1997 Annual Report

Project Title: Long-term Ecological Monitoring Research and Development, Olympic Peninsula (81071-10003-S4)

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Period Covered: October 1996-September 1997

Introduction:

Developing a long-term ecological monitoring program has been a long-standing priority at Olympic National Park (ONP). Designation of ONP as a Biosphere Reserve in 1976 and a World Heritage Site in 1981 identified the park as an internationally significant example of a largely undisturbed coniferous forest ecosystem, and recognized its value as an ecological benchmark for comparison to more altered ecosystems elsewhere. Over twenty project statements in the park's Resource Management Plan describe multidisciplinary monitoring projects needed to provide early warning of impacts to these unique park resources and identify necessary measures for protection. In 1993, ONP was selected as a prototype park to develop long-term ecological monitoring (LTEM) protocols in the coniferous forest biome as part of the National Park Service Inventory and Monitoring Program. Additionally, the President's Northwest Forest Plan (NWFP) requires federal agencies to design a science-based approach to monitor status and trends of selected resources on federal lands in the Pacific Northwest.

In 1996, the Olympic Field Station of the Forest and Rangeland Ecosystem Science Center (FRESC) proposed to create a monitoring framework and to develop protocols for LTEM that: 1) integrated the monitoring needs of ONP with those of other agencies on the Olympic Peninsula, and 2) contributed to the monitoring required by the President's NWFP (Jenkins et al. 1997). The focus of our efforts is to design the scientific underpinning of a credible monitoring program and to field test selected monitoring protocols. Full program implementation and development of additional protocols will occur when funding becomes available through the National Park Service's (NPS) Inventory and Monitoring Program.

Project Goals and Objectives:

Our goal is to plan and develop an ecosystem-level LTEM program that reflects management priorities, ecological rationale for attribute selection, and statistical sufficiency of sampling designs. The scope of our planning and monitoring activities includes coniferous forest ecosystems of ONP and adjoining lands on the Olympic Peninsula, including aquatic components. While our monitoring activities will be limited primarily to ONP, we will foster cooperative relationships with adjoining land-owners and managers so that monitoring is developed at the regional/ecosystem level.

Specific project objectives are:

1. Review conceptual issues relevant to long-term monitoring of natural resources using ONP as a case-study.

2. Develop a strategy for designing an integrated long-term ecological monitoring program.

3. Identify potential monitoring projects that reflect diverse objectives and agency representation.

4. Inventory resource data that currently exists on the Olympic Peninsula.

5. Develop an ecological approach for selecting monitoring attributes.

6. Compare sampling designs and statistical efficiency of selected monitoring approaches as to their ability to detect changes along gradients of human impact and climate.

Summary of Progress:

During FY1997, we 1) finalized our study plan (Jenkins et al. 1997), 2) conducted a workshop to review conceptual issues associated with long-term monitoring and selection of indicators, 3) conducted a series of workshops to determine which natural resources were of greatest concern to ONP staff and other potential cooperators on the Peninsula, 4) developed a tactical approach to indicator selection, and 5) conducted a workshop with several forest ecologists to begin selecting indicators of forest ecosystem processes. Here, we report our progress in completing tasks associated with each project objective.

Objective 1: Review Conceptual Issues of LTEM Design and Indicator Selection

The most effective long-term ecological monitoring programs are based on sound ecological principles (Noon, In Prep). Ecological considerations are fundamental in developing conceptual models of how biological systems function and identifying the most 'information rich' ecosystem attributes to measure. Although there has been a fair amount of discussion on what constitutes a good indicator, there is little practical advice given on the actual process of indicator selection (but see Noss 1990, Schmoldt et al. 1994). Moreover, despite the obvious need for reliable ecological information to support local and regional management activities, many monitoring programs have suffered from common problems: vague objectives, a piecemeal approach to indicator selection, and vague linkages between monitoring attributes and the decision-making process. Avoiding these pitfalls and designing a credible long-term monitoring program is particularly challenging when monitoring must meet multiple objectives and diverse expectations of several landowners on a limited budget as exemplified on the Olympic Peninsula.

To help elucidate these difficulties and to develop an effective strategy for developing LTEM in ONP, we held a workshop entitled "Indicator Selection for Ecological Monitoring: In Theory and Practice" in May 1997. Staff from the Olympic Field Station and FRESC co-sponsored the workshop with Barry Noon (formerly U.S.F.S Redwoods Sciences Lab, presently Colorado State University), who is currently preparing a review of conceptual issues of LTEM and indicator selection (Noon, In Prep). Objectives of the workshop were to explore ecological advances in the process of selecting ecological indicators using the LTEM program in ONP as a case example for discussion. We invited 18 federal and university research scientists with experience and an interest in designing LTEM projects to participate in the discussions. A brief synopsis of key points is provided below; results of the workshop are currently being prepared for publication.

The Process of Indicator Selection

Workshop participants agreed that developing long-term ecological monitoring is not a purely ecological process. Sustained support for monitoring requires that monitoring decisions reflect socio-political considerations, agency mandates as well as ecological rationale. Consequently, species appropriate to monitor fall in three categories: 1) *target species* that have value for social and political reasons, 2) *bioassay species* that are sensitive to ecosystem disturbance or disruption (i.e., stressors such as environmental contaminants or changing climate), and 3) *indicator species* that are chosen to represent system status. Although all monitoring decisions reflect ecological reasoning, monitoring ecosystem status is the most challenging from an ecological perspective and was the focus of much of the discussion.

One important ecological issue is whether or not it is possible to measure ecosystem properties that represent more than the sum of its individual parts. Examples of such properties include ecosystem "health", resiliency, biodiversity, and stability. These are nebulous concepts, but participants concluded that a monitoring program based on individual species can describe "holistic" ecosystem properties if subjects are distributed across taxonomic groups, trophic levels, and if appropriate geographic linkages are made. A conceptual model of interactions among ecosystem components can also help determine which parameters to measure that best characterize the system. Participants agreed that there are emergent properties of ecosystems such as heat production, biodiversity, or ethylene production that can be monitored. This approach recognizes that ecosystems are complex, self-organizing systems with a number of possible stable states. Changes in emergent properties can indicate whether an ecosystem is moving toward the boundary of its stable state. Other potential monitoring tools include 'interaction assessment' (INTASS, Emlen et al. 1989, 1992), which quantitatively describes the effects of species interactions and local environmental variables on population growth and allows for predictions of the consequences of disturbance or management actions.

