Great Smoky Mountains Research Needs List, Annotated —version 9/27/2010

Understanding Ecological Processes and Ecological Health

Climate Change— [Issues generally/often imbedded in other areas]

- Downscale climate models to the park level. What are the anticipated local expressions of **climate change in the Park** and what will they mean to refugia, endemic species, threatened and endangered species, and the distribution, extent, and health of various natural communities?
- Can the Park be used as a case for testing forest **carbon sequestration** opportunities and limitations given recent history after becoming a park?
- Can changes in community distributions and conditions be used as **indicators** of climate change? High elevation communities are likely to be most affected but are also stressed by air quality, acid deposition, and invasive pests but may offer special climate change monitoring opportunities. Can monitoring of changes for ecological health and species inventories be used as indicators of climate change?
- How might changes in the **phenology** of natural events best be monitored to detect change and how can any changes be linked to their appropriate cause(s)? Phenology of selected events (e.g. egg laying, bud set/break, first or last frost, insect hatches/instars, migration, flowering, etc) may be changing in response to climate change and/or other stressors. What are the best indicators or combinations of indicators? How should elevation and other be factored into monitoring phenology?
- What difference is there in **fog precipitation** "harvest" by needle leaf conifers now and in future years, vs. what it was like pre-adelgid, about 25-30 years ago? Needle leaf conifer forests in fog prone areas generate their own "fog precipitation" by allowing clouds to penetrate the branches/crown, instead of deflect around them like in hardwoods. This can be a significant amount over what is recorded in the standard precipitation gauges. We are losing our conifer species that tends to dominate on the highest elevation (=most fog prone) sites. Fraser firs even tend to dominate on the windward sides of slopes where fog would presumably be at maximum occurrence. If there is a loss, can an amount be estimated in annual losses? What are the impacts of that loss to other (endemic, rare, sensitive) species?
- Have there been changes in **snow pack** extent in the Park over the past few decades? Is there a trend? Satellite data examination should be able to do this in a gross fashion....but I am not sure that the snow depth recorded at NFG and Le Conte could be used park wide to produce a model of snow depth park-wide. Will this put our many mountaintop endemics at greater risk for being squeezed off the peaks than temperature alone? Are there additional impacts to aquatic systems and hydrology?
- Determine what **management actions** might be the most appropriate responses, and to possible aid in the detection of climate change itself.
- How is **climate change effecting** hydrology, soils, disturbance events, mercury methylation, zoonotic and wildlife diseases, exotic plant and animal distribution, etc.?

Ecosystem Modeling and Ecological Processes—

- Develop a **model of precipitation** for the park to assist with ecological investigations and monitoring.
- Utilize existing **intact ecosystems/communities** to identify important functional, structural, compositional (species composition), and distributional ties/relationships with other ecosystems/communities necessary for the sustained health of one or both of those systems.
- How can **ecological health indicators** be identified in a way that addresses quite diverse ecological issues while remaining simple in approach?
- How can ecological functions and processes that integrate diverse ecological health issues be simply monitored and yet be accurate and sensitive to change.

Paleclimate— [see also Archeology and Paleontology]

- Investigate the faunal and floral make-up within/near the park at past (quaternary) intervals and link them with climatic records to help create conceptual models on vegetation responses to climatic conditions to help predict potential effects of climate change scenarios on the ecological condition of the park. Potential sources for this information include insect remains preserved in high elevation heath balds, pollen in wetland sediments, wetland vegetation preserved by earth movements in certain portions of the park, fossils in caves, and deposits/fossils in possible microcaves in the park's limited karst areas.
- What can be learned about paleoecology and paleoclimate from excavation of sub-fossil plant debris found 5 meters deep at the Tight Run site at Ravensford, hypothesized to be ~9,000 BP.
- What can be learned about the ages of wetlands and the paleoecology and paleoclimate of the surrounding area from studying charcoal and pollen samples from wetlands.
- Construct a better picture of the humans, plants, and animals in and around the park. Employ scientific methods that can help construct findings such as blood residue analysis of projectile points and other tool forms (what animals killed). What information can the **environmental record of archeological sites** provide concerning the forest, wetland, and grassland types that were present on and adjacent to the park over the past 18,000 years? Is there evidence for change in vegetation communities in relation to documented and hypothesized changes in global and regional climate (e.g., Gunn 1994; Kutzbach et al. 1998; Liu and Fearn 2000) during this period?
- What evidence can the data from archeological sites provide concerning the recognition and dating of **the Pleistocene-Holocene boundary** and the onset of Holocene aggradation in the Southern Appalachians? Do the data support indications from elsewhere that the regional climate may have been warming as early as 16,500 to 12,500 B.P. (Goodyear 1999)?
- Does the paleoenvironmental record continue to support emerging indications of a wet period during the middle Holocene in the mountains (Dwyer et al. 1996; Leigh 2002; Leigh and Feeney 1995; Liu and Fearn 2000)? Are the apparent changes in occupation density in the Oconaluftee and other drainages throughout the Archaic period potentially related to climatic factors (in addition to those of landform stability and site preservation)?
- Is there evidence for **deforestation or increased burning during periods of intense occupation** of the park, such as the Late Archaic, Middle Woodland, and Historic Cherokee periods? Can differences in fire history between pre-human times, Native American occupations, and historic times be seen in the archaeological record? Is it possible to document changes in the local environment during and between individual site occupations, and, if so, to determine how those changes are related to horticultural practices and episodes of site abandonment and reoccupation?

