Review of the Denali National Park and Preserve (DENA) Long-Term Ecological Monitoring Program (LTEM)

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Summary

We could not review the fine details of the long term ecological monitoring (LTEM) program at Denali National Park and Preserve (DENA) because of unresolved program level issues. Paul Geissler (Geissler 1998) was very diplomatic in his review remarks this summer, but his message is very clear: the program level issues must be addressed before significant progress can be made on the fine details such as statistical power to detect changes or trend. Only a few of the components qualify as protocols for extensive long-term monitoring, e.g., the point counts for birds. Others could be modified easily, but would require some work and evaluation. For example, at aquatic sites one might: select fewer samples and use less precise classification for aquatic macro invertebrates, reduce the chemistry analysis for water samples, snap-trap small mammals at sites on a 5-year rotation, etc. To implement these less intensive variables in the near future, i.e., 2001, researchers will have to reduce their tactical (intensive research) study components and, in some cases, define new Design Protocols (Study Plans) and Standard Operating Procedures (SOPs).

Our recommendations are:

Realistic Expectations

1. Acknowledge the limitations of monitoring.

Design Considerations

2. Data should be unbiased.
3. Use limited stratification.
4. Do not limit program by issues of today.
5. Integrate components of the monitoring program.
6. SOPs should be economical and fast.
7. Use standard design-based inferences.
8. Determine current conditions.

General Operational Considerations

9. Program must be someone's pet project.
10. Write design protocols and SOPs.
11. Issue regular, timely reports.
12. Good data management is imperative.

Linking the LTEM Program to Resource Management Decision Making

13. Program should have some current management value.
14. Have reasonable expectations for assessment of management practices using monitoring and research data.
15. Establish an Independent Scientific Review of monitoring and research data (Meffe et al. 1998).
16. Use ‘best available science’ from monitoring *and* research in adaptive resource management.

INTRODUCTION

WEST, Inc., was asked by BRD to provide a statistical review of the current DENA LTEM program, and provide recommendations for improvements. We relied upon an extensive set of documents provided by Ms. Karen Oakley, ABSC, including the following list:

Anonymous. 1997. Data management protocol, Denali National Park and Preserve, Dated August, 1997. National Park Service, Denali Park, Alaska.

Anonymous. 1997. Strategic Plan, Long-Term Ecological Monitoring Program, Denali National Park and Preserve. Final Draft, dated October, 1997.

Holland-Bartels, L., and S.P. Martin. 1997. Joint NPS-BRD Funding Request for Operations and Research for the LTEM Program at Denali National Park & Preserve in FY 1998. Memo to Norita Chaney, BRD, and Gary Williams, NPS, dated November 5, 1997.

Knuckles, P. 1998. Long-Term Ecological Monitoring Program. Annual Administrative Preport, Fiscal Year 1997, Denali National Park and Preserve, Denali Park, Alaska.

Paton, P.W., and T.H. Pogson. 1996. Relative Abundance, migration Strategy, and Habitat Use of Birds Breeding in Denali National Park, Alaska. Canadian Field-Naturalist 110: 599-606.

Rexstad, E. 1994. Detecting Differences in Wildlife Populations Across Time and Space. In Trans. 59th No. Am. Wildl. & Natur. Resour. Conf. Pp 219-228.

Stottlemyer, R. 1992. Nitrogen Mineralization and Streamwater Chemistry, Rock Creek Watershed, Denali National Park, Alaska, U.S.A. Arctic and Alpine Research 24: 291-303.

Thorsteinson, L.K., and D.L. Taylor. 1997. A Watershed Approach to Ecosystem Monitoring in Denali National Park and Preserve, Alaska. J. American Water Resources Association 33: 795-810.

We reviewed annual reports from the following components of the LTEM program: monitoring landbird populations using point counts, monitoring avian productivity and survivorship (MAPS), and small mammal monitoring. Consideration was given to the 'methods' in the annual reports which are related to the design protocols and standard operating procedures of the LTEM program. We reviewed a research proposal from Dot Helm and other memos and letters from park personnel on vegetation monitoring. These reports were not fully reviewed for technical issues on results or statistical analyses.

