Appendix J: Protocol Development Summaries

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In this section, we present 12 protocol development summaries that include all SCPN core vital signs. Some of the summaries are grouped according to a theme and include multiple vital signs, while others contain an individual core vital sign. Each summary contains a list of the vital signs and SCPN parks where the protocol will be implemented, a justification and description for each sign, specific monitoring questions and objectives to be addressed, the protocol development approach, information on the principal investigators and NPS leads, a development schedule, and expected products.

Atmospheric and Climate Conditions

Vital Signs Included:

- Air Quality (ozone, wet and dry deposition, visibility and particulate matter)
- Climate Conditions and Soil Moisture

Parks Where Protocol will be Implemented:

- Air Quality: BAND, GRCA, MEVE, PEFO (monitored by other existing programs)
- Climate Conditions and Soil Moisture: AZRU, BAND, CACH, CHCU, ELMA, ELMO, GLCA, GRCA, HUTR, MEVE, NAVA, PEFO, PETR, RABR, SAPU, SUCR, WACA, WUPA, YUHO

Justification/Issues Being Addressed:

Programs that monitor ecosystem health need to consider the composition of the atmosphere and its interactions with the biological and physical components of the ecosystems under investigation (Nash et al. 1995). In our surveys of natural resources within SCPN parks, clear skies with low pollution was rated as a significant resource in the majority of parks. Specific threats to air quality on the southern Colorado Plateau include emissions from fossil fuel production and combustion, housing developments, and fine pollutant particles that increase haze and reduce visibility. These threats are of particular concern in the SCPN because of the large number of significant natural and cultural resources contained in the 19 park units. Air pollution affects natural and cultural resources through impaired visibility, threats to biotic health, and degradation of historic structures and artifacts (National Park Service Air Resources Division 2002).

Climate is a key ecosystem driver and one of the four interactive controls of ecosystem sustainability (Chapin III et al. 1996). Because observed changes in other vital signs may be in response to a variety of factors (including climate, stressors, intrinsic variation), monitoring climate is crucial to help distinguish among these possible factors of change. Climate monitoring will focus on characterizing seasonal and annual precipitation and temperature patterns, and comparing these patterns to historical ranges of variability.

Most SCPN parks are dominated by ecosystems that are sensitive to climate change. This is evidenced by large acreages of pinyon trees under stress or killed in part by the recent drought (Cobb and Anderson 2004, Breshears et al. 2005). Because all of the top-rated significant natural resources in the SCPN parks (i.e., unique or sensitive habitats, intermittent and ephemeral water sources, and dominant vegetation; Chapter 1) are influenced by climate conditions, it is imperative to monitor climate in these habitats of paramount importance to aid in the analysis and interpretation of their trends. SCPN will focus on monitoring and interpreting climate (including extreme events such as droughts and floods) at different scales to understand both regional patterns to interpret landscape-scale processes (such as widespread changes in vegetation productivity) and local patterns to interpret ground-based sampling of upland and riparian vegetation.

1. ***Air Quality***: *This vital sign was ranked 3rd in the Wildland Values Workshop, 12th in the Montane Ecosystems Workshop, 15th in the Landscape Patterns Workshop, and was selected as a core vital sign at the Vital Signs Workshop.*

   Monitoring this vital sign describes the status and trends in air quality for four parks which are rated as Class I areas under the Clean Air Act (CAA) of 1970, as amended in 1990. The CAA requires that new sources of emissions must not adversely impact air quality or visibility of Class I areas. The SCPN does not perform air quality monitoring in network parks. That work is being done by park staff, the NPS-ARD, the EPA, and affiliated contractors. Measures include ozone, particulate sulfate, nitrogen, atmospheric deposition, dry deposition, and visibility.

2. ***Climate Conditions and Soil Moisture:*** *This vital sign ranked 1st in the Dryland Ecosystem and Montane Ecosystem Workshops, 2nd in the Landscape Pattern Workshop, 5th in the Riparian Workshop, and was selected as a core vital sign at the Vital Signs Workshop.*

Monitoring this vital sign characterizes seasonal and annual precipitation and temperature patterns and compares these patterns to historical ranges of variability. Winter precipitation is particularly important with respect to soil moisture conditions and vegetation establishment, survival, and vulnerability to fire. In semiarid landscapes, the composition and structure of plant communities depends largely on the amount and spatial distribution of soil moisture (Breshears and Barnes 1999). Measuring soil moisture will provide a critical link between monitoring climate and vegetation composition and structure. Sample measures include temperature, precipitation, snow fall, snow depth, wind parameters, relative humidity, fuel moisture, and soil moisture content.

Specific Monitoring Objectives and Questions to be Addressed by the Protocol:

Objective 1: Provide monthly and annual summaries of climate data, including precipitation and temperature, and determine long-term trends in seasonal and annual patterns of climate parameters.

Objective 2: Determine long-term trends in soil moisture.

Objective 3: Provide summaries of air quality data and determine long-term trends in air quality.

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Questions Addressed:

- What are the localized and regional climate trends in seasonal and annual patterns of precipitation and temperature within and across SCPN park units?
- What are the relationships among localized climate conditions and local upland and riparian vegetation conditions?
- What are the annual trends in air quality across the southern Colorado Plateau?

Protocol Development Approach:

Air quality monitoring follows established protocols of four existing programs: the Clean Air Status and Trends Network (CASTNET), the National Atmospheric Deposition Program (NADP), the National Park Service Air Resources Division continuous ozone monitoring, and the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program. Field collection of air quality samples and data is mostly automated, except for the changing of sample collectors (filters and buckets). Field operations consist of weekly visits for inspection, routine maintenance, and sample collection by park staff, and annual maintenance by program specialists. Annual reports are prepared, and include monthly and annually summarized data, calculated standard indices, identification of extreme conditions, and comparisons to historical conditions. SCPN does not plan to fund additional air quality monitoring beyond these existing programs.

Climate conditions are also monitored at existing climate and precipitation monitoring stations following the protocols of several ongoing monitoring programs. An inventory of climate stations across all NPS I&M networks is currently being conducted by the Western Region Climate Center. When completed for SCPN, the inventory results will be used to evaluate the existing protocols, metadata, and spatial coverage of climate data across the network.

Principal Investigators and NPS Lead:

NPS lead is Chris Lauver.

Development Schedule, Budget, and Expected Interim Products:

Air quality monitoring is fully implemented through other programs. Pending completion of the climate station inventory for SCPN, a draft protocol for monitoring climate conditions and soil moisture will be developed during FY 2007.

Aquatic Macroinvertebrates

Parks Where Protocol will be Implemented:

BAND, CACH, GLCA, GRCA, and MEVE

Justification/Issues Being Addressed:

This vital sign ranked 6th in the Riparian and Aquatic Ecosystems Workshop and was selected as a core vital sign at the Vital Signs Workshop.

Aquatic macroinvertebrates serve as effective bio-indicators of overall aquatic integrity. Because living organisms are sensitive to environmental change, biological monitoring can detect chemical, physical, and biological impacts to aquatic ecosystems, as well as their cumulative effects (Karr and Chu 1999). Low flow conditions and the relatively short length of many Colorado Plateau streams result in comparatively small macroinvertebrate populations. Monitoring methods and site selection must be adapted to these conditions and must consider potential sampling impacts to the communities of interest. The status of aquatic macroinvertebrate populations is a high priority vital sign for SCPN parks (Thomas et al. 2004), and monitoring this vital sign will contribute directly to achievement of the Water Quality (Ia4A) Land Health Goal. Monitoring will occur within selected predominant ecological sites occurring in thirteen streams across five SCPN units and will include relatively undisturbed reference sites and sites with a range of degraded conditions (Table J2). The resulting data will complement water quality and integrated riparian monitoring and provide an additional indicator of the overall condition of these ecosystems.

Specific Monitoring Objectives and Questions to be Addressed by the Protocol:

Objective 1: Determine status and trends in the composition and abundance of aquatic macroinvertebrate assemblages in selected perennial streams or stream reaches.

Objective 2: Determine status and trends in the distribution and condition of aquatic macroinvertebrate habitats in selected perennial streams or stream reaches.

Questions Addressed:

- How are species composition and abundance of aquatic macroinvertebrates changing over time in selected water bodies?
- Does variability in water quality correlate with changes in aquatic macroinvertebrate population composition and abundance?

Protocol Development Approach:

The primary focus of the aquatic component of the protocols is the assessment of the status of benthic macroinvertebrate communities and associated habitat characteristics. Periodic sampling of benthic macroinvertebrate communities will employ standard quantitative methods based on established USGS North American Water Quality Assessment (NAQWA) and EPA Environmental Monitoring and Assessment Program (EMAP) protocols. The States of Arizona and New Mexico are in the process of developing regulatory criteria relating to bio-indicators, and SCPN aquatic macroinvertebrate monitoring protocols will ensure that individual State criteria or requirements are met. Field trials compare qualitative vs. quantitative sampling and within-year temporal variability. Field trials to compare methods began in 2005 and will continue in 2006. Qualitative and/or quantitative sampling methods will be used.

Quantitative samples are collected from the community with the richest fauna (typically located in riffles) using a sampler that collects from a known area. Qualitative samples are collected from all available habitat types within a reach. Qualitative samples provide a comprehensive species list. Initial sorting of the samples will be done in the field, and identification of species will be done to the lowest feasible taxonomic level by a contract laboratory. Physical habitat characteristics will be measured at the reach and the transect scale. These include substrate, embeddedness, stream width, depth and velocity, water temperature, riparian canopy cover, and geomorphic channel units.

Aquatic macroinvertebrate monitoring sites will be co-located with water-quality monitoring sites when possible. In some cases, aquatic macroinvertebrate sites will be co-located with integrated riparian monitoring sites and will be selected using a linear-based sampling frame and a stratified GRTS sampling method. Each monitoring site will be revisited once per year. Data analyses will include ordination of community data, and summaries of community metrics.

Principal Investigators and NPS Leads:

The SCP and NCP networks are working collaboratively on this protocol. The Principal Investigator is Anne Brasher, USGS-WRD. NPS leads for SCPN are Lisa Thomas and Steve Monroe. Steve Garman is the NPS lead for NCPN.

Development Schedule, Budget, and Expected Interim Products:

This project is funded jointly by the SCPN, the NCPN, and the USGS-BRD. In FY05, SCPN provided $40,025, NCPN contributed $10,000, and the USGS provided $56,243 towards protocol development. Interim products include a draft protocol report (February 28, 2006), a field trials report on qualitative vs. quantitative sampling (June 30, 2006), and a field trials report on within-year temporal variability (June 30, 2007). Final products include a final protocol report, with all USGS components of protocol documentation (February 28, 2007).