Role of Fire—

- Evaluate the roles of fire (intensity, size, distribution, frequency, forest cover types) as a natural phenomenon in the Smokies and how it can be better used as a tool for achieving the restoration of species, habitats, and their landscape patterns. This should involve how fire should best be used to move from present to future desired conditions. Assure associated aspects of fire under today's circumstances are understood for how they may respond differently than in the past (invasive species, ozone, acid deposition, etc.), especially for invasive plant species.
- What's the **link between fire and reptile distribution and abundance**? Some of the least common species in the park are known from dry pine and oak-pine communities in the western part of the park. Is there any evidence that fire has benefited or harmed these species in the park?
- What is the relationship between **wildfire intensity/frequency and habitat change** (i.e. vegetation composition, invasive plants & animals, soil alteration, native animal community composition)?
- What are the interactions between fire **and exotic species invasions** for their introduction and spread, as well as for their management?

Ecological Relationships (Pollination, Herbivory, Predation, Symbiosis, Parasitism, etc.)—

- Evaluate the relationships that exist between endemic plants and insects (**pollinators, defoliators, obligate hosts**, etc.) to help understand how to manage endemic plants with a view of a more complete life cycle. [see specific relationships below]
- Evaluate the extent and type of **herbivory** (vertebrate and invertebrate) on various plant species to understand how these plant populations are being altered by herbivory
- Evaluate the use of **herbivory** conditions as an indicator of herbivore population conditions, for possible management, especially for management of large vertebrates.
- Evaluate the disruption of **pollination** processes (pollinator disruption) of native endemic plants and its effects on **population genetics and distribution**.
- How can we better understand how to respond to the decline of at-risk plant species responding to **pollination** disruption? This may require establishment of baselines of normal pollination as well as causes of the disruption (pest species, fragmentation/isolation, pollution, etc.).
- Evaluate is the role(s) of **parasitism** in ecological processes for key guilds/groups of species, aquatic and terrestrial to determine how these stress on key species may be managed for achieving desired population levels. [see Invasive Species section]
- Define the role of **micorrhizal fungi** in forest health (along with soil microbial ecology) for major forest types and forest types and risk, especially to assist restoration management with added important ecological management tools not presently known. [see Invasive Species]
- Develop profiles of **soil microbial ecology** for **forest types (or trees) at risk** to establish a baseline of health and dynamics from which to ascertain changes, to identify key indicators, and to help identify possible risks to species of concern (to understand the role of soil microbial ecology in managing the health of habitats at risk).
- Conduct studies of large mammal **predator-prey relationships** to understand how to keep problem (large) populations under control and very small populations more sustainable. These include deer, hogs, bear, elk, red wolf, bobcat, etc.
- Where do the seven **southern Appalachian endemic races of birds** spend the winter? How much of their wintering range is protected within the park? Are there specific partnerships that can be developed with land management entities that control their wintering range (including Caribbean nations)?
- What are the natural population cycles and interactions of the park's **small mammals** in different habitats—what is the "normal range of population sizes—and how is this changed by climate/disease/invasive-induced vegetation community changes?

Biological Hot Spots and Disturbance—

- Refugia and selected biological hot spots in the park need to be evaluated for their vulnerability (sustainability/extirpation) to the various regimes of **disturbance** that now occur and might be expected to occur in the foreseeable future, both natural and anthropogenic. This should include fire, severe storms (flooding/erosion/sedimentation), recreation, drought, invasive species/diseases infestations, succession (or its maintenance), atmospheric deposition, possible climate changes, various species introductions, ozone events, air pollution, water pollution, and other types of disturbances.
- What are the trends of **physical effects of wind**: blowdowns (and erosion changed forest structure), increased evapotranspiration, cloudwater inputs (percentage of precipitation/deposition as rain or fog)?
- Are there **changes in slide event frequency and magnitude** on a decadal scale associated with climate and forest structure/composition changes?

Transient Species, Habitat Use by—

- Inventory of over-wintering sites & migratory routes of migratory organisms (**neotropical migratory birds, bat species, butterflies**) to manage and conserve quality sites in appropriate locations.
- What are the distribution, abundance, phenology, and species composition of **transient migratory birds** in spring and fall? Are there areas of the park, habitats, and/or food plants that are especially important to migrating birds in the park? Does this vary from year to year, with wind patterns, soft mast crop, or other factors?
- What are the distribution, abundance, phenology, and species composition of **overwintering bird species** in the Smokies? Are there areas of the park, habitats, and/or food plants that are especially important to wintering birds in the park?

Primary Productivity and Mast—

- Model primary productive across multiple gradients across species to understand their distribution/success and response to stressors, and thus their management
- Model mast production phenological variability and its prediction/cause (as with weather, climate change, and other stressors)
- Study the link between mast production variability and dependent fauna life cycles, to help anticipate management of bear, deer, turkey, and hog issues and to begin understanding of stressor effects to mast production and potential management responses

Stream Salamanders— [see also Diseases]

- How can the park best monitor stream salamander populations, especially in 1st order streams, to watch for signs of population decline in response to various stressors?
- Why does only one of the park streams appear to have a demographically healthy hellbender population? Can anything be done to improve conditions for hellbenders in some of the Park's other large streams?

Environmental Quality (acid deposition, ozone, mercury, nitrogen, particulate/haze, pesticides, light)