Given the inability of ecological theory alone to provide structure for a monitoring program, workshop participants provided some practical advice and direction. After reviewing examples of monitoring programs, the group concluded that objectives for monitoring are determined by management goals, legal mandates, and constituencies for resources. The specific objectives will determine the approach to monitoring. However, the monitoring plan can be developed with a

stressor-based (NWFP effectiveness monitoring), a comprehensive ecosystem (e.g., Long-term Ecological Research Program), or an objective management approach (used by USFW for individual wildlife species) and be an effective program. The comprehensive ecosystem approach is less likely to miss important aspects of the system. That is, there is a risk with a stressor-based program that some critical system driver could be overlooked in the model. The comprehensive ecosystem approach is less likely to miss important aspects of the system. Further, the comprehensive model can help reveal linkages among system components and identify those that are most sensitive or important to monitor. On the other hand, the stressor-based approach arose because of critical reviews of the EMAP program. The reviewers advised bringing those things you expect to be affecting the ecological system to the front of the modeling process.

Choosing indicators may be the most challenging step in developing a monitoring program. Desirable characteristics of indicators were discussed by the group and a list of 14 positive attributes resulted. Some attributes were statistical, some political, some were conceptual, and no single indicator could have all 14 attributes. As a case example, we asked the group what criteria should be used to decide between monitoring flying squirrels versus owls--the answer was that arguments could be made to monitor either squirrels or owls because both have value. In other words, there is no single, 'correct' approach to selecting indicators, and there is no purely ecological filter that can be used to extract the 'best' indicators. The group concluded that while it is important to choose indicators with desirable characteristics that cover as many bases as possible (i.e., trophic, taxonomic, political, geographic, etc.), it was perhaps more important to describe the rationale for indicator selection so that the choice could be critically evaluated. In general, participants thought that indicators based on populations, and perhaps genetic and landscape-level measurements would have many desirable characteristics.

Workshop participants concluded that the goal of monitoring need not be to determine a uniquely best set of indicators, because that goal may be too daunting and impede progress. Rather, the goal should be to develop a set of *effective* indicators that meet program objectives. The selection of indicators can be modified as information builds on the relative performance and properties of alternative monitoring approaches. Additionally, participants pointed out that developing any monitoring program is an iterative process that should follow these steps:

- Identify the objects of interest to monitor (species, ecosystem properties or processes) and reconsider them often.
- Build conceptual models that incorporate stressors, major ecosystem components and functions, and major management issues. Put them on paper.
- Articulate criteria or general categories of information that are needed.
- Select measurable indicators with desirable properties.
- Develop and test protocols.
- Document what you have done and your reasoning.
- Collect data.
- Repeat the process.

Sampling Issues

Once indicators are chosen, it is necessary to consider statistical and sampling issues. When taking repeated measurements of biological or environmental variables through time, one expects to see some level of natural variation. It may be difficult to separate human-induced from natural components of variation, particularly because systems may naturally experience step functions of variation or episodic events that are difficult to interpret in relation to a natural range of variation. Finally, estimates over time will include variation due to sampling which must be separated from biological variation. Some statistical approaches to addressing these problems include extreme value theory, tests for stability of distributions, and methods for partitioning variance. In addition, one might use indicators with high signal-to-noise ratios such as developmental instability, integrative indices, or the minimum values of cyclical variables.

Sampling design must reflect the ecological scale of the process of interest, and must address the problem that estimation of a few points in time and space lacks statistical power. For example, intensive measurements might be used to monitor system properties in selected sites that represent a widely distributed resource, while extensive measurements might be used for risk assessment in order to know what proportion of a resource is affected. One way to address these issues is to use a nested grid approach to look at the degree to which land areas are nested, based on properties of presence/absence measurements at different grid sizes. This approach coupled with GIS technology offers the potential for collecting enough data to achieve statistical power.

Components of an Effective Monitoring Program

Workshop participants identified several elements common to all effective monitoring programs. These are outlined below as essential elements of a successful monitoring program:

- Monitoring needs to be publicly supported and must shows tangible benefits that are politically relevant.
- Monitoring should be designed to provide a quick response to land managers. A general rule is that monitoring should tell a story in 2-3 years.
- Monitoring must be sensitive to the needs of managers in terms of addressing the decisions they expect to make with appropriate data and statistical power to detect change.
- Monitoring must have clear objectives and definitions which can be reevaluated and adapted as monitoring provides new understanding.
- Monitoring programs should be designed in a geographic context, taking into consideration who else is measuring the same thing and at what scale. The result will be a geographically based strategy, possibly nested or hierarchical, that could be implemented by a consortium of agencies within an ecoregion.
- Monitoring programs must anticipate that approximately one-third of their funding will be required for data management and accommodation must be made for analysis of large, complex, compound data sets.

Objective 2: Develop a Design Strategy

The goals of LTEM in ONP are to: (1) understand how components of forest ecosystems change over time, (2) provide an early warning of anthropogenic change that may require management intervention, (3) provide a benchmark for comparison to more altered landscapes elsewhere, and (4) coordinate with other regional and national monitoring programs to the extent possible. These goals are too broad for any single strategy of indicator selection to meet all the monitoring needs. For example, we reasoned that a completely stressor-based approach to indicator selection, although responsive to the goal of detecting anthropogenic change, may not describe ecosystem structure and function sufficiently to understand forest change and provide complete baseline data. Further, selection of a 'comprehensive ecosystem' approach to indicator selection may not address key management concerns of the park. Therefore, we used a three-part strategy for indicator selection that recognizes the need to consider park management concerns, focal species, and ecosystem status independently at the initial planning stage. Lists of indicators developed from these three perspectives can then be integrated by examining commonalities among lists and supportive roles of potential indicators. This general approach borrows extensively from the many points of view expressed at our recent workshop on indicator selection, while also encapsulating the ideas on indicator selection articulated by Davis (1989) and Peterson et al. (1995).

Following Davis et al. (1994), we use a step-down diagram to illustrate a tactical plan for developing LTEM and selecting monitoring attributes in ONP (Figure 1). The LTEM goals are shown at the top of the diagram, with each step needed to fulfill those goals shown on the next lower level (Figure 1). Each layer is accomplished after completing the lower level. Because the scope of our monitoring project is so broad, encompassing forests, rivers, lakes, and shorelines, tactical planning will proceed independently for four broad biotic zones of the park: lowland coniferous forests, upper montane-subalpine forests, aquatic-riparian systems, and coastal. Integration across biotic associations is the final step not shown in the tactical plan diagram.

During the reporting period, we identified and selected potential monitoring attributes for management concerns, focal species and ecosystem status of lowland coniferous forests (Layer 4, Figure 1). Specific methods and results are described in subsequent sections for Objectives 3-5.

Objective 3: Identify Potential Monitoring Projects

Potential monitoring projects for management concerns, focal species, and ecosystem status were identified during two information-gathering workshops sponsored by the Olympic Field Station. We held workshops open to ONP employees in February, and to resource managers from other agencies on the Olympic Peninsula in April. Here we report the results of those two workshops, from which we compiled the initial lists of management concerns and potential resources to monitor.

Olympic National Park Workshop:

The process of identifying potential monitoring projects began with the park staff because they are most familiar with its resources. The main objectives of this, our first, planning workshop were to: 1) introduce park staff to the LTEM planning process, objectives, and status, and 2) ask park staff to identify ecological resources we should consider monitoring in ONP and why we should monitor them.