Water Quality of Streams and Springs

Vital Signs Included:

- Water quality of streams and springs
- Stream flow and depth to groundwater (also included in Integrated Riparian Monitoring)

Parks Where Protocol will be Implemented:

AZRU, BAND, CACH, GLCA, GRCA, HUTR, MEVE, PEFO, and PETR

Justification/Issues Being Addressed:

Water quality is a high priority vital sign for the SCPN (Thomas et al. 2004). National Park Service Management Policies for water quality commit the Park Service to protect, maintain, or restore the quality of surface waters and ground waters within the parks consistent with the Clean Water Act and all other applicable federal, state and local laws and regulations (NPS 2001: 4.6.3). Monitoring this vital sign will demonstrate whether or not park water quality is being protected or maintained, inform the need for mitigation or restoration, and contribute directly to the Water Quality (1a4A) and Water Quantity (Ia4C) Land Health Goals. The resulting data will complement aquatic macroinvertebrate and integrated riparian monitoring and provide an additional indicator of the overall condition of these ecosystems. Appendix C provides a detailed description of SCPN water resources and associated resource concerns and issues.

1. ***Water Quality.*** *This vital sign ranked 4th in the Riparian and Aquatic Ecosystems Workshop and was selected as a core vital sign at the Vital Signs Workshop.*

   This includes the NPS-WRD core parameters of temperature, specific conductance, pH, dissolved oxygen, and instantaneous flow of streams and springs. We have added turbidity as a core parameter for SCPN streams. External land use activities and/or park management actions may alter natural turbidity levels, negatively affecting aquatic biotic communities. Major ions, nutrients, and selected trace elements may be monitored on a quarterly basis. Additional parameters (e.g. bacteria, synthetic organics, metals, or pesticides) may be monitored on a site-by-site basis to meet park-specific concerns. This vital sign integrates the influence of climate, hydrologic function, geomorphology, and impacts resulting from recreational use, grazing, resource extraction, exotic species, fire, and flood.

2. ***Stream flow.*** *This vital sign ranked 1st in the Riparian and Aquatic Ecosystems Workshop and was selected as a core vital sign at the Vital Signs Workshop.*

   Stream flow, expressed as a discharge (volume per unit time), is fundamentally linked to the water quality of streams and springs. Streamflow measurements are useful for interpretation and comparisons of water quality data, and calculation of parameter load.

   Four SCPN parks (AZRU, BAND, GLCA, GRCA) contain waters that have identified water quality impairments and are included on State 303(d) lists (Table J1). Other known water-quality issues include grazing-related nutrient enrichment, increased sediment loads associated with upstream land uses and catastrophic wildfire, and contaminants from a number of sources.

   There are no current Outstanding National Resource Water (ONRW) designations among SCPN park waters. It is anticipated that Level 1 inventories and initial water quality monitoring activities will support the identification and nomination of potential ONRW designations of NPS waters.

Table J1. Impaired waters included on Section 303(d) list that are inside SCPN park unit boundaries[1].

Name of Waterbody	Description	State	Park Unit	Exceedances
Animas River	From Estes Arroyo to the NM-CO border	NM	AZRU	Temperature
Capulin Creek	From the mouth on the Rio Grande to the headwaters	NM	BAND	Benthic/macroinvertebrate bioassessment and sedimentation
Rito de los Frijoles	Rio Grande to headwaters	NM	BAND	DDT, Fecal coliform, temperature, and turbidity
Colorado River	Parashant Canyon to Diamond Creek	AZ	GRCA	Selenium and suspended sediments
Paria River	Utah border to Colorado River	AZ	GLCA	Suspended sediments and possibly turbidity

[1]Information for this table from 2004 Integrated 305(b) Assessment and 303(d) Listing Report for Arizona and 2004-2006 State of New Mexico Integrated Clean Water Act 303(d)/305(b) Report Water Quality and Water Pollution Control in New Mexico.

Specific Monitoring Objectives and Questions to be Addressed by the Protocol:

Objective 1: Determine status and long-term trends in water quality for impaired stream reaches within SCPN parks.

Objective 2: Determine status and long-term trends in water quality for pristine waters within SCPN parks.

Questions Addressed:

- Are core water quality parameters changing in relation to historical conditions?
- Is the degree of impairment of 303(d) listed waters changing over time?
- What are the relationships between discharge rates and concentrations of core and site-specific water-quality parameters for SCPN streams?

Protocol Development Approach:

In FY2003 and FY2004, SCPN funded an interagency agreement with USGS-WRD to complete a synthesis of existing water quality data for SCPN parks. In a report to be completed in 2006, this project will summarize past water-quality data for water bodies in and near SCPN parks and will evaluate current trends and issues of concern (see Appendix C). In addition, NPS-WRD provided FY2005-2006 funding to conduct Level 1 Water Quality inventories of 57 key water bodies in 13 SCPN units. These projects will contribute information necessary to identify key needs for long-term water quality monitoring. Results of the Level 1 Water Quality inventories will assist in identification of impaired waters, pristine waters, and waters affected by sources of impairment such as grazing and resource extraction.

SCPN water quality monitoring protocols will ensure that individual State criteria or requirements defined under the Clean Water Act are met. Water quality protocols will be consistent with standard procedures prescribed by the USGS (USGS 1998). Where alternate procedures are followed, documentation and justification will be included in SCPN water quality protocols. In addition to the protocol objectives presented above, specific data objectives are listed below.

Quality control and quality assurance measures will be included in SCPN water quality protocols to ensure that:

- All data shall be comparable throughout the network and with other water quality monitoring programs in the region.
- All data shall be representative of the measured parameters with respect to time, location, and site conditions. The use of the standard methodologies contained in the QAPP insures that the data generated is representative.

***Site Selection**:* Specific sample sites will be selected that are: 1) well mixed and representative of the larger water source; 2) not influenced by nearby inputs from tributaries, major springs or pollutant discharges, (if these are present the sampling location will be far enough downstream to permit thorough mixing); 3) near an established stream flow gage or where a flow measurement is practical; 4) reasonably

accessible; 5) where past sampling provides a historic record; and 6) that are complementary of other vital signs monitoring. Tables J2 and J3 provide preliminary lists rivers, streams, and springs selected for monitoring riparian and aquatic vital signs. These sites were selected based on our current level of understanding of the natural resource waters of SCPN parks and the long-term threats and concerns associated with them (see Chapter 4 and Appendix I).

***Field Measurements**:* The core parameters (temperature, pH, specific conductance, and dissolved oxygen) and turbidity will be measured in the field using a multimeter or with individual meters. Discharge will be measured accepted techniques (current meter, flume, or volumetric), with specific techniques selected based on site characteristics. For sites located near a stream flow gage, the gage-height will be noted at the time of the sampling and the corresponding discharge will be obtained from the appropriate agency.

***Sample Collection**:* Grab samples will be collected (i.e. samples collected at one point in time) in labeled bottles. Composite samples may be assembled from sub-samples collected across a channel for streams larger than 10cfs. Surveys for specific conductance across the channel will be used as an indicator of the need for composite sampling. Standard procedures for preparing sampling bottles and processing equipment for inorganic samples will be used. This involves a detergent wash when needed, a deionized water rinse and an acid rinse for non-metallic equipment. Sample bottles will be rinsed a minimum of three times in ambient water (for unfiltered samples), or filtered ambient water (for filtered samples) prior to the final filling with sample water. For bacteria samples, 100ml to 200ml of water will be collected depending on expected bacterial concentrations. Sample bottles will be treated with sodium thiosulfate if a discharge of chlorinated wastewater or potable water occurs upstream. Samples will be kept chilled after collection.

***Sample Processing**:* Processing will take place on-site, in the field vehicle, or in nearby laboratory space and will be done as soon after sample collection as possible with a maximum holding time of four hours. Samples collected for dissolved constituent analysis will be filtered using a peristaltic pump and 0.45um micron filter. After filtering, samples for major ions and trace elements will be fixed with HNO3. Nutrient samples will be unfiltered (for total concentration) or filtered (for dissolved concentration) and preserved with H2SO4. Samples will be chilled to less than 4°C and shipped to the laboratory in coolers. Samples for bacteria will be placed on ice as soon as possible after collection, and maintained on ice until analyzed. Analysis will be initiated a maximum of six hours after collection.

Lab Processing: Laboratory facilities must have a current EPA certification for the specific analyses to be performed, must meet all relevant State requirements, and must have the capability to analyze to limits of detection that are significantly lower than the water quality standards applied to park waters and sufficient to meet data objectives. Local laboratories will be used for bacteria analysis to accommodate the 6-hour limit between collection and incubation.

Laboratory Results and Data Management: The responsibility for entering data into STORET will rest with NPS-Water Resources Division following receipt of an SCPN data deliverable. Results will be examined as soon as possible after they are available: 1) to ensure the results are within the range of expected values; 2) to identify problems with the sampling program, laboratory or data entry; and 3) to identify important occurrences or trends that might warrant a modification in the monitoring program or a management response.

Training Requirements: Appropriate training will be obtained from either State or USGS training programs. Training for new staff and biennial refreshers for all staff and will be required.

Principal Investigators and NPS Leads:

The NPS leads for protocol development is Steve Monroe, with technical support provided by NPS-WRD and USGS-WRD. NPS, USGS-WRD, or Navajo Nation personnel may provide field assistance.

Development Schedule, Budget, and Expected Interim Products:

A draft protocol will be developed during 2006 and implementation will begin during 2007. Some aspects of the protocol will require field testing, including: selection of specific sample sites; field data recording; flow measurement methodology; field sample processing; and logistics of sample transport.

Table J2. Preliminary list of perennial (P) and intermittent (I) rivers and streams selected for monitoring riparian and aquatic vital signs. "L" designates vital signs monitored using linear-based sampling, and "I" denotes those signs monitored using index sites.