Pollution Deposition—

- How is the distribution/deposition of organic mercury different from that of total mercury and is inorganic mercury being methylated to a significant extent in the park (and if so, where and under what conditions)? Do heath balds and/or wetland/riparian communities in the park serve as **methylation** sites of importance to the park? Where in the park is mercury deposition the worst, in amounts/rates of deposition and most vulnerable communities?
- What are good **indicator species for monitoring the ecological effects of mercury** deposition in the park? Feather and blood samples collected from several resident bird species have had high concentrations of mercury (Keller); several aquatic invertebrate species have had high but not alarming levels of mercury in them (Buchwalter); and several species of salamander, especially those that frequent the sides of streams, have shown fairly high levels of mercury (Bank). There are no indications of the deleterious effects of these mercury levels.
- Aerosol, particulate concentrations and cloud cover may reduce the amount of solar radiation reaching forest trees. What is the **effect of aerosol, particulate concentrations, and cloud cover on forest productivity**, measured at different scales with remote sensing, on-the-ground particulate sensors, etc.? Evaluate the concentration and sources of particulate matter affecting haze and its impact on visibility, solar radiation, and plant growth. Use findings to help establish critical/target loads and model effects to determine where key source areas and types may be most critical to regulate.
- What are the **critical loads** for the park (or for different major habitats in the park) for deposition of sulfate, nitrate, ammonium, major cation concentrations and wet deposition; dry chemistry and deposition, and cloudwater/throughfall deposition?
- Establish more precise records and arrangements of acid deposition, precipitation, and the deposition of selected isotopes, heavy metals, and pesticides utilizing **dendro-chronology** and other methods appropriate over the **pre- and post-European** settlement times, especially since the advent of nearby industrialization periods. This is to establish additional information on how **natural environments have been stressed** and to detect more recent changes and trends and to take a stance on various emission standards. Work may help validate predicted changes from atmospheric deposition models.
- Develop methods for using aquatic/stream **macroinvertebrates** to accurately infer and monitor stream acidity changes, especially in high elevation, low buffered, high acid deposition locations.
- Develop a water quality monitoring system able to **model storm discharge** and water quality changes that should detect possible effects of acid deposition, mercury deposition, and possibly pesticides. This may be especially effective at high elevations, areas of geologically based low buffering capacity, and in watersheds of particularly high discharge. [see Hydrology, third question]
- What are the interactive effects of air quality, climate, precipitation, N deposition, drought, and ozone on selected species groups/sites for such species groups as mating birds/ozone, salamanders/climate, fish/stream acidity, and plants/ozone (to identify and managed stressed organisms, their habitat, and perhaps stressors themselves)
- How are **bats, birds, and other species affected by particulates** in the air above Great Smoky Mountains National Park? Is there any evidence that higher particulate levels have an adverse impact on these species (foraging, reproduction, longevity, etc.)?
- Evaluate the extent and effect/influence of agricultural **herbicide/pesticide deposition** in the park from land use adjacent to the park. This will first require a broad-spectrum search and identification of herbicide/pesticide deposition as well as indicators of accumulated occurrences for herbicides/pesticides in known use around and regionally upwind from the park. More detailed studies within the park of selected herbicide/pesticide deposition and effects will then be needed to locate hotspots and identify critical/target load factors.
- How is **ammonia** (NH4) deposition/formation contributing to, or changing, N deposition and can the sources be identified?

- What are the expected effects of **ammonia** deposition/formation on communities and ecological functions and are there particularly vulnerable ones to monitor/manage? Includes both terrestrial and aquatic systems.
- Evaluate the distribution of ambient air and water pollution throughout the park in a way that enables **local pollution sources** to be differentiated from ambient regional levels/sources. This is to assess park emissions, their sources, possible effects and contributions to overall problems, and needed management responses to control them.

Acid Deposition— [see also under Pollution Deposition]

- Conduct research on the role of **calcium** and **phosphorus** in bio-geochemical **cycling** in different soils, communities, elevations, and situations of acid deposition to determine…
  - Which soils/communities/conditions are the most vulnerable to change?
  - How do ecosystems respond/change?
  - Which are the most crucial communities—nearest to thresholds of instability/non-sustainability?
  - Which soils/communities/conditions are amenable to management inputs to correct, and which kinds of inputs are most suitable?
- Examine the effects of acid deposition and ozone periods outside of baseline levels on ecological processes in old growth stands. Processes of concern are succession/regeneration, nutrient cycling, and productivity/biomass accumulation.
- Assess the viability of old growth stands in light of acid deposition and ozone damage to determine if/what management actions are needed.

Water Quality— [see also Run-off and Related Issues]

- How is **water quality impacted by point-sources** (i.e. waste-water treatment plant, sedimentation, concession waste, septic systems, mines, etc.) and non-point sources (i.e. road runoff, fertilizer, de-icers, crush & fill, trampling, moving rocks, erosion, acid deposition, etc.) of pollution? Conduct an inventory of the anthropogenic point-sources of water pollution that affect the park, then identify and describe the impact on the affected communities in those areas.
- How are **deformities of diatoms in high elevation springs** linked to water quality, especially as it affects human health? Can monitoring of the prevalence of these deformities be a cost-effective way of monitoring the water quality of these springs, especially by trained volunteers? Do the causative agents of these deformities have impacts on the macroinvertebrate and salamander communities in these habitats? Why are high elevation springs showing such differences in conductivity, nitrogen, aluminum, etc. even when on similar geology and even when adjacent?

Ozone—

- What are the most critical effects of ozone on breeding birds in high ozone-prone sites?
- Are there additional species of important native/rare plants especially affected by high ozone levels other than those tested already?
- How might the habitats/communities in which they occur be affected due to ozone stress on particular plants?
- Which habitats/communities might be most vulnerable/stressed?

Particulate Pollution and Haze—

- Evaluate the **concentration and sources of particulate matter** affecting haze and its impact on visibility, solar radiation, and plant growth. Use findings to help establish critical/target loads and model effects to determine where key source areas and types may be most critical to regulate.
- Conduct a systematic evaluation of visibility and haze problems with respect to human perceptions of these problems. How might both **haze and perception of haze** be managed to improve visual satisfaction?

Sound—

- How is **anthropogenic sound affecting human recreational experiences** (backcountry, hiking, driving, camping, picnicking, and interpretation)? Establish baseline sound qualities and levels: better sound monitoring technologies and human response/opinion patterns. How is anthropogenic sound above baseline affecting wildlife resources, such as bird territory placement and size and large animal movements?

Light Pollution—

- Document and research the effects of light pollution (lighted night sky) on natural resources and visitor experience. Natural resources affected might include **lepidoptera populations** or **salamander foraging and reproduction**, for example.
- Attempt to predict future conditions and effects (of more light pollution and their effects). Where are new future effects likely to occur?
- Are there particular sources and areas more dramatically affected? How can they be managed?

