BOSTON NEON BIOTIC SUBPLENARY REPORT: BIODIVERSITY, INVASIVE SPECIES, AND INFECTIOUS DISEASE

The second NEON Design Consortium (NDC) planning meeting was held in Boston, March 15-17, 2005. The three biotic science and human dimensions (SHDC) subcommittees, Biodiversity, Invasive Species, and Infectious Disease, met as a group (Biotic Subplenary) to discuss common ecological questions, NEON infrastructure, and program requirements.

This report contains a summary of common systems (instrument platforms), facilities, experimental needs, and programs required by the Biotic Subplenary. Minimum requirement, value added, and high-end parameters for instrument platforms and facilities are specified to meet the needs of the biotic SHDC subcommittees, according to specified overarching scientific questions contained in the traceability matrices (TMs).

TMs link specific scientific questions to the data types, system components, sensors, and cyberinfrastructure needed to address these questions. The tabular format of the matrices makes the links between these elements easily traceable. All of the information contained in these TMs was taken directly from the SHDC reports from the January NDC meeting. TMs for the Biodiversity, Invasive Species, and Infectious Disease subcommittees are also included in this report.

As requested, this report contains bulleted lists of equipment. This report does not contain elegant prose and is instead presented in telegraphic style.

1) COMMON SYSTEMS

a) Fixed Sensors—Small-scale sensors

i) Sensor MicroNet

Definition: Distributed sensor arrays measure microclimate and related physical characteristics above and below ground, incorporating acoustic, image, and physical sample data collection.

(1) ***Minimum set***: Continuous coverage across entire NEON site, including terrestrial and aquatic environments, to detect biotic emissions (acoustic, biochemical, etc). With current technology, sensors may be placed about 20 meters apart. The number of sensors will depend on habitat type, and the range, accuracy, and precision of the sensors themselves.

(2) ***Added value***: Expand area over which coverage occurs, have additional sensors that will be available to investigators for additional projects.

(3) ***High end*****:** Expand area over which coverage occurs, additional sensors deployed at higher densities for additional information.

(4) ***Frequency of measurements***: Once every second to annually, depending on specific data type (see TM's for each group for specifications of frequency of measurements).

(5) ***Volume of data stream***: Terabytes (high-frequency, fine resolution measurements in numerous localized areas).

ii) Organism tracking system

Definition: Tracks organisms in North America from sizes of cicadas to brown bears, implemented via handheld receivers, commercial aircraft, uninhabited aerial vehicles, satellite platforms, and/or in fixed locations.

(1) ***Minimum set***: Devices to track the geographic location of a large number of individuals, ideally the majority of individuals in a population, in both terrestrial and aquatic environments.

(2) ***Value added***: Deploy devices on smaller organisms, such as disease vectors. Near real-time measurements. Ability of the tracking devices to measure physiological properties, such as pheromones, heart rate, infection status, and others.

(3) ***High end***: More sensors, on smaller organisms, over a larger area. Near real-time measurements. More physiological measurements for each organism.

(4) ***Frequency of measurements***: Need to detect movement of these organisms frequently (up to one reading every second) so that we can monitor and forecast organismal spread. Frequency: every second to annually, depending on specific data type (see TM's for each group for specifications of frequency of measurements).

(5) ***Volume of data stream****:* Terabytes (intense measurements in a localized area).

b) <u>Fixed Sensors—Large-scale sensors</u>

i) BioMesoNet

Definition: Distributed sensor network to measure biotic and abiotic characteristics, including PAR, UV, solar radiation, air temperature, relative humidity, wind speed and direction, rainfall, species abundance and distribution, soil properties, and more. Includes terrestrial, lentic, lotic, and groundwater monitoring capabilities.

(1) ***Minimum set***:
   (a) Ability to install, and later service, biotic sensors at each tower throughout NEON land unit.
   (b) Aerial pathogen sensors are essential.
   (c) Aquatic sensors need to measure oxygen and chlorophyll, at the minimum. Vertical resolution of aquatic sensors would be 3-20 sensor stations, depending on stratification of the water body. Horizontal extent would be 100 lakes across the country, with 2-10 per lake.
   (d) For groundwater, the minimum set would include the ability to take biologically meaningful water samples from wells and to deploy artificial substrate to measure biological activity in groundwater.

(2) ***Value added***:
   (a) Terrestrial: Attach light traps, video sensors to towers (20 towers per each habitat type).
   (b) Aquatic sampling: Would need more lakes, more units per lake, and measurements of pigments other than chlorophyll.

(3) ***High end***: All types of sensors present on each tower throughout NEON land unit.

(4) ***Frequency of measurements***: Once every second to annually, depending on specific data type (see TM's for each group for specifications of frequency of measurements.

(5) ***Volume of data stream***: Terabytes (intense measurements in a localized area).

ii) Canopy crane

Definition: Provides access for groups of people to forest canopies under most weather conditions for observation and experimentation. Allows for the lifting of heavy and bulky sampling gear. Accesses spaces unavailable by climbing alone: space above canopy, voids in canopy, snags.

(1) ***Minimum set:*** One or two across NEON network in old growth, deciduous and coniferous forests.

(2) ***Value added:*** 5-10 across NEON network.

(3) ***High end:*** Make canopy crane moveable to extend beyond diameter of crane coverage; One canopy crane per site as appropriate to habitat.

c) <u>Fixed Sensors: Capabilities Wish List</u>

i) Ability to pick up chemical signals as indicators of biological activity or diversity.
ii) Ability to detect genetic sequences of organisms in air (flow-through chip) and soils.
iii) Ability to detect decomposition in soil.

d) <u>Mobile Sensors—Small-scale</u>

i) Biodiversity Tricorder

Definition: This wirelessly connected, field-capable device will provide GPS, digital camera, acoustic and chemical sensors, electronic field guide, DNA barcoding, hyperspectral observations, and other capabilities in a single instrument package. A broad range of research programs may use the Biodiversity Tricorder, including K-12 education, citizen science, and professional scientific research.

(1) ***Minimum requirements*:**
- (a) Taxonomic identification.
- (b) Morphology/size.
  - (i) Photography and measurement (Digital camera and laser range finder).
  - (ii) Microscopic/micrographic capabilities for microbes/pathogens.
- (c) Reflective characteristics (hyperspectral imaging).
- (d) Sound – Acoustic sensor.
- (e) Chemical detection and analysis (e.g., pheromones, volatiles).
- (f) Genetic (DNA, RNA) detection and analysis.
- (g) Electronic field guide – wireless access to reference databases.
- (h) Location and movement (GPS with GIS capability).
- (i) Data recorder.
- (j) Assign barcode to each specimen to match with associated preparations (e.g., tissues), voucher, data/images/samples.
- (k) Wireless capability to transmit and receive data, access databases.
- (l) Taxon-specific chips (is this species X?) vs. What species is this (match signal from library of signals for many species).
- (m) Number required 50-100 per NEON site with distributed real time capability.
- (n) Need development of databases for comparisons/taxonomic identification.

(2) ***Value Added**:* Condition/health status – thermal sensing via hyperspectral imaging.

(3) ***High end**:* Genetic architecture/variation at hierarchical levels; Gene flow.

e) <u>Mobile Sensors—Large-scale sensors</u>

i) Mobile NEON Laboratory

Definition: Consists of a fleet of vehicles (roving field lab, uninhabited rovers, micro-vehicles) with monitoring, storage, and communication capabilities.