Park	Rivers and Streams	Stream Type	Integrated Riparian			Aquatic Macro-invertebrates	Water Quality
			Riparian Vegetation Composition & Structure	Stream Flow and Depth to Groundwater	Channel Morphology		
AZRU	Animas River	P	-	-	-	-	I
BAND	Capulin Creek	P	L	L	L	I	I
	Rito de los Frijoles	P	-	-	-	I	I
CACH	Tsaile Creek	P	L	L	L	L	I
	Tsaile Creek	I	L	L	L	-	I
	Chinle Wash	I	L	L	L	-	I
CHCU	Chaco Wash	I	L	L	L	-	-
GLCA	Paria River	P	-	-	-	-	I
	Wahweap Creek	P	-	-	-	-	I
	Escalante River	P	L	L	L	I	I
	Coyote Gulch	P	L	L	L	I	I
	Stevens Canyon	P	L	L	L	L	I
	Lake Canyon	P	L	L	L	L	I
GRCA	Cottonwood Creek	I	L	L	L	I	I
	Hermit Creek	P	L	L	L	I	I
	Havasu Creek	P	L	L	L	I	I
	Nankoweap Creek	P	L	L	L	L	I
	Robbers Roost Creek	P	L	L	L	L	I
HUTR	Pueblo Colorado Wash	I	L	L	L	-	I
MEVE	Mancos River	P	L	L	L	I	I
NAVA	Keet Seel Canyon	P	L	L	L	-	-
PEFO	Puerco River	I	L	L	L	-	I
PETR	North Boca Negra Arroyo	I	-	-	L	-	I
SAPU	Abo Arroyo	I	L	L	L	-	-
WACA	Walnut Creek	I	L	L	L	-	-
WUPA	Little Colorado River	I	-	L	L	-	-

Integrated Riparian Monitoring

Vital Signs Included:

- Stream Flow and Depth to Groundwater (also included in Water Quality of Streams)
- Riparian Vegetation Composition and Structure
- Channel Morphology

Parks Where Protocol will be Implemented:

BAND, CACH, CHCU, GLCA, GRCA, HUTR, MEVE, NAVA, PEFO, SAPU, WACA, and WUPA

Justification/Issues Being Addressed:

Riparian ecosystems of the Colorado Plateau are critical landscape elements with unique, high levels of biological diversity. Monitoring of these vital signs will provide information on current status and trends in the condition of riparian ecosystems. Monitoring will occur within selected predominant ecological sites occurring in twenty streams across twelve SCPN units and will include relatively undisturbed reference sites and sites with a spectrum of degraded conditions (Table J2). Physical and biological processes structure and maintain these systems across a broad range of scales. Regional precipitation patterns and upland watershed conditions produce the primary drivers of these ecosystems: stream flow regime and flow-related geomorphic processes. Data obtained from these vital signs will complement water quality and aquatic macroinvertebrate monitoring and provide an additional indicator of the overall condition of these ecosystems. Monitoring these vital signs will contribute directly to achievement of the Riparian and Stream Areas (Ia1D), Wetland Areas (Ia1C), and Water Quantity (Ia4C) Land Health Goals.

1. ***Stream Flow and Depth to Groundwater.*** *Stream flow ranked 1st and depth to groundwater ranked 2nd in the Riparian and Aquatic Ecosystems Workshop. They were merged and selected as a core vital sign at the Vital Signs Workshop.*

   The maintenance of natural hydrologic regimes is widely recognized as essential for sustaining the structure and functioning of riparian and aquatic ecosystems (Baron et al. 2002, Bunn and Arthington 2002, Naiman et al. 2002). Discharge is a measure of flow in a stream channel. Depth to groundwater to includes existing or new alluvial wells.

2. ***Riparian Vegetation Composition and Structure.*** *This vital sign ranked 3rd in the Riparian and Aquatic Ecosystems Workshop and was selected as a core vital sign at the Vital Signs Workshop.*

   Riparian vegetation integrates the influences of hydrology, geomorphology and disturbance regimes. Native riparian ecosystems are threatened by altered hydrology, grazing impacts, and invasion by non-native species in many SCPN parks.

3. ***Channel Morphology.*** *This vital sign ranked 12th in the Riparian and Aquatic Ecosystems Workshop and was selected as a core vital sign at the Vital Signs Workshop.*

   Channel morphology is shaped by (1) the delivery of sediment from adjacent uplands, (2) the competence of the channel to transport the delivered sediment downstream, and (3) the direct and indirect influence of vegetation on these processes. Geomorphic metrics include channel cross section, planform, slope, and bed material. Many SCPN parks have concerns regarding anthropogenic alterations to channel dynamics. There is an expressed need to understand the range of natural variability of cut and fill cycles in relation to ecosystem function, and in relation to the preservation of archeological sites in floodplains.

Human land use activities have profoundly altered characteristics of riparian/aquatic flow regimes throughout much of western North America, with numerous implications for native biodiversity and resource management (Stromberg 2001). Most riparian ecosystems within the Colorado Plateau have been severely degraded through alterations to river flooding regimes and subsequent invasion of non-native species such as tamarisk (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*) (Tuhy et al. 2002). The majority of SCPN parks cite groundwater depletion, surface water flow diversion or alteration,

and invasion of riparian habitats by exotic plants as important management issues. Natural disturbance processes such as fire, and human land-use activities including livestock grazing, timber harvesting, agricultural clearing and groundwater pumping alter watershed conditions, thus influencing downstream riparian ecosystems. Localized activities such creation of roads and trails within riparian corridors further degrade site-specific riparian conditions and contribute to arroyo cutting or channel incision. Arroyo cut-fill cycles occur naturally throughout the southwestern U.S.; however, at parks such as GLCA and CACH the human activities described above have clearly contributed to the frequency and intensity of these erosive events.

Specific Monitoring Objectives and Questions to be Addressed by the Protocol:

Objective 1: Determine status and trends in stream flow and depth to groundwater along selected streams or stream reaches.

Objective 2: Determine status and trends in composition and structure of riparian vegetation along selected streams or stream reaches.

Objective 3: Determine status and trends in channel morphology of selected stream reaches.

Questions Addressed:

- How are stream flow and depth to groundwater changing in relation to historical conditions?
- What are the status and trends of riparian vegetation in relation to reference or desired conditions?
- Are exotic control and restoration efforts effective in returning riparian plant communities to target conditions? How are exotic control and restoration efforts affecting stream flow and depth to groundwater?
- How are channel morphology and patterns of sediment erosion/aggradation changing in relation to historical conditions?
- What are the relationships among these vital signs?

Protocol Development Approach:

The SCP and NCP networks are working collaboratively with the USGS Biological Resources Division to develop integrated riparian monitoring protocols. Sampling of the integrated riparian vital signs will employ methods based on established USGS North American Water Quality Assessment (NAQWA) and EPA Environmental Monitoring and Assessment Program (EMAP) protocols. Where necessary, NAWQA EMAP protocols will be adapted or integrated with methods specific to physical and biotic conditions unique to the Colorado Plateau. Field trials will be conducted at pilot sites to compare site selection methods; develop a hierarchical, process-based stream classification system; quantify between-observer error; and determine the number of transects required to provide representative data at each sample reach.

Integrated riparian monitoring of stream reaches will include measures of physical variables including channel morphology and hydrology, measures of riparian vegetation and may employ both remote-sensed and plot-based methods. Monitoring sites will be selected using a linear-based sampling frame and a stratified GRTS sampling method. Each monitored site will be revisited once every five years, and a subset of the entire group of sites will be visited each year. Streams on the Colorado Plateau are subject to random high magnitude flood events. If an extreme flood occurs at one of the monitored sites, the site will be visited to document the effects of the disturbance event. The sampling design will be replicated within similar geomorphic settings, for example, fan-eddy complexes in bedrock canyons or flood plain meanders in unconfined alluvial reaches. These geomorphic features will thus serve as a sampling template for measurements of related biotic response variables.

Physical variables - In each stream reach, we will: 1) survey and construct a plan-view map of the reach, 2) permanently locate channel cross-sections by placing surveyed head-pins at transect endpoints above high-water marks on either side of the bottomland; 3) determine channel substrate size and composition; and 4) determine substrate composition and size of alluvial surfaces. We will measure stream stage and

discharge and, where possible, in conjunction with existing streamflow gauges, will establish site-specific stage discharge relationships. Where available, we will use existing alluvial well information or establish new alluvial wells to develop functional relationships between surface water and alluvial groundwater dynamics. These data will be used to develop hydrologic gradients based on depth to groundwater or duration of surface water inundation for geomorphic surfaces or specific groups of plants (e.g. Auble et al. 1994, Auble et al. 2005) and used to develop a process based understanding of vegetation response to streamflow dynamics and channel change.

Riparian vegetation variables - At each sample location we will measure vegetation in plots and belt transects co-located with the channel cross-sections described above. Herbs (cover and richness by species) will be sampled by randomly locating and surveying in plots on all identifiable alluvial surfaces from waters edge to the upland boundary (following G. Auble and M. Scott, unpublished data). Similarly, the percent cover of all woody riparian species will be quantified. Patches of woody vegetation intersected by a line will also be measured for vertical structural diversity (following Lite and Stromberg In press). Vegetation structure and composition metrics re-sampled precisely over time can be directly and quantitatively linked to key physical variables.

Principal Investigators and NPS Leads:

The SCP and NCP networks are working collaboratively on this protocol. The Principal Investigator is Mike Scott, USGS-BRD. NPS leads for SCPN are Lisa Thomas and Steve Monroe. Steve Garman is the NPS lead for NCPN and Mark Miller is the USGS/BRD Canyonlands Research Station lead.

Development Schedule, Budget, and Expected Interim Products:

This project is funded jointly by the SCPN, the NCPN, and the USGS-BRD. In FY05 each network provided $30,000 for fieldwork associated with protocol development. Field trials to compare methods begun in 2005 and will continue in 2006. Interim products include field trials reports (February 28, 2006 and December 30, 2006) and a draft protocol report (February 28, 2006). Final products include a final protocol report, with all USGS components of protocol documentation (February 28, 2007).

Spring, Seep, and Tinaja Ecosystems

Vital Signs Included:

- Spring, Seep, and Tinaja Ecosystems
  - Spring flow
  - Water quality
  - Habitat area
  - Vegetation composition and structure
  - Aquatic and riparian invertebrates
  - Amphibians
  - Human alterations and impacts

Parks Where Protocol will be Implemented:

BAND, CACH, CHCU, ELMO, GLCA, GRCA, MEVE, NAVA, PEFO, SAPU, WACA, WUPA, YUHO

Justification/Issues Being Addressed:

Springs, seeps, and tinajas provide sources of water in dry landscapes, support unique plant associations (e.g., hanging gardens), and sustain high levels of biotic diversity including rare and endemic species. Monitoring of these vital signs will provide information on current status and trends in the condition of spring ecosystems – contributing directly to the Wetland Areas Land Health Goal (Ia1C), as well as to the Water Quantity (Ia4C) and Water Quality (Ia4A) goals.

