Review of Long-Term Monitoring Program at Great Smoky Mountains National Park

National Biological Service

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United States Department of the Interior

NATIONAL BIOLOGICAL SERVICE
Washington, DC 20240

MEMORANDUM

To: Superintendent, Great Smoky Mountain National Park

From: Assistant Director, Inventory and Monitoring Doyle Frederick

Subject: Report and Review Recommendations for the Great Smoky Prototype Monitoring Program

On July 11-14, 1995, the National Park Service (NPS) and the National Biological Service (NBS) participated in a cooperative review of the Great Smoky Mountain National Park (GRSM) prototype monitoring program. The purpose of the review was to provide GRSM a measure of technical and programmatic feedback or guidance for the prototype monitoring program. The review was to examine monitoring objectives, protocol design, implementation and program integration, statistical design, data management and its ability to provide the park and other natural resource managers with useful products to meet needs for protecting the resource and identifying agents of change.

A review panel of 10 members (4 NPS, 5 NBS & 1 FS) with expertise in the protocol areas was selected. The review panel included the following individuals:

Mr. Dale Enquist, NPS-Indiana Dunes Superintendent
Dr. Mary Foley, NPS-Reg. Chief Scientist, N. Atlantic
Dr. Suzette Kimball, NPS, Assoc. Dir., SE Field Office
Dr. Tom Stohlgren, NBS, Colorado State U.
Dr. Gary Williams, NPS, I&M Coord., Water Res. Div.
Dr. Noel Birkhead, NBS, SE Biological Sci. Ctr.
Dr. Paul Geissler, NBS, Nat'l. Ecol. Survey Team
Dr. Barry Noon, FS, Redwood Science Laboratory
Dr. Francis Singer, NBS, Colorado State U.
Ms. Norita Chaney. NBS, WASO, Nat'l Parks/Pub. Lands Mgr.

It was clearly recognized that this Park has a keen perception of their purpose. The people involved demonstrate a high level of energy and a real ability to "get the work done" even under limitations of funds, time and personnel. Also, staff competence and dedication was very apparent.

Included in the report are the priority recommendations, a combined summary of all reviewer responses (containing 2 in-depth reports, one by Paul Geissler and one by Barry Noon & Francis Singer) and a working draft copy of conceptual issues on the monitoring of ecological resources, by Barry R. Noon, for consideration and comment. Because the review areas of protocol design and protocol implementation are in very good order these areas have no additional or priority recommendations.

Thank you for your patience in the unavoidable delay of this report. It was indeed a pleasure to get to know more about GRSM and the fine jobs that are being done there. If there are questions regarding the review report we welcome the opportunity to respond.

Priority Recommendations

1. **Monitoring objectives need to be more clearly articulated and reflect the support of management needs and the long-term monitoring program. In addition, the process by which monitoring results feed into the management decision making process must be clearly stated and institutionalized.**

A successful park monitoring program helps evaluate the effectiveness of management practices and develops a predictive understanding of environmental changes. Therefore, it is important that a consensus is reached by the park management and monitoring staff. A facilitated workshop, with active participation by scientists, managers and technicians, should identify park threats and focus on developing a common understanding of park resource management needs and park monitoring goals. .

2. **Improve the integration of monitoring programs through a formalized process.**
   a. **Responsibility for integration meetings/efforts should be assigned to a lead person.**
   b. **Establish a Scientific Advisory Committee.**

A major value of an environmental monitoring program is the ability to relate causes and effects across various protocol areas. However, understanding causation often requires additional scientific input, such as the development of new research hypotheses, and designing and testing better census or sampling techniques. Therefore, the establishment of a Scientific Advisory Committee (SAC) is strongly recommended to look at issues of scientific and ecological integration. The members of the committee should be individuals of stature in their area of expertise and have no direct link to the GRSM monitoring program or to the Park. To ensure integration efforts are fully executed, responsibility for doing so should be assigned to one individual. That individual should arrange and lead annual or biannual meetings that include program leaders, staff members and scientists to facilitate the integration process and allow the adjustment of protocols.

3. **Demonstrate the value and importance of ecological monitoring by linking the results to interpretation for better understanding and protection of the natural resource.**

Monitoring and interpretation staff members need to work more closely to communicate the value and importance of monitoring. Providing information that clearly indicates the saving of a species or the sustaining of a healthy environment gives credibility and confidence to the funding process. This can be accomplished if monitoring projects and results are interpreted in the context of contemporary ecological theory (i.e., importance of temporal and spatial scale; spatial distribution of plant and animal communities; relationship between population size and distribution and persistence likelihoods; landscape heterogeneity and the role of natural disturbance processes).

Monitoring is expensive, and support for it can only be strengthened by demonstrating and communicating its value.

4. Improve the analysis, evaluation and dissemination of existing data.

The whole purpose of a long-term monitoring program is to provide managers with timely and relevant information on which to base management decisions. Observations are of no value unless they are reported regularly in a manner that allows park managers to respond quickly. Monitoring data need to be entered into a computerized database and edited for spurious measurements. The data should be accessible to the data management staff and the staff must have the tools to manipulate and analyze them. Standard analyses should be run on an annual basis. Thresholds or other criteria for activating management action should be identified in advance. An integrated and accessible database permits combined analysis of observations from different protocols, allowing the identification of major effects across protocols and informs researchers and others of the current results. In addition, results of the annual monitoring efforts should be reported regularly and published in technical reports or publications targeted for resource managers.

PROTOTYPE MONITORING PROGRAM REVIEW QUESTIONS
GREAT SMOKY MOUNTAINS NATIONAL PARK

I. Monitoring Objectives

A. Have specific monitoring objectives been developed?

Monitoring objectives in the Water Quality program are developed but not clearly articulated. In addition, specific objectives need to be identified that link watershed and landscape issues to important landscape changes in the Great Smoky Mountains National Park (GRSM), i.e., forest decline, alien pests, nitrogen saturation, and public health.

Monitoring objectives in the Vegetation monitoring program are well defined but each is not clearly linked to other portions of the vegetation monitoring program or other monitoring programs. Like the Water Quality program, specific objectives need to be identified to link watershed and landscape scale issues such as forest decline and alien pests.

Monitoring objectives in the Benthic Macroinvertebrate program are concise and within the overall monitoring objectives defined in the 1993 Long-Term Monitoring Plan.

Monitoring objectives in the Exotic Forest & Insect monitoring program specifically address insects and diseases which are of park management concern. This is very important, however these are short term needs. There needs to be additional objectives that fit appropriately into a long-term monitoring program.