We invited the entire park staff to participate in the workshop. To ensure wide representation, we also asked division chiefs to ensure that at least 5 individuals participated from each park division, including rangers, resource educators, resource managers, and maintenance workers. Twenty-eight ONP staff members attended.

We used nominal group techniques to solicit input on potential resource monitoring projects. To keep groups as small as possible and maintain an informal 'round-table' atmosphere, we divided the participants into three work groups, each seated around a table, with a BRD scientist facilitating the discussions at each table but not contributing ideas. A resource management specialist from the park recorded ideas at each table, while also contributing to the discussion. We tried to spread participants from within park divisions among the three groups to maximize within-group diversity. We asked the question, "What resources in Olympic National Park should be monitored and why?'. We intentionally phrased this question in very general terms so as not to focus the discussion solely on management concerns, but also to gain a sense of how supportive the park was of monitoring natural ecosystem components and processes (i.e., LTEM goals 2-3). Within each group, participants answered the question with one idea at a time, taking turns around the table until everyone's ideas were exhausted. The ideas were recorded and the lists from the three groups were combined over lunch. We then asked participants to prioritize resources for monitoring by identifying their top 5 choices, and rating the emphasis each resource should receive in a monitoring program as 'high', 'moderate', or 'low'. After the workshop, a more refined list was circulated to the entire resource management staff, division chiefs, and park administrators who were not present at the workshop. They were also asked to choose the top 5 resources and to rank all resources by high, medium and low priority.

We have summarized the wide variety of discrete resources (e.g., cougar, beargrass), resource categories (e.g., old-growth obligate species, threatened and endangered species), and ecosystem processes (e.g., old-growth forest dynamics, small watershed processes) the park staff identified as important monitoring projects. Responses were grouped into 5 categories: physical resources, forest ecosystems, aquatic/riparian ecosystems, subalpine/upper montane ecosystems, and miscellaneous (Appendix A). We quantified the relative interests of park staff in each potential topic of monitoring by assigning the values 3, 2, and 1 to high, medium, and low responses, respectively, and then computing the average. Results are presented separately for workshop participants (Staff) and the resource management staff (RM) because each group had a slightly different list to rank.

Both groups of respondents felt that air quality and climate are high priority physical resources

to monitor. They also agreed that threatened and endangered species, old-growth forest dynamics, old-growth obligate species, elk, and exotic plants are high priority forest resources. High priority aquatic/riparian resources included anadromous and native fish, and exotic plants. Exotic plants were identified as high priority in subalpine/upper montane ecosystems.

The reasons given by park staff for monitoring these resources varied tremendously, but were grouped into 13 categories (Appendix A):

1. Resource has cultural/archeological value
2. Resource is subject to commercial/consumptive uses
3. Park policies or visitor affect the resource
4. External forces and policies affect the resource
5. Climate change
6. Resource can help explain ecosystem function
7. Resource is indicator of health or change
8. Need for baseline information
9. Special (endemic, threatened, rare, unique; not including legal mandate)
10. Resource is, or is threatened by exotic/alien species
11. Resource is keystone attribute of the system
12. Resource is politically important (charismatic, legal mandate, public interest)
13. Resource is changing, although the source of stress might not be known

These categories were also grouped according to whether they indicate a resource should be monitored because it is affected by a specific stress, because a resource is special in some way (e.g., threatened, endangered, endemic, enabling legislation), or because the resource has an unique information value. Viewed broadly, those three categories correspond to potential indicators of stressors, focal species, and ecosystem status, the basis of our tactical plan of indicator selection. The breadth of reasons for monitoring indicates there is park-based support for choosing projects to monitor stressors, focal species, and ecosystem status alike.

The specific stress acting on a resource has consequences for the rate and amount it might be expected to change, potential management actions, and the monitoring approach. Six of the 13 categories of reasons for concern about resources indicated that the resource was subject to a specific stress. These stressors are described in Appendix B. Specific stresses for each category and priority of resources are given, grouped by category of reason. The categories of reasons are listed by the frequency they were mentioned for each resource category.

Workshop participants and resource management staff also chose their top 5 resources for monitoring from the list of resources generated at the workshop (Appendix C). Although respondents had a wide range of opinion on which resources should be in the top 5, there was some consensus. The five resources having greatest support were old-growth forest dynamics, anadromous fish, threatened and endangered species, climate data, and elk. These results strengthen and clarify the results given in Appendix A.

Olympic Peninsula Resource Managers Workshop:

The Olympic Field Station of FRESC and the Olympic Natural Resources Center (ONRC) jointly hosted an 'Olympic Peninsula Long-term Ecological Monitoring Workshop' in April 1997. The primary purpose of the workshop was to facilitate the exchange of information on the status of long-term monitoring projects and plans of state, federal, and tribal governments and private land-owners on the Olympic Peninsula. We invited each government agency, tribe, and private timber company on the Peninsula to send a representative to the workshop and provide an overview of their long-term monitoring projects. Our intent was to help participants identify resources of mutual interest and foster collaboration in monitoring that would enhance or expand the value of individual monitoring efforts. The workshop was designed to move us closer to achieving two of our goals for LTEM in Olympic National Park: (1) establish benchmark ecological conditions for comparison to other areas or management mandates, and (2) collaborate with other regional and national monitoring efforts to the extent possible.

Twenty participants from 12 agencies and tribal governments attended the workshop. Each participant was asked to suggest resources or ecological monitoring programs in ONP that they would find useful for comparisons to their lands. We have summarized the diversity of monitoring ideas expressed, categorized by lowland forest ecosystem, aquatic/riparian ecosystem, and coastal systems (Appendix D). Participants expressed considerable interest in monitoring natural ecosystem components and processes (both biotic and abiotic) in ONP to document benchmark ecological conditions of unmanaged landscapes and ecosystems. There was also consistent support for developing comparative monitoring programs using paired plots inside and outside the park. However, only one example of an existing network of sampling appeared suitable to expansion into the park (USFS-PNW vertebrate monitoring in streamsides, Appendix 4).

Objective 4: Inventory Monitoring Projects and Resource Data on the Peninsula

To work toward our goal of integrating monitoring programs on the Olympic Peninsula, staff at the Olympic Field Station conducted an inventory of existing monitoring projects on the Peninsula. We conducted the inventory in concert with organizing the Olympic Peninsula Long-term Ecological Monitoring Workshop, and distributed results of the inventory as a product of the workshop. In advance of the workshop, we sent a questionnaire to all participants requesting the following information: resources monitored, reasons for monitoring, specific variables measured, location(s) of study sites, and key contacts (with phone numbers) associated with each monitoring project. We compiled information on 145 monitoring projects that are underway or proposed on the Peninsula, reported by 4 federal agencies, 4 state agencies, 4 tribal governments, and 2 private timber companies. The compilation has already been put to good use by ONRC in preparing a coordinated proposal for monitoring aquatic/riparian ecosystems on the Peninsula. The compilation of monitoring projects is available from the Olympic Field Station of FRESC upon request.