This is a synthetic vital sign that reflects the high conservation value and localized distribution of these scarce water sources within SCPN parks. The importance of springs across Colorado Plateau was repeatedly emphasized during the SCPN expert workshops:

- *Depth to groundwater, which includes spring flow, was ranked 3rd in the Riparian Ecosystems Workshop.*
- *Hanging gardens and related spring sites ranked 2nd, small patch wetlands ranked 7th, and low elevation alkaline seeps and cienegas ranked 9th in the Flora Workshop.*
- *Amphibians at water sources ranked 2nd and spring-associated aquatic and terrestrial invertebrates ranked 4th in the Fauna Workshop.*

1. ***Spring flow***, expressed as a discharge (volume per unit time), is the primary hydrologic component of springs ecosystem function and is essential for geomorphic, soil, and biological integrity of the ecosystem. For tinajas and other water catchments, measures of water presence, or hydroperiod, may be important attributes to track through time.

2. ***Water quality*** involves the geochemistry of water emerging from spring orifices and may include the following parameters: pH, dissolved oxygen, specific conductance, temperature, major ions, alkalinity, turbidity, stable isotopes, nutrients, selected trace elements, and bacteriology.

3. ***Habitat area*** describes the area of unique habitat created by and associated with springs ecosystems. Twelve discrete spring habitat types were identified in the Springer et al. (in prep) springs classification system as being of concern for managers.

4. ***Vegetation composition and structure.*** Vegetation plays an essential role in the biotic integrity of springs ecosystems by preventing soil erosion from water and wind, retaining soil resources and moisture, providing organic matter input for nutrient processing, and providing food and refuge for vertebrate and invertebrate species. In addition, springs on the Colorado Plateau are isolated pockets of biodiversity in surrounding dry landscapes and often harbor unique and rare plant species (Spence 2004).

5. ***Aquatic and riparian invertebrates.*** Aquatic invertebrates serve as bio-indicators of overall aquatic integrity. Because living organisms are sensitive to environmental change, biological monitoring can detect chemical, physical, and biological impacts to aquatic ecosystems, as well as their cumulative effects. It is estimated 70% of the more than 80 aquatic beetles of the Grand Canyon region require springs or spring-fed streams (Grand Canyon Wildlands Council 2004). Riparian invertebrates migrate to or naturally occur in riparian corridors of springs ecosystems. They are good indicators of the biotic integrity of spring ecosystems because of their dependence on riparian cover, affiliation with microclimates created by springs riparian zones, and because they are a diverse group with many unique species. In the arid landscapes of the Grand Canyon region, 93% of the known species are facultatively or obligatorily-associated with the vegetation, litter, shade, and soil moisture conditions provided around springs (Pilsbry 1948, Bequaert and Miller 1973, Spamer and Bogan 1993a, b)

6. ***Amphibians.*** Leopard frogs (*Rana pipiens* complex) have declined throughout the Southwest in recent years (e.g. Clarkson and Rorabaugh 1989, Degenhardt et al. 1996) and several species are federally listed or candidate species under the federal Endangered Species Act. Leopard frogs are known to occur at GLCA, GRCA, MEVE and NAVA. Known and potential threats to leopard frogs in SCPN parks include direct loss of habitat area, introduction of invasive exotic species, and disease. Canyon treefrogs (*Hyla arenicolor*) are common inhabitants of rocky streams and canyons, and often breed in tinajas in rocky canyons. They are known to occur at BAND, CACH, GLCA, GRCA, NAVA, and WACA. Monitoring of canyon treefrogs across these parks may serve as a conspicuous, easily sampled indicator species for tinaja habitats.

7. ***Human Alterations and Impacts.*** Describes alterations to spring hydrology and human-related impacts (e.g., vehicular access, trampling and soil compaction, livestock grazing). Human activities have greatly reduced the ecological integrity of many wetland, riparian, and spring ecosystems through competing exploitative uses including groundwater depletion, fuel wood harvest, recreation, livestock grazing, and wildlife management (Thomas et al. 1979, Johnson et al. 1985, Gregory et al. 1991, Mitsch and Gosselink 1993, Glennon 2002). Overall estimates of riparian habitat loss range from 40% to 90% among the southwestern states (Dahl 1990). The array of specific anthropogenic stressors at springs was documented at more than 220 springs in northern Arizona on the southern Colorado Plateau (Grand Canyon Wildlands Council 2002, 2004, Stevens and Springer unpublished data). These data demonstrate that more than 93% of springs on federal, non-National Park Service lands have been ecologically devastated or are functioning at risk. Even springs within highly protected management units, such as Grand Canyon National Park, have a lengthy history of anthropogenic use and alteration (Grand Canyon Wildlands Council 2002).

Specific Monitoring Objectives and Questions to be Addressed by the Protocol:

Objective 1: Determine status and trends in spring discharge (or tinaja hydroperiod) for selected spring/tinaja sites.

Objective 2: Determine status and trends in core and site-specific water quality parameters for selected spring/tinaja sites.

Objective 3: Determine status and trends in habitat area for selected spring/tinaja sites.

Objective 4: Determine status and trends in vegetation composition and structure for selected spring/tinaja sites.

Objective 5: Determine status and trends in diversity and abundance of aquatic and riparian invertebrates at selected spring/tinaja sites.

Objective 6: Determine status and trends in occurrence (for Leopard frogs) and abundance (for Canyon treefrogs) of selected amphibians associated with spring/tinaja sites.

Objective 7: Determine status and trends in human alterations and impacts to spring/tinaja ecosystems.

Questions Addressed:

- Is spring discharge changing in relation to baseline or historical conditions? Are changes in spring discharge correlated with site alterations?
- Is spring water quality changing in relation to baseline conditions? Are changes in water quality correlated with human use?
- What is the natural range of variability for habitat area in selected spring sites? How does habitat area change in relation to spring discharge? Are changes in habitat area correlated with human use?
- What is the natural range of variability for vegetation composition and structure in selected spring sites? How does vegetation change in relation to spring discharge? How are trends in vegetation composition and structure influenced by disturbance regime? Are changes in vegetation correlated with human use?
- How are aquatic and riparian invertebrate communities changing through time? How do aquatic invertebrate communities change in relation to spring discharge, habitat area, and water quality? How do riparian invertebrate communities change in relation to these factors? Are changes in invertebrate communities correlated with human use?
- How are amphibian communities changing through time? How are they changing in relation to spring discharge, water quality, vegetation, and human use?

Protocol Development Approach:

The SCP and NCP networks are working collaboratively through a CP-CESU agreement with Northern Arizona University to develop inventory protocols and conduct a baseline inventory of springs across both networks. Inventory work was completed at 79 springs in 27 NPS units during the summer of 2005. Inventory data will provide the basis for selecting a representative group of index springs for long-term monitoring and will also serve as a field trial for survey methods. See the Water Quality of Streams and Springs section of this appendix for a summary of SCPN water quality protocol development.

In many SCPN parks, there are few occurrences of springs or tinajas; for these parks the most significant examples were selected as index sites (Table J3). For GRCA, a park that has significant numbers of springs, proposed index sites were selected to represent springs discharging from principal aquifers of the north and south rims, to include a variety of spring types, and to include pristine and developed sites. List-based sampling of spring ecosystems will occur in GLCA. Sampling sites will be selected by using an unequal probability GRTS sample, with selection probabilities based on accessibility, groundwater flow systems, and spring type. Both CACH and MEVE have numerous seeps and springs. Information describing these resources is limited and monitoring sites at these parks will be selected following further inventory and reconnaissance.

Principal Investigators and NPS Lead:

Principal investigators for the inventory portion of this cooperative SCPN/NCPN project are Abe Springer and Larry Stevens, Northern Arizona University. Investigators for the monitoring portion of this study remain to be determined. The NPS leads are Angie Evenden (NCPN), Lisa Thomas (SCPN) and Steve Monroe (SCPN). John Spence, GLCA Botanist, serves as a project advisor.

Development Schedule, Budget, and Expected Interim Products:

Following submission of final products for the NAU Springs Inventory Project (January 2006), the NPS leads will evaluate the suitability of the inventory protocols for monitoring and develop a schedule and budget for completing monitoring protocols. We expect to complete monitoring protocols in FY 2007 and implement monitoring in 2008.

Table J3. A preliminary list of springs (S) and tinajas (T) selected for monitoring.

Park	Site Name	Site Type	Vegetation Composition & Structure	Spring Flow	Macro-invertebrates	Water Quality
BAND	Frijoles Spring	S	X	X	X	X
CACH	TBD	-	-	-	-	-
CHCU	Wijijii Spring	S	X	X	X	X
ELMO	Historic Pool	T	X	NA	X	X
GLCA	TBD	-	-	-	-	-
GRCA	Cottonwood Spring	S	X	X	X	X
GRCA	Hawaii Spring	S	X	X	X	X
GRCA	Nankoweap Spring	S	X	X	X	X
GRCA	Roaring Springs	S	X	X	X	X
GRCA	Robbers Roost Spring	S	X	X	X	X
MEVE	TBD	-	-	-	-	-
NAVA	Keet Seel Ruin Spring	S	X	X	X	X
PEFO	Kokopelli Spring	T	-	X	-	X
SAPU	Abo Spring	S	X	X	X	X
WACA	Cherry Spring	S	X	X	-	X
WUPA	Heiser Spring	S	-	X	-	X
YUHO	Aztec Spring	S	X	-	-	X

Integrated Upland Monitoring

Vital Signs Included:

- Vegetation Composition and Structure
- Soil Stability and Upland Hydrologic Function

Parks Where Protocol Will Be Implemented:

AZRU, BAND, CACH, CHCU, ELMA, ELMO, GLCA, GRCA, MEVE, NAVA, PEFO, PETR, SUCR, WACA, WUPA

Justification/Issues Being Addressed:

Monitoring of these vital signs will provide information on current status and trends in the condition of upland ecosystems – contributing directly to the Upland Land Health Goal (IaIE). Monitoring will occur within selected predominant ecological sites occurring in 15 SCPN units and will include relatively undisturbed reference sites and a range of degraded conditions.