We read original comments from statistician Chris Bunck concerning the 1995 review of the LTEM program (Bunck 1998) and the summary of the 1995 review written by Doyle Frederick. The comments on the LTEM program written by statistician, Paul Geissler, after his visit to DENA in June 1998 (Geissler 1998) were reviewed. Finally, we visited with park staff and research cooperators during a site visit to Denali National Park, 31 August to 3 September 1998, to develop our recommendations.

Our review comes 6 years into the "pilot study" for the LTEM program, which gives us a chance to assess current procedures and recommend changes before the program is implemented park-wide. We found that we could not review the fine details of the Design Protocols (Study Plans) and Standard Operations Procedures (SOPs) in the long term ecological monitoring (LTEM) program at Denali National Park and Preserve (DENA) because of unresolved program level issues. Paul Geissler (Geissler 1998) was very diplomatic in his review remarks this summer, but his message is very clear: the program level issues must be addressed before significant progress can be made on the fine details such as statistical power to detect changes or trend. Only a few of the components qualify as protocols for extensive long-term monitoring, e.g., the point counts for birds. Others could be modified easily, but would require some work and evaluation. For example, at aquatic sites one might: select fewer samples and use less precise classification for aquatic macro invertebrates, reduce the chemistry analysis for water samples, snap-trap small mammals at sites on a 5-year rotation, etc.

If the variables selected for extensive long-term monitoring in DENA are part of the current protocols, and methods are not changed appreciably, then some of the finer details concerning statistical power to detect important changes or trend can be addressed during the winter of 1998-99 for a few

selected studies, e.g., point counts for birds. Otherwise, flexible Design protocols for selection of systematic sets of sampling sites should be developed, for example, for riparian habitat (streams, rivers, and adjacent flood plain) and for the remaining uplands habitat. Certain discrete resources (e.g., glaciers) may require unique Design protocols. These Design protocols will allow the intensity of sample sites to be increased or decreased without loss of representativeness of the data in the future. Simple, economical Standard Operating Procedures should be developed for implementation in some of the monitoring components in 1999. Other components will require additional planning and peer review before implementation. Better integration of many components should be made including integration of monitoring of large mammals with monitoring of the more basic food and habitat resources. If not all of the selected sites can be monitoring in the near future because of costs, then inferences will be restricted to the sampled areas (e.g., those close to roads). However, sample sites should be identified in the rest of the DENA so that when resources are available, sampling can move into those regions and unbiased inferences can be made to larger areas.

The terms *protocol* and *standard operating procedure* need to be defined for this report, and for use in developing and implementing the LTEM program. As defined by the Webster's New Collegiate Dictionary, a protocol is "the plan of a scientific experiment or treatment." The Design protocols that we refer to in this report are the overall plan for the LTEM program and the plans for each aspect of the program (e.g., glaciers, vegetation, birds). The umbrella Design protocol for the LTEM program will include the justification and need for the program, the objectives for DENA LTEM, the variables that will be measured and the overall sampling design (site selection) for the program, plans for data management, analysis, and reporting, total costs for implementing the program annually, etc. Design protocols for each of the variables that are selected for inclusion in the LTEM program will include the same information, but specific to the application. While the Design protocols provide guidance for the LTEM program, the Standard Operating Procedures (SOPs) give details on how all aspects of the protocols will be carried out, from selecting study sites and measuring variables, to managing the data and writing reports. The SOPs may be considered the "cookbooks" for implementing the program.

PROGRAMMATIC ISSUES

Original Study Design

The current Protocols and SOPs which we reviewed are more appropriate for intensive watershed research programs (tactical work) on very specific questions with limited life span on a small scale than for long-term, or "strategic," components providing basic knowledge about status and trends of park resources. The Protocols and SOPs do not even lead to valid statistical inferences to the entire Rock Creek Watershed, because of the lack of probability based 'random' sampling procedures for selection of study sites within the watershed. Rather, 'representative' sites were subjectively selected within the watershed and inferences to the watershed are by assumption, not by design of the sampling plan. Perhaps, the inferences are valid, but they are based on assumptions and the subjective judgement of the principal investigators.