Objective 5: Ecological Approach to Identify Monitoring Attributes

We have completed the initial screening of indicators for management concerns and ecosystem status for the lowland coniferous forest biotic association. Similar screening of potential monitoring projects still needs to be completed for aquatic/riparian, coastal, and subalpine forest zones.

To identify monitoring attributes that address park management concerns, we began with the list of important management issues identified by park staff. Following guidelines first established by Noss (1990), we used a hierarchical approach to identify effects of each management concern that could be measured at four levels of biological organization: landscape, community-ecosystem, population-species, and organismal. The hierarchical approach helped us to consider the effects of any specific management concern at a variety of spatial, temporal and ecological scales. For example, the landscape view helped us consider how to measure the extent and pattern of management concerns; the community-ecosystem view helped us to consider the effects of management concerns on ecosystem processes and functions, while the population and organismal view helped to focus on effects of management concerns on specific components of communities. In August 1997, we gathered an invited group of forest ecologists to review the list for completeness, and identify potentially fruitful attributes for monitoring. The resulting matrix of monitoring attributes is presented as Appendix F.

We followed a similar process to identify indicators of ecosystem status. Here, we worked independent of the management concerns in an attempt to envision potential indicators that may not arise from considerations of immediate or obvious threats to park resources. First, we identified potential indicators of community/ecosystem status at the landscape, community/ecosystem and species/population levels of hierarchy. We included levels of organization above and below the ecosystem level because ecosystems comprise landscapes, while at the same time they consist of populations and abiotic components that influence ecosystem status. Second, so no attributes of ecosystems were overlooked, we developed conceptual models of biotic components of ecosystems (Figures 2-4), and of ecosystem processes. Following a recommendation stemming from our 'Conceptual Issues' workshop, our intent was to monitor key species distributed representatively across trophic levels and taxonomic groups. The trophic-based conceptual models (Figures 2-3) were developed as a template to ensure broad representation of monitored species, irrespective of immediate management concerns.

Screening for focal species is incomplete. To date, we have identified over 100 vascular plant species or varieties that are listed as rare by the Washington Natural Heritage Program, many more species of exotic plants, and a flora and fauna that is rich in endemic plant and animal species and varieties (Appendix E). Many of those focal species have also been identified as components of monitoring programs that address management concerns and ecosystem status. Focal species not included in those monitoring programs will be selected or prioritized based largely on park support or availability of outside funding.

We have recently completed the first iteration in the process of integrating our lists of potential indicators (Table 1). The integration was a subjective process in which the Olympic Field Station staff independently examined the lists of park resources of concern, monitoring priorities of the neighboring agencies, hierarchical effects of management concerns, and conceptual models of ecosystem components and processes. Each member identified what he or she believed were the important monitoring components needed to meet the overall goals and objectives of the LTEM program in Olympic National Park. While recognizing that the list of potential indicators is preliminary, the integrated list will provide the basis for additional park-management and scientific review (see below).

Plans for Next Year:

Our revised objectives, plans, and timelines for FY98 are:

Objective 1: Review and refine monitoring priorities. Twenty-one high-priority monitoring needs have been identified for lowland coniferous forest ecosystems, reflecting diverse monitoring goals, ecological disciplines, and levels of ecological organization. BRD staff will solicit input from ONP resource management staff to help determine priorities for inititating research and development of selected monitoring protocols (October-December 1997).

Objective 2: Research and development of selected monitoring programs. We will assign principal investigator(s) to identify alternative monitoring approaches and design research programs needed to evaluate statistical and spatial properties of potential indicators and relative efficiency of sampling designs. We will convene groups of subject-matter experts to help in this process (December 1997-March 1998).

Objective 3. Conduct Pilot Studies. We will conduct field studies to evaluate selected monitoring approaches and sampling designs (April-September 1998).

Objective 4. Increase partnerships with federal and state agencies, tribal governments, and private companies. We will hold a second Olympic Peninsula Long-term Ecological Monitoring Workshop to present plans for protocol development in ONP. We will seek opportunities for collaboration with other research scientists (April 1998).

Objective 5. Technology transfer. We will publish papers on the conceptual and tactical planning of park-level LTEM programs. Further, we will assist Olympic National Park in the process of planning LTEM programs for aquatic/riparian, upper montane/subalpine, or coastal biotic zones not covered in this progress report.

Publications and Technology Transfer Activities:

Presentations

Seaman, D.E. 1997. Abundance and population characteristics of northern spotted owls in Olympic National Park. Presented paper at 2nd International Symposium of the Biology and Conservation of owls of the Northern hemisphere, Winnepeg, Manitoba, February 1997.

Woodward, A. Planning long-term ecological monitoring in Olympic National Park. Seminar presented to: U.S.G.S.-B.R.D., Northwest Biological Science Center, Seattle, WA, March 1997.

Schreiner, E. The long-term ecological monitoring program at Olympic Field Station. Presentation part of the Forest and Rangeland Ecosystem Science Center Review, Corvallis, OR, June 1997.

Seaman, D.E. 1997. The effect of sample size on kernel home range estimates. Presented paper at the Telemetry Forum, Annual meeting of the Wildlife Society, Snowmass, CO, Sept. 1997.

Reports

Jenkins, K. J., D. E. Seaman, D. B. Houston, E. G. Schreiner, and A. Woodward. 1997. Planning long-term ecological monitoring for the Pacific Northwest coniferous forest ecosystem: proposed work plan. U.S.G.S.-B.R.D., Forest and Rangelands Ecosystem Science Center.

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Woodward, A., K. J. Jenkins, E. E. Schreiner, D. E. Seaman. 1997. Long-term inventory and monitoring on the Olympic Peninsula: summary of ongoing monitoring activities. Unpublished report on file at Olympic Field Station, U.S.G.S.-B.R.D, Port Angeles, WA.

Woodward, A., K. J. Jenkins, E. E. Schreiner, D. E. Seaman. In Prep. Ecological theory and LTEM: synopsis of a workshop. Olympic Field Station, Forest and Rangelands Ecosystem Science Center.

Publications

Forsman, E.D., S. G. Sovern, D.E. Seaman, K. J. Maurice, M. Taylor, and J. J. Zisa. 1996. Demography of the northern spotted owl on the Olympic Peninsula and east slope of the Cascade Range, Washington. Studies in Avian Biology 17:21-30.

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Woodward, A. Manuscript accepted. Environmental gradients at high elevations: a case study from the northeastern Olympic Mountains, Washington. Northwest Science.

Manuscripts In Preparation or Submitted

Woodward, A., K. J. Jenkins, E. G. Schreiner, D. E. Seaman. In prep. Conceptual issues in designing long-term ecological monitoring for national parks. In prep for submission to Natural Areas Journal.

Seaman, D. E. and D. W. Smith. In Prep. Handbook for monitoring spotted owls in wilderness parks. 110 pp.