Road Run-off and Related Issues

- We have a number of gravel or gravel-added dirt roads in the park, the most significant being around Cades Cove and around another valley in North Carolina called Cataloochee. The park road crew in Cades Cove has used limestone gravel, in keeping with the bedrock geology of the site, but most of the North Carolina roads use granitic gravel. We have anecdotal reports from lichenologists that the limestone dust from the Cades Cove roads has killed off most species of tree trunk lichen several meters back from the roads. This does not appear to be happening along granitic gravel roads. What are the relative impacts of different sorts of gravel and its dust on the areas adjacent to roads, terrestrial and/or aquatic?
- We are in the process of changing how we operate at our four maintenance yards, all adjacent to streams or rivers, with the goal of reducing any storm run-off. Are there any indications of lingering damage from past actions or continued threats that can be identified and rectified?
- High elevation sites are likely more at risk from disturbance because of continual impacts of acid deposition, mercury deposition, and climate change. The park has several high elevation parking areas, most notably at New Found Gap and Clingmans Dome. If we are going to see impacts from storm run-off we might assume we'd see it there. Salamander pathogens in the park found in high elevation stream species may be triggered by stress events, perhaps like storm run-off. What are the impacts upon salamanders, headwater streams, and adjoining terrestrial habitat of road run-off from high elevation parking areas in the park?
- We have a lot of oil and break fluid deposited on the lower reaches of both ends of the road across the mountain (highway US 441). This would seem like the highest probable stretch for accumulation of chemicals on road surface in the park and both run along rivers. What is the impact of run-off upon aquatic and riparian communities?

Geophysical Processes

Hydrology— [see also Caves under Unique Habitats]

- What are the **changes in ground water hydrology/water quality due to anthropogenic sources in high elevations**? Will vegetation change from acid deposition, climate change, forest pests, and/or ozone levels alone effect water discharge rates at high elevation springs?
- What is the **role of ground water in surface water features** and how is this changing with climate change, etc.? For example, why are Pumphouse Marsh and other Cove wetlands drying up and is there is any action that can be taken to protect rare plants found there? What is ground water input under different circumstances to surface streams?
- Develop better hydrologic models capable of receiving present input data to better predict stream discharge and provide management considerations regarding habitat protection and human safety and warning precautions.
- Identify links between water quality, storm events, atmospheric deposition, ecological changes, recreational use, and resource management actions.
- Better describe the wetlands of the park, both an inventory of locations and description of their type, with the possibility that some are an undescribed type.
- What is the recharge basin for our caves and where do they discharge to; is there any connection between our sinkholes and the caves; is there any pollution risk from septic systems and other activities outside the park or around the park's developed areas.
- What is the capture of water, depth, ecology, and input into surface streams of perennial streams under boulder fields in northeastern quarter of the park?

Soils—

- How and where did **soil structure change in relation to legacy land-use practices** and how is it recovering? Can a map be produced of the different classes of soil disturbance in the Smokies? Even in nature soils get disturbed with tree uprooting, fires, etc. can "natural disturbance" of soils in old growth forest be characterized? Are areas of former alterations more prone to exotic invasion and if so, why?
- **How does soils disturbance affect biogeochemical cycling**? Are there differences in residence time of elemental nutrients or metals moving thru the disturbed vs. undisturbed soils? Moisture retention? How might that affect terrestrial and aquatic species/resources?
- How will forecast **increases in temperature** (via new NOAA report), **and** differing **precipitation** regimes **affect our soils resources**? Will oxidation increase? Will soils in particular environments become more stressed than others (e.g. steep slopes, on SW aspects at low elevations)? Will carbon sequestered in finer soil textures be mobilized? Interpret soil data for susceptibilities to other expected stressors (acid deposition, mercury deposition, etc.). Model/identify soils with highest potential for change under these stressors.
- How is **soil structure changing** in relation to invasive exotics (worms, pigs, etc.), fire (or lack thereof), current land-use, and forest change impacts? [a series of research questions here to identify previous conditions and identify mechanisms of change]
- How is **soil quality impacted by point-sources** (fertilizer application, spills, concession waste, etc.) and non-point sources (i.e. road runoff, fertilizer, de-icers, trampling, erosion, acid deposition, etc.) of pollution?
- Formulate protocols for monitoring soil changes and possible changes in species composition.

Geology— [see also Caves under Unique Habitats]

- Complete geologic and surficial geology studies and **interpretation** to identify their relationships to
  - water quality (high acidity especially at high altitudes),
  - high hazards for debris slides,
  - high acidity (heavy metals coming into solution),
  - unique geologic formations, and
  - likely unique plant and animal communities.
- Identify potential threats to human safety, transportation, development, and economic activity infrastructure.
- What have been the roles of **landslides** in the Park's geological and ecological history?
- Identify the age of selected waterfalls and their **barrier to selected fish movement** as a means of understanding the isolation of fish populations and their respective management.
- Identify locations where headwaters have switched drainages through erosive or other geologic forces and assess how this might affect distribution of aquatic organisms.