(1) ***Minimum requirements***:

(a) Taxonomic identification – same as biotricorder.
(b) Abundance measurements (density, biomass) by taxon/groups (tricorder).
(c) Genetic architecture/variation at hierarchical levels (sequencing; sample processing; sample freezers; level three capability in two or three labs).
(d) Movement/dispersal of individuals (tracking equipment, recorders).
(e) Morbidity/mortality analysis capabilities (blood analysis, necropsy capabilities, tricorder).
(f) Capability to sample soil, air and water and extract organisms for analysis.
(g) Ability to test for biogeochemical characteristics of samples.
(h) Capability to collect and analyze data on abiotic factors as defined by HBC.
(i) Location and movement (GPS with GIS capability).
(j) Data recorder.
(k) Assign barcode for each specimen to match with associated tissues, vouchers, data/images/samples.
(l) Wireless capability to transmit and receive data, access databases.
(m) Ultracold (liquid nitrogen) storage capabilities.
(n) Boats, off-road vehicles as needed depending on ecosystem sampled.

(2) ***Added value***:

(a) Logistics module – living and working space for scientists.

(3) ***High End***:

(a) Unmanned vehicles/robots for sample collection.

ii) Airborne Satellite Remote Sensing

Definition: A variety of platforms (aircraft, uninhabited aerial vehicle, satellite) will regularly gather multi-scale spectral, spatial, and temporal data and respond, as necessary, to unforeseen disturbances.

(1) ***Minimum requirements*:**

(a) Multiple spatial, temporal, spectral resolutions.
(b) Rapid-response capabilities (access to airplane overflight).
(c) Biomass estimation.
(d) Phenology monitoring.
(e) Canopy height and structure measurements.

(2) ***Value added*:**

(a) Taxon identification.

iii) Mobile - SOCIAL: Social Observation Community Information Analytical Lab

Definition: Ability to generate virtual, 3-dimensional realities simulating sight, sound, smell, and temperature of various biodiversity / land use environments. These environments could be current, historic, or future scenarios; and would host single and multi-participants and facilitate the collection of attitudinal and preference data as well as system knowledge (i.e., how a socio-ecological system works).

(1) ***Example Deployments***:

(a) The mobile lab could be used to model different scenarios of biodiversity in residential landscapes and solicit the attitudes and preferences of different social groups to biodiversity and land-use scenarios.

(b) The mobile lab could be used with farmers in a community to learn what social and biophysical factors affect their farming decisions and how changes in the system would affect their decisions. This facilitates the collection of expert knowledge about a land use system.

(2) ***Collaborative and Educational Tools***:

(a) Collaborative modeling tools would be linked to the reality simulation environment, enabling model and forecast scenarios to be realized in the simulation environment.

(b) Education tools would be developed based upon the simulation and collaborative modeling environment for individual and group learning, evaluation of learning, and decision-making.

2) Common NEON Laboratory Facilities

e) Biocollection Facilities

i) Sample Processing labs

(1) ***Ecological Samples:***
- (a) Sediment/Soils/Mud
- (b) Water
- (c) Other (e.g., leaf litter)

(2) ***Biological Samples***:
- (a) Traditional Sampling
- (b) Ethanol preserved DNA
- (c) RNA-RNA later preserved

ii) Sample Storage labs

(1) ***Minimum***:
- (a) -80 Freezers
- (b) -20 Freezers
- (c) Humidity controlled rooms
- (d) Room temperature
- (e) Biosafety Level II

(2) ***Value Added***:
- (a) Biosafety Level III

(3) ***High End***:
- (a) Completely Robotic Retrieval system (currently in-use and widely-available).

iii) Partnerships:

(1) Natural History and Science Museums

(2) Biocollections facilities

iv) Other Comments:

(1) Biocollections Facilities should recognize microbial culture collections, especially ATCC and USDA ARS culture collection, as synergies.

(2) All microbial specimens (cultures) in the world are searchable at the World Data Center for microorganisms (WDCM) -- (http://wdcm.nig.ac.jp).

(3) The Ribosomal Database Project (RDP) hosts all the 16S rRNA gene sequences in the world (130,000) with a classified validation against all Type cultures.

f) Structure, Composition, and Distribution of Physical Laboratory Network

i) Regional – 5-10 co-located laboratories, including:

(1) **Molecular Genetics/Genomics Laboratory**

(a) ***Minimum:***

One standard, yet complete lab = $500 k - $750 k (PCR Amplification 1 pg.)*:*

(i) Gel electrophoresis
(ii) PCR machines
(iii) gel imaging
(iv) pipettors
(v) spectophotometer
(vi) hybridization ovens
(vii) gene quant
(viii) incubators
(ix) shaking incubators
(x) refrigerators
(xi) centrifuges
(xii) ultracentrifuges
(xiii) -80, -20, 4C refrigerators
(xiv) scintillation counter
(xv) ELISA tools
(xvi) Robotic PCR
(xvii) Gene Arrayer
(xviii) Robotic Liquid Handling
(xix) Real Time PCR
(xx) Array Scanner
(xxi) Chip hybridization oven
(xxii) SNP detection technology
(xxiii) Bioanalyzer
(xxiv) Capillary DNA Sequencers

(b) ***Value Added***:

(i) Powerful Bioinformatics, Data Mining, and Analysis.
(ii) Rapid Creation of Genechips for non-model systems (i.e., Affymetrix-NimbleGen custom arrays).
(iii) IBead Arrays.
(iv) High throughput QTL gene mapping.
(v) Gene expression mapping (non-model systems).
(vi) High throughput SNP detection for non model systems.

(c) ***High End***: (currently in use and widely available)

(i) Remote, Transactional, Near-Real-Time Robotic High-Throughput Screening.

(d) **Partnerships**:

(i) High throughput (e.g. full genome) sequences.
(ii) For sequencing, consider Joint Genome Institute (JGI), TIGR, SANGER (Whitehead, MIT) websites for high capacity, for robotics at a bigger scale.
(iii) Genome Canada may have some good images from its regional platform.

(2) **Proteomics Laboratory**

(a) ***Minimum:***

(i) Refer to Protein Biochemistry Lab One-pager
(ii) LC Coupled Nano-scale Capillary Tandem Spectrometry
(iii) Circular Ion Resonance Mass Spectrometer

(iv) 2D gels

(b) ***Partnerships:***

(i) Consider EMSL at the Pacific Northwest National Lab (PNNL) – Dick Smith is the lead.

(3) **Biochemical and Metabolomics Laboratory**

(a) ***Minimum:***

(i) Standard Biochemistry Laboratory
(ii) HPLC, GC Mass Spectrometry
(iii) Plate reader spectrophotometry
(iv) NMR
(v) Enzyme kinetics
(vi) Enzyme structure function

(4) **Stable Isotope Analysis Laboratory**

(a) Please refer to Williams, Evans, and Ehleringer Draft Document.

(5) **High Throughput Trait Screening Facility**

(a) ***Rationale****:* We cannot hope to answer all the NEON questions for every one of the many million species on earth. To make ecological forecasts beyond the data available for particular species, we need to characterize species in functional terms as a basis for generalization. E.g., what traits are correlated to different levels of response to key global change drivers? Such "trait databases" are beginning to be developed, especially for plants, but making progress requires speeding up the rate of acquisition of data for new species by several orders of magnitude, as well as expanding to many other kinds of species. This requires facilities to raise individuals under a variety of standardized conditions and the infrastructure to measure the traits, as well as the cyberinfrastructure to organize, archive, and make the data accessible.