Monitoring objectives in the White-tailed Deer and Black Bear monitoring program appear to be linked to actual or perceived major impacts/threats/stressors to the park. Specific objectives are needed to provide information on long-term ecological effects of the impacts on vegetation plots, rare plants, etc.

A. Recommendation.

Protocols need to be reevaluated to ensure that all specific objectives answer questions that meet long-term and short-term monitoring goals, allow for the integration of appropriate programs and are clearly stated.

B. Describe how monitoring objectives are tied to management objectives as described in an approved Natural Resources Management Plan.

There is tremendous potential to link the Water Quality monitoring objectives with the park's natural resource management plan, but this has not been formally done.

Monitoring objectives for Rare Plants and the Vegetation monitoring program are linked to the resource management plan.

The Park's Resource Management Plan recognizes that a vast majority of the biodiversity lies in its aquatic invertebrates but states that "most groups are not even at the simple checklist stage".

B. Recommendation.

Monitoring objectives for all protocols should be linked to the needs of park resource management, as well as basic science.

C. Provide an overall assessment of the quality of monitoring objectives.

Overall assessment of the quality of monitoring objectives are good in the Water Quality program. However, the objectives require some reevaluation, specifically in relation to its intensive and extensive measurements and integration with other programs.

The quality of monitoring objectives in the Rare Plants and Vegetation monitoring program is high.

Separation of basic science questions from management concerns is required by the large mammal monitoring programs before linking these concerns through specific monitoring objectives. This requires working more closely with the resource management staff to articulate objectives and integrate the program.

The Black Bear and White-tail deer programs need to ask whether the objectives address the questions that provide monitoring results which indicate the environmental integrity of GRSM or meet the needs of the park management decision making process.

The Benthic Macroinvertebrate program indicates that the lengths of stream reach segments to be sampled, selection of distinct habitat types, habitat characterization, and sampling gear are appropriate for the monitoring objectives.

C. Recommendation.

No recommendation.

D. What are suggestions for improvement?

The Rare Plant program should separate basic science questions from management concerns, then link each of these to specific monitoring objectives.

Objectives of all Vegetation monitoring should be linked at multiple spatial and temporal scales. Specific objectives should be articulated for different plant populations if the methods are different. Specific objectives should be articulated for different threats to forest ecosystems, (i.e., alien pests, air pollution, historical logging, and loss of biodiversity).

Because so much of the aquatic macro invertebrate fauna in the GRSM is virtually unknown, it is recommended that an additional objective to inventory macro invertebrates be added to the protocol. This objective would be part of a larger goal to eventually document the entire aquatic fauna of the park.

Amphibians are key components of terrestrial and freshwater ecosystems in North America and their permeable skins expose them to the effects of anthropogenic influences on these ecosystems more than any other vertebrate class. Concern over their decline has been expressed by members of the scientific community and society at large. The Great Smoky ecosystem is an excellent one to support amphibian monitoring. The objective to monitor amphibians is recommended. The project could be designed to determine the species population and the links between 3 riparian habitats: 1) wetted banks, 2)flowing stream and 3)stream bottom.

Based on a thorough analysis of the bear capture/recapture data, a monitoring objective that includes the question, what is the current status of the black bear population, is suggested.

Given numerous existing studies of habitat associations, the question what is the trend in those habitat attributes most associated with suitable bear habitat, should also be asked.

D. Recommendation

No additional recommendation.

II. Monitoring Protocol Design

A. Do published monitoring protocols exist?

Published Water Quality monitoring protocols exist in the form of peer-reviewed published articles.

The Rare Plant program has no published monitoring protocols. They are only documented by in-house reports.

Published Vegetation monitoring protocols exist in peer-reviewed literature, but need to be revisited. For example, nested, non-independent quadrants are still being used but are of no added value. Previous long-term plots may have had some bias in site selection. Also there are a disproportionate number of plots in one small area of the park.

Even though there is a long history of many independent black bear studies at GRSM, there is little synthesis of these data and they have not been published in refereed, scientific journals.

A. Recommendation.

One of the most important products of a scientifically credible monitoring program is a design that allows the program to be used by resource persons in similar studies and programs. It is suggested that all monitoring protocols be peer reviewed and published to be accessible to the resource manager.

B. Describe how monitoring protocols were developed.

Standardized Water Quality protocols have existed for years.

The scientists are using well-accepted techniques and analytical procedures.

Rare plant monitoring protocols have been developed that are site and species-specific. There was a review of the overall monitoring strategy but no review of the methods used for specific species or sites. Some of the techniques may work quite well, but they have not been tested in the peer-reviewed literature.

Monitoring protocols were developed by a series of vegetation scientists for different goals and objectives.

B. Recommendation.

Revisit the vegetation protocols to determine the ability to provide results that achieve the objectives. Also consider links to other protocols such as the deer monitoring protocol.

C. Describe the protocol peer-review process.

Water Quality sampling methods appear, as methods, in scientific papers. Most are referenced in accepted water quality manuals or textbooks.

The general protocol of the Rare Plants program was peer-reviewed but site-specific or species-specific monitoring techniques have not been peer-reviewed.

The Vegetation program has usually been conducted as part of the peer-review journal publication process.

C. Recommendation.

Implement a peer review process.

D. How do protocols address sampling design, field sampling procedures, QA/QC, data handling, and reporting?

The Water Quality monitoring program publications show that all pertinent issues merit peer-reviewed, scientific journal status.

Rare Plant detailed sampling procedures exist in binder format. These contain little information on QA/QC, data handling, proposed statistical approaches, or hypotheses.

The Vegetation program sampling protocols do not assess problems associated with nested plots and biased site locations.

Quantitative sampling and analyses are not included in the protocol in the Benthic Macroinvertebrate monitoring program.

The apparent high overlap of macro invertebrates and fish sampling sites is highly desirable; however, the number of shared macro invert./fish sites is not stated. It is not clear how many sites will be sampled or how often.

D. Recommendation.

Standard procedures which verify a high quality of data and data reports should be initiated. All protocols should address sampling design, field sampling procedures, quality assurance/quality control, data handling and reporting criteria to ensure a high quality publishable product.

E. Is the protocol unique to the park, or is it broadly accepted and applied by other agencies/entities?

Water Quality protocols are broadly accepted.

Rare Plant protocols appear unique to the species and the site, although some of the methods are commonly used in plant ecology.

The Vegetation program protocols are not unique to the park. Some have been broadly accepted and applied by other agencies and entities, but may still need some enhancement.

E. Recommendation.

No additional recommendation.

F. Provide an overall assessment of the monitoring protocols.

Overall assessment of the Water Quality monitoring protocols is very good.