A valid long term monitoring program could be developed for DENA using watersheds as sampling units if: a sampling frame (list) of watersheds were developed and a probability based sample were selected, watersheds were subsampled selecting sites by a probability based method, and simple

inexpensive variables were developed (or selected from the current research projects). Using watersheds as sampling units is feasible and may be the preferred option, but will essentially require starting over with the process of Design protocol and SOP development. The rest of this document is generally applicable if the decision is made to use watersheds as sampling units with subsampling within watersheds. However, we recommend consideration of a simpler grid or systematic sampling plan with equal size units and to avoid the more complex analyses required in nested (hierarchical) subsampling plans.

Need for an Extensive Sampling Plan for DENA

There is a need to break away from the intensive research project protocols which we reviewed if DENA is to develop a statistically valid LTEM Program. We believe this is what Paul Geissler (Statistician in 1998 review of DENA LTEM) was addressing in his review of the Small Mammals work this summer when he wrote that "the small mammal study appears to be very well designed to investigate demographics and population dynamics at an intensive site. In my opinion, it is very important from a scientific perspective to continue this long-term study of community dynamics that clearly has a very substantial investment in seven years of data collection. However, the current design is incapable of achieving the stated objective: 'to learn whether the dynamics of small mammal populations that have been tracked in Rock Creek for the past six years are indicative of the dynamics of populations in similar watersheds along the park road,' because it lacks an extensive monitoring component" (Geissler 1998). Chris Bunck (Statistician in 1995 review of DENA LTEM) wrote "...the projects that I reviewed (small mammal project, watershed 'monitoring', inverts, veg) were good/solid 'research' projects." (Bunck 1998).

Paul went on to recommend, "I suggest the objective should be expanded to include representation of all of DENA. In my opinion, a number of sites in different habitats and areas of the Park are required to adequately monitor small mammal populations, because conditions and environmental factors are likely to be quite different in different areas of such a large Park" (Geissler 1998). Chris Bunck "...watershed approach was an in-depth study of a 'process' (abiotic component of the ecosystem); again seemed to be solid/thorough research, but not clear how this strategy would provide a 'basis' for monitoring throughout Denali or other Alaskan Parks" (Bunck 1998). We strongly agree with these assessments.

The nature of tactical intensive research on very specific questions with limited life span on a small scale is that:

1. SOPs are too time consuming and expensive to survive the necessary waiting period to provide data in a long-term monitoring program;
2. cause and effect relationships are the end objective;
3. measures of success are peer reviewed journal publications;
4. the latest and most expensive methods are used over about 3 to 5 years;
5. researchers do not like monitoring studies until the program is about 15 to 20 years old and 'interesting' data arise;
6. SOPs are too intensive and the sampling sites tend to wear out, in the sense that the research causes them to evolve and not represent the area/habitat for which they were selected;
7. study sites may also wear out because they are treated differently than the rest of the park and

hence evolve into something not representative (e.g., backcountry camping may not be allowed in Rock Creek Drainage, caribou and Dall sheep may not frequent Rock Creek Drainage to graze because of presence of researchers).

We believe there is a need for research in monitoring programs, but we are critical of research disguised as long term monitoring. The two, monitoring and research, just need to be carefully defined and separated. Monitoring can determine correlations over time or space at best, and correlations over space only if sample sites are collocated. Research can establish cause and effect, test hypotheses, and build useful models. A research component is needed to study rare resources, endangered species, important management issues, study cause and effect relationships suggested by monitoring data, establish simpler, more economical procedures, and build models for prediction into the future or the unsampled area. Monitoring data must be based on sound science and be able to stand on their own merits for the long term, say at least 50 years, but they rarely answer research questions on ecological processes and uncertainties.