1. ***Vegetation Composition and Structure:*** *This vital sign ranked 2nd and 4th, respectively, in the Dryland and Montane Ecosystem Workshops and was selected as a core vital sign at the Vital Signs Workshop.*

   Biotic functional groups are described as one of the four interactive controls of ecosystem sustainability because of their capacity to shape the structure and functioning of whole ecosystems. This vital sign would focus on monitoring vegetation composition and structure because of its central role in primary production, nutrient and hydrologic cycles, earth-atmosphere interactions, disturbance regimes, and in the provision of resources and habitat structure for wildlife at multiple scales. Sample measures include foliar cover by species, diameter at breast height (dbh) of overstory trees, and density of tree seedlings/saplings.

2. ***Soil Stability and Upland Hydrologic Function:*** *This vital sign ranked 7th in the Dryland Ecosystem Workshop and was selected as a core vital sign at the Vital Signs Workshop.*

   Soil, water, and nutrient dynamics represent another of the four interactive controls of ecosystem sustainability in the Jenny-Chapin model. Soil stability is the capacity of a site to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water (Pellant et al. 2000). Hydrologic function is defined as the capacity of a site to capture, store, and safely release water from rainfall, run-on, and snowmelt, to resist a reduction in this capacity, and to recover this capacity following degradation (Pellant et al. 2000). Sample measures include plant cover, litter/rock cover, presence/absence of erosional features, and cover and development of biological soil crusts.

The legacy of past livestock grazing, altered fire regimes, and the effects of adjacent land use activities are the major park issues relating to upland ecosystems. Livestock grazing is permitted in portions of GLCA and trespass grazing occurs in a number of SCPN parks. Reduced fire frequencies accompanying livestock grazing and active fire exclusion have dramatically changed the structure and/or composition of many vegetation types across the Colorado Plateau (see Dryland and Montane Ecosystem Models). Accelerated soil erosion in Colorado Plateau uplands is a predictable response to many stressors, including altered fire regimes and overgrazing by livestock on adjacent lands. Other anthropogenic stressors include visitor use, exotic plant invasions, air pollution, and global climate changes.

Specific Monitoring Objectives and Questions to be Addressed by the Protocol:

Objective 1: Determine status and trends in composition, diversity, and vegetation structure of plant communities associated with selected predominant upland ecological sites.

Objective 2: Determine status and trends in soil stability and upland hydrologic function within selected predominant upland ecological sites.

Questions Addressed:

- How is the vegetation changing in relation to reference or desired conditions?
- What are the status and trends of vegetation and soil resources in relation to degradational thresholds?
- What are the relationships between vegetation patterns and soil stability/hydrologic function?

Protocol Development Approach:

For dryland ecosystems across the Colorado Plateau, methods will largely be based on assessment and monitoring protocols developed for grassland, shrubland and savanna ecosystems (Herrick et al. 2005a, b), with adaptations to meet specific network needs not otherwise addressed (e.g., a different approach for biological soil crust, consideration of additional or alternate measures for vegetation). For montane forests, the protocol will be adapted to include overstory and fuels monitoring consistent with the NPS Fire Effects Monitoring Program. The protocol will employ transect-based measures of plant cover, composition, litter, and spatial structure, biological soil crust, fuel load, and indicators of soil stability and movement. It is anticipated that monitoring of integrated upland vital signs may partially meet the information needs associated with the landscape pattern protocol development; that is, to provide much-needed ground-based data for assessment, classification, and validation of remotely sensed data.

Sampling sites will be selected using a grid-based sampling frame and GRTS sampling (see Chapter 4). A split panel revisit design will be used to monitor only a subset of sites each year. SCPN has adopted the characterization of landscapes into ecological sites as the basis for stratification. Ecological sites have characteristic soils, hydrology, plant communities, and disturbance regimes and responses (Natural Resources Conservation Services 2003), and are associated with NRCS soil map units. SCPN is monitoring selected ecological sites that correspond to predominant vegetation types. For medium-sized and larger parks (BAND, CACH, CHCU, ELMA, GLCA, GRCA, MEVE, PEFO and WUPA), our goal is to achieve park-level inference for one to four ecological sites per park (with a minimum sample size of 30 sampling sites per ecological site). Many of our monitoring questions pertain to changes that occur within the predominant vegetation types (e.g., what are the trends in bare soil and canopy cover within pinyon-juniper woodlands?). These and other related questions are evaluated through the use of domains during data analysis.

Principal Investigators and NPS Leads:

The SCP and NCP networks are working collaboratively on this protocol. The principal investigator is Mark Miller, USGS-BRD. NPS leads for SCPN are Lisa Thomas and Chris Lauver. Thom O'Dell and Steve Garman are the NCPN leads.

Development Schedule, Budget, and Expected Interim Products:

Protocol development is being jointly funded by USGS-BRD, the NCPN and the SCPN with a FY 2005 budget of $122,000 ($61,000 from SCPN). Field trials for methods comparisons were conducted in FY 2005. Additional field trials will occur in FY 2006 to 1) evaluate methods in forested systems, 2) provide data for variance estimation, and 3) provide field verification of ecological site maps. Interim products include a report summarizing the results of field methods assessment (December 2005), preliminary data analyses (December 2005) and a draft protocol (by March 2006). Implementation will begin in 2007.

Habitat-Based Bird Communities

Parks Where Protocol will be Implemented:

- Riparian Bird Communities: BAND, CACH, GLCA, GRCA, MEVE
- Upland Bird Communities: BAND, GRCA, MEVE, PEFO, WUPA

Justification/Issues Being Addressed:

Riparian bird communities ranked 3rd and the broader vital sign, habitat based bird communities, ranked 5th at the Fauna Workshop. The latter was selected as a core vital sign at the Vital Signs Selection Workshop. It includes riparian bird communities.

The goal is to provide status and trends data on bird communities in several habitats where integrated upland or riparian monitoring is occurring, and to provide status and trends data on ground-dwelling arthropods in one or two upland habitats. The resulting data will complement integrated upland or riparian monitoring and provide an additional indicator of the overall condition of these ecosystems. In some parks, bird monitoring may contribute to the Species of Management Concern Goal (Ia2B).

Bird communities were selected as a core vital sign to serve as an indicator of the overall condition of SCPN park ecosystems. Their high body temperature, rapid metabolism, and high ecological position in most food webs make them a good indicator of the effects of local and regional changes in ecosystems. Many bird species are obligates in habitats that are widely distributed across the network. Some of these bird species and habitats are considered to be of conservation concern due to changes in habitat condition. For many of these habitats, relatively undisturbed NPS sites serve as a reference for comparison with more degraded conditions on adjacent lands. Bird communities are also relatively easy to monitor with established methods and monitoring results can be integrated with other monitoring efforts (e.g., vegetation composition and structure). Comparable regional and national data sets exist and there is a history of monitoring bird species at many SCPN parks. Moreover, it has been suggested that birds are perhaps the most highly valued component of North America's biological diversity (Rich et al. 2004). Many parks provide information on the status and trends of birds through their interpretive programs.

The Colorado Plateau ecoregion has experienced degradation and/or loss in areal coverage of major ecosystem types and their constituent plant communities (Tuhy et al. 2002). Other regional resource concerns include the legacy of previous livestock grazing, fire management issues, recreational use, and forest management. All of these practices have been found to affect associated bird communities, sometimes detrimentally. Bird species that deserve special attention within the region, including species within habitats that are priorities for conservation, have been identified by Partners in Flight and The Nature Conservancy (Latta et al. 1999, Biedleman 2000, Parrish et al. 2002, Tuhy et al. 2002, Rustay et al. 2003). These species may be candidates for more intensive monitoring of nesting success. Table J4 provides a preliminary list of predominant Colorado Plateau habitats and associated species of concern.

Specific Monitoring Objectives and Questions to be Addressed by the Protocols:

Riparian Bird Communities:
Objective 1: Determine status and trends in composition and abundance of breeding bird communities associated with riparian vegetation of selected streams or stream reaches.

Objective 2: Improve our understanding of breeding bird-habitat relationships in riparian zones by correlating changes in species composition and relative abundance/density with changes in specific habitat variables.

Upland Bird Communities:
Objective 1: Determine status and trends in composition and abundance of breeding bird communities associated with selected upland habitats.

Objective 2: Determine status and trends in reproductive success for selected breeding species, in selected upland habitats.

Objective 3: Improve our understanding of breeding bird-habitat relationships and the effects of management actions or land use practices (e.g., fire management, grazing) by correlating changes in species composition and abundance/density with changes in specific habitat variables.

Questions Addressed:

- What trends in breeding bird communities are occurring in a particular upland habitat (e.g. pinyon-juniper woodland)?
- Are trends in nesting success of indicator species correlated with changes in habitat condition?

Protocol Development Approach:

Bird Communities:
Bird community monitoring will include breeding season surveys that employ variable circular plot (VCP) methodology (Reynolds et al. 1980, Scott et al. 1986, Buckland et al. 1993, Fancy 1997, Nelson and Fancy 1999, Buckland et al. 2001). At each of the transect points, an 8-10 minute survey is performed. Observations of birds by sight or call are recorded along with the distance from point center to the first detection of an individual.

Riparian bird communities will be monitored in five SCPN parks (BAND, CACH, GLCA, GRCA, and MEVE). The target populations are the riparian corridors along the streams and rivers in these parks that are also the focus of integrated riparian monitoring. The bird sampling frame corresponds to individual stream systems. As with the monitoring of upland bird communities, points will be sampled along linear transects and spaced 250m apart. The number of sampling points required for monitoring riparian bird communities within a stream ecosystem remains to be determined. The sampling points selected for integrated riparian monitoring (using a GRTS sample with unequal probabilities) will represent the starting locations for the riparian bird transects. Each sampling point along a transect will be sampled 3 times during the breeding season. The revisit design has not been determined.

Upland bird communities will be monitored in 5 SCPN parks (BAND, GRCA, MEVE, PEFO, and WUPA). The goal is to provide status and trends of bird communities in several upland habitats (e.g., pinyon-juniper woodland, mixed-conifer forest, grassland) that commonly occur across these parks. The initial target populations for bird monitoring will be represented by a subset of the target ecological sites designated for integrated upland monitoring. For each of the target ecological sites, the sampling frame will be a randomly-oriented systematic grid of points that are evenly spaced 250m apart. Sampling sites (and corresponding transects) will be allocated by generating a GRTS sample with unequal probabilities. Selection probabilities will be based on travel costs. Each sampling point along a transect will be sampled 3 times during the breeding season. The revisit design has not been determined.