Species of Concern: Threatened, Endangered, Extirpated, Harvested, and Reintroduced Species

T&E Species— [see also Fish Resources]

- Conduct evaluations to look across the T&E species issues and conditions to determine which research and management efforts and tools will provide the most beneficial use of limited management resources
- Of globally or regionally **imperiled taxa and/or communities**, which are leading indicators of environmental changes? Is there any economy that can be reached by monitoring a sub-set of them or more common species that would track their status and trends?
- Model the effects of **climate change** on T&E species, to prepare for risks to park resources, and to help verify the existence and form of climate change at different elevations. Information may also help tease out different stressor sources causing changes in species & habitat conditions.
- Conduct studies on the **Indiana bat**'s population, population trends, distribution, hibernacula requirements/use, and issues related to population sustainability to know how to manage for sustained populations
- Conduct surveys for **gray bats** in the park along likely stream areas and determine the extent to which park resources are important for this species

Extirpated and Reintroduced Species— [see also Fish Resources]

- Conduct an evaluation of preparatory and re-establishment needs for extirpated species on a comparative basis to understand what opportunities are most doable and which obstacles, needs, or evaluation processes come up most often and how they might efficiently be addressed.
- With selected re-introduced species (American chestnut, otter, elk, red wolf), examine the likely effects of re-introductions on extant species and what population levels of the re-introduced species are necessary for sustaining a population and/or imposing unwanted impacts—what's too few and too many.
- Estimate pre-Columbian population levels for extirpated and reintroduced species, assess whether they may be applicable today, and from this develop target management levels if they can be sustained within park boundaries.
- Determine what if any impacts elk may have on plant communities in the park and individual species, especially old growth hemlock stands in Cataloochee Valley, T&E species, etc.
- Determine for reintroduced elk:
  - Habitat use/preferences and feeding preferences; potential for over-browse
  - Movement patterns by individuals, age class, social status, and gender
  - A target carrying capacity
  - The effects of brain worm on the long-term viability of the herd
  - Natality and Mortality rates

Fish Resources (especially in Abrams Creek)—

- What is the relative abundance of each T&E fish species within their Abrams Creek distribution and how does their abundance compare to populations outside of GRSM? What is the genetic composition of each of the **three T&E fish species** throughout their GRSM range in comparison to populations outside of GRSM?
- Are there **locally adapted gene complexes** present in the three Abrams Creek T&E fish populations and how do these complexes contrast/compare to regional populations? Are intra-population transplants (i.e. from Citico Creek to Abrams Creek) a responsible and ecologically necessary tool to augment genetic diversity within the source population? What do we gain/lose genetically and in terms of population viability?
- What is the **effective population size** of T&E fish species in Abrams Creek?
- What level of abundance, viability, and/or distribution would afford **"recovered" status** to a population within Abrams Creek? Is the allelic diversity of the population indicative of a healthy population or is further management needed?
- Establish peer reviewed **long-term monitoring protocols** for each T&E fish species in Abrams Creek. Do standardized protocols exist from other regional state and/or federal agencies for sampling any of the four T&E fish species found on Abrams Creek? Can we assess year-class strength of madtoms using techniques other than spring nest rock sampling (e.g., fall leaf litter counts)?
- What are the differential survival rates of **wild versus propagated** madtom nests from eggs to hatching, age-1, etc? What is the differential survival rate of wild and propagated fish stocked at different ages, times of day, season's, etc.? What are the cost benefits associated with using differential stockings of wild and propagated fish at different seasons, sizes, and times of day?
- Identify potential **extirpated fish species to be reintroduced** into GRSM streams. Data needs *prior to* reintroduction would include:
    a. Justification that the historic distribution of species occurred within proposed system.
    b. Determine historic genotype/phenotype of extirpated species.
    c. Is there suitable habitat available (i.e. similar to other known populations) in the target stream to support the species?
    d. Approved HACCP plan to ensure no Aquatic Nuisance Species (ANS) or other foreign contaminants are brought into GRSM with transplant.
- What are the **responses of the aquatic communities in restored brook trout** streams after restoration?

Harvesting—

- Does **poaching** and other collection affect amphibian, reptile, rare plant, and moss populations, and if so, to what extent does it alter abundance, reproduction, and distribution?
- What is the status and trend of **legal consumptive collecting** in the park, and what (and where, in terms of concentrated use) are the impacts of this on the consumed species in the park, especially fungi?
- Identify and evaluate the distribution of commercially important medicinal plants (those sustaining heavy harvest/poaching pressures) from which to identify a list of associated or indicator species to
    - Determine where restoration efforts might be applied.
    - Identify the extent of potential losses.
    - Along with species biology, ascertain how best these sites/species can be managed and protected.

Unique Habitats/Communities

Grasslands—

- Determine the effectiveness of the various **methods of management** (prescribed burning, cutting, etc.) on the sustainability (or establishment) of these grasslands. Grassland communities play an important role in the Park with respect to cultural sites (grassy balds and valley fields associated with Cades Cove and Mingus Mill). Their maintenance as native grass communities has been challenging in establishment, maintenance, and protection from encroachment of shrub and forest vegetation.
- Conduct research on **grassy bald** maintenance, sustainability, disturbances, and compositional/ successional changes to understand what methods/actions are needed to maintain them as near to desired historical conditions as possible.

Wetlands—

- Examine the relationship of wetlands (and different types of wetlands) for
  - wetlands as a network or system for re-invasion by species locally extirpated,
  - maintaining species diversity within the park,
  - response/recovery to disturbances and degradation, especially the potential for wetland and/or species loss.

Caves— [see also Geology section]

- **Inventory** cave species and their distributions within park caves
- Describe and model cave **atmospheric conditions** (temperature, humidity, and movement) and any threats to the quality of this air (pollution)
- Determine the **ecological relationships** between cave species/conditions and **external species/conditions** (e.g., organic inputs and dependencies)
- Describe the **hydrology** and determine the desired condition for each of the caves in the park and develop management direction that attains those conditions. Hydrologic situations include source areas/routes of movement as well as water quality and discharge timing changes.

Unique Communities: Beech Gaps, Canebreaks…—

- Examine beech gaps, canebrakes, and other unique communities for their conditions regarding
  - biodiversity,
  - sustainability,
  - model responses to climate change, disturbance, disease threats and other stressors, and
  - their roles in the diversity of the larger surrounding landscape. These examinations may start out as studies of either two different habitat connections or the study of species known to depend (at some life stage) on both habitats.
- What are the **status of riparian community** species abundance, species composition, and distribution related to human disturbance (invasive species, recreation, Elkmont restoration, Chilogatee reclamation, compaction, trampling) and natural disturbance regimes (floods, drought, rock slides, etc), and what is a baseline for undisturbed riparian communities upon which to compare future trends, especially for globally imperiled Montaine Alluvial Forest Community?