Also, the role of scientific information in making management (public policy) decisions should be clarified. Use long-term monitoring data and relatively short term research results and modeling to reach 'best scientific advice' for input into decisions on 'public policy management decisions.' Clearly separate best scientific advice from decisions on public policy management decisions. To help in obtaining the best scientific advice it is advisable to have consensus of an Independent Scientific Review. Consensus among grey haired scientists concerning 'best scientific advice' for input on policy decisions will minimize influence of bias and special interest groups, help separate science from policy, help make assumptions of models and statistical analyses explicit, and articulate the risks of different policy decisions (Meffe *et al.* 1998).

Finally, all participants in the long-term monitoring program need to coordinate activities to successfully implement the program. We suggest involving all participants in the DENA LTEM program to develop a Master Plan. Aspects of the Master Plan will include input from DENA principal investigators and outside specialists to determine the most important variables to measure and how to sample quickly and economically; consensus on clear, attainable objectives for the monitoring program; protocols for determining sample site locations and logistics; overall Design protocols and SOPs for variables to be measured; estimated current and future costs to implement the program; and strategies to implement and evaluate the program. Producing the Master Plan will involve give and take by all participants to incorporate a valuable, cost-effective, flexible, and integrated sampling structure that will withstand scrutiny through the 21st century and beyond.

For successful implementation of the DENA LTEM program, the acceptance, or "buy-in," by everyone involved cannot be underestimated. Park managers need to understand the value of the LTEM program, or they will divert funds from LTEM to other projects they feel are more important or relevant to current park management. Principal investigators need to allocate substantial time and effort (their own &/or technicians) to coordination with other LTEM participants, field sampling, data management and analysis, and reporting. If LTEM is not perceived as an important aspect of their work, the program will fail.

We recommend designing a monitoring program which expands the sampling into the rest of DENA, recognizing that not all of the selected sites will be visited every year and some may not be visited in the foreseeable future. We recommend some type of systematic sampling procedure on a grid, or uniformly spaced intervals along riparian zones. David Graber (NP-SEKI) wrote that "...a grid system such as we used was excellent for characterizing the biota of the Parks and for determining how to

stratify [post stratify] monitoring..." However, he cautioned that "...travel costs are too high for long-term repeated sampling." Also, see Graber *et al.* (1993). We recommend that the cost constraints be met by using rotating panels of sites where one panel would be visited every year, but the others would be visited only periodically, perhaps every five years, effectively increasing the sample size by a factor of 5 to 10 for monitoring of change and trend over the long run. Such strategies are compatible with the objectives of a LTEM Program in DENA: measure current average conditions, measure distribution of variables, measure trend over the long term, measure change between two periods of time, etc.

RECOMMENDATIONS

For easy reference our recommendations are presented in a series of discrete boxes, organized into four groups: (1) realistic expectations, (2) design considerations, (3) operational considerations for acceptance and credibility, and (4) linking LTEM to resource management decision making.

Realistic Expectations: Acknowledge the Limitations of Monitoring

- Monitoring is designed only to show trend &/or change over time.

Example:

- Consider the national breeding bird survey (BBS). Problems have been detected, i.e., decreasing trend in certain song bird species. Data from the BBS does not indicate why. Maybe, the intensive tactical research MAPS component will give some answers when data are combined over large areas.

Example from Prince William Sound:

- Seabird data collected in 1986, and 1989-1998.
- Differences still exist between oiled and unoiled sites in rates of change in abundance of some species.
- The monitoring data does not indicate why there are differences. Differences may be due to residual oil, less food, demographics, competition with other species, etc.
- With ten years of continuous data and trends, is little chance that monitoring for seabird numbers in Prince William Sound will be cut by the U.S. Fish and Wildlife Service.

- Monitoring does not show cause and effect.
  - Cause and effect are research problems that will not be solved by monitoring!
  - Correlations can be obtained by a well designed monitoring program, but not cause and effect relationships.