Over the next year we will consider whether to include monitoring of reproductive success in all upland habitats where VCP monitoring occurs, and if so, which species to target. For monitoring nesting success of selected bird species, SCPN will employ a dual frame approach to sampling. Within the target ecological sites, a second list-based sampling frame will be composed of known locations of nesting sites, derived from previous and current sampling. Sampling sites will be selected from the list-based sampling frame for each target ecological site by using an unequal probability GRTS sample. Selection probabilities will be based on accessibility (travel costs), and inferences are made within target populations from sampled to unsampled nests. The revisit design has not been determined.

Bird community and population monitoring will employ fairly standard sampling methods. Much of the protocol development effort will focus on carefully selecting the habitats of interest in each park and providing park-specific recommendations regarding which species are most appropriate for monitoring of nesting success.

Principal Investigators and NPS Lead:

Bird protocol development will be accomplished through a CP-CESU agreement with Northern Arizona University. Principal Investigators are Matthew Johnson and Jennifer Holmes. Lisa Thomas is the NPS lead.

Development Schedule, Budget, and Expected Interim Products:

The SCPN funded bird protocol development through a CP-CESU agreement with Northern Arizona University, providing $98,500 in FY 2005. Bird protocol development will continue through FY 2007. Interim products include habitat-specific conceptual models and a pilot study plan (January 2006), draft monitoring methods (January 2006), a pilot study report (August 2006) and the final protocol (March 2007). Implementation will begin in FY 2008.

Table J4. Predominant bird habitats of the Colorado Plateau, related issues and bird species of concern. Sources used for identifying bird species of concern were Partners in Flight Bird Conservation Plans for Utah, Colorado, New Mexico and Arizona (Latta et al. 1999, Biedleman 2000, Parrish et al. 2002, Rustay et al. 2003) and The Nature Conservancy's Conservation Assessment of the Colorado Plateau Ecoregion (Tuhy et al. 2002).

Habitat	Linked Ecological & Management Issues	Bird Species of Concern
Riparian	Water diversions, altered flow regimes, groundwater pumping; Exotic plant management & restoration of native vegetation; Grazing, recreational use & adjacent land use/development.	Southwest Willow Flycatcher, MacGillivray's Warbler, Western Wood Pewee, Western Yellow-billed Cuckoo, Lewis's Woodpecker, Lucy's Warbler, Bell's Vireo
Ponderosa Pine Woodland/Forest	Wildfire & fire management; insect outbreaks; Timber harvest, fuelwood cutting & grazing on adjacent lands	Mexican Spotted Owl, Flammulated Owl, Lewis's Woodpecker, Pygmy Nuthatch, Brown Creeper, Western Bluebird, Grace's Warbler, Cordilleran Flycatcher, Virginia's Warbler, Red-faced Warbler, Band-tailed Pigeon
Mixed Conifer Forest	Wildfire & fire management; insect outbreaks; Timber harvest, fuelwood cutting & grazing on adjacent lands	Mexican Spotted Owl**,** Brown Creeper, Western Bluebird, Virginia's Warbler, Band-tailed Pigeon, Williamson Sapsucker, Red-faced Warbler
Piñon-Juniper Woodlands	Legacy of past grazing; exotic plant management (e.g. cheatgrass); wildfire & fire management; grazing & adjacent land use/development	Gray Flycatcher, Black-chinned Hummingbird, Pinyon Jay, Juniper Titmouse, Cassin's Kingbird, Gray Vireo, Black-throated Gray Warbler
Shrublands (e.g. sagebrush, greasewood, saltbrush)	Legacy of past grazing, exotic plant management (e.g. cheatgrass), wildfire & fire management; grazing & adjacent land use/development	Brewer's Sparrow, Gunnison Sage Grouse, Greater Sage Grouse, Scaled Quail, Loggerheaded Shrike, Green-tailed Towhee, Black-throated Sparrow, Black-chinned Sparrow, Sage Sparrow
Grasslands	Legacy of past grazing; exotic plant management (e.g. cheatgrass); wildfire & fire management; woody plant encroachment; grazing & adjacent land use/development	Ferruginous Hawk, Prairie Falcon, Mountain Plover, Long-billed Curlew
Cliff/Rock	Recreational use; mining & adjacent land use/development; pesticide use	Peregrine Falcon, Prairie Flacon, White-throated Swift, Black Swift, California Condor

Ground-Dwelling Arthropods

Parks Where Protocol will be Implemented:

GRCA, MEVE

Justification/Issues Being Addressed:

Elements of this vital sign were considered at the Montane and Faunal Workshops. It was selected as a core vital sign at the Vital Signs Workshop to broaden our coverage of trophic levels to include both a vertebrate and invertebrate group.

The goal of monitoring this vital sign is to provide status and trends data on ground-dwelling arthropods in one or two upland habitats as an indicator of ecosystem condition.

Invertebrates are critical to ecosystem function and can make excellent bioindicators of soil and vegetation health (Marcot et al. 1997). Invertebrates are sensitive to change and can be used to detect changes in the environment at small, spatial and short, temporal scales. Because of a lack of information concerning which arthropod group(s) would best serve as indicators across different ecosystems, the specific group was left undefined, pending completion of a literature review.

Monitoring a terrestrial invertebrate assemblage provides important data on the connection between primary producers and consumers. Because invertebrates are low in the food chain, changes in their populations may reflect changes in the health of terrestrial ecosystems much faster than other higher-level groups of plants or animals. For example, responses of ant species can be grouped into 'increasers' and 'decreasers' in relation to different disturbances on Australian rangelands (Andersen et al. 2004). Monitoring this vital sign will focus on tracking relative abundance and diversity patterns, as well as species distribution.

Specific Monitoring Objectives and Questions to be Addressed by the Protocols:

Objective 1: Determine status and trends in the composition and relative abundance of ground-dwelling arthropods in selected upland habitats.

Questions Addressed:

- What are the seasonal and annual trends in invertebrate composition and abundance?
- What are the relationships among invertebrate composition and abundance, vegetation structure and composition, soil stability, and soil moisture?

Protocol Development Approach:

A literature review to evaluate terrestrial arthropod groups as candidates for long-term monitoring resulted in the recommendation that the SCPN focus arthropod monitoring on ground-dwelling arthropods in one common habitat type. Advantages of ground-dwelling arthropods include: 1) sufficient diversity to identify indicator taxa, 2) well known taxonomically compared to other arthropod groups, 3) easily monitored compared to other groups, and 4) sufficiently studied to assess biotic linkages.

Monitoring of ground-dwelling arthropods will be restricted to a few sites within pinyon-juniper woodland habitat in two SCPN parks (GRCA and MEVE). The sampling frame (one for each park) consists of a list of accessible upland sites (derived from the upland vital signs grid-based sampling frame) of the target habitat. Sampling sites will be allocated by generating a GRTS sample with equal probabilities. Arthropod sampling will employ pit-fall traps which will be visited at least three times during the growing season. The revisit design has not been determined.

Principal Investigators and NPS Lead:

A literature review to evaluate terrestrial invertebrate groups as candidates for long-term monitoring and assess their utility as indicators of ecosystem integrity was accomplished through a CP-CESU agreement with Northern Arizona University. The Principal Investigator was Neil Cobb who may also serve as the Principal Investigator to develop monitoring protocols. Lisa Thomas is the NPS lead.

Development Schedule, Budget, and Expected Interim Products:

The schedule and budget for developing ground-dwelling arthropod protocols has not been determined. We anticipate that protocol development will occur in FY 2006 and FY 2007 with implementation in FY 2008.

Early Detection of Invasive Exotic Plants

Parks Where Protocol will be Implemented:

CACH, ELMO, GLCA, GRCA, HUTR, MEVE, NAVA, RABR, SAPU, YUHO

Justification/Issues Being Addressed:

This vital sign ranked moderately high in four of the expert workshops (Riparian, 5th; Dryland, 5th; Montane, 7th; Landscape Pattern, 9th) and was selected as a core vital sign at the Vital Signs Workshop.

This vital sign involves detecting new populations of invasive species before they are well established in areas of management significance. Monitoring will provide information on current status and trends regarding new infestations of invasive species – contributing directly to the Invasive Plants Goal (Ia1B).

Hobbs and Humphries (1995) identified a significant time lag between the initial establishment of an invasive exotic and its rapid expansion toward local carrying capacity. Control efforts initiated during this lag phase are likely to cost less and achieve higher success rates compared to efforts begun later in the invasion cycle (Hobbs and Humphries 1995). Early detection of new invasions will assist park managers in effectively targeting exotic control efforts. Monitoring may include plot-based and remotely sensed data.

Concern regarding the ecological impacts of invasive exotic plants is consistently high among SCPN and NCPN parks. Exotic plants can alter community structure via competitive effects on native species, but the most serious threat to native biodiversity comes from exotic species that significantly alter disturbance regimes or soil-resource regimes, two of the interactive controls of ecosystem sustainability (Vitousek 1990, Chapin III et al. 1996, Chapin III et al. 1997). Examples of ecosystem-altering effects of invasive exotics on the Colorado Plateau include conversion of grasslands and shrublands to cheatgrass (*Bromus tectorum*), dominance and altered riparian hydrology associated with tamarisk (*Tamarix* spp.), and Russian olive (*Eleagnus angustifolia*) invasion. Rather than documenting status and trends of established invasive exotics, this vital sign will focus on detecting new exotic invasions that pose a threat to the integrity of Colorado Plateau ecosystems.

Specific Monitoring Objective to be Addressed by the Protocol:

Objective 1: To detect incipient populations and new occurrences of selected invasive exotic plants before they become established in areas of management significance.

Protocol Development Approach:

Our approach to detecting new invasions of exotic plant species is to monitor those areas where invasive species are likely to establish first. Important aspects of this strategy include 1) narrowing the reference frame to those areas where new invasions are most likely to occur (versus attempting complete spatial coverage), 2) relying on fairly rapid survey methods that could efficiently detect new species occurrences over large plots/areas, and 3) using search-based methods, adaptive sampling, or other approaches suitable for detecting rare occurrences. Sampling strategies should emphasize:

- Key vectors and pathways for invasive species and their propagules.
- Park areas most vulnerable to exotic invasion (e.g., disturbed or degraded sites, particular soil types, etc.).
- Park areas exposed to major disturbance events (e.g., fire, flood, etc.)