Seaman, D. E., D. B. Griffith, and R. A. Powell. Submitted. KERNELHR: a program for estimating animal home ranges. Wildlife Society Bulletin.

Buchanan, J. B., R. J. Fredrickson, and D. E. Seaman. Submitted. Mitigation of habitat 'take': a response to Bingham and Noon. Conservation Biology.

Seaman, D. E. Submitted. The effect of sample size on kernel home range estimates. Journal of Wildlife Management.

Acknowledgments:

The LTEM program at ONP is a partnership between the Olympic Field Station of FRESC and park staff. We are grateful for the considerable contributions already made by the Resource Management Staff in helping to initiate and design this LTEM program. We appreciate the support and inputs of the park's management team and staff, resource managers throughout the Olympic Peninsula, and scientists who have contributed immensely to our discussions and ideas.

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Davis, G. E., K. R. Faulkner, and W. L. Halvorson. 1994. Ecological monitoring in Channel Islands National Park, California. Pages 465-482 in W. L. Halvorson and G. J. Maender (eds.), The Fourth California Islands Symposium: Update on the Status of Resources. Santa Barbara Museum of Natural History. Santa Barbara.

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Schmoldt, D. L., D. L. Peterson, and D. G. Silsbee. 1994. Developing inventory and monitoring programs based on multiple objectives. Environmental Management 18:707-727.

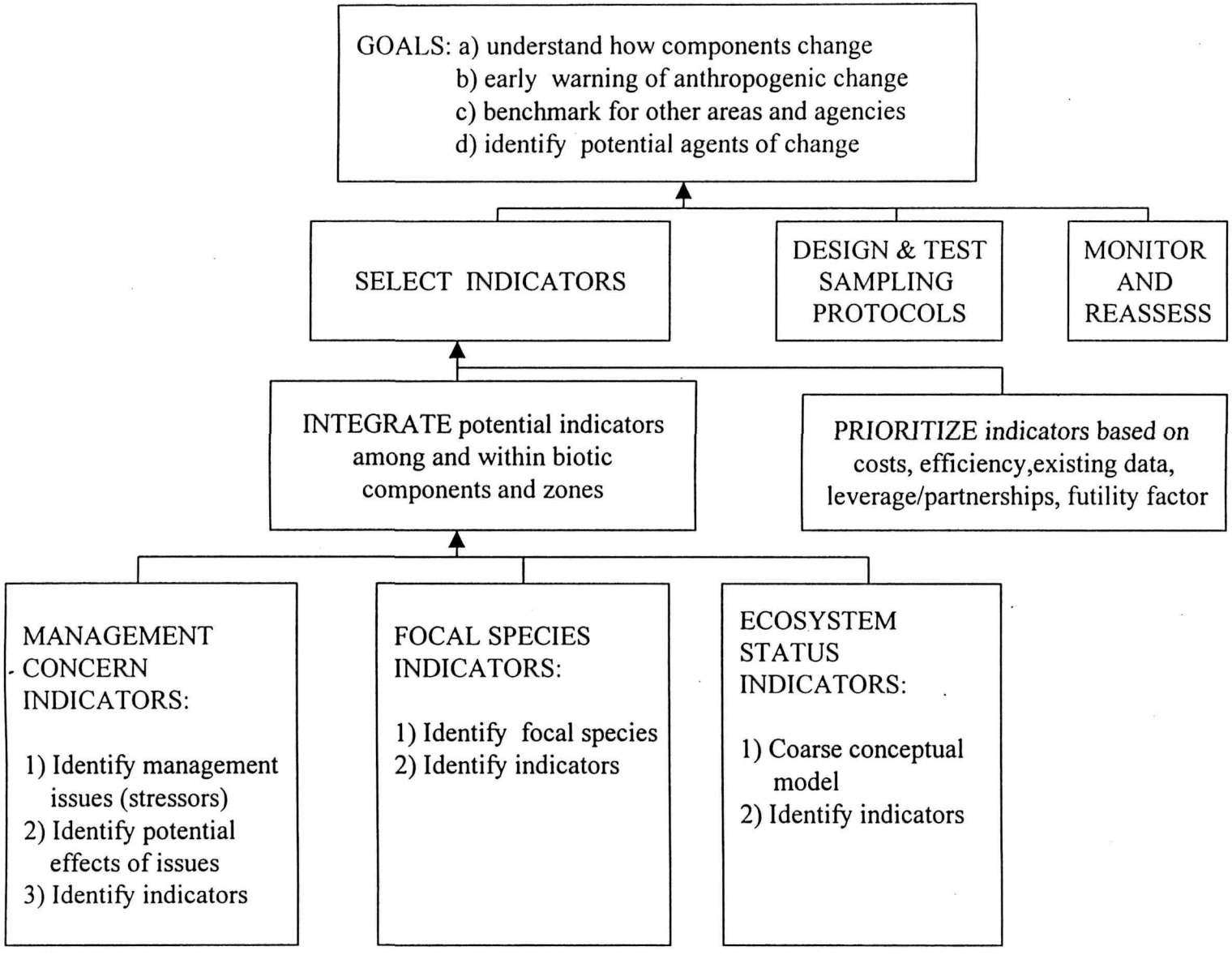

Figure 1. Step-down tactical plan for developing integrated LTEM program in Olympic National Park.

