover change can be derived from existing high-resolution sensors such as LANDSAT and IKONOS. Regular acquisition of standard satellite data will allow sensors within the NEON regions to be "tied together" to provide regional coverage.

Landscape patterns and seasonal events can be augmented by development and use of high spectral and high spatial resolution sensor deployment. Current sensors exist which can define landscape level pattern of vegetation structure and composition, disturbance events, and fine spatial scale pattern of biological activity on land and in water. This instrumentation can be deployed via aircraft platforms can be scheduled to fly over selected areas based on NEON requests and requirements. In time, there is a need to establish a NEON-directed aircraft system that can be deployed by NEON sites, and to acquire an airborne hyperspectral imaging spectrometer. Such a sensor can measure a large number of terrestrial and aquatic biological properties, at high spatial resolution. No space-based hyperspectral sensor is currently available on an operational basis. No existing airborne sensor has the flexibility to acquire data over 2-10 sites often enough to provide coverage of the seasonal cycle and interannual change. In time, as the NEON network expands, purchasing or leasing an aircraft could be required.

VII. Special training needs

The plan for NEON will require a significant ongoing training program to provide the technical skills for the scientific and support staffs of these large programs. Ongoing skills training will be needed in molecular techniques, meteorological measurements, analytical and isotopic chemistry and informatics. The NEON network, to guarantee data quality and standardization will need to organize training courses, curricula and distance learning programs. In addition, knowledge will need to be captured in manuals and documentation. This will be an ongoing effort due to staff turnover or expansion, technology evolution and the advent of new methods. We suggest that a training coordinator and documentation and manuals specialist be included in the coordination group and that links be made with groups with experience in this area (such as UCAR’s COMET program) to assess and develop a NEON-wide training program.

VIII. Facilities and Estimated Costs

1. Centralized NEON Molecular Laboratory

For economy of scale and to provide standard protocols and data plus rapid turnaround, we recommend that a centralized NEON laboratory be established for molecular sampling. This facility would receive (and possibly archive) samples, extract DNA, and amplify and sequence the genes needed for molecular identification of samples. This process will involve cloning and library construction for most, if not all, samples. Phyloinformatics will play a major role in the activities of the centralized facility. We estimate that this laboratory can be established for approximately $1 million; this level of funding would provide a high throughput sequencer, robotics, and basic molecular equipment. A director (salary $60,000-$100,000 per year) plus a high-level technician (salary perhaps $50,000 or more) will be necessary to operate this facility.

2. Observatory Laboratory

The laboratory(ies) at the core site of the observatory will need to accommodate multiple researchers in a variety of activities related to biodiversity monitoring.

- Molecular ($400,000): The molecular lab will need to have all of the basic molecular equipment for extraction and amplification of DNA, with gel rigs, powerpacks, and imaging to evaluate samples and products. Other pieces of equipment will be (minimally) centrifuges, hoods, and drying cabinets (for preparing soil samples).

- Microscopy ($100,000): A set of dissecting microscopes and perhaps compound scopes will be necessary, each equipped with digital imaging capabilities.
- Digital field equipment ($50,000): Digital cameras, GPS and imaging equipment for field monitoring and archiving should be available at each site.
- Surveys ($50,000): Traditional survey equipment for all phylogenetic groups should be available at each site. In addition, microcam and acoustic recorders may be valuable at some observatories.

IX. On Assessments of Costs of NEON Observatories

One way to estimate the cost structure of a NEON implementation is to scale up from an environmental research platform of known costs. The infrastructure costs for a new LTER site research project is on the order of $5M (labs, accommodations and field implementations). In comparison, a NEON infrastructure of $20M + $4M university match and $5 M of existing infrastructure totals to $29M or six times the cost of an LTER start up. Using 6X as a scaling factor we estimate that the core NEON site and its satellite sites will require an operations budget of $2.1M/yr excluding overhead. This does not include the addition of new and replacement equipment in the out years. We estimate that awards to meet this need could well approach $500,000/yr.

A second assessment of NEON operations cost was achieved by building a staffing model for the laboratory and field implementations planned for NEON. A budget follows:

Staffing		
Senior Scientists Leader	100K	
"CEO" system administrator	100K	
Technical Staff		
PhD level (3) at 60K	180K	
MS Level (8) at 35K	280K	
BS Level (12) at 25K	300K	
Summer Aids (10) at $5K	50K	
Shop technicians (4) at 45K	180K	
Office support staff (3) at 30K	90K	
SUBTOTAL		1,170K
Overhead	1,170K	
Expendables	700K	
TOTAL		3,140K

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