Invasive and Nuisance Species

General Invasive Species—

- Determine the ecological impacts on native species at risk from non-native fauna associated with **urban development and encroachment** (hogs, cats, cows, dogs, starlings, house sparrows, garden plants, etc.)
- What are the impacts **of loss of host species** (e.g. hemlock, fir, beech) to watersheds, soils, associated species and ecosystems?
- What are the **best integrated pest management techniques** for garlic mustard, Japanese grass, mimosa and ailanthus (including selective herbicides, time of treatment, biological and mechanical control options)?
- What are survey **techniques for rapid detection** and early response for new exotics, particularly: wood-borers (such as emerald ash borer, Asian longhorned beetle, sirex wood wasp); plant diseases (such as Sudden Oak Death) which are difficult to detect from remotely sensed data; and exotic diseases of native species wildlife, including birds, amphibians, pollinators.
- Are there **genetic mechanisms of resistance** to exotic forest insects and diseases, including HWA, BWA, beech scale, dogwood anthracnose, and if so, what are they?
- What are the interactions between fire **and exotic species invasions** for their introduction and spread, as well as for their management?
- What is the exact **threat to soils and native soil life offered by exotic earth worms**, esp. *Amenthas*? *Amenthas* feed in the litter layer, not so much in mineral horizons, and reduce native invertebrates, maybe salamanders. They may also impact rare plants, assist exotic plant establishment, and have an effect on soil transport. Can their current status be mapped? Are disturbed soils more easily invaded then undisturbed soils? Can the future spread of these species be modeled for the park as a whole? What will the ecological impact be if they will become widespread? [note: preliminary work conducted by Snyder and Pechmann studies.]
- **Pear thrips** (*Taeniothrips inconsequens*) were discovered in the park in recent years and have been associated with die-backs of **sugar maples** (*Acer saccharum*) in the Northeast, especially under conditions of drought and low cation availability, factors many park maples experience. Decline is most likely to occur in higher elevation (greater than 4000 feet) northern hardwood forests. These forests occur over poorly buffered and acidic sandstone bedrock and are subject to relatively high levels of acid deposition. Sugar maple trees occurring in protected coves on lower slope are less likely to experience decline. What is the current status and distribution of thrips and related injury in the park's sugar maples, and what is the potential for this becoming a serious threat to the park's maples?
- Conduct an evaluation of the problems of invasive species around the park (species, threat, vectors, landowner types, and awareness levels), how people understand and manage them, and how the park can find better ways to work with these landowners to better manage invasive species infringing on the park. Landowners who understand and manage their invasive exotic species problems in various ways surround the park. Landowners are agencies, corporations, smaller commercial ventures, individuals, and absentee owners. What are successful programs for preventing **the introduction of invasive exotics**, as far as educational programs within the park, outreach to surrounding areas, and regulations and enforcement?
- Evaluate how paved **roads and other corridors** of human movement/activity provide important vectors/avenues for the invasion of exotic plants and invertebrates, and to which invasive species these corridors are most important. How can these corridors be managed and monitored more efficiently?
- Are there ways to improve **roadside management** to reduce maintenance efforts, reduce exotic species invasions, and improve native species presence and variety?
- What are the distribution, impacts, and management of **fire ants**?
- Within and adjacent to the Smokies, identify sources, vectors, timing issues (season of dispersal and season of site disturbance for invasion/establishment) for problematic invasive species for better prevention and control. This may be species specific although some overlap between species will occur for some sources and vectors (e.g., wind-dispersed from a common location).

- How should/can the Park evaluate the risks and benefits in a more useful way and perhaps identify those problem species (or biological control techniques) that offer the safest ecological solutions? **Biological controls** of problem (invasive) species offer special effective opportunities along with potential environmental risks.
- What are the anticipated invasive species and their cumulative effects? How are these to be prepared for to minimize or direct long term ecological effects? Are better methods of **early detection** available and worth investing in and could rapid response be sufficient to the task?
- Identify potential invasive **fungi and soil microbes** and how to address importation risks.
- What are the effects of acid deposition, heavy metal deposition, climate change, and other **stressors** on the impacts of exotic forest insects and diseases, as well as any potential for these stressors to increase the impacts of native forest insects and diseases?
- How does the **management of reservoirs** effect the introduction of exotics?

Hemlock Wooly Adelgid—

- What is the best **integrated pest management for hemlock woolly adelgid** (including new insecticides, seasonal timing of treatments, treatment intervals, individual tree and. or stand factors in chemical uptake, biological control applications?
- Evaluate hemlock replacement processes in response to HWA infestations in contrast to (establish a baseline for) normal hemlock regeneration processes over successive generations. This includes regeneration of hemlock as well as those species replacing the lost hemlocks.
- Examine faunal changes (vertebrates and invertebrates) associated with loss of hemlock stands and implications to the broader forest system (to help define what management actions will help forests compensate for the loss of hemlock stands).

Balsam Wooly Adelgid—

- What are possible **biological controls for balsam woolly adelgid** on Fraser fir?
- Conduct studies on Fraser fir to tease apart the damages and stresses caused by the Fraser wooly adelgid and **other stressors** of
    - acid deposition/nutrient loss,
    - soil microbial changes,
    - climate change, and
    - other possible stressors,
- Determine if fir regeneration is appropriate, sustainable, or in need of management actions that can accomplish positive results; also to identify best actions and a possible threshold levels for action

Wild Hogs—

- What is the level of ecological damage by hogs that can be tolerated in different habitats/communities?
- How does the level of ecological damage relate to hog populations levels?
- Is it possible to reduce and maintain hog population levels low enough to maintain ecological damage below the tolerable level, given what is known about controlling them?
- Is eradication possible? Are there feasible biological controls, and what methods and strategies show the most promise? The management of wild hogs in the Park needs to be more clearly developed and assessed.
- What are the distribution, impacts, and mgt. of **pseudo rabies** in exotic wild hogs?