A challenge in developing early detection protocols for NPS units within NCPN and SCPN is the range of park sizes, area configurations, and adjacent landscape contexts surrounding the parks. We anticipate that optimal survey designs and approaches will vary depending upon these factors. An important component of protocol development will be to identify and test a range of approaches that are appropriate for these differing scales and contexts. For example, in the smallest SCPN park units, the most efficient strategy for detecting new invasions may involve a complete search of the park. One product of protocol development will be a decision support framework to guide network/park personnel through the process of selecting an optimal survey design and survey methods for a particular NPS unit. Another component

will be to develop species profiles for invasive plants in the ecoregion. These profiles will be used to generate rankings to target monitoring toward exotic species that represent the greatest emerging threat.

USGS-BRD is sponsoring several research efforts to develop early detection monitoring for NPS. One of these efforts, a collaborative SCPN/NCPN project, is focused on developing and testing invasibility models for Colorado Plateau ecosystems. Directed toward medium-sized and large parks, predictive models of exotic plant invasion and dispersal will be used to create geospatial zones of invasibility for each park. The invasibility zone GIS layer will then be used as a guide for sampling allocation. Sampling will occur across most probability zones, but, more sampling will be focused on those zones with the highest invasion probabilities. These zones differ in their degree of vulnerability to invasion based on several factors, including (1) propagule pressure and invasion pathways, (2) resource availability, (3) physical site attributes, and (4) vegetation cover.

In FY 2006, work will focus on analyzing patterns and modeling non-native species distribution and abundance in relation to biotic and abiotic landscape factors or environmental variables for 3-6 SCPN/NCPN park units. Following this step, models will be validated using existing vegetation mapping data, and a plan for further validation using new field data will be developed.

Principal Investigators and NPS Leads:

Protocol development will be accomplished for SCPN and NCPN through an interagency agreement with USGS/BRD. Principal Investigators are Kathryn McEachern and Matt Brooks, USGS/Western Ecological Research Center, Noel Pavlovic, USGS/Great Lakes Science Center and Robert Klinger, University of California - Davis. Lisa Thomas is the SCPN lead and Thom O'Dell is the lead for NCPN.

Development Schedule, Budget, and Expected Interim Products:

Model development and validation will continue through FY 2006 and FY2007 with a final report due in 2008.

Land Use/Land Cover and Landscape Vegetation Pattern

Parks Where Protocol will be Implemented:

AZRU, BAND, CACH, CHCU, ELMA, ELMO, GLCA, GRCA, HUTR, MEVE, NAVA, PEFO, RABR, SAPU, SUCR, WACA, WUPA, YUHO

Justification/Issues Being Addressed:

Monitoring land use/land cover and landscape vegetation patterns within and surrounding SCPN parks is critical to understanding present and future ecosystem states and dynamics, biodiversity patterns, available habitats, movements of organisms, and flows of energy and materials. Land management and development on adjacent lands are among the most significant issues common to all SCPN parks. Increased development and intensification of land use practices (including grazing, logging, and recreation) on lands bordering parks have several ecological consequences, including sharper contrasts (and edge increases) in vegetation structure and function along park boundaries, change in the effective size of the parks' natural ecosystems, changes in ecological flows into and out of the park, loss of adjacent habitat, and increased exposure to human activity along park boundaries (Hansen and Jones 2004). Combining these exterior issues of adjacent land use with past legacies of livestock grazing and altered fire regimes within SCPN parks further creates this demand to monitor land cover and vegetation patterns.

Land Use/Land Cover and Landscape Vegetation Pattern**:** *This vital sign was ranked 3rd (landscape pattern) and 4th (land use/land cover) in the Landscape Patterns Workshop, 3rd (landscape pattern) and 6th (land use/land cover) in the Montane Ecosystem Workshop, 8th (landscape pattern) in the Riparian Workshop, 10th (land use/land cover) in the Wildland Values Workshop, 13th (landscape pattern) and 15th (land use/land cover) in the Dryland Ecosystem Workshop, and was selected as a core vital sign at the Vital Signs Workshop.*

We will monitor two types of landscape pattern with the use of digital satellite data: land use/land cover describes relatively coarse patterns in land cover (e.g., forest/shrub/grassland vegetation, water, manmade features) and land use (e.g., urban, agriculture, rangeland, forest, water, wetland, barren land) within and surrounding SCPN parks; and landscape vegetation pattern describes landscape structure (the extent, patch size, spatial configuration, and connectivity of vegetation types) and landscape composition (the distribution, richness, and proportion of vegetation types) within SCPN parks. Other vegetation patterns will also be monitored including total percent vegetation cover and/or bare ground cover as continuous variables, and age-class structure of selected wooded ecosystems. Collectively, this monitoring will characterize a multitude of landscape patterns including changes in landscape context (e.g., habitat fragmentation and connectivity), changes in vegetation patterns (e.g., forest structure changes as a result of disturbances), and adjoining land use patterns of areas surrounding NPS park units. Sample measures include spatially explicit data sets that describe the composition, extent, and distribution of numerous land cover/land use and vegetation types, and indices of habitat fragmentation and connectivity.

Specific Monitoring Objectives and Questions to be Addressed by the Protocol:

Objective 1: Determine status and trends in the composition, extent, and distribution of land use/land cover and vegetation types on lands within and adjacent to SCPN parks.

Objective 2: Determine status and trends in fragmentation and connectivity of selected land cover and vegetation types within and adjacent to SCPN parks.

Objective 3: Determine status and trends in land cover and vegetation patterns along park boundaries, and compare patterns within and adjacent to SCPN parks.

Questions Addressed:

- What are the trends in the types, extent, and distribution of general land cover/land use on lands within and adjacent to SCPN parks?
- What are the landscape level trends in vegetation structure and composition within and among ecosystems in SCPN parks?
- What are the landscape level trends in habitat fragmentation and connectivity on lands within and adjacent to SCPN parks?
- What are the relationships among changes in land cover/land use on lands adjacent to SCPN parks and habitat fragmentation and connectivity within and adjacent to parks?

Protocol Development Approach:

The data source for monitoring is satellite imagery with medium spatial and spectral resolution (e.g., digital Landsat data). Monitoring is a census approach (rather than sampling) because imagery is acquired for the full spatial extent of the park or for the full extent of the greater park ecosystem. The greater ecosystem includes the area of the park and the lands surrounding it that potentially influence the park area.

Satellite scenes are classified to create geospatial layers of the initial conditions (i.e., baseline maps) of land cover and vegetation indicators. Where available, the NPS vegetation mapping products will be used to guide classification of lands within the greater park ecosystem. Additionally, ground-based plot data collected from monitoring other vital signs (Integrated Upland and Integrated Riparian protocols) may be used to inform the classification process. With subsequent monitoring and additional imagery, change detection methods are employed at the pixel level to assess direction and magnitude of spectral change. Pixels with spectral changes of sufficient magnitude are assigned to new land cover or vegetation types. Ground-based assessments (from other vital signs monitoring) and/or supporting information (e.g., aerial photographs) will be used to verify changes, and attribute reason for change where possible.
The costs associated with acquiring and classifying digital images require a minimum revisit design of once every five years.

Status and trend assessments will be performed using a set of landscape metrics that individually describe independent pattern components but collectively cover the complexity of spatial patterns. These metrics will characterize the composition, extent, configuration (e.g., mean patch size, patch shape) and connectivity (using indices) of land cover and vegetation types. Composition, extent, and configuration measures will be generated for all types, whereas connectivity and fragmentation indices will be derived for specific or combined land cover or vegetation types. Metrics will be generated using spatial pattern analysis programs (e.g., FRAGSTATS). All land and vegetation cover related metrics will be generated separately for park and for adjacent lands. Fragmentation and connectivity-related measures will apply to park lands, and to park and adjacent lands combined.

Principal Investigators and NPS Lead:

Protocol development is a joint effort with the Northern Colorado Plateau Network (NCPN), and the following P.I.'s: Warren Cohen and Robert Kennedy, USDA Forest Service, Corvallis, Oregon, and Zhiqiang Yang, Department of Forest Science, Oregon State University, Corvallis, Oregon. NPS leads are Chris Lauver (SCPN) and Steve Garman (NCPN).

Development Schedule, Budget, and Expected Interim Products:

Protocol development funding was initiated jointly in FY 2005 by NCPN and SCPN at $123,000, split evenly between the two networks. A draft review of literature and potential data sets was completed in November 2005. A detailed study plan will be completed in early 2006 describing pilot studies for mapping existing conditions and methods for detecting change. A draft protocol for monitoring land cover and vegetation patterns in Colorado Plateau ecosystems is expected in December 2006, with final protocols completed during 2008.

Vegetation Condition and Disturbance Patterns

Parks Where Protocol will be Implemented:

BAND, CACH, CHCU, ELMA, ELMO, GLCA, GRCA, MEVE, NAVA, PEFO, PETR, SAPU, SUCR, WACA, WUPA

Justification/Issues Being Addressed:

To monitor ecosystem dynamics and their functional status at the landscape level across the network, it is essential to monitor not only the patterns of vegetation but also its health or condition and the patterns of disturbances that affect vegetation. Information on vegetation condition (vigor and productivity) is critical to understanding how ecosystems are impacted by and responding to current land management practices and natural factors. Historical and current factors affecting vegetation condition in the southern Colorado Plateau include droughts, floods, livestock grazing, logging, thinning, fire suppression, increasing fire extents and severity, insect outbreaks and disease, and increasing development and recreation. Ecosystem degradation on lands adjacent to parks can impact park lands by increasing soil erosion and contrasts of vegetation composition, structure, and condition along park boundaries. Changes in vegetation conditions are occurring and will continue to occur within parks. The combined effect of recent climate change (drought), altered fire regimes, and an associated response in insect outbreaks (increases in extent and severity) has increased the need to monitor these disturbance patterns in SCPN semiarid and montane ecosystems. Because these changes to ecosystem drivers (climate, fire) are having widespread effects (e.g. Cobb and Anderson 2004, Breshears et al. 2005) and are operating on rapid and variable temporal scales, use of remotely sensed data to monitor vegetation condition and disturbance patterns is desired. Monitoring this vital sign on park lands will allow managers to develop effective mitigation actions (where possible), and monitoring of vegetation conditions on adjacent lands will inform park managers of potential impacts along boundaries and promote effective mitigation strategies with adjacent landowners.