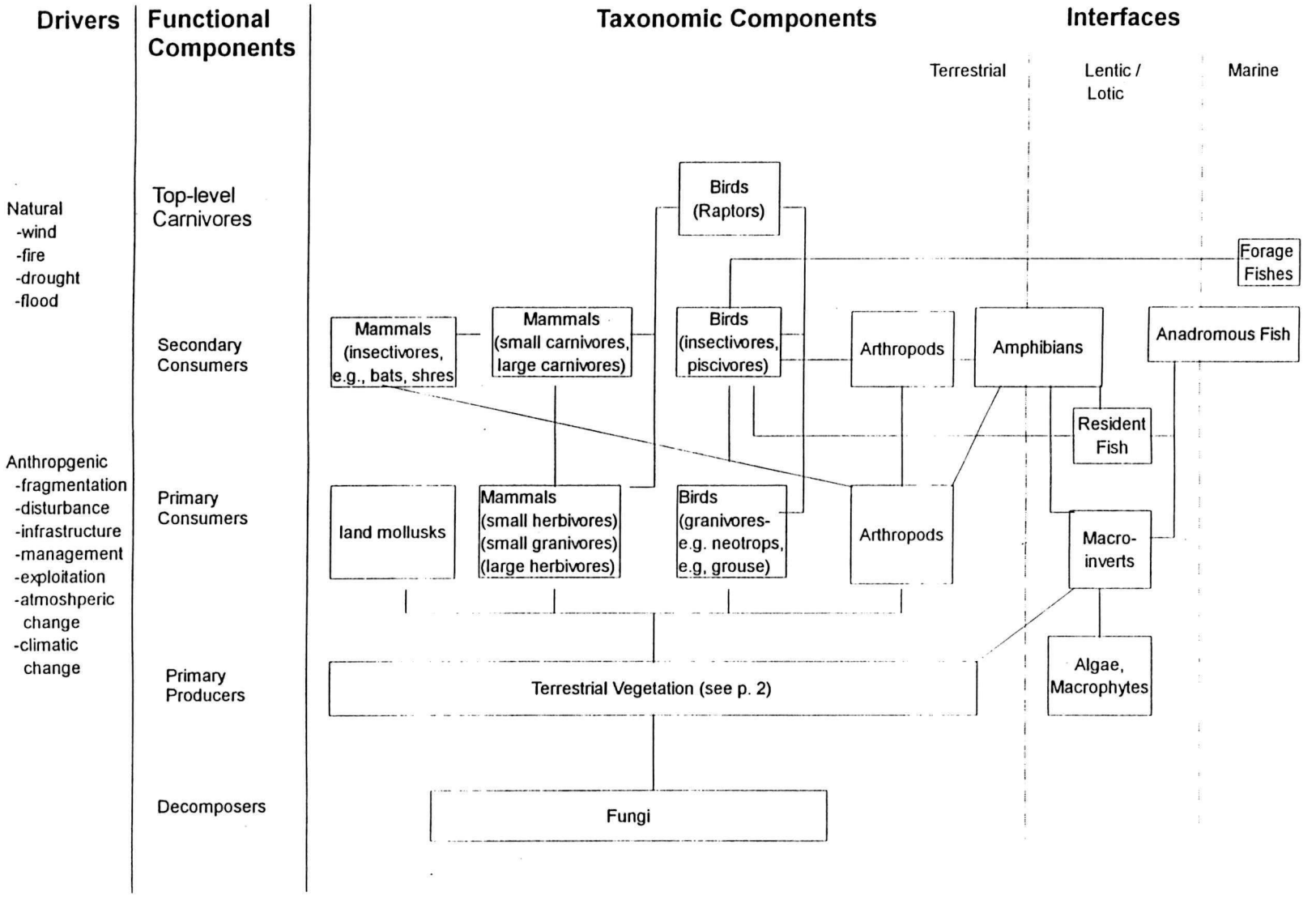

Figure 2. Trophic-based conceptual model of biotic components of lowland coniferous forests in Olympic National Park.

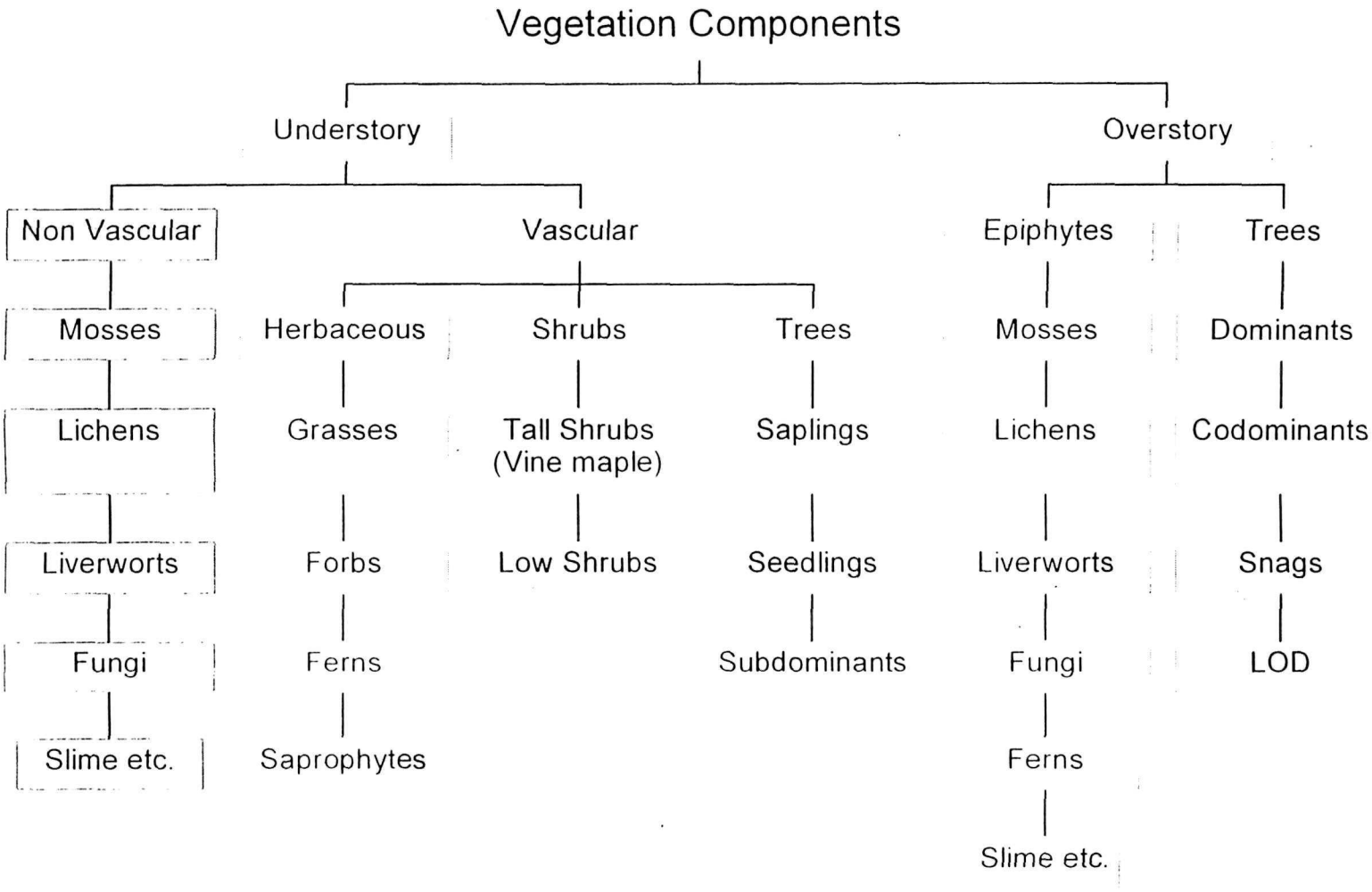

Figure 3. Conceptual model of vegetation components of lowland coniferous forests in Olympic National park.