It is difficult to assess the overall effectiveness of the Rare Plants monitoring protocols because each site and each species has not been evaluated.

The assessment of the protocol for long-term vegetation monitoring is quite high.

The Exotic Forest Insect & Disease protocols do not always meet the stated objectives. For example, it appears that the purpose of adelgid population monitoring is mostly to evaluate pre and post-treatment of the adelgid. This is not stated as an objective, however from the design of the protocols this appears to be the main purpose.

Although quantitative sampling and analyses are omitted from the Benthic Macroinvertebrate protocol, overall, the protocol is well-conceived.

F. Recommendation.

None

G. Is there a mechanism in place to review and modify as necessary?

It is not clear how modifications to Rare Plant sampling protocols are incorporated or reviewed by outside scientists.

There are many excellent vegetation ecologists nearby or affiliated with the park monitoring program who are accessible for review and modification of protocols, where necessary.

G. Recommendation.

The peer-review process is recommended and is a great place to review and modify protocols that study the ecological integrity and management of ecosystems.

H. What are suggestions for improvement?

The Water Quality sampling protocols should be linked (in one document) to the protocols for brook trout monitoring and stream invertebrate sampling.

All vegetation sampling protocols should be linked.

The vegetation protocols should be combined with the aquatic chemistry and biology monitoring programs or to the deer monitoring program. Additional review of species-specific methods is in order. A science advisory team or university colleague could be a great help.

The Fish monitoring protocol is sufficient to accomplish stated goals. However, amphibians represent several levels of aquatic-terrestrial linkage (upland ponds, stream-riparian, and terrestrial) and are hypothesized to be particularly sensitive to atmospheric quality. Given the high number of amphibians in the GRSM and their reported sensitivity to atmospheric/water quality conditions, the inclusion of an amphibian monitoring program would provide an important link between aquatic faunas and processes and terrestrial landscapes. Therefore, we strongly recommend that the GRSM develop and implement an amphibian monitoring

program. A model for an amphibian protocol may be found in "Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians," W. Ronald Heyer et al. (editors), 1994, Smithsonian Institution Press, Washington, D.C. In addition, the NBS is a key player in a the coordination of a National amphibian monitoring program. (Sam Droege, NBS Inventory and Monitoring is a contact person - 301/497-5840)

The Exotic Forest Insect & Disease protocol requires a treatment regimen with a statement about the objectives of the treatments. Without some discussion about the objectives of the treatments it will be difficult to learn much from other data collected. It appears enough data has been collected on the impact of the infestation on crown ratio, etc., to be able to conclude sampling or at least sharply reduce the frequency. With the extent of the infestation it might be useful to rewrite the objectives to use the monitoring to guide the level and type of treatment. In this way the program may be similar to the fire program where certain fire data collected guides the level of fire preparedness. Perhaps a step-up plan is indicated. That would allow for the targeting of indicators for infestation.

H. Recommendation.

No additional recommendation.

III. Protocol Implementation

A. Are the monitoring protocols (as developed) being fully implemented at this time?

Full implementation is not achieved throughout the park because of the funding constraints.

A. Recommendation.

Complete implementation of a monitoring protocol to guarantee that the methodologies and practices include all components necessary to achieve the results is required for a successful monitoring program. Once protocols have been peer-reviewed and revised, where indicated, the protocols should be fully implemented.

B. Are monitoring protocols being implemented in-house, or through cooperative/contractual arrangements with non-NPS?

Water Quality protocols are being implemented in cooperation with NBS scientists at the University of Tennessee.

Some assistance by NBS or University scientists would be helpful to the Rare Plant and Vegetation Programs.

B. Recommendation.

No additional recommendation.

C. Have there been problems in utilizing non-NPS cooperators in implementing protocols?

There have been no problems noted in utilizing non-NPS cooperators.

C. Recommendation.

No recommendation.

D. Are monitoring protocols implemented by properly qualified personnel? How are personnel qualifications defined and assured?

The monitoring protocols are implemented by properly qualified personnel. Sometimes students are used to collect data, but there is quality assurance on all field sampling and laboratory analysis.

The resource managers and staff are a highly professional and productive group.

F. Provide an overall assessment of the implementation of monitoring protocols.

The sampling protocols are being implemented well.

F. Recommendation.

None

G. What are suggestions for improvements?

Structurally the protocols are excellent.

A more extensive review of species-specific methods is recommended.

More extensive review of the Vegetation long-term monitoring methods is needed, specifically with regard to site selection and nested quadrants.

Benthic Macroinvertebrate quantitative sampling methods need to be incorporated for one or more specific habitats that typically support sensitive taxa.

It is suggested that the focus of the Fish protocol objectives be shifted from fisheries to fish community monitoring where the overall objectives are to monitor long-term trends of fish communities at selected sites, and to monitor special interest species (brook trout and imperiled species) throughout the park and at selected sites. Also incorporate the objective of creating and maintaining a long term fish distribution data base for all species within the park.

Methods may need to be reorganized to incorporate the faunal approach, but note descriptions of individual methodologies do not need to be changed except as noted below. Because there

is voluminous detail provided in the protocol methods, it is suggested that the authors provide a succinct summary by including a step-down outline of the methods at the end of the methods section. The outline will help facilitate comprehension of the sampling schedule and the main focus.

In the protocol, under II. Population Monitoring (Brook Trout and Large Stream) the reviewer recommends a subsample of three or four nongame species be worked-up in a similar manner to game species.

G. Recommendation.

No additional recommendation.

IV. Monitoring Program Integration

A. Does the overall monitoring program facilitate integration between protocols in terms of study design, implementation and reporting?

The water quality aspects of the I&M program have tremendous potential for integration. Already, shared sample sites among the fish, stream biota, and water quality investigators create an exciting interdisciplinary opportunity. These three programs create a strong core for a long-term monitoring program in Great Smoky Mountains National Park. The watershed site is important regionally, nationally, and internationally as one of the highest sites for air pollution. Chronic acid deposition 30 times greater than that in remote areas of the world will have profound effect on many park resources. The integration among protocols (fish, stream biota, and water quality) should be the cornerstone of future work.

There is little evidence of integration among the vegetation sampling projects or the aquatic and wildlife projects.

Exotic Forest Insect and Disease program integration between protocols is lacking. There is a disjunct set of protocols with each protocol meeting its own specific needs. Several examples are presented. In a recent draft report submitted by Dr. Nikki Nicholas a number of concerns are raised about the projected increase if Fraser Fir decline on the summits. These include: 1) the likelihood of increased blowdowns, 2) increased soil desiccation and erosion, and 3) increased fire hazard. All the implications for endemic, rare or other species found on the summits, in the watersheds and water resources, as well as for the Fraser Fir.