- Monitoring provides data for models but does not include modeling.
  - Models are built according to certain assumptions in research programs.
  - Models should not be used to modify basic monitoring data stored in the permanent data management program.
  - Monitoring data can be used to validate models.

Examples of monitoring data:

- numbers of song birds from breeding bird surveys;
- annual visitor use from visitor counts and surveys;
- seasonal/annual air and water quality from permanent stations;
- caribou/calf ratios from aerial surveys; and
- numbers of wolves from aerial surveys.

Design Consideration: Data Should be Unbiased

- Monitoring sites should be randomly located:
  - all randomly located, or
  - systematically located with a random start;
  - limit the use of subjectively placed sites that are judged to be 'representative'.

- Establish rotating panels of sites:
  - keep one panel of sites for annual visits for x years, then drop the panel and select a new random panel for the next x-year period;
  - revisit the remaining panels on a rotating basis, 1 panel per year;
  - include some special interest sites in each panel;
  - in addition, one could include a random panel each year to improve coverage across the park.

- When changes or trend are detected, inferences from subjectively selected 'representative' sites will be questioned by critics.

- The value of a few, simple, design-based inferences cannot be overemphasized when monitoring data are being questioned by critics.

Hypothetical example for DENA Uplands:

- Establish a systematic grid over the designated uplands area of the park with potential sample sites located at each grid point.
- Randomly or systematically select 6 panels of grid sites, each panel with an equal number of sites;
- Randomly assign one panel to visit annually for 5 years, rotate the panel out and select a new random panel for the next 5-year period;
- Randomly assign the remaining 5 panels to be visited on a 5-year rotation, one panel each year.

Hypothetical example for DENA Riparian:

- Establish regularly spaced points along each riparian zone to create, say, m sampling reaches.
- Rank stream-rivers in a list;
- Determine sample size for reaches, say, n, where n = m/k;
- Select a random number from 1 to k as a random starting point and select every kth reach thereafter;
- Rotating panels of sites could be selected as above.

Hypothetical Example for DENA discrete resources, e.g., glaciers:

- Rank glaciers in the park in a list. Select a systematic sample as for stream reaches.

Design Consideration: Use Limited Stratification

- The best recommendation may be to stratify only by major extensive resources (e.g., uplands, riparian, glaciers).
  - At most, use 2 or 3 strata that will work well for all species, processes, and variables to be collocated on sites within strata;
  - Sites are often misclassified in the office and must be reclassified into the proper stratum after site visits;
  - Stratification and misclassification of sites leads to unequally weighted data which must be released to the public and critics who may not understand or properly use the weights when considering the data;
  - Strata boundaries change over time (e.g., a pool may become a run after a flood);
  - If everyone stratifies separately, collocation of sites is not possible, and correlations over space cannot be easily made or design based;
  - Stratification can be made optimum for only one variable at a time.

- Post stratify (classify) sample sites into domains of interest for reporting data.
  - For example, classify wetland sites into National Wetlands Inventory categories after site visits, because wetland sites will change from one category to another over the long-term.

Hypothetical example for DENA:

- A riparian area might be stratified based on riffles, runs and pools in the stream/river.
  - Riffles, runs and pools change over time with changing weather regimes and floods (50-100 years);
  - How are sites treated that change into a different stratum?
  - The stratification may not be good for variables that do not correlate well with stream characteristics (e.g., bird abundance in adjacent habitat).

Design Consideration: Do Not Limit Program by Issues of Today

- Management issues should be considered when designing a monitoring program, but the monitoring plan should not be limited by the issues of today because they will change.
- Must do monitoring correctly based on sound science.
- Let the data stand on their own merits.
- The LTEM Program should be designed to last for at least 50 years.

Example from DENA:

- LTEM program was influenced by concern for global warming;
- Current park management issue is visitor impact;
- Future park management concern is adding roads into the Park;
- A well designed monitoring program will relate to future issues, including ones we cannot foresee.