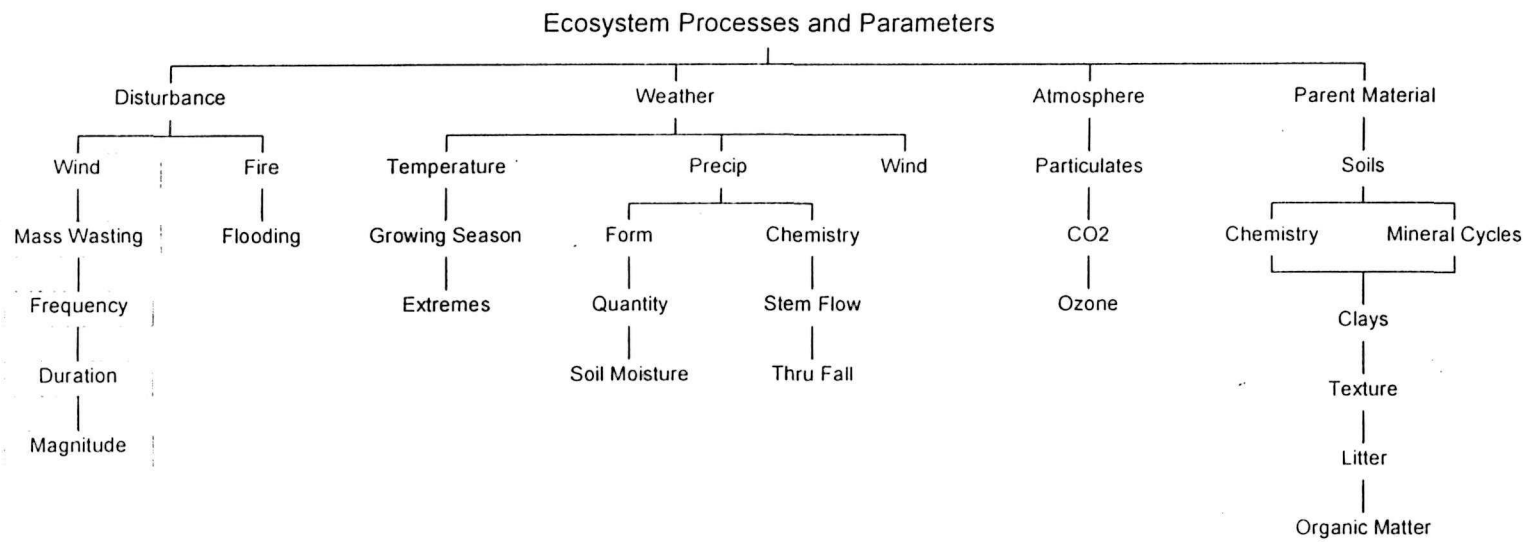

Figure 4. Organizational diagram of ecosystem processes and parameters of lowland coniferous forests in Olympic National Park.

Table 1. List of potential indicators for coniferous forests of Olympic National Park. Additional lists will be developed for riparian/aquatic, subalpine and coastal resources.

Attributes/Measurement	Monitoring Objective	Tools/Strategy
Landscape Scale		
Geographic patterns in weather, atmospheric composition, pollutants	Is climate, pollution changing?	Network of weather, atmospheric sampling stations utilizing predicted precipitation and elevation gradients. SNOTEL sites? Create a database of/gather existing weather data for all OP stations, house in one place Link weather/atmospheric work with permanent plots Establish linkages between weather/atmospheric patterns and potential vegetation (Link with Henderson and Peter maps) Create an updated map of estimated precipitation on the Olympic Peninsula
Composition and structure of landscapes outside the park	How is adjacent landscape composition affecting park resources, such as blowdown at boundary, population status of park wildife?	Landsat imagery every 5-10 years
Age-distribution of stands inside the park	What is large-scale disturbance history? How are fires suppression activities affecting landscape composition? Is landscape composition changing? Are insect outbreaks detectable and have these changed landscape-scale patterns of vegetation?	Landsat imagery every 5-10 years
Fine-grain patch processes in unmanaged landscape	Are comparatively small-scale processes such as landslide, insect damage, flooding, windthrow changing? Relationship to park boundary?	Landsat, SPOT, photographic imagery of landscape-scale plots every 5-10 years (~10-100+ km2 plots, replicated among drainages and forest zones ??)

Park-boundary edge, road density	How is adjacent land-use affecting park resources?	Define edge types in terms of species age and composition along park boundary. Determine road densities within 1 mile of park boundary segments (every 5-10 years).

Community/Ecosystem Scale

Vegetation Characteristics Structure Biomass/abundance/composition Lichens, bryophytes, micorrhizal fungi, epiphytes, vascular plants Species list Herbivory Mortality Seedling Establishment Soil C/N Snags Dead and down logs/fuels Disease&insects Key browse species Water relations	Is climate changing forest processes? Baseline reference for comparison to managed landscapes (NWFP Survey and Manage species). Is pollution, atmosphere changing forest processes? Are changes in herbivore numbers influencing forest processes? Are exotic diseases and insects such as white pine blister rust or wooley adelgid (aphid) affecting/altering species abundance/community composition and or successional pathways.	0.25-ha permanent plots, replicated among key vegetation types and ecotones. Estimate 10 to 15 plots per vegetation type/ecotone - perhaps east and west. Link with USFS, PNW, DNR, private permanent plot network. Permanent photo points for counting mortality. - Remote sensing??
Animal Characteristics Measure abundance/relative abundance of animal populations suited to 0.25 ha plots Land molluscs Arthropods Small mammals Bird detections Pellet groups?	Same as above	Same as above - but some sampling will be kept outside of (adjacent) to permanent plots.
Streamside Wildlife Communities Neotropical Migrant Birds Relative Abundance and nest success Amphibians (Relative abundance) Small Mammals (Relative abundance) Medium Carnivores (Relative Abundance)	Baseline characteristics needed as reference for developing standards and guidelines for buffer strip design outside park.. Are park populations influenced by changes in anadromous/resident fish (carnivores), changing UV radiation (amphibians), nest parasitism or winter range habitat destruction (neotropical migrant birds).	Expand USFS-PNW sampling design into the park replicated among head-water (1st order) and main-stem streams/rivers (2-3 order). Paired plots in uplands?

Park Boundary Wildlife and Plant Communities Indices of relative abundance of small mammals, birds, ratios of exotic/native plants and animals	How are park wildlife populations affected by adjacent land-uses. Are nonnative species introductions occurring/causing community changes (molluscs)	Paired replicated plots <.25, 1, 5 km inside park boundary, stratified by two primary vegetation types (Sitka spruce, Western Hemlock-Douglas Fir). Transects across park boundary.
Old-growth forest wildlife communities Bats, swifts, woodpeckers (other old-growth obligate wildlife species that may not be sampled adequately in .25-km reference plots)	Baseline reference values for comparison to managed landscapes.	Develop sampling protocols
Rare-plant communities Lowland cottonwood communities (cottonwood size, structure, recruitment) Englemann spruce Rocky Mountain juniper Whitebark pine	Baseline reference values How are naturally-regulated elk and deer populations influencing plant community dynamics. Exotic diseases/effects	Permanent plots targeted toward unique plant communities - persistence, controlling factors
Exotic Plant Communities Species composition Rates of spread Ratios native:exotic plants Changes in ratios over time Plant cover Seedling establishment Mortality	How are disturbances associated with park visitation, herbivory influencing relative abundance of exotic plants. Are exotic plants displacing native species/altering community composition over time.	Transects away from trails campsites to document relative abundance of native vs.:exotic plants (also molluscs). Permanent plots measuring change in vegetation structure over time in relation to herbivory. Permanent plots and transects measuring rates of invasion/change Species lists and permanent photo points along trails throughout the park.
Visitor Impacts/Revegetation Similarity indices Species composition Survival of transplants Rate of Change in community structure Plant cover/density Seedling establishment mortality	How and at what rate are vegetation communities changing around backcountry campsites? What revegetation efforts are most successful? Has the hazard tree program altered native plant communities	Permanent reference plots/transects through undisturbed and rehabilitated areas (trails/campsites).