Another example is found in the Bear Monitoring Program. Staff wildlife biologists discussed the importance of the annual oak mast production for bears. It is expected that gypsy moth infestation will soon reach GRSM. As oak is the primary host of gypsy moth, some integration among the insect and disease, rare species, wildlife, and vegetation monitoring programs is needed.

On the other hand, the park has opted to integrate the prototype monitoring program with the resource management program. In theory this allows routine monitoring to proceed without risk of funds being redirected and to focus on more short term critical resource management concerns. The down side of that theory is it becomes harder to appropriate the resources for specific program needs (especially for long term needs). This was evident in the insect and disease monitoring program. Staff is overburdened trying to achieve two very important program goals, natural resource management and long term ecological monitoring.

A. Recommendation.

It is strongly suggested that annual or biannual (twice a year) meetings take place between program leaders and staff members to begin the integration of protocols within a specific program and across programs. This will facilitate better understanding of the overall resource protection and management needs and allow adjustment of protocols required for short-term and long-term goals.

B. How is the I&M program coordinated with other park program such as maintenance, interpretation, visitor services, etc.?

There was little evidence of coordination with other park programs such as maintenance, interpretation, and visitor services in the Water Quality, Rare Plants or Vegetation program.

There is great opportunity for park management to provide a very good interpretive program for aquatic organisms and stream hydrology which does not appear to be occurring at this time.

B. Recommendation.

See recommendation A.

C. How is the program coordinated/integrated with other similar or complimentary programs of other agencies or entities?

The watershed aspects of the program are integrated with similar watershed studies programs throughout the National Park Service.

The Rare Plants program is partially integrated with The Nature Conservancy method of setting priorities for rarity, but there is little evidence that the same methods are being used for the same species in other sites.

The Vegetation program is partially integrated with historic long-term vegetation plots.

C. Recommendation.

Efforts to evaluate and integrate protocol sampling designs and methodologies across the park as well as with other outside monitoring programs are suggested. If monitoring programs are to share information that allows each to examine and enhance sampling designs and methods from similar biomes, some measure of standardization to meet data comparability needs is required.

D. Provide an overall impression of the level of program integration.

The Rare Plants, Vegetation and Water Quality Program potential for integration is high, but the level of integration is presently low.

The best integrated protocols were clearly those for water quality, macro invertebrates, and fishes. They are united spatially by shared sampling sites, and come the closest to providing park management with an integrated picture of aquatic and terrestrial systems.

D. Recommendation.

As indicated in several of the above sections, there are opportunities to strengthen the program and provide a much more enhanced understanding of ecosystem function by increased integration of the monitoring programs.

E. What are suggestions for improvement?

The Water Quality program should develop shared objectives with the fish and stream biota programs that cross spatial, temporal, and organizational scales. The program should develop a central clearing-house for data for all the projects to provide on-line access to any and all investigators. In addition the program should produce a list of "deliverables" such as publication titles with authors and roles of responsibility clearly stated.

Shared objectives are needed among the vegetation monitoring programs, i.e. long-term vegetation plots, forest insect and disease monitoring, other research projects. Also, develop a central clearing-house for all vegetation data to provide on-line access to any and all investigators. Lastly, these programs should produce a list of "deliverables" such as publication titles with authors and roles of responsibility clearly stated.

It is suggested that a science advisory group be formed to look at the monitoring programs issues of scientific and ecological integration.

V. Monitoring Program Reporting

A. Are annual data summaries prepared and published?

Only a small portion of the Water Quality data are analyzed each year. We did not see any annual reports. One publication was in press and three others in review, but surprisingly little information has been published from such an extensive and expensive research program.

Only a small portion of the Rare Plants and Vegetation data are analyzed each year.

A. Recommendation.

See B. Recommendation.

B. Are annual reports developed? What is the purpose, intended audience, and content of annual reports?

A nice poster presentation was developed by the Water Quality program staff for scientific meetings, but feedback to the park staff seemed to be limited.

No annual reports were noted for the Vegetation or Rare Plants programs.

B. Recommendation.

Data summaries and annual reports provide and assessment of the condition of an ecosystem. Also they often provide an early warning signal of system decline and allow researchers to compare results. To provide full value for the funds invested in monitoring, reports should be regularly produced. These should be peer reviewed and targeted to specific audiences: 1) park management, 2) general public and, 3) scientists.

C. What sorts of professional papers have been developed by the program?

Professional papers on the water quality aspects of the program have been developed but there has been little effort to integrate the information from the other monitoring efforts.

No professional papers were noted for the Rare Plants or Vegetation programs.

C. Recommendation.

Data summaries and reports provide an assessment of the condition of an ecosystem. When report findings are provided on an annual basis it allows programs to report findings to others which also often provides an early warning signal to system decline and also allows researchers to compare results.

D. What are the internal review requirements for I&M Program reports?

None were noted for any monitoring program.

D. Recommendation.

The whole purpose of long-term monitoring programs is to provide managers with relevant information in a timely and clearly defined manner. There should be internal review requirements that follow a consistent format and time schedule and contain basic elements such as; an introduction, methods, results, links to protocols and other research and a bibliography. The reports generated using these requirements should clearly indicate their purpose and their intended audience..

F. Are written interpretations of monitoring program results prepared for park management on a regular basis?

No written interpretations of the monitoring program results prepared for park management were noted.

F. Recommendation.

See recommendation D.

G. Provide an overall impression of the reporting requirements of the program.

Reporting of monitoring program data gets little priority.

G. Recommendation.

See recommendation D.

H. What are suggestions for improvement?

Time needs to be set aside for analyzing data and writing up results.

Integrate the activities of the Water Quality, Rare Plants, and Vegetation program with the other monitoring programs. Prepare scientific papers, annual reports, and popular articles for ease of integration into park management.

Clearly define the requirements, the intended audience and the purpose for each internal report and do so on a consistent or regular basis.

VI. STATISTICS AND DATA REVIEW SUMMARY

Note:
The information provided in the following report requires comment that is more extensive than required by the questionnaire responses and is therefore reported in its entirety.

The competence and dedication of the monitoring staff were evident. The extensive data have substantial potential, but their potential has not been achieved. Like other parks, there is an emphasis on data collection, but, in my opinion, there is insufficient emphasis on providing the Superintendent with timely and relevant monitoring information. That information is an important factor in resource management decisions that will protect the Park's biological resources.