Design Consideration: Integrate Components of the Monitoring Program

- Collocate sites for monitoring data when possible.

- Interyear correlations over space will be limited unless measurements are made on the same sites.

- Geissler (1998) hit on this point in his review:
  - "...investigators did not comment on efforts to share data or to use an interdisciplinary approach to understanding ecological processes. As monitoring efforts expand beyond Rock Creek, I can see advantages of collocating at least the vegetation, bird and small mammal monitoring. Collocation will facilitate the understanding of the relationships among these ecosystem components."

- Bunck (1998) also pointed out the problem:
  - "...need to articulate/define an overall framework that 'connects the disjoint parts' .... need to tie into the other monitoring efforts on the park (e.g., big mammals-wolves, bears, moose)"

Hypothetical example for DENA:

- Stream/riverine components: water quality/hydrology, aquatic invertebrates, stream/riverine vegetation, small mammals, birds, stream channel, etc. might be collocated on a sample site in a riparian stratum.
- Similarly, in an uplands stratum, small mammals, birds, vegetation, soils, etc. might be collocated.

Design Consideration: SOPs should be Economical & Fast

- The 'wish list' of species, processes, and variables of interest must be trimmed down in all but the best funded programs.
- Simpler is better. Use simple variables, simple design protocols, and simple SOPs.
- Involve species/processes experts before beginning with protocols and SOPs, but be certain that they are aware of the objective to determine simple economical procedures
- The program must be economical and fast to implement because it has to survive the first 10-12 years without being cut by the administration.

Hypothetical examples for DENA:

- For wetlands examine aerial photography every 5 years;
- For breeding birds conduct annual point counts;
- For ground temperature set up remote, automatically recording thermometers 12 inches below the ground surface.
- Geissler (1998) used the bird monitoring as an example when he stated "...the bird monitoring integrates an intensive component (MAPS) with an extensive component (BBS routes and point counts). This integration allows them to couple detailed information on avian community dynamics from the MAPS station with expansive spatial distribution and relative abundance information to understand population dynamics throughout a major section of the park."

Design Consideration: Use Standard Design-based Inferences

- Report empirical data and statistical inferences which are justified by the design (no modeling and no assumptions).
- Use graphical presentation of basic statistics.
- Evaluate models by providing empirical data.

Remember:

- Dueling models and complicated statistical analyses will not impress decision makers on management and public policy issues.

Design Consideration: Determine Current Conditions

- Define 'Baseline' conditions
  - Baseline can only be estimated by design based inferences if baseline is defined to be current conditions.
  - Conduct modeling exercise to estimate baseline if not current conditions.

- Reach consensus on what magnitude of change will be considered important in monitoring data.

- Plan for estimation of current and future conditions by an unbiased sampling procedure with standard error adequate to detect important changes.

Acceptance & Credibility: Program Must be Someone's Pet Project!

- There must be someone who is enthusiastic about the monitoring program and is in charge:
  - can overcome adversity and manage people well;
  - sees that work gets done, and has authority to do so;
  - trains technicians on SOPs;
  - sees that reports are issued annually and on time;
  - sells the program to administration--attitude toward the program is set by administration;
  - sells the program to participants for development and implementation;
  - has faith; and
  - acknowledges that it will take at least 10-12 years for the program to take on a life of its own.

- "Successful long-term studies have dedicated leaders" (Strayer *et al.* 1986).

Acceptance & Credibility: Write Design protocols and SOPs

- Require written Protocols and SOPs.

- When possible, use standardized design protocols for site selection and standardized SOPs within DENA, with other parks, and with other government agencies.
  - After the Exxon Valdez oil spill, Trustee NRDA scientists, NOAA scientists, and Exxon funded scientists all used different design protocols and different SOPs. Results were not easily compared.

- Overlap old and new procedures for a number of years to correlate results. For example, visual counts of fish compared to sonar counts.

- Inferences from monitoring are to the study area; subject to the design protocols and the SOPs.