(i) "*Taxon*" in this context is used at multiple levels: It oulc refer to populations, subspecies, species, genera, etc., as desired by individual researchers using the facility.

(b) ***Capabilities:*** Quantify life history, demographic, physiological, behavioral traits – both ecological and candidates surrogates more susceptible to high throughput measurements. (See spreadsheet for candidate traits and possible surrogates for higher throughput measurement.)

(i) Fixed facilities to culture individuals (e.g., laboratory (growth rooms) with light, temperature, humidity control), greenhouses, experimental ponds, common gardens, aviaries, etc.)

1. Microbes, plants, invertebrates and vertebrates.
2. Aerial, surface, soil, lotic, lentic, marine.
3. Range of standardized environments: temperature, nutrients, water, substrates light, toxins/stress, diet.

(ii) Mobile facilities to quantify traits for organisms in the field (range of habitats).

(iii) Cyberinfrastructure to facilitate entry and access of data from facility AND access-related data from other sources (existing trait databases, distributional data, genetic data – e.g., GenBank).

(c) ***Deployment:***

(i) 3-5 regional facilities.

(ii) Perhaps specialized for different kinds of organisms, habitats, or traits

(d) ***Use:***

(i) Facility to characterize taxa of interest to be used by individual research projects (buy time?).

(ii) Need oversight committees to prioritize/schedule time and space use

(iii) Commitment that all results be entered into open database.

ii) Distributed Facilities

(1) Specimen processing laboratory at every observatory site

(a) ***Minimum –*** Trait Measurement tools:

(i) Morphology:

1. Microscopy
    a. Compound and Dissecting Microscopes + Camera
    b. Video 3D Montage Microscopy
    c. Fluorescent Microscopy
    d. Remote Visualization of Microscopic Imagery
2. Morphometrics tools
3. Image Analysis: Pattern recognition (robotic eye + software)
4. Movement Detection Systems for Identification
5. Laboratory Information Management Systems
6. Laminar Flow Hoods

(ii) Metabolic Characterization of Microbes:

1. Functional Metabolic Lab for Microbes (Metabolic Array)
2. Culture Facility

(2) Manipulative Experimental Laboratory distributed at a subset of sites (diverse biomes, habitat types).

(a) ***Measurements:***

(i) Ecological Experiments (interactions)

(ii) Basic Quantitative Genetics

1. Heritability (breeding and selection experimental facilities)
2. G x E
3. Common garden (plasticity)
4. Selection Response

(iii) Physiology

(b) ***Experimental Facilities:***

(i) Green Houses

(ii) Incubators

(iii) Walk-in Rooms

(iv) Basic Wet Laboratory (glassware)

(v) Bioreactor Systems (microbial)

(vi) Flumes (artificial streams)

(vii) Artificial Lakes
(viii) Animal Holding
1. Insectories
2. Aviaries
(ix) Physiology Laboratory
1. Oxygen Concetration (Respirometer)
2. Hemolymph Concentration (Osmometer)
3. Plant Physiology

iii) Development

(1) Phase I (Immediate)
(a) Establish the sites
(b) Incorporate and utilize new genomic technology
(2) Phase II
(a) Facility upgrade

3) Common NEON Field Experimentation Needs

a) <u>Experimental Facilities</u>

i) ***Rationale***

(1) Long-term experimental facilities need to be distributed across key land use gradients in the NEON network and encompass a representative set of "control environments" that include a range of
(a) aquatic (lakes, streams, wetlands, etc) habitats.
(b) terrestrial (grasslands, forests, desert, etc) habitats.
(c) the dominant land uses in the area/region.
(2) Shorter-term experimental facilities will be needed as part of NEON in order to respond to emerging events (diseases, invasive species, wildfires, changes in human land use) that will affect biodiversity.
(3) Collectively, these two types of experiments will allow us to test forecasts developed from the synthesis and analysis of observational data from NEON facilities.
(4) It is premature to specify details of how to establish long-term experiments (i.e., the size, distribution, and numbers of "plots.")

ii) ***Questions***

(1) How do critical variations in climate and human activities (including land use) affect biodiversity (from genes through landscapes and across space and time), infectious disease dynamics, and invasiveness/invasibility of pristine and managed ecosystems?
(2) How do critical changes in biodiversity affect the infectious disease dynamics, and invasiveness/invasibility of pristine and managed ecosystems?
(3) Do changes in biodiversity and risk of infectious diseases affect people's attitudes and behaviors towards their environment and the ecosystem benefits they derive?
(4) Do changes in biodiversity and risk of infectious diseases affect ecosystem benefits (air and water quality, vegetation productivity, etc.)?

iii) ***Capacities***

(1) Inventories and assessments of patterns of biodiversity (genes to landscapes) from local site to continental scales at sufficient temporal scales to detect trends and changes.

(2) Large-scale field experiments to determine what factors (singly and in combination) are critical "drivers" of patterns and trends.

(a) In biodiversity (decreases and increases).

(b) In frequency, incidence, spread of invasive species and infectious diseases

(c) Smaller-scale, flexible responsive experiments.

iv) ***Manipulations***

(1) Climate

(a) Water availability to terrestrial environments (increase and decrease; vary temporal distribution and amount).

(b) Hydrologic cycles in aquatic environments (increase and decrease; vary temporal distribution and amount).

(c) Temperature- ability to increase and decrease; mean and variance.

(2) Nutrients (N, P, CO2/carbon, etc).

(a) Increases and decreases inputs (N, P,CO2).

(b) Variation in inputs (rates biogeochemical cycling).

(3) Biodiversity changes.

(a) Removal and addition of species (native/nonnative, infectious/noninfectious).

(b) Manipulation of genotypes and populations.

(c) Manipulation of propagule pressure.

(4) Manipulations of "disturbance" regimes- e.g. fire, harvesting rates, etc.

(5) Containment facilities for manipulations of invasive/infectious species .

(a) Fences

(b) Trenches

(c) Species-specific

(i) pollen

(ii) bird

(iii) wind dispersed seeds/propagules, etc.

4) Common Neon Programs

b) <u>Citizen Scientist Involvement in NEON Research</u>

i) ***Rationale***

(1) While the Education Subcommittees have described in more detail the educational justification for citizen scientist involvement, we have focused on the needs from the perspective of the scientific questions pursued by NEON.

(2) Citizen scientists are critically important for gathering certain kinds of data relevant to biodiversity, invasive species, and infectious disease research.

(3) Citizen scientists can serve as a nationwide, information-gathering, sensor network.

(a) They can provide early monitoring for the appearance of invasive species and report on the status of rare and endangered species.
(b) Their observations of changes in the health and/or abundance of animal, plant, and fungal populations can expand the scale and grain of NEON monitoring activities.
(c) Involvement in infectious disease research could include monitoring for changes in
(i) Distribution and abundance of arthropods (e.g., aquatic insect "hatch" dates).
(ii) Birds (arrival dates on breeding and wintering grounds).
(iii) Other animals that serve either as potential vectors or reservoir hosts for pathogens (disease-causing agents).

(4) At the same time, these citizens will gain a better understanding of the value and excitement of ecological science.
(5) Citizen scientists can be citizens of all types, including, but not restricted to, those affiliated with organizations such as Earthwatch, native plant societies, fishermen, Audubon and birdwatching groups, mushroom and butterfly groups, and museum-associated groups.
(6) Students (K-12) and in higher education should also be considered as potential citizen scientists.
(a) They can provide data on ecological observations.
(b) They should be exposed to the technological advances in ecological research.
(c) Many young people (and the general public) view ecological research solely as observational and may not have been exposed to the exciting applications of technology to this field of research.