The Park has an exceptional clear statement of the purpose of the Park and the objectives of the monitoring program, but references to these objectives were not seen in the descriptions of the individual monitoring programs. These objectives were good. Each of the monitoring programs should explicitly reference these objectives and show how the monitoring achieves the objectives. A handout states that "the Park's purpose is therefore to preserve its exceptionally diverse resources, and to provide for public benefit from and enjoyment of those resources in ways which will leave them basically unaltered by modern human influences." Long term monitoring provides an early warning system that will allow the Park to identify threats to critical resources in time to take corrective action. The monitoring handout states that "maintenance of biodiversity is the primary resource-related goal of park management. Towards this end, monitoring efforts are aimed at: (a) assessment of changes in park biota; and (b) identification and assessment of environmental impacts which threaten the status of park biotic systems." Four objectives are stated:

1. **"Establishment and implementation of a monitoring program to measure change over time in the biotic condition of selected key population, communities and systems."**

The selected indicators (measured variables) should provide an early warning system to protect the Park's natural resources from all credible threats. However, everything cannot be measured everywhere, and the indicators should be carefully selected to provide best possible protection to the Park. I think the goal should be:

a. to assure that all plausible threats can be reliably detected,
b. to monitor the most sensitive ecosystem components and components that would be the first to react to stressors, and
c. to focus all indicators on the protection of Park resources.

This approach will require an examination of plausible threats and an evaluation of the most sensitive ecosystem components. It may be important to give special emphasis to charismatic

species, such as the black bear because of its value to the public as the symbol of the Smokies. The Park should be able to articulate the rationale used to select indicators. For example, some of the Park staff have suggested monitoring amphibians. There are endemic amphibian species and some investigators have suggested that amphibians are especially sensitive. Why did the Park decide not to monitor amphibians, and what indicators will signal threats to amphibians? The Forest Service/EPA Forest Health Monitoring survey monitors ants and birds. Why did the Park not adopt this protocol to allow comparisons with that nationwide survey? All taxa cannot be monitored, and we are not suggesting that the Park should necessarily change its monitoring strategy. However, the Park should be able to articulate a rational basis for selecting the taxa to monitor and to demonstrate a reasonable level of protection for its natural resources. These are very difficult questions, and we do not have completely satisfactory answers for our surveys. NBS staff are available to help the Park clarify these issues, but all decisions should be made by the Park. Gary Davis at Channel Islands National Park has done some outstanding, pioneering work in this area and has developed a sound basis for that park's monitoring program. If he has time, he would have important insights to share with the Park.

To avoid inadvertently redirecting the monitoring effort to achieve other objectives, it is suggested that all monitoring indicators should be focused on the protection of Park resources. For example, the objectives of two programs seem to be related to national and regional issues and not specifically focused on Park protection. The objective of the high altitude chemical monitoring seems to be the evaluation of the Clean Air Act and the monitoring of contaminants in air masses that move long distances. Other sites would probably be more effective in protecting the Park resources. The objective of the black bear population dynamics project seems to be the management of the regional bear population so that the Park can supply surplus bears to provide recreational opportunity in the surrounding states. A less expensive program may be adequate for the more limited objective of protecting the Park's bear population. These programs are clearly very important. However, the Park should decide if these programs contribute important information to the long-term monitoring objective. If not, it may be appropriate to seek other funding for this valuable work.

There should be a clear distinction between research and monitoring and an appropriate balance should be maintained between these two essential activities. Although a single project may have both research and monitoring components, these activities have very different objectives. Research is designed to answer a specific question or to evaluate a specific management practice. A research project should have a definite end point, with a report answering the question. On the other hand, monitoring is a continuing activity with the objective of providing an early warning system to detect threats to the Park's natural resources. Monitoring results will often raise questions that require research answers. However, a collection of research projects focused on specific questions does not provide the necessary early-warning system. For example, the forest insect and disease monitoring detects the presence of exotic insects such as the woolly adelgid.

Their presence raises a number of important research questions, such as the effect on the forest and a search for resistant trees. Although it is important to answer these research questions, the monitoring effort to detect other pests should also be continued at a reasonable level. Based on past experience, there is a temptation to divert long-term monitoring funds to support short-term research questions, although no indication of this was observed at GRSM.

The operational monitoring objectives must be very specific and stated in terms of measurable quantities. For example, the objective of maintaining biodiversity is too general to be useful. Instead, the objective should be to detect a 50% or greater decrease in black bear bait station indices between a 10-year base period and the current 2-year period with 10% type 1 and 10% type 2 error rates, for example. A type 1 error (false positive) occurs when one reports that a species is in trouble when it is all right, while a type 2 error (false negative) occurs when one does not detect a real problem. In research, the probability of a type 1 error (A) is usually set at 5%, while the probability of a type 2 error (B) is usually set at 20%, because a false report is considered to be much more serious than failing to detect a phenomenon. However, with monitoring, failing to detect a problem may be at least as serious as a false report. For that reason, it is suggested that both error rates be set at 10%. Because the interest is in detecting decreases, use a one-sided test to increase the power. Thus, the level of protection provided by each indicator is described by three values: the detectable difference, and the type 1 and 2 error rates. The Superintendent should be provided with a graph of the protection levels (detectable differences) as a function of cost (sample size) so that she will have a basis for allocating Park resources. As with personal insurance decisions, the Superintendent will have to decide how much protection the Park can afford. If the budget will not provide adequate protection, the Superintendent will have a justification for seeking additional funding.

The survey designs and measurement protocols should be reviewed. For example, a consideration of variance components and measurement costs could result in an optimal sampling strategy for vegetation plots, reducing costs or increasing precision. Stratification by watershed, elevation and vegetation type are possible, and it will be important to select the optimal stratification and to sample an appropriate number of plots in each stratum. Whenever possible, measurement protocols should be standardized to allow comparisons with other areas. Standards should be used unless an alternate protocol is clearly superior to the standard. Cross checking measurement methods with other groups will help to identify problems and maintain quality. For example, aquatic macro invertebrates are counted by both the Park and a North Carolina group to validate their methods.

Coordination of different monitoring efforts and the co-location of sampling sites strengthen the monitoring effort by allowing the Park to look at the relationships among indicators. For example, coordination of stream flow, water quality, aquatic Macro invertebrate, and fish sampling provides an excellent opportunity to understand and manage the entire aquatic ecosys-

tem.