- Considerable effort should be spent on defining the sampling frames in each stratum. The sampling frame would be archived and serve as a basis of extrapolation of data and design of intensive tactical studies in the future.

Acceptance & Credibility: Issue Regular, Timely Reports

- Reports provide regular updates on the monitoring program, can be related to current management issues, and can show changes in trends that are detected, annual variation, and correlations.

- Data are valuable as part of national or international monitoring programs. Issue reports showing how your park compares to national results.

- Some monitoring data on current study sites has not been entered into electronic files, and reports have not been prepared.

- Administration will not support a program unless regular reports are issued!

Acceptance & Credibility: Good Data Management is Imperative

- Enter new data now, with methods and a history file (metadata).
  - Give old data lower priority. Remember Wayne Fuller's comment "the good old data, is not that good." (Wayne Fuller, Iowa State University, personal communication).

- Keep a master copy of the original raw data, the 'official' copy:
  - separate the original data from summary and derived data;
  - one person is responsible for the official data, makes necessary corrections to the data, etc.
  - History files should describe all changes in the data files.

- US EPA's Good Laboratory Practice (GLP) is a valuable guide for data management. GLP is tedious, but it catches mistakes, and everyone knows where the 'official' data are.

Linking LTEM & Resource Management: Program Should Have Some Current Management Value

Hypothetical examples for DENA:

- Correlate environmental data with park visitors, backcountry use, density of roads;
- Correlate caribou cow/calf ratios with wolf abundance;
- Correlate glacier mass with air temperatures (or show lack of correlation).

Sell the monitoring program:

- Find out what the administration is interested in (song birds, water quality, wolves, etc.) and sell the project.

Linking LTEM & Resource Management: Have Reasonable Expectations for Assessing Management Practices using Monitoring and Research Data

- Managers will need to use monitoring and research data for assessment of management practices and policies.

- Monitoring does not provide cause and effect relationships.

Hypothetical Example for DENA:

- Managers may wish to assess the effect of closing backcountry use on distribution of Dall sheep.

- Monitoring data on distribution of Dall sheep within a relatively small region may be limited, and assessment will not be easy.

- Any assessment of management policy will have its critics.

- Changing management, mixing management strategies, and incremental application of management strategies will complicate assessment of monitoring data.

Linking LTEM & Resource Management: Establish an Independent Scientific Review of Monitoring and Research Data (Meffe *et al.* 1998)

- Consensus among grey haired scientists concerning the "best scientific advice" for input on management decisions.
- Minimize influence of bias and special interest groups.
- Separate science from policy and management.
- Assumptions of models and statistical analyses are made explicit.
- Articulate risks of different management decisions.
- Scientific Review committee should be compensated for their time. Paying specialists for their advice is more cost effective than collecting data that have no use to the monitoring program or management.

Linking LTEM & Resource Management: Use 'Best Available Science' from Monitoring *and* Research in Adaptive Resource Management

- Use long-term monitoring data and short term research results and modeling to reach the 'best scientific advice' for input into 'public policy management decisions'.
- Clearly separate 'best scientific advice' from 'public policy management decisions'.

Expectation:

- Monitoring and research data will be used through Adaptive Management to decide the 'effect' of management over a fairly short period of time (say, 13-15 years).

Reality:

- Ability to directly relate results of monitoring and research to cause and effect of management is limited.
- Use monitoring to determine if change or trend has occurred.
- Use research to determine cause and effect on a limited scale.
- Use modeling with associated assumptions to make predictions.

NEXT STEPS FOR DENA LTEM

Using knowledge gained from the Rock Creek 'pilot study,' and reviews and recommendations of the existing program, DENA needs to develop the umbrella Design Protocol for the LTEM program and the more focused Design Protocols for the various components (small mammals, large mammals, birds, vegetation, soils, etc.), and SOPs for the variables to be measured. This will not be a simple task. The park-wide sampling frames need to be developed, sampling methods need to be determined, the important variables for measurement need to be selected, and the procedures need to be written/tested. The recommendations in this report provide the basis for these decisions.

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