Vegetation Condition and Disturbance Patterns: *This vital sign was ranked 1st (disturbance patterns) and 5th (vegetation condition) in the Landscape Patterns Workshop, 2nd (disturbance patterns) and 5th (vegetation condition) in the Montane Ecosystem Workshop, 4th (disturbance patterns) and 11th (vegetation condition) in the Dryland Ecosystem Workshop, and was selected as a core vital sign at the Vital Signs Workshop.*

The phenology of terrestrial vegetation generally responds to seasonal and annual climate and hydrologic dynamics (Zhang et al. 2003) and associated disturbance regimes. Monitoring vegetation condition focuses on using satellite data to track broad-scale patterns in the vigor or greenness of vegetation and in vegetation phenology (or production) throughout the growing season. This includes identifying vegetation under stress from climate (drought), pests, and human influences, and areas with high vegetation mortality due to fire or other disturbances. Monitoring vegetation disturbance focuses on using satellite data to determine spatial and temporal patterns that describe the frequency, extent, seasonality, and severity of disturbances such as fire and insect pest outbreaks. The Normalized Difference Vegetation Index (NDVI), derived from satellite data, will be the primary measure of plant growth (vigor) and biomass production; NDVI data have been correlated with green leaf area index (LAI), green biomass, and percent green vegetation cover (Tucker 1979, Asrar et al. 1989, Baret and Guyot 1991). Other sample measures include the start and end dates and duration of the growing season and dates of maximum production for the dominant vegetation types, and spatially explicit data sets of the frequency, extent, and severity of disturbances.

Specific Monitoring Objectives and Questions to be Addressed by the Protocol:

Objective 1: Determine annual status and trends in vegetation condition of the dominant land cover and/or vegetation types within and adjacent to SCPN parks.

Objective 2: Determine long-term trends in disturbance patterns within SCPN parks.

Questions Addressed:

- What are the regional trends in vegetation condition within and among dominant land cover and/or vegetation types across the southern Colorado Plateau?
- What are the trends in the types, extent, distribution, and severity of disturbances of the dominant vegetation within SCPN parks?
- What are the relationships among changes in the patterns of the dominant land cover and/or vegetation types, vegetation condition, and vegetation disturbance patterns?
- What are the relationships between trends in vegetation condition and climate patterns?

Protocol Development Approach:

The data source for monitoring vegetation disturbance patterns is satellite imagery with medium spatial and spectral resolution (e.g., Landsat data). Digital data from the MODIS instrument aboard the Terra satellite (with a spatial resolution of 250 m) are used as surrogates to monitor vegetation greenness, annual productivity, length of season, and date and level of maximum production. Monitoring is a census approach (rather than sampling) because imagery is acquired for the full spatial extent of the park or for the full extent of the greater park ecosystem. The greater ecosystem includes the area of the park and the lands surrounding it that potentially influence the park area.

Methods using MODIS NDVI data (available every 16 days) are employed to derive vegetation phenological metrics. Seasonal and annual NDVI curves are used to track vegetation green-up times, production levels, and senescence periods. Vegetation condition is monitored for each greater park ecosystem, and changes are identified with year-to-year comparisons of NDVI curves. Monitoring data of associated vital signs (climate, land use/land cover patterns, vegetation disturbance patterns, and vegetation structure and composition) are used to evaluate and understand changes to vegetation condition. As part of the protocol, monitoring data will be displayed as maps to illustrate current and past productivity and areas experiencing changes in vegetation condition.

To monitor vegetation disturbance patterns, satellite scenes are classified to create baseline maps that delineate the type, extent, and severity of disturbance. Existing maps are used (when available) in cases involving large and recent disturbances. With subsequent monitoring and additional imagery, change detection methods are employed at the pixel level to assess direction and magnitude of spectral change. Pixels are assigned to new disturbance classes if spectral changes of sufficient magnitude are detected. Monitoring data of associated vital signs (vegetation condition, climate, and vegetation structure and composition) are used to understand large-scale changes to vegetation disturbance patterns.

Principal Investigators and NPS Lead:

Protocol development is a joint effort with the Northern Colorado Plateau Network (NCPN), and the following P.I.'s: (1) For Vegetation Condition: Mike White, Utah State University, Logan, Utah, and Brad Reed, USGS, Flagstaff, Arizona; and (2) For Vegetation Disturbance Patterns: Warren Cohen and Robert Kennedy, USDA Forest Service, Corvallis, Oregon, and Zhiqiang Yang, Department of Forest Science, Oregon State University, Corvallis, Oregon. NPS leads are Chris Lauver (SCPN) and Steve Garman (NCPN).

Development Schedule, Budget, and Expected Interim Products:

(1) Vegetation Condition: Funding was initiated jointly in FY 2005 by SCPN and NCPN at $66,400 (split evenly) to perform a proof of concept field trial to determine the relationships among ground-based measures of vegetation condition with MODIS satellite data. A report of this field trial is due December 2005. However, due to delays in the 2005 field trial, additional field work may be performed in 2006, delaying a final report until spring or summer of 2006. During FY 2006, both networks have interest in jointly funding an agreement with USGS to develop protocols for monitoring vegetation condition.
(2) Vegetation Disturbance Patterns: Protocol development funding was initiated jointly in FY 2005 by NCPN and SCPN at $123,000, split evenly between the two networks. A draft review of literature and potential data sets was completed in November 2005. A detailed study plan will be completed in early 2006 describing pilot studies that include methods for detecting vegetation disturbance patterns. A draft monitoring protocol is expected in December 2006, with final protocols completed during 2008.

Wildland Values

Vital Signs Included:

- Night Sky Condition
- Natural Soundscape Condition

Parks Where Protocol will be Implemented:

- Night Sky Condition: BAND, CHCU, ELMA, ELMO, GLCA, GRCA, MEVE, PEFO
- Natural Soundscape Condition: CACH, ELMA, ELMO, GLCA, GRCA, NAVA, PEFO, RABR, WUPA

Justification/Issues Being Addressed:

Monitoring these vital signs will provide information on current status and trends in two natural features of wildlands and wilderness areas. Monitoring night sky and natural soundscape condition will also contribute to determining potential change in the human experience of these wildland values in response to changes in wildland conditions, and will be relevant in assessing the Wilderness Character Goal (NPS GPRA Goal Ia10).

In our surveys of natural resources, clear skies with low pollution were rated as significant resources in the majority of SCPN parks. The companion survey of stressors indicated viewshed and soundscape intrusions as the 4th most important resource concern. As human population density increases throughout the southwest, SCPN park units offer relief from crowding, and increasing noise and light pollution for both human visitors and faunal populations. However, these population changes and consequent increases in traffic, development, aircraft overflights, and other anthropogenic activities are rendering direct and indirect effects on night sky and natural soundscape condition. In addition to the negative impacts these changes are having on the human values of these vital signs, light pollution can alter or extend day length, and may be disrupting natural diurnal and nocturnal rhythms of organisms.

1. ***Night Sky Condition***: *This vital sign was ranked 1st (in the selection of sets) and 7th(using the standard evaluation criteria) in the Wildland Values Workshop, 20th in the Landscape Patterns Workshop, and was selected as a core vital sign at the Vital Signs Workshop.*

   Dark night skies are an important resource for many NPS units in the Intermountain Region (National Parks and Conservation Association 1999). High quality night skies are typically associated with wilderness areas in western US parks. SCPN has extensive wildlands: over 750,000 ha within network parks are designated or proposed as wilderness. Over the last 40 years, night sky condition has degraded in many areas by the widespread growth of light pollution (Duriscoe and Moore 2001), both within and external to NPS parks. Monitoring will focus on assessing the visibility of stars and other natural components of night skies at sites within selected parks. Dark night skies are a hallmark of southwestern landscapes, and many SCPN parks offer opportunities for experiencing this resource. Bandelier NM, Chaco Culture NHP, and the Flagstaff area parks (SUCR, WACA, and WUPA) in particular have been active in promoting dark night skies (e.g., Shattuck and Cornucopia 2001). Sample measures include sky background brightness levels from ground-based cameras, where individual photos are joined together to show panoramic sky brightness for a given site.

2. ***Natural Soundscape Condition:*** *This vital sign was ranked 2nd (in the selection of sets) and 6th (using the standard evaluation criteria) in the Wildland Values Workshop, and was selected as a core vital sign at the Vital Signs Workshop.*

   Natural soundscapes are a resource considered to be of value both to NPS and to human visitors of NPS units. A natural soundscape can be defined as "*an area characterized by certain ambient acoustical and sound level qualities, absent the intrusion of sounds caused by humans or human technology*" (NPS; http://www.nature.nps.gov/naturalsounds/). In a 1995 report to Congress, the National Park Service stated that "*Preserving natural quiet is an integral part of the mission of the NPS. This is confirmed in law, policy, and the beliefs of NPS managers*" (Report to Congress, p.76). NPS made further statements reflecting the value of natural quiet, particularly within wildlands: "*Parks*

and wildernesses offer a variety of unique, pristine sounds not found in most urban or suburban environments. They also offer a complete absence of sounds that are found in such environments. Together, these two conditions provide a very special dimension to a park experience… Quiet itself, in the absence of any discernible source (especially man-made), is an important element of the feeling of solitude" (NPS Report to Congress on Effects of Aircraft Overflights on the National Park System, 1995, p.78). Monitoring will describe the condition of the natural soundscape of wildlands and adjacent areas, including anthropogenic sound and its effect on the natural soundscape. Sample measures include the use of recording devices to detect and measure the kinds and time periods of natural and anthropogenic sound, and percent-time-audible methods (which use the human ear to determine the time a targeted sound is audible).

Specific Monitoring Objectives and Questions to be Addressed by the Protocol:

Objective 1: Determine long-term trends in night sky condition.

Objective 2: Determine long-term trends in natural soundscape condition.

Questions Addressed:

- What are the trends in night sky condition across a gradient of remoteness (from SCPN parks that are remote to those near urban areas)?
- Are the trends in natural soundscape and night sky condition within SCPN parks related to park size, wildland or backcountry area, and adjoining land use?
- What are the relationships between night sky and soundscape condition, and are these relationships strongest in wildland areas?

Protocol Development Approach:

Monitoring of night sky and natural soundscape condition will occur at index sites selected from parks that contain substantial wilderness or backcountry areas. Protocol development will be initiated in FY 2006 with an inventory of current monitoring related to these natural features within SCPN parks. The inventory will include a review of existing protocols and spatial coverage of soundscape and night sky data across the network.

Principal Investigators and NPS Leads:

NPS lead is Chris Lauver.

Development Schedule, Budget, and Expected Interim Products:

An interim report of current monitoring efforts within SCPN parks related to night sky and natural soundscape condition is expected in FY 2006, with implementation the following year.

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