2. **"Analysis and presentation of data in a manner which will provide managers with practical information to help them preserve park natural resources."**

This is the critical step. The whole purpose of the long-term monitoring program is to provide managers with timely and relevant information on which to base management decisions. Reports to Park management were not seen, and the Park has a substantial opportunity to improve this objective. The biologists need to devote more time to analyzing and reporting their data, even if they have to reduce their field observations. The observations are of no value to the Park, if they are not analyzed and reported to the Park management. Note that objective 3 (an accessible data management system) must be in place to permit the analyses required to provide management information.

The monitoring data should be routinely analyzed soon after the data are collected, and Park management immediately notified if any threats are detected. There should be an annual report to the Superintendent on the status of the Park's natural resources, detailing the evidence for potential threats and evaluating alternative management actions. To achieve these results, there are several steps:

a. The monitoring data are collected using reviewed protocols and sampling designs.

b. The data need to be entered into a computerized database and edited for spurious measurements. The effort required for quality control is often grossly underestimated. There should be procedures in place for periodically checking the accuracy of the measurements and for screening data for unusual values. Unusual but possible values should be checked, but accepted unless a valid reason for deleting them is found.

c. The monitoring data needs to be accessible to the staff in data management system (Objective 3), and the staff must have the necessary tools for manipulating and analyzing data available to them. If it is difficult to access or analyze the data, the busy staff may become discouraged and not produce any results.

d. Standard analyses should be run each year to detect population decreases. A split-block (also known as split-plot in time) analysis of variance (see Principles and Procedures of Statistics: A Biomedical Approach by Robert G. D. Steel and James H. Torrie, 1980, McGraw-Hill Book Company, page 324) will probably be appropriate, although modifications may be required if autocorrelation is detected.

maps are very impressive, and an interactive GIS display would generate much interest. Graphs of population trends are also interesting to the public. Interactive lectures are possible with a laptop computer and LCD projector.

4. **"Establishment and implementation of a prototype monitoring program from which information can be gained to develop valid monitoring programs in other National Park Service managed areas."**

The Park has much to contribute to other parks. A workshop for key staff of the parks participating in the prototype monitoring program would be very useful. The development of the program is a learning experience for all involved, and the workshop would allow the parks to share their experiences on what did work and what did not.

Acknowledgments: Many of the ideas synthesized above were generated by other members of the review team during our discussions. They form a major part of our joint report. We appreciate the insights of the Park staff.

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C. Recommendation.

Maintaining rare plant populations and vegetation communities is an important component of maintaining the biodiversity in the park.

D. Provide overall impressions of the applicability of the I&M program to park management.

Basic water quality and biogeochemistry are key components of the functioning of park ecosystems. The water quality monitoring program is a key component of the I&M program and park management.

Rare plant monitoring is highly applicable to park management. If plant populations disappear from our protected areas and parks, they are likely to have disappeared from the surrounding unprotected countryside.

Vegetation monitoring is highly applicable to park management. Vegetation and fish communities are the most rapidly changing ecosystem components in the Great Smokies.

D. Recommendation.

No recommendation.

E. What are the suggestions for improvement?

There should be more emphasis on extensive sampling sites in the Water Quality program. The number of samples at the intensive watershed site can be reduced.

More emphasis should be placed on locating undiscovered populations of rare plants.

More extensive vegetation sampling is required throughout the park, corresponding to local and regional threats.

Water Quality, Rare Plants and Vegetation protocols need to have more data integration with other projects, more synthesis and publication of results, and more data analysis.

E. Recommendation.

No additional recommendation.

VIII. Budget

A. Is there an adequate budget to carry out a comprehensive I&M program?

The budget for Water Quality is probably appropriate if there is the appropriate tradeoff between intensive and extensive measurements.

The budget and manpower of the Rare Plants and Vegetation appear require some increases.

A. Recommendation.

Protocol funding and objectives should be reevaluated and prioritized in a manner that allows maximal use of resource staff and ensures intensive and extensive measurements are given appropriate attention.

B. Provide an overall impression of budget accountability.

Budget accountability is quite high.

B. Recommendation.

No recommendation

C. What are suggestions for improvement?

The Water Quality program should continue to fund the work through the cooperative agreement with the University of Tennessee.

Continue to seek greater funding for Rare Plant and Vegetation monitoring and coordinate efforts with similar species research outside of Great Smokies.

C. Recommendation.

No additional recommendation.

GREAT SMOKY MOUNTAINS INVENTORY AND MONITORING PROGRAM

REVIEW: LARGE MAMMAL SUBCOMPONENT

Francis Singer, NBS, Fort Collins, CO

Barry R. Noon, U.S. Forest Service, Arcata, CA

Note: Many of the comments which follow are a consequence of inadequate funding/staffing to address the pressing resource issues in the Park. We wish to emphasize that our comments are not intended to reflect negatively on the enthusiasm or abilities of the current Park staff.

Note: The information provided in the following report requires comment that is more extensive than required by the questionnaire responses and is therefore reported in its entirety.

GENERAL COMMENTS

Within the large mammal monitoring program we were impressed with the high energy level of the people involved, and the ability to "get things done" with limited funds and personnel. The existing program seems best at "hands on" data collection and animal management. The program was well focused on several species with high management implications. Because the available resources for the large mammal program were small, many long hours and much conscientious effort was required by the individuals involved.

Though our overall impression was quite positive, we did, however, identify a number of areas where the program could be improved. The wildlife biologists were so busy in so many program areas that they rarely had an opportunity to step back to evaluate their successes (see synthesis suggestions) or to think about their priorities and time allocations. All of the Inventory and Monitoring effort in this component were focused on two species, black bears and white tailed deer. The monitoring questions ask from the study of these two species were not integrated *with* each other, nor into the larger context of a comprehensive monitoring program. That is, few linkages were apparent with the other I&M components (with the single exception of rare plants-deer interactions). We believe this lack of integration to be a major deficiency.

In particular, we saw an opportunity and need for greater integration between the

1. The wild boar control program and the water quality monitoring. Previous research in the Park has demonstrated that wild boar rooting can increase nitrates in stream water of upper watersheds several-fold (Singer et al. 1984. J. Wild]. Manage. 48:454-473), and nitrogen saturation was identified as a problem in the parks upper watersheds.

2. The wild boar control efforts, deer population monitoring, and the long-term vegetation monitoring. Examples of integrative questions include: To what extent were efforts to reduce pig population size affecting the plant community? Were the effects of deer browsing on the vegetation additive to pig rooting effects?

3. The red wolf restoration program and the wild boar control program. A key question is whether red wolf populations are being encouraged in places where they would have the most opportunity.