(7) Citizen scientists need to see how their data contributes to research projects in near "real time."
(8) If possible, they should have access to data sets through a user-friendly interface that allows for data exploration and analysis.
(9) Citizen scientists should have the opportunity to develop and test original research hypotheses through interactions with NEON scientists.

ii) ***Infrastructure Requirements***

(1) Regional NEON centers and/or sites should be equipped with both physical and virtual public interface capacity.
(2) Physical facilities need to include the following:
(a) Lecture hall and meeting rooms with audiovisual and computer capabilities where scientists and staff can instruct and interact with citizen scientists.
(b) Equipment and support for video-conferencing.
(c) Computers (e.g., 15-30) with high-speed internet access and adequate capacity for data analysis and GIS applications.
(d) Instructional facilities that include state-of-the art wireless video camera and microscope projection systems.
(e) Equipment for production and distribution of "tool kits" and other materials relevant to citizen scientist projects (e.g., laser color photocopier and printer, laminator).

Boston NDC Meeting Traceability Matrix BIODIVERSITY							
Overarching Questions	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
1) How do critical changes in biodiversity affect the infectious disease dynamics, and invasiveness/invasibility of pristine and managed ecosystems?	1) What are the variations in biodiversity from genes through landscapes and across space and time that affect ecosystem function and human activities?	1) Legacy "biodiversity data" already digitized and georeferenced	Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
2) How do critical variations in climate and human activities (including land use) affect biodiversity (from genes through landscapes and across space and time), infectious disease dynamics, and invasiveness/invasibility of pristine and managed ecosystems?			Not Applicable	Not Applicable	Very high throughput genetic analysis of samples collected from existing museum and herbarium collections hierarchically from "genes to landscape"	Biocollections Facilities	Not Applicable
3) Do changes in biodiversity and risk of infectious diseases affect people's attitudes and behaviors towards their environment and the ecosystem benefits they derive?						NEON Laboratory Facility	
4) Do changes in biodiversity and risk of infectious diseases affect ecosystem benefits (air and water quality, vegetation productivity, etc.)?		3) Baseline data for species assemblages	BioMesoNet	Not Applicable	Traps and/or environmental sampling; Video/Photography; Audio Sensing; Chemical Sensing ;	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Biodiversity Tricorder	Not Applicable	Genetic analysis for rapid in-field species identification	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Airborne/Satellite Remote Sensing	Not Applicable	Satellite Imaging	NEON Data Archive, Analysis and Visualization Facility	Not Applicable

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Overarching Questions	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			Organism tracking system	Not Applicable	Remote Biosensing	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
		4) Baseline data for habitat composition	Airborne/Satellite Remote Sensing	Not Applicable	Satellite Imaging	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			BioMesoNet	Not Applicable	Traps and/or environmental sampling; Video/Photography; Audio Sensing; Chemical Sensing ;	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Biodiversity Tricorder	Not Applicable	Genetic analysis for rapid in-field species identification	NEON Data Archive, Analysis and Visualization Facility	
			Atmospheric Sensor Array Platform	Not Applicable	Airborne chemicals; Video/Photography	NEON Laboratory Facility	Not Applicable
		4) Baseline data for landscape structure	Groundwater Monitoring Network	Not Applicable	See HBC3 sensors	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Lentic Sensor Array Platform	Not Applicable	See HBC3 sensors	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Lotic Sensor Array Platform	Not Applicable	See HBC3 sensors	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Airborne/Satellite Remote Sensing		Hyperspectral and thermal sensors (time: biologically meaningful, seasonally and annually)		
			Not Applicable	Not Applicable	Environmental, organic, and stable isotope chemistry	NEON Laboratory Facility	Not Applicable
			Mobile Socio-economic Assessment Lab	Not Applicable	Socioeconomic data (i.e. population density, land use, demographics, attitudes)	NEON Data Archive, Analysis and Visualization Facility	Not Applicable

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Overarching Questions	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
		5) Abundance of appropriate taxa	BioMesoNet	Not Applicable	Traps and/or environmental sampling; Video/Photography; Audio Sensing; Chemical Sensing ; (from hours to years depending on the organism)	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Biodiversity Tricorder	Not Applicable	Genetic analysis for rapid in-field species identification	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Airborne/Satellite Remote Sensing	Not Applicable	Remote Imaging -- satellite and airborne (depends on ecosystem and organism -- has to be biologically meaningful)	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Organism tracking system	Not Applicable	Remote Biosensing	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
		6) Composition and distribution of appropriate taxa	Airborne/Satellite Remote Sensing	Not Applicable	Satellite Imaging	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			BioMesoNet	Not Applicable	Traps and/or environmental sampling; Video/Photography; Audio Sensing; Chemical Sensing ; Animal tracking	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Biodiversity Tricorder	Not Applicable	Genetic analysis for rapid in-field species identification	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Atmospheric Sensor Array Platform	Not Applicable	Airborne chemicals; Video/Photography	NEON Laboratory Facility	Not Applicable
		7) Measures of 'ecosystem function'	Mobile Rapid-Response Ecoinvestigation Laboratory	Not Applicable	See Biodiversity Tricorder	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			BioMesoNet	Not Applicable	Productivity, phenology, organism stress/health, tissue nutrient chemistry, gas fluxes	NEON Data Archive, Analysis and Visualization Facility	Not Applicable

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Overarching Questions	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			Groundwater Monitoring Network	Not Applicable	chlorophyll sensors, organism presence, metabolic activity indicators	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Lentic Sensor Array Platform	Not Applicable	chlorophyll sensors, organism presence, metabolic activity indicators	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Lotic Sensor Array Platform	Not Applicable	chlorophyll sensors, organism presence, metabolic activity indicators	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
		8) Genetic information that reveals relevant lineages among study species	Not Applicable	Not Applicable	Molecular sequencing	NEON Laboratory Facility	Not Applicable
		9) Organism movement in subpopulations	BioMesoNet	Not Applicable	Traps and/or environmental sampling; Video/Photography; Audio Sensing; Chemical Sensing ;	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Biodiversity Tricorder	Not Applicable	Genetic analysis for rapid in-field species identification	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Airborne/Satellite Remote Sensing	Not Applicable	Satellite Imaging	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Organism tracking system	Not Applicable	Remote Biosensing	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Atmospheric Sensor Array Platform	Not Applicable	Airborne chemicals; Video/Photography	NEON Laboratory Facility	Not Applicable
		10) Organism divergence in subpopulations	Not Applicable	Not Applicable	Molecular sequencing; stable isotope (?)	NEON Laboratory Facility	Not Applicable
			Not Applicable	Not Applicable	Molecular sequencing data	NEON Data Archive, Analysis and Visualization Facility	Not Applicable

Boston NDC Meeting Traceability Matrix BIODIVERSITY							
Overarching Questions	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
		11) Genetic, genomic, phenotypic, and species diversity of appropriate taxa that can serve as metrics (indicators) of changes in ecosystem functions/services	Not Applicable	Not Applicable	Molecular sequencing; genetic identification; correlation between gene frequency and functional trait; species identification	NEON Laboratory Facility	Not Applicable
			Biodiversity Tricorder	Not Applicable	Portable high throughput genetic analysis	Biocollections Facilities	Not Applicable
			Not Applicable	Not Applicable	Not applicable	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
			Not Applicable	Not Applicable	hydrological observations (?); stable isotope measurements; phenological observations	NEON Laboratory Facility	Not Applicable
		13) Similarities of traits of assemblages of organisms	Not Applicable	Not Applicable	Genetic information	NEON Laboratory Facility	Not Applicable
		14) Measures of major local drivers	Not Applicable	Not Applicable	Greenhouses, standardized plots, aquatic facilities	Manipulative Experiments	Not Applicable
		15) Measures of major regional drivers	Not Applicable	Not Applicable	Greenhouses, standardized plots, aquatic facilities	Manipulative Experiments	Not Applicable
		16) Measures of ecosystem services at regional to continental scales	Not Applicable	Not Applicable	Greenhouses, standardized plots, aquatic facilities	Manipulative Experiments	Not Applicable
	2) Which incidences and properties of infectious disease and invasive species affect critical variations in biodiversity in pristine and managed ecosystems?	See Invasives and Disease Matrices					
	3) How do human activities affect biodiversity (from genes through landscapes) and ecosystem function, across space and time?						