Diseases and Parasites—

- What are the distribution, prevalence, and interactions between **ranavirus and the chytrid fungus** (Bd) within the park, especially in stream-dwelling and terrestrial salamanders? What are the strains of ranavirus in park amphibians and why have they varied so significantly within site from year to year? Under what conditions do these pathogens cause mortality in park salamanders and are there compounding factors (drought, acid deposition/run-off, etc.)?
- What role do mammals play in **zoonotic disease transmission**, such as Rocky Mountain spotted fever, hanta virus, or Lyme disease? How do trends in mammal population affect disease incidence/transmission? What are the status and trends of mammal populations serving as disease reservoirs?
- Is the White Nose Virus present in sediment samples from any park caves?
- Examine the risks and potential patterns of spread of **brucellosis, pseudorabies, and chronic wasting disease** (CWD) associated with swine and ungulates in and nearby the park to determine what actions may be necessary if the disease is detected.
- Assess the risks and precautionary measures needed for, and risks to, ungulate re-introductions and augmentations related to **brucellosis, pseudorabies, CWD**, etc.
- Determine how to monitor the incidence and impact of **West Nile virus** in the park with the objective to learn how the disease affects wildland ecology and to manage and minimize the most crucial impacts and control of the disease itself.
- Determine a baseline for existing strains of **avian influenza** in park birds, monitor for appearance of the H1N5 strain, and assess the potential impacts on native species, natural communities, and the health of park visitors and staff, along with generating proposals for how to mitigate negative impacts.
- Investigate and establish for selected vertebrate populations what might be considered baseline disease and parasite levels so that monitoring can detect changes from these levels and assess the need for actions to manage them.

Visitor/Public Experience, Use/Effects, and Safety

Public/Visitor Values—

- Through surveys, inventories, or other appropriate means, construct a holistic view of public/visitor values of the park to better understand what is valued, how its value can be improved/managed, and which segments of the public are, or are not, receiving value (and ideas on how to correct this). This is to help in managing and marketing Park resources.
- Identify the **economic conditions** driving the park, its use, and surrounding uses to better understand the economic role the park plays in the region and which economic drivers the park should endeavor to manage to its benefit.

Visitor Protection/Safety—

- Conduct an evaluation of visitor protection and safety issues related to interactions with **wildlife** (bears, ticks, snakes, spiders, dead trees, poisonous plants, biting and stinging insects, mice, skunks, boars, etc.) to understand what and where safety issues of a particular type can be managed. This may also involve the broader issues of human-wildlife interactions as to the effects on wildlife from human activity. Compliance with regulations on wildlife harassment and similar violations are involved.
- Evaluate risks of terrorist acts in and around the park, opportunities for improving security at these sites, and effects such a terrorist act would have on the park resources, visitors, infrastructure, and personnel. Concerns exist about potential public water contamination, biological terrorism (release of biological agents), and security of large crowds or locations of periodic high congestion. Study of backcountry and camping/picnicking security risks and emergency access are also involved.

Visitor Experience—

- Can the resources of the Park be sustained under heavy and increasing visitor use? Research is needed to identify which resources are most negatively affected by visitor use and how the negative impacts can be reduced or eliminated while retaining a quality visitor experience. Modes and extent of transportation (car, horse, foot, bicycle, bus, etc.), surface conditions, and management of wastes and emissions/noises are involved. Effects of concern involve wildlife/biota, air quality, trampling, invasive species, stormwater runoff, safety, maintenance, and habitat fragmentation. One special concern is aquatic resources being physically disturbed as affected by wading visitors, kids moving rocks, etc.

Backcountry Experience and Resource Protection—

- How do backcountry experiences compare with expectations? Can impacts can be ameliorated or visitor behavior/activity redirected. How can differences be brought into alignment through management and marketing?
- Determine how to measure human over-use of wildland, across diverse use types, and conduct studies that help identify how to mitigate specific important effects.
- With backcountry experiences and visitor use patterns that lead to dissatisfactions, are there ways impacts can be ameliorated or visitor behavior/activity redirected? This could apply to several areas of visitor use mentioned in other questions.
- Are there special considerations of recreational uses and effects to plants and animals associated with high elevation resources? This may involve selected recreational uses and unusual conditions associated with species at risk or ecosystems vulnerable to damage and slowness of restoration.
- Are resource education displays at the Abrams Creek campground effective in restraining visitors from building **rock dams and channelizing** the stream? What else would be effective at altering this visitor behavior?

Transportation—

- Evaluate **transportation efficiency** and associated energy use/emissions (i.e., role of local transportation emissions in addition to regional air quality dynamics) in the Park for impacts, management options, and development of thresholds of critical loads. This may be especially appropriate in specific geographically vulnerable corridors or sites during specific seasons, weather conditions, and predictable heavy transportation use periods.
- How can **visitor behavior and vehicle use** in the park be better monitored or assessed where problems of overuse or inconsistent use might occur? Can this be accomplished to identify which uses are the primary problems without infringing on individual privacy?

Land Use and Fragmentation Surrounding Park—

- How is land use changing through time and where do projections of this change, given reasonable assumptions, might lead with respect to managing Park resources?
- At the landscape scale, define the dynamics and characteristics of adjacent development, fragmentation, and habitat loss in ways that enable the effects on Park resources to be better understood. This might require focus on certain habitats or species believed more vulnerable to such effects (e.g., bobcats, pileated woodpeckers, bears, dear, raccoon).
- Examine possible relationships between general wild area loss/fragmentation/disturbance and the condition of several key indicator species sensitive to these changes for the Smokies, to be able to assess and predict the likely impacts of future habitat loss and fragmentation as well as particular aspects of these that are worse than other aspects. This will help address internal park development planning and provide input to adjacent land development. Do the same principles apply as with tropical forests?