It was not clear how the vertebrate monitoring being conducted related to the actual or perceived major impacts/threats/stressors to the Park. For example, there were no studies of the relationships of vertebrates to (a) nitrogen saturation and air pollution in high elevation areas, (b) wild pig rooting, or forest succession following exotic insect defoliation. Further, no small mammal or amphibian monitoring was being done in response to those major perturbations. We believe an attempt to prioritize the vertebrate studies with regards to Park threats, or Park management programs would be beneficial.

We detected some confusion as to the most strategic time to employ research versus monitoring, For example, the monitoring of black bears in the southwest quarter of the Park appeared to be a research, not a monitoring, question. There was a perception that monitoring results might "tell " park managers why bear densities were lower in that area of the Park. We believe the "why" question is best answered with a research study specifically designed to test the major hypothesis (poaching induced declines in population density) and any alternative hypotheses (e.g. inadequate habitat). Such research studies should be relatively short-term and hypothesis-driven. Monitoring would subsequently become important to assess the effects of any new management action (e.g. increased poaching control efforts) on bear populations.

The results of monitoring programs often raise new questions, particularly about cause/effect relationships. However, understanding causation often requires the initiation of a focused research program. We perceived a lack of appreciation of when to encourage the involvement of scientists into the program. For example, we observed a need for more scientific input into periodic one-time problem analyses, periodic or final synthesis efforts, development of new research hypotheses, and designing and testing better sampling, census or modeling techniques.

There is a need to institutionalize regular and periodic data analysis and report writing. There was an obvious need for synthesis of several large data sets, particularly the wild pig population control work (19-year span) and the black bear populations.

No true inventory work was being attempted. For example, how do the deer populations in Cataloochie, Tremont and other areas compare to Cades Cove? What are the characteristics of the black bear populations in the other two quarters of the Park? What is known of the species composition and distribution of taxa such as birds, small mammals, and amphibians?

It was not clear if the monitoring program was designed to be dynamic. That is, if one monitoring component suggested that a particular threat had been ameliorated, would monitoring funds then be shifted to a program with more immediate information needs? Due to continuing funding limitations, shifting monitoring priorities may be the only way that the range of issues affecting vertebrate populations can be addressed.

Based on the above comments, it is clear we recommend enlarging the large mammal component of the I&M program. All efforts should be made to bring in other funds, NBS, University, or other researchers to address specific large mammal resource questions.

SPECIFIC SUBJECT AREAS

White-tailed Deer

White-tailed deer are counted on a year-round basis in Cades Cove. The deer are counted in open fields only in count units that represent about 20% of the entire area of fields. The deer are spotlighted at night by three people; two of the counters are always consistent.

Strengths: Strong points of the program included the long-term nature of the counting, the fact that the methodology was well-documented and the same key personnel conducted the counts across the years. A single population estimate is attempted. The counting has occurred during the recovery of two keystone predators to the system, coyotes and red wolf. The abomasum counts and deer counts are done on a regional basis. Thus, there are comparisons to nearby hunted herds. There were obvious connections to the demographic studies of the rare plant, Frasera. The Frasera studies included measures of frequency and rates of deer herbivory, recruitment, seed production, and death of plants that could be paired with the deer count data.

Weaknesses: The sampling of deer was not done on a stratified, or random basis. There was no estimate of variance between sample units, nor any estimate of the precision (i.e., a confidence interval) on the deer population count. Several key assumptions were untested, including: (1) That essentially all deer were in the fields at the time of the counts, (2) The sample units were representative of the open pastures of the entire area, (3) All deer within a count unit are observed.

There was no obvious connection between the deer counting and the long-term vegetation monitoring, in spite of the fact that 35 vegetation survey plots were located in Cades Cove. There was no assessment of herbivory on the large plots, nor any quantification of the effects of deer on biomass production, recruitment, or species composition shifts in the plants. No response on the part of plants to a 75% decline in deer over the time span of the plots could be demonstrated-- ecological perturbations of this

quantified. The long-term vegetation plots in Cades Cove and in wild pig concentration areas should be completely reevaluated in terms of their location, size, and their sensitivity to reflect changes in large mammal populations.

Recommendations:

(1) A new method should be employed that generates both a population estimate for the entire Cades Cove population, and a confidence interval on the estimate. We suggest that variable-distance, line transect methodology be used (see discussion in Lancia et al. 1994. Estimating the number of animals in wildlife populations. Pp 2 1 5-253 in Research and Management Techniques for Wildlife and Habitat. T.A. Bookout (ed.); also Buckland et al. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall). No captures or markings would be required with variable-distance, line transect methods. Additional measurements are taken during each survey, and the data analysis is more complicated. However, the variable distance data would be compatible with previous count data (though considerably more reliable). Short courses are taught at Colorado State University on these techniques and user-friendly statistical programs are available (Drs. Dave Anderson and Ken Burnham, NBS, CO Coop. Res Unit, Colorado State Univ., Ft. Collins).

(2) The assumptions of representative sample units needs to be tested. The proportion of deer in fields versus forests needs to be determined or adjusted for. Variable distance, line transacts methods can estimate deer numbers in both forest and pasture, but sampling effort may have to be increased in forested habitats.

(3) the deer inventory should be expanded to other site(s) where wolves do not yet occur, and, if feasible, in other locations where deer densities are lower. Population trends in Cades Cove may not parallel trends of populations in other areas of the Park. Such comparisons may allow insights into the effects of wolves on deer population dynamics.

(4) Deer should be counted intensively only during the season when their delectability is greatest; that is, in spring. Within the spring period, attempt to standardize the annual sampling period according to plant phenology.

(5) The apparent lack of recruitment in the deer population (zero fawns were seen out of 130 deer during our visit), in spite of a large mast crop last fall, should be investigated. NBS scientists should be encouraged to write proposals for additional research into this question.

European wild boar control

Wild pigs are controlled by trapping and shooting by a team of six, long-term seasonal employees. This program is base-funded by the Resources Management Division. No I&M dollars are currently directed to monitoring the extent of wild pig rooting, variation in pig population size, or to the effects of control activities on the amelioration of adverse impacts on other natural resources.

Strengths: The current control program is expensive and labor intensive, but very successful in controlling pig numbers, possibly to about 1/5- 1/4 of uncontrolled numbers. The program is aggressive and flexible. An inexpensive, catch-effort population model has been developed by R. Lancia, North Carolina State University, to estimate the pig population size. The control program has apparently reduced the effects of pig rooting. Rooting effects are largely negative and include impacts on small mammals, rare plants, nutrient leaching, ecosystem process, and increased nitrates in water.