Boston NDC Meeting Traceability Matrix BIODIVERSITY							
Overarching Questions	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
	4) How do changes in biodiversity affect people's attitudes and preferences towards their environment and the ecosystem benefits they derive?	Attitudinal and preference data	Mobile Socio-economic Assessment Lab		To be determined based upon stratified samplings, purposeful and found experimentation.		
						NEON Data Archive, Analysis and Visualization Facility	
	5) How do changes in biodiversity affect people's behaviors towards their environment and the ecosystem benefits they derive?	Land use/Land cover data, supplemental data on land management practices such as consumer purchasing data, agricultural census data, NRI, administrative records, and telephone surveys.	Other	Analogous to LU Comm -- Remote Sensing Digesters	Survey-based and administrative reporting (annual/ parcel or property level)		
						NEON Data Archive, Analysis and Visualization Facility	
	6) Do changes in biodiversity and risk of infectious diseases affect ecosystem benefits (air and water quality, vegetation productivity, etc.)?	See above for characterizations of biodiversity and infectious disease data. See biogeochemical cycling for characterizations of ecosystem function.					

Boston NDC Meeting Traceability Matrix INFECTIOUS DISEASE								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
1) How do critical changes in biodiversity affect the infectious disease dynamics, and invasiveness/invasibility of pristine and managed ecosystems?	1) Forecast which organisms or types of organisms are most likely to become health risks or transmit pathogens to humans, non-human animals, and plants.	1) What are the patterns of, and explanations for variation in pathogenic effects of disease-causing organisms and their vectors?	1) Abundance (host, vector, pathogens)	BioMesoNet	Not Applicable	Traps and/or environmental sampling (hosts: seasons, event-based; vectors: days to months, event-based; pathogens: days to seasons, event-based); Video/Photography; Audio Sensing; Chemical Sensing (hosts: seasons, vectors: days to months); Sentinel Host Network (days to seasons, event-based); Genetic/Immunologic (seasons, event-based) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
2) How do critical variations in climate and human activities (including land use) affect biodiversity (from genes through landscapes and across space and time), infectious disease dynamics, and invasiveness/invasibility of pristine and managed ecosystems?				Airborne/Satellite Remote Sensing	Not Applicable	Satellite Imaging (hosts: seasons, vectors: days to months) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
3) Do changes in biodiversity and risk of infectious diseases affect people's attitudes and behaviors towards their environment and the ecosystem benefits they derive?				Mobile Rapid-Response EcoInvestigation Laboratory	Not Applicable	Traps and/or environmental sampling (hosts: event-based; vectors: event-based; pathogens: event-based); Video/Photography; Audio Sensing; Chemical Sensing (hosts: event-based, vectors: event-based); Genetic/Immunologic:event-based	Not Applicable	Not Applicable
4) Do changes in biodiversity and risk of infectious diseases affect ecosystem benefits (air and water quality, vegetation productivity, etc.)?				Biodiversity tricorder	Not Applicable	Taxonomic identification, genetic architecture	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Specimen processing and identification	NEON Laboratory Facility	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable

Boston NDC Meeting Traceability Matrix INFECTIOUS DISEASE								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			2) Distribution & Change in Location over time (host, vector, pathogens)	BioMesoNet	Not Applicable	Traps and/or environmental sampling (hosts: seasons, event-based; vectors: days to months, event-based; pathogens: days to seasons, event-based); Video/Photography; Audio Sensing; Chemical Sensing (hosts: seasons, vectors: days to months); Sentinel Host Network (days to seasons, event-based); Genetic/Immunologic (seasons, event-based); Spore sampling (seasons, event-based) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Airborne/Satellite Remote Sensing	Not Applicable	Satellite Imaging (hosts: seasons, vectors: days to months) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Organism tracking system	Not Applicable	GPS Chip Tracking; Fluorescence Tracking; Molecular Tracking; Stable Isotope Tracking (host, vector, and pathogen: days to seasons, event-based)	Not Applicable	Not Applicable
				Sensor MicroNet	Not Applicable	Smart Dust, Sampling Surrogate Microspheres (days to seasons, event-based) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Biodiversity tricorder	Not Applicable	Individual tracking, GPS location	Not Applicable	Not Applicable
				Mobile Rapid-Response EcoInvestigation Laboratory	Not Applicable	Traps and/or environmental sampling (hosts: event-based; vectors: event-based; pathogens: event-based); Video/Photography; Audio Sensing; Chemical Sensing (hosts: event-based, vectors: event-based); Genetic/Immunologic:event-based	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	Biocollections Facilities	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	NEON Stable Isotope Facility
			3) Patterns of Morbidity/ Mortality (host or vector)	Organism tracking system	Not Applicable	Remote Biosensing (days to seasons, event-based) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				BioMesoNet	Not Applicable	Longitudinal/cross sectional sampling (days to seasons, event-based) (Hierarchical Sampling Design)	Not Applicable	Not Applicable

Boston NDC Meeting Traceability Matrix INFECTIOUS DISEASE								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
				Mobile Rapid-Response EcoInvestigation Laboratory	Not Applicable	Environmental sensors; Molecular Identification Capabilities; Microarrays; Sample Quarantine (event-based), Host cellular immune response quantification (event-based)	Not Applicable	Not Applicable
				Biodiversity tricorder	Not Applicable	Physiological status of hosts, vectors	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
				Not Applicable	Not Applicable	Sampling processing and diagnostics	NEON Laboratory Facility	BSL III Laboratory
				Not Applicable	Not Applicable	Not Applicable	Not Applicable	Link to CDC, Health departments, NIH to measure human exposures to infectious agents
				Not Applicable	Not Applicable	Not Applicable	Not Applicable	Link to USDA, National Plant Diagnostic Network, Cooperative Extension to measure agricultural species' exposures to infectious agents
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			4) Identity (pathogen causing outbreak)	Mobile Rapid-Response EcoInvestigation Laboratory	Not Applicable	Pathogen genotype identification; Microarrays (event-based)	Not Applicable	Not Applicable
				Biodiversity tricorder	Not Applicable	Pathogen species and genotype identification, genetic architecture, gene expression	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Pathogen species and genotype identification, genetic architecture, gene expression	NEON Laboratory Facility	Sample processing, genomics, proteomics, and BSL III laboratories
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable

Boston NDC Meeting Traceability Matrix INFECTIOUS DISEASE								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			5) Abiotic parameters influencing patterns of host and vector morbidity and mortality	Mobile Rapid-Response EcoInvestigation Laboratory	Not Applicable	Air temperature, precipitation, relative humidity, cloud cover, wind speed, wind direction, soil moisture, nutrient concentrations (event-based)	Not Applicable	Not Applicable
				Sensor MicroNet	Not Applicable	Air temperature, precipitation, relative humidity, cloud cover, wind speed, wind direction, soil moisture, nutrient concentrations (hourly to annually)	Not Applicable	Not Applicable
				BioMesoNet	Not Applicable	Air temperature, precipitation, relative humidity, cloud cover, wind speed, wind direction, soil moisture, nutrient concentrations (hourly to annually)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
		2) What are the ecological and evolutionary properties of pathogenic organisms and vectors that influence health risks?	6) Pathogen and vector behavior in response to a variety of ecological variable manipulations	Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	Trait-screening facilities, genomics and proteomics laboratories, BSL III laboratories
							Manipulative Experiments	Manipulative experimental laboratory, manipulative field experiments with containment facilities, trait-screening facilities
			7) Host susceptibility to pathogens in response to a variety of ecological variable manipulations	Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	Trait-screening facilities, genomics and proteomics laboratories, BSL III laboratories

Boston NDC Meeting Traceability Matrix INFECTIOUS DISEASE								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
				Not Applicable	Not Applicable	Not Applicable	Manipulative Experiments	Manipulative experimental laboratory, manipulative field experiments with containment facilities, trait-screening facilities
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			8) Genetic makeup of pathogens at outbreak sites compared to that of archived specimens	Mobile Rapid-Response EcoInvestigation Laboratory	Not Applicable	Target pathogen gene sequence identification capabilities (event-based)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	Biocollections Facilities	Not Applicable
				Biodiversity tricorder	Not Applicable	Target pathogen gene sequence identification capabilities	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Target pathogen gene sequence identification capabilities	NEON Laboratory Facility	Genomics, proteomics laboratories
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			9) Primary voucher specimens (pathogens)	Not Applicable	Not Applicable	Not Applicable	Biocollections Facilities	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	Sample processing
				Mobile Rapid-Response EcoInvestigation Laboratory	Not Applicable	Primary voucher specimens	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable

Boston NDC Meeting Traceability Matrix INFECTIOUS DISEASE								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
	2) Forecast where and when infectious diseases of humans, non-human animals, and plants will emerge.	3) What biotic and abiotic factors regulate distributions and control ecological and evolutionary dynamics of key vectors, hosts, reservoirs, and pathogens?	10) Genetic variation within and between populations (host, vector, and pathogens)	Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	Genomics, proteomics laboratories, BSL III laboratories
				Biodiversity tricorder	Not Applicable	Gene expression, genetic architecture	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			11) Human behavior and demography	Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
				Mobile Socio-economic Assessment Lab	Not Applicable	Socio-economic data, human movement, behavior	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			12) Wind patterns	BioMesoNet	Not Applicable	Wind Direction; Wind Speed (days) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Atmospheric Sensor Array Platform	Not Applicable	Wind Direction; Wind Speed (days) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Sensor Micronet	Not Applicable	Wind Direction; Wind Speed (days) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			13) Particle transport	Sensor MicroNet	Not Applicable	Smart Dust: measure abundance, distribution, density of particles (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Atmospheric Sensor Array Platform	Not Applicable	Wind Direction; Wind Speed (days) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable

Boston NDC Meeting Traceability Matrix INFECTIOUS DISEASE								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			14) Soil quality, including physical structure, chemical composition, biological activity	Sensor MicroNet	Not Applicable	Smart Dust to measure: Soil chemistry, microbial community composition (including viruses and prions), organic matter content, physical characteristics (daily to annually) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Soil chemistry, microbial community composition (including viruses and prions), organic matter content, physical characteristics (daily to annually)	NEON Laboratory Facility	Stable isotope laboratory, sample processing
				Other	Soil Sensor Array Platform	Soil chemistry, microbial community composition (including viruses and prions), organic matter content, physical characteristics (daily to annually)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	Biocollections Facilities	Not applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			15) Water quality, including physical, chemical, biological characteristics	Sensor MicroNet	Not Applicable	Smart Dust -- see hydroecology subcommittee measurements (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Lentic Sensor Array Platform	Not Applicable	see hydroecology subcommittee measurements (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Lotic Sensor Array Platform	Not Applicable	see hydroecology subcommittee measurements (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Groundwater Monitoring Network	Not Applicable	see hydroecology subcommittee measurements (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	Stable isotope laboratory, sample processing
				Not Applicable	Not Applicable	Not Applicable	Biocollections Facilities	Not applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			16) Air quality, including particulates (like boogers; biotic and abiotic), pollutants, dry deposition	Sensor MicroNet	Not Applicable	Smart Dust -- particulates (biotic and abiotic), pollutants, dry deposition (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable

Boston NDC Meeting Traceability Matrix INFECTIOUS DISEASE								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
				BioMesoNet	Not Applicable	Particulates (biotic and abiotic), pollutants, dry deposition (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	Stable isotope laboratory, sample processing, molecular genetics laboratory
				Not Applicable	Not Applicable	Not Applicable	Biocollections Facilities	Not applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			17) Climate	BioMesoNet	Not Applicable	Air temperature, precipitation amount, precipitation runon rate, relative humidity, cloud cover, wind speed, wind direction (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Atmospheric Sensor Array Platform	Not Applicable	Air temperature, precipitation amount, precipitation runon rate, relative humidity, cloud cover, wind speed, wind direction (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			18) Land Use Change	Airborne/Satellite Remote Sensing	Not Applicable	Disturbance, Development, Agriculture, Grazing, Recreation (seasons to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Mobile Socio-economic Assessment Lab	Not Applicable	Socio-economic data, human demography, behavior	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis and Visualization Facility	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			19) Watershed scale hydrologic measurements, including flow rates and pathways	Lentic Sensor Array Platform	Not Applicable	See hydroecology subcommittee measurements on flow rates and pathways through watersheds (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable

Boston NDC Meeting Traceability Matrix INFECTIOUS DISEASE								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
				Lotic Sensor Array Platform	Not Applicable	See hydroecology subcommittee measurements on flow rates and pathways through watersheds (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Groundwater Monitoring Network	Not Applicable	See hydroecology subcommittee measurements on flow rates and pathways through watersheds (days to years) (Hierarchical Sampling Design)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			20) Community productivity (plant)	Airborne/Satellite Remote Sensing	Not Applicable	Satellite Imaging (seasons)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	Stable isotope laboratory, specimen processing
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable
			21) Community composition (plant)	Airborne/Satellite Remote Sensing	Not Applicable	Satellite Imaging (seasons)	Not Applicable	Not Applicable
				Biodiversity Tricorder	Not Applicable	Taxonomic identification, biochemistry, abundance over time	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable

Boston NDC Meeting Traceability Matrix INVASIVE SPECIES								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
1) How do critical changes in biodiversity affect the infectious disease dynamics, and invasiveness/invasibility of pristine and managed ecosystems?	1) What species are most likely to become invasive, and how can we manage them?	1) How can we detect the occurrence of introduced species at early stages of invasion (before they are damaging)?	1) Identity (invasive and potentially invasive species)	Other	Airborne Remote Sensing, Tricorder, Biomesonet, Mobile Rapid-Response Experimental, Lab, Groundwater Monitoring, Lentic, Lotic, Organism tracking system, Citizen Science, Sensor Micronet		NEON Laboratory Facility	Molecular Genetics Lab, Specimen Processing, Biochemistry/Metabolomics (microbes)
2) How do critical variations in climate and human activities (including land use) affect biodiversity (from genes through landscapes and across space and time), infectious disease dynamics, and invasiveness/invasibility of pristine and managed ecosystems?				Not Applicable	Not Applicable		Biocollections Facilities	Not Applicable
3) Do changes in biodiversity and risk of infectious diseases affect people's attitudes and behaviors towards their environment and the ecosystem benefits they derive?			2) Abundance (invasive and potentially invasive species)	Other	Airborne Remote Sensing, Tricorder, Biomesonet, Mobile Rapid-Response Experimental, Lab, Groundwater Monitoring, Lentic, Lotic, Socio Mobile Lab, Organism tracking system, Citizen Science, Sensor Micronet	Aerial Photography/ Hyperspectral Sensors (seasonal measurements)	Not Applicable	Not Applicable
4) Do changes in biodiversity and risk of infectious diseases affect ecosystem benefits (air and water quality, vegetation productivity, etc.)?				Biodiversity Tricorder	Not Applicable	Hyperspectral Sensors	Not Applicable	Not Applicable

Boston NDC Meeting Traceability Matrix INVASIVE SPECIES								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
				BioMesoNet	Not Applicable	Audio & Chemical Sensors (continuous measurements); Video/Photography; Atmospheric particulate, Soil, Water, Air, Sweep & Bulk Leaf/Stem/Root Samplers (Continuous measurements, bulked monthly for archive)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	Other	Citizen Science Program
				Not Applicable	Not Applicable	Not Applicable	NEON Laboratory Facility	Not Applicable
			3) Distribution & Change in Distribution over time (invasive and potentially invasive species)	Other	Airborne Remote Sensing, Tricorder, Biomesonet, Mobile Rapid-Response Experimental, Lab, Groundwater Monitoring, Lentic, Lotic, Socio Mobile Lab, Organism tracking system, Citizen Science, Sensor Micronet	Aerial Photography/ Hyperspectral Sensors (seasonal measurements)	Not Applicable	Not Applicable
				Biodiversity Tricorder	Not Applicable	Hyperspectral Sensors	Not Applicable	Not Applicable
				BioMesoNet	Not Applicable	Audio & Chemical Sensors (continuous measurements); Video/Photography; Atmospheric particulate, Soil, Water, Air, Sweep & Bulk Leaf/Stem/Root Samplers (Continuous measurements, bulked monthly for archive)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	Other	Citizen Science Program
		2) Why are only a subset of species introduced from a given source region?	4) Historical range (native range of introduced species)	Other	Partnerships, legacy data	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	Not Applicable

Boston NDC Meeting Traceability Matrix INVASIVE SPECIES								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			5) Important traits related to invasive capacity: life history, expression gene array, morphology, demography, biochemistry, sensory traits (smell, taste), trophic structure, heritability, genetic architecture, etc	Other	See traits section below	Not Applicable	Other	Trait Screening Facility, Lab Manipulative Experiments, Molecular Genetics Lab, Proteomics Lab, Biochemical/Metabolomics Lab, Field Experiments
		3) How can we predict potential rates of geographic spread and population growth?	6) Change in location over time (invasive and potentially invasive species)	Airborne/Satellite Remote Sensing	Airborne Remote Sensing, Tricorder, Biomesonet, Mobile Rapid-Response Experimental, Lab, Groundwater Monitoring, Lentic, Lotic, Socio Mobile Lab, Organism tracking system, Citizen Science, Sensor Micronet	Aerial Photography/ Hyperspectral Sensors (seasonal measurements)	Biocollections Facilities	Not Applicable
				Biodiversity Tricorder	Not Applicable	Hyperspectral Sensors	Not Applicable	Not Applicable
				BioMesoNet	Not Applicable	Audio & Chemical Sensors (continuous measurements); Video/Photography; Atmospheric particulate, Soil, Water, Air, Sweep & Bulk Leaf/Stem/Root Samplers (Continuous measurements, bulked monthly for archive)	Not Applicable	Not Applicable
				Not Applicable	Not Applicable	Not Applicable	Other	Citizen Science Program
			7) Propagule pressure (invasive and potentially invasive species)	Not Applicable	see below (#16)	Not Applicable	Other	Trait Screening Facility, Lab Manipulative Experiments, Molecular Genetics Lab, Field Experiments, NEON CELL

Boston NDC Meeting Traceability Matrix INVASIVE SPECIES								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			8) Dispersal mode (invasive and potentially invasive species)	Not Applicable	see below (#17)	Not Applicable	Other	Molecular Genetics Laboratory, Field Experiments, NEON CELL, Data Archive (partnerships with other agencies)
			9) life history (invasive and potentially invasive species)	Not Applicable	#18	Not Applicable	Other	Trait Screening Facility, Lab Manipulative Experiments, Molecular Genetics Lab, Proteomics Lab, Biochemical/Metabolomics Lab, Field Experiments
			10) Genetic variation (invasive and potentially invasive populations)	Not Applicable	see below	Not Applicable	Other	Molecular Genetics Laboratory, Lab Manipulative Experiments, Field Experiments
			11) Geographic source (invasive and potentially invasive species)	Not Applicable	see below	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	& partnerships with other agencies
			12) Response to environmental extremes (invasive and potentially invasive species): life history, expression gene array, morphology, demography, biochemistry, sensory traits (smell, taste), trophic structure, heritability, genetic architecture, etc	Not Applicable	see below	Not Applicable	Other	Trait Screening Facility, Lab Manipulative Experiments, Molecular Genetics Lab, Proteomics Lab, Biochemical/Metabolomics Lab, Field Experiments

Boston NDC Meeting Traceability Matrix INVASIVE SPECIES								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			13) Response to environmental resources (invasive and potentially invasive species): life history, expression gene array, morphology, demography, biochemistry, sensory traits (smell, taste), trophic structure, heritability, genetic architecture, etc	Not Applicable	see below	Not Applicable	Other	Trait Screening Facility, Lab Manipulative Experiments, Molecular Genetics Lab, Proteomics Lab, Biochemical/Metabolomics Lab, Field Experiments
			14) Response to natural enemies (invasive and potentially invasive species): life history, expression gene array, morphology, demography, biochemistry, sensory traits (smell, taste), trophic structure, heritability, genetic architecture, etc	Not Applicable	see below	Not Applicable	Other	Trait Screening Facility, Lab Manipulative Experiments, Molecular Genetics Lab, Proteomics Lab, Biochemical/Metabolomics Lab, Field Experiments
			15) Response to competition (invasive and potentially invasive species): life history, expression gene array, morphology, demography, biochemistry, sensory traits (smell, taste), trophic structure, heritability, genetic architecture, etc	Not Applicable	see below	Not Applicable	Other	Trait Screening Facility, Lab Manipulative Experiments, Molecular Genetics Lab, Proteomics Lab, Biochemical/Metabolomics Lab, Field Experiments