Cultural and Archaeological Heritage/Resources

Archaeology and Paleontology— [see also Paleoclimate]

- Determine/define the condition and patterns of **pre-European** vegetation and fauna to establish a target/goal for park management and measure progress toward it. This will have to be defined in such a way as to project pre-European conditions forward to present day as the target since pre-European conditions are probably not possible.
- Conduct an **archaeological survey** of the park using sampling methods to determine settlement patterns across time and space. Include a recognizance survey and sample surveys in likely historic/archaeological sites (Indian dwelling areas, lumber mills, mines, CCC camps, etc.). Assess potential National Register eligibility and utilize information on site location to develop survey priorities.
- Conduct historical/archaeological evaluations of **urban areas/land use** in and around the park to understand how past and present settlement has, and is, affecting the present and future condition of the park. Use this and other information to assess how population growth affects site selection for such growth in the conditions around the park.
- Determine potential effects of **fire** on above and below ground cultural resources. Determine the thermal property of common cultural materials and test these objects under conditions replicating that of natural fire.
- Can **the Middle Archaic** contexts provide evidence of settlement structure and subsistence practices that are generally lacking at more shallow upland sites from these time periods? Was the use of this area limited to short-term occupations, or is there a direct or indirect indication of more intensive use? Do the artifacts and features resulting from those occupations provide insight into the ranges of activities carried out on-site? How do the occupations at these components fit into larger patterns of Middle Archaic settlement (cf. Bass 1975; Ward and Davis 1999; Yu 2001), and how do they correlate with evolving ideas concerning regional paleoenvironments during the period?
- Do the intensive **Late Archaic** artifact distributions result from multiple, recurrent short-term occupations related largely to stone tool production, or is there evidence for more substantial, multi-seasonal occupations as well? How do the feature types, tool assemblages, and tool/debitage ratios compare to those at documented upland lithic workshop sites in the region, such as at 31SW265 (Shumate and Kimball 2001a), as well as those at more similar terrace sites, such as Warren Wilson (Keel 1976) and Iddins (Chapman 1981)? How do the Late Archaic components fit into the larger regional settlement pattern?
- What is the nature of the **Middle Woodland occupations** of the area? Do the Woodland components represent multi-seasonal or year-round farmstead or village occupations? If structures are present, what is their form, and how do they compare with Woodland structures documented elsewhere in the Southeast by Webb (i.p.), Wetmore (1996), Anderson (1985), and others?
- Is there any evidence for **Mississippian occupations**? Can analysis of these materials provide any information concerning the relationships between the Pisgah and Early Qualla cultures?
- What was the nature of the **Historic Cherokee diet**? What suite of cultigens was grown, and how were these plants supplemented by wild plant foods? Is there archaeological evidence for the type of gardening practices used by the Cherokee inhabitants? Is there any archaeological evidence at the Cherokee components for intensive harvesting of medicinal plants, as has been documented ethnohistorically? What evidence is available for Cherokee food storage methods and how do they compare with those documented elsewhere.
- What roles did **hunting, fishing, and (possible) animal husbandry** play in Cherokee subsistence? What information can faunal and shellfish remains provide concerning the pre-modern animal, fish, and shellfish populations of the area?
- Is there any archaeological evidence at the Cherokee sites for **harvesting of medicinal plants** or other plant materials for non-food uses, as has been documented ethnohistorically?

Archival Materials—

- Assess the various forms of archival materials that are in need of preservation, restoration, transfer to digital technology/retrieval, accurate identification, protection, and cataloguing/records management, to systematically prioritize and schedule specific actions. These involve such things as microfiche, oral history tapes, genealogy records, historical/archaeological artifacts, various resource collections, etc. A procedure for accomplishing this must be identified and applied.
- Track down sources and analyze for public education **oral history collections** and findings analyzed for public education.
- Develop more detailed **ethno-history stories** about Afro-Americans, the various Indian periods especially the Cherokee period, logging and mining camps, early settlements, and the evolution of transportation/economies as relate to the resources of the park. Themes might be contributions to present day heritage, humans as part of the environment, early American habitat use, domesticated versus native plants and animals, settlement patterns, subsistence patterns (prehistory to history), barriers shaping relationships, cultural linkages/disconnects with natural resources from prehistory to now.

Cultural Landscapes and Viewsheds—

- Develop a more accurate account of **cultural landscapes** in and around the park, where they occurred and how they related to the surrounding landscape conditions. A particular challenge for the park is to accurately depict conditions of cultural and natural landscapes (to a feasible degree).
- Document, inventory, and analyze for significance and public education the **rock and tree art** in the park.
- Map existing **stone walls** and other boundary features within the park and identify them with land-owners and uses.
- Document, inventory, and retain samples of existing **hierloom plants** and/or fruit trees within the park.
- Inventory and analyze visual resources (views) in the park with respect to **surrounding development and haze** to evaluate more specifically the effects of haze and development on the visual resource experience and which factors/resources are the most important to manage.

Historical Restoration—

- What impacts are generated by the retention and maintenance of Cades Cove, Mingus Mill, and other cultural sites/landscapes on both the natural resources of the Park and the cultural resources of society? Answering such a question may provide insight on how to manage these sites more effectively.
- Is increased air pollution causing accelerated deterioration of gravestones and other cultural monuments in the park and, if so, what are the best ways to reduce or halt the accelerated deterioration? [**Acid Deposition]**

Other Issues

New Technologies—

- Examine the applicability of technologies for identifying species through digital imagery and labeling the imagery properly.
- Evaluate how cell phone technology can be better employed to educate visitors and affect their behavior. This could involve uploading visitor information from cell phones on current conditions/situations, etc.

Threat Analysis—

- Identify a way of determining the greatest threats to the park's health, safety, and sustainability for which the park can take useful management actions. Develop techniques that can help identify reasonable expectations from actions taken. This should help prioritize actions.