Weaknesses: We could find no data indicating when the last population estimate had been made. Thus, the true impacts of the control program on pig population dynamics are unknown. Further, there is no connection between the vegetation monitoring program, and pig control.

Recommendations: A synthesis and summary of the program are long overdue. A specific focus should be on changes in pig population size, the relationship between changes in population size and extent of control effort, and the effects of the control program on soil and vegetation resources. Such a summary analysis should not be expensive. The effort should include a cost/ benefit analysis of the effects of a reduction in budget (i.e., a reduction in control effort). Specifically, at what point do cuts in the program result in an increase in the pig populations?

Black Bear

Strengths: In many ways, black bear is the wildlife species most symbolic of the Park. There is much enthusiasm among Park personnel for bear management, and the resource managers have great expertise in bear capture and handling. There is wide recognition of the symbolic importance of the bear to the Park. Given its status, bear population(s) in GSMNP have appropriately had a long history of many independent studies.

Weaknesses: However, there has been very little synthesis of these studies, and for the most part, the studies have not been reported in the refereed, scientific literature. Most are available as master theses or doctoral dissertations. Perhaps as a consequence, there was little evidence that the results of these studies were directly used in Park management decisions. Examples of relevant questions to be addressed using existing information include: Based on a thorough analysis of the bear capture/recapture data, what is the current status of the population? Given numerous existing studies of habitat associations, what is the trend in those habitat attributes most associated with suitable bear habitat?

Because of the lack of a comprehensive synthesis of existing information, it appeared that

the following fundamental question could not be answered: " Do the population trend and dynamics of black bears within the Park suggest that Park management is sustaining a viable population?" Given the belief by Park management that the Smoky Mountain population is the key source population for the entire S. Appalachian region, the answer to this question becomes critical.

Recommendations: Many of the resources within the Park are affected by decisions and actions occurring outside of Park boundaries. This effect may be most pronounced for black bear populations. Thus, the bears within the park should be viewed as part of an open, larger population subject to emigration and immigration dynamics from the surrounding southern Appalachians. Given this understanding, a regional landscape perspective is necessary to understand bear population dynamics within the Park.

There is a great need for synthesis and integration of existing data on black bear populations in the southern Appalachian Mountains, with specific reference to the significance of the population within the Park. Perhaps one way to facilitate this effort is for NBS to organize (provide funds for) a comprehensive workshop that would evaluate current population and habitat status and trends, and produce a report specifically aimed to enhance (if necessary) the effectiveness of Park management practices.

As mentioned above, bear population status and dynamics in the SW portion of the Park are poorly known. There is also a suspicion that this population may be subject to illegal poaching. The status of this population and the various sources of mortality should be a high research priority within NBS.

Elk Reintroduction

Rocky Mountain Elk Foundation has funded a study of the feasibility of reintroducing elk to the park. Elk will feed mostly on graminoids, and elk will likely concentrate in the forest openings in Cades Cove, Elkmont, Cataloochie and the grassy balds. If sufficient elk migrate to the balds, there might be cascading effects of their introduction on wolves, wild pigs, and other mammals. One possible effect is that more wolf activity might occur during summer on the ridge line, if wolves follow the elk, thus wolves might prey more on pigs during the farrowing season. This might be viewed as advantageous to the wild pig control program. Possible disadvantages might be elk grazing effects on rare plants or other vegetation resources. The possible impacts of elk reintroduction are complex and difficult to predict. For example, the deer population may decline if elk are reintroduced, and elk will likely impact different plant groups than deer currently do.

If elk are restored to the system, we suggest vegetation monitoring be designed to evaluate the effects of elk on key vegetation attributes. We suggest elk not be reintroduced until all the cattle and the fences are removed from Cades Cove.

Mammalian Predators and Other Mammalian Herbivores

The return of two keystone predators, as a result of coyote invasion and wolf reintroduction, presents an unparalleled opportunity to study the cascading effects of keystone predators on the overall dynamics of the Smoky Mountains ecosystem. For example, we were informed that deer populations have declined about 75%, and woodchucks and skunks have declined since the return of coyotes. Deer have further declined in the four years since wolves have entered onto the scene. Coyotes, however, will likely decline as wolves fully recover, and, as a result of the coyote decline, foxes will likely increase. All of these possibilities can be restated as hypotheses to be tested by monitoring data.

Recommendations :

(1) To the extent feasible, monitor other mammal species possibly influenced by wolf recovery. The invasion dynamics of coyotes into the system are especially likely to be affected by the wolf reintroduction, and to change other components of the food web.

(2) To the extent feasible, investigate changes in deer recruitment, and the magnitude of predation on wild pigs. This topic would ideally be a NBS-funded research project. Inform NBS of the significant research opportunities available in the Park, and encourage NBS scientists to argue for the necessary funds to carry out the studies.

GENERAL RECOMMENDATIONS APPLICABLE TO THE OVERALL PROGRAM

(1) The monitoring "team" needs to specifically address the following question: "What do the monitoring results indicate in terms of the environmental integrity of the Great Smoky Mountain ecosystem?" To the extent possible, use inductive inference to extrapolate from the monitoring studies to the larger ecosystem.

(2) Greater effort is needed to report, on a regular basis, the results of the annual monitoring efforts. Results should appear in technical reports or publications targeted to resource managers.

(3) The monitoring studies and results should be interpreted in the context of contemporary ecological theory (i.e., importance of temporal and spatial scale; spatial distribution of plant and animal communities; relationship between population size and distribution and persistence likelihoods; landscape heterogeneity and the role of natural disturbance processes).

(4) The process by which the monitoring results feed into the management decision making process needs to be clearly articulated and institutionalized. In the absence of this connection, monitoring becomes vulnerable during times of budget reductions.

(5) In collaboration with NBS, form an interdisciplinary, scientific advisory committee to aid in implementing the recommendations you have received.

WHAT ASSISTANCE CAN NBS PROVIDE?

Implementing and explaining the rationale for many of the technical recommendations made above should be the responsibility of one or more NBS scientists. There are a number of ways in which this process can be facilitated. Perhaps the **most** expedient would be for NBS to offer a workshop for the GSMNP personnel that: (1) covers the conceptual and technical aspects of an effective environmental monitoring program, (2) offers the specific guidance and technical expertise needed to address the monitoring issues unique to the GSMNP.

Further, the results of the monitoring program will continually lead to questions of causation which can only be answered through focused research studies. Thus, some segment of the NBS research organization needs to be responsive to the information needs of the National Parks, including "as needed" advice and assistance on all components of environmental monitoring.

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CONCEPTUAL ISSUES IN THE MONITORING OF ECOLOGICAL RESOURCES

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