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Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
		4) How can we predict the consequences of an introduced species for native biodiversity, ecosystem function, and human economies, and understand the reasons for differences among species in their impacts?	16) Propagule pressure (invasive and potentially invasive species)	Other	Airborne Remote Sensing, Tricorder, Biomesonet, Mobile Rapid-Response Experimental, Lab, Groundwater Monitoring, Lentic, Lotic, Socio Mobile Lab, Organism tracking system, Citizen Science, Sensor Micronet	Variable	Other	see #7
			17) Dispersal mode (invasive and potentially invasive species)	Other	Airborne Remote Sensing, Tricorder, Biomesonet, Mobile Rapid-Response Experimental, Lab, Groundwater Monitoring, Lentic, Lotic, Socio Mobile Lab, Organism tracking system, Citizen Science, Sensor Micronet	Not Applicable	Other	see above
			18) life history (invasive and potentially invasive species)	Not Applicable	Not Applicable	Not Applicable	Other	See Above
			19) Genetic variation (invasive and potentially invasive populations)	Biodiversity Tricorder	Not Applicable	Not Applicable	Other	See Above
			20) Geographic source (invasive and potentially invasive species)	Other	Partnerships: museum, legacy data, other countries and institutions	Not Applicable	NEON Data Archive, Analysis & Visualization Facility	See Above
			21) Response to environmental extremes (invasive and potentially invasive species): life history, expression gene array, morphology, demography, biochemistry, sensory traits (smell, taste), trophic structure, heritability, genetic architecture, etc	Other	Biodiversity Tricorder, Organism tracking, see #34 (climate data), all environmental data	Not Applicable	Other	See Above

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Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			22) Response to environmental resources (invasive and potentially invasive species): life history, expression gene array, morphology, demography, biochemistry, sensory traits (smell, taste), trophic structure, heritability, genetic architecture, etc	Other	Biodiversity Tricorder, Organism tracking, see #34 (climate data), all environmental data	Not Applicable	Other	See Above
			23) Response to natural enemies (invasive and potentially invasive species): life history, expression gene array, morphology, demography, biochemistry, sensory traits (smell, taste), trophic structure, heritability, genetic architecture, etc	Other	Airborne Remote Sensing, Tricorder, Biomesonet, Mobile Rapid-Response Experimental, Lab, Groundwater Monitoring, Lentic, Lotic, Socio Mobile Lab, Organism tracking system, Citizen Science, Sensor Micronet	Not Applicable	Other	See Above
			24) Response to competition (invasive and potentially invasive species) : life history, expression gene array, morphology, demography, biochemistry, sensory traits (smell, taste), trophic structure, heritability, genetic architecture, etc	Other	Airborne Remote Sensing, Tricorder, Biomesonet, Mobile Rapid-Response Experimental, Lab, Groundwater Monitoring, Lentic, Lotic, Socio Mobile Lab, Organism tracking system, Citizen Science, Sensor Micronet	Not Applicable	Other	See Above

Boston NDC Meeting Traceability Matrix INVASIVE SPECIES								
Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
	2) What are the species and ecosystems at greatest risk from invasive species, and how can they be effectively protected?	5) Which native taxa will be most affected by invasives?	25) Potential for hybridization (with invasive species)	Other	Airborne Remote Sensing, Tricorder, Biomesonet, Mobile Rapid-Response Experimental, Lab, Groundwater Monitoring, Lentic, Lotic, Socio Mobile Lab, Organism tracking system, Citizen Science, Sensor Micronet	Not Applicable	Other	Manipulative Experimental Lab, Molecular Genetics Lab, Trait Screening lab, Specimen Processing
			26) Mating system (natives)	Not Applicable	NA	Not Applicable	Other	Manipulative Experimental Lab, Field Experimental Facility, Trait Screening lab, Specimen Processing
			27) Life history (natives)	Biodiversity Tricorder	Not Applicable	Not Applicable	Other	Manipulative Experimental Lab, Field Experimental Facility, Trait Screening lab, Specimen Processing
			28) Natural enemies (shared between natives and invasives)	Organism Tracking System	Micronet	Not Applicable	Other	Manipulative Experimental Lab, Field Experimental Facility, Trait Screening lab, Specimen Processing
			29) Competitive ability (natives)	Organism Tracking System	Not Applicable	Not Applicable	Other	Manipulative Experimental Lab, Field Experimental Facility, Trait Screening lab, Specimen Processing
		6) Which communities are most susceptible to high densities and/or diversity of invasives based on environmental factors?	30) Land Use (extent and configuration)	Other	Airborne Remote Sense, Biomesonet, Mobile lab	Diverse	Other	Field Experimental Facility
			31) Disturbance History (e.g. fire, flood, frequency, climate change, past land use, etc)	Other	Airborne Remote Sense, Biomesonet, Mobile lab, sensor micronet, lentic, lotic	Diverse	Other	Field Experimental Facility

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Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			32) Resource Levels (nutrients, primary production, water, food source, habitat area, vegetation type and biomass, etc.)	Other	Airborne Remote Sense, Atmospheric Sensor Array, Tricorder, Biomesonet, Mobile lab, sensor micronet, lentic lotic, groundwater, Mobile Socioeconomic lab	Diverse	Other	Field Experimental Facility
			33) Heterogeneity (temporal and spatial) (of items #32 above)	Other	Airborne Remote Sense, Atmospheric Sensor Array, Tricorder, Biomesonet, Mobile lab, sensor micronet, lentic lotic, groundwater, Mobile Socioeconomic lab	Diverse	Other	Field Experimental Facility
			34) Climate (temperature, precipitation, water balance, etc.)	Atmospheric Sensor Array Platform	Airborne Remote Sense, Atmospheric Sensor Array, Tricorder, Biomesonet, Mobile lab, sensor micronet, lentic lotic, groundwater, NPOL radar	Climate sensors (need to be more specific)	Not Applicable	Field Experimental Facility
		7) Which ecosystem processes and ecological services will be most affected by invasion? Definition: Ecosystem processes: nutrient leakage, primary production, decomposition, nutrient cycles, biogeochemical cycles, fluxes between trophic levels, etc. Ecosystem services: water, air quality, disease control, biodiversity maintenance, etc.	35) Land Use (extent and configuration)	Other	Airborne Remote Sense, Biomesonet, Mobile lab	Diverse	Other	Field Experimental Facility
			36) Disturbance History (e.g. fire, flood, frequency, climate change, past land use, etc)	Other	Airborne Remote Sense, Biomesonet, Mobile lab, sensor micronet, lentic, lotic	Diverse	Other	Field Experimental Facility

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Overarching Questions	**Question**	**Specific Question**	**Data Type**	**System Component**	**If "Other" System Component, Please Explain**	**Sensors/Measures (option: add specification regarding minimum required [space/time])**	**Facility and Experimental Needs**	**If "Other" Facility and Experimental Needs, Please Explain**
			37) Resource Levels (nutrients, primary production, water, food source, habitat area, vegetation type and biomass, etc.)	Other	Airborne Remote Sense, Atmospheric Sensor Array, Tricorder, Biomesonet, Mobile lab, sensor micronet, lentic lotic, groundwater, Mobile Socioeconomic lab	Diverse	Other	Field Experimental Facility
			38) Heterogeneity (temporal and spatial) (of items #32 above)	Other	Airborne Remote Sense, Atmospheric Sensor Array, Tricorder, Biomesonet, Mobile lab, sensor micronet, lentic lotic, groundwater, Mobile Socioeconomic lab	Diverse	Other	Field Experimental Facility
			39) Climate (temperature, precipitation, water balance, etc.)	Atmospheric Sensor Array Platform	Airborne Remote Sense, Atmospheric Sensor Array, Tricorder, Biomesonet, Mobile lab, sensor micronet, lentic lotic, groundwater, NPOL radar	Climate sensors (need to be more specific)	Other	Field Experimental Facility