Phenology of Herbaceous Communities	How is climate change, herbivore populations influencing green-up and phenology of low-elevation herbaceous communities	Monitor Normalized Differential Vegetation Index (NDVI) from AVHRR imagery in open-canopy forests.

Population/Species

Abundance, composition, and recruitment of elk and black-tailed deer populations.	Are consumptive uses influencing population characteristics in the park? Evaluate feasibility of wolf restoration activities and monitor effects.	Develop protocols for black-tailed deer. Aerial helicopter surveys for elk abundance and composition ratios. Ground-based composition ratios during rut.
Abundance of Black bears and cougars.	Are changes in consumptive uses outside the park influencing population levels in the park?	Expand WDFW hair/scat sampling in park for DNA analysis and mark/recapture estimation. May be feasible only for bears. Explore feasibility of monitoring bears from helicopter in early summer.
Nesting success of Northern spotted owls.	Baseline reference for comparison to managed landscapes and contribute to regional demographic/habitat modeling under NWFP.	Monitor survival and reproduction rate at 60 known territories..
Marbled Murrellets	Baseline reference for comparison to managed landscapes. Are park management activities/use affecting population trends?	Patti, Shelley, help please.
Demography, cover, spread of selected exotic plants Ecophysiological characteristics Density Seedling establishment Weather patterns Mortality and causes of Age Historical distributions Rate of spread	Are selected plant species increasing in park, threatening native plant communities?	Establish permanent plots targeted toward populations of selected exotic species (e.g., Geranium robertii, what else) Couple work with experiments on methods of control/elimination??

Demography of selected rare plants Genetic composition changes over time Ecophysiological characteristics Density Seedling establishment Weather patterns Mortality and causes of Age Historical distributions	Are selected rare plant species increasing, decreasing?	Establish permanent plots targeted toward populations of selected rare plants. Map individual plants Map populations
Peregrine falcons and eagles	Are park nesting populations of falcons and/or eagles affected by regional/global contamination or local visitor use patterns?	Monitor nest occupancy and nesting success of know nest sites.

Appendix A. Potential resources to monitor in ONP, reasons to monitor, and mean ratings of emphasis given by park staff (Staff) and park resource management staff (RM) at the Olympic Monitoring Workshop for ONP staff, February, 1997. Emphasis ratings were ranked (1) low emphasis, (2) moderate emphasis, and (3) high emphasis, and were averaged among respondents.

				Reason Category												
				Stressor					Information			Special				
Prior.	Resources	Staff	RM	2	3	4	5	10	13	6	7	8	11	1	9	12
	Physical Resources:															
High	Water Quality	2.69	2.27													
	Air quality	2.69	2.64									x	x			
	Climate	2.56	2.72				x					x	x			
Med	Glaciers	1.88	2.30				x									
	Forest Ecosystems:															
High	T & E Species	2.87	2.91									x			x	
	Murrelet Habitat Use	2.56	2.45									x			x	
	Lowland OG Ecosystems	2.78	2.64													x
	Forest Biodiv & Succession	2.72	2.00		x											
	Old-gwth Forest Dynamics	2.57	2.91			x		x		x	x					
	Forest Health	2.56	2.54			x										
	Migratory Fauna	2.69	3.00									x				
	East-side Elk	2.67	2.73			x										
	Elk Populations	2.60	2.91	x								x	x			x
	Ungulate Populations	2.36	1.91		x	x										
	Trampling Sensitive Plants	2.63	1.82		x											
	Exotic Fauna	2.57	2.36					x							x	
	Endemic Animals & Plants	2.57	2.27			x									x	
	Old-gwth Obligate Species	2.56	3.00			x										
	Exotic Plants	2.56	2.55					x				x			x	
	Natural Disturbance	2.53	1.73							x			x		x	
Med	Wolves & Fisher	2.43	2.00		x											
	Fisher	2.06	2.18									x				
	Mustelids	1.93	1.64								x	x	x		x	
	Developed Area Old-Gwth	2.31	1.64		x											
	For. Health-Frt-Cntry Cmpgd	2.06	1.64		x											
	Forest Floor Fungi	2.25	2.30	x						x			x			
	Forest Fungi & Decay Proc.	2.07	1.82	x		x										
	Large Mammals	2.23	2.09	x							x					
	Cougar	2.19	1.82	x	x	x						x				

	Black Bear	2.13	2.00	x					x							
	Forest Canopy-Lichens,Fauna	2.19	1.91	x							x					
	Epiphytes	2.00	1.91	x	x										x	
	Lichens	1.93	1.73								x		x			
	Predator Diversity & Range	2.06	1.36									x				
	Neo-tropical Birds	2.06	2.18			x						x				
	Migratory Birds	2.00	1.73			x			x							
	Bats	2.06	1.82						x							
	Wilderness Campgrounds	2.06	1.91		x											
	Wilderness	2.00	2.27		x											
	Salal, Fungi, Moss	1.93	1.73	x												
	Downed Wood in Forest	1.77	1.09	x												
	Meadow Survey	1.56	1.09											x		
Low	Small Mammals	1.50	1.73										x			
	Olympic Jumping Slug	1.33	1.30								x				x	
	Cedar	1.27	1.18	x										x		
	Rubber Boa	1.27	1.10								x					
	Pacific Yew	1.25	1.10	x					x							
	Beargrass	1.25	1.10	x										x		
	Porcupines	1.25	1.27						x	x						
	Band-winged Grasshoppers	1.13	1.10								x		x			
	Aquatic/Riparian Ecosystems															
High	Anadromous Fish	2.88	3.00								x		x			
	Native Fish	2.81	3.00			x										
	Elwha Native Fish	2.38	2.45			x										
	Resident Native Fish	2.31	2.09	x												
	Exotic Fauna	2.57	2.36					x							x	
	Fresh-water Mussels	1.63	2.09								x	x				
	Endemic Animals & Plants	2.57	2.27			x									x	
	Lk. Crescent Endemic fish	1.93	2.36	x	x	x										
	Olympic Mud-minnow	1.63	2.09									x				
	Exotic Plants	2.56	2.54					x				x			x	
	Riparian For. Dyn./Fluvial Proc.	2.50	2.27				x						x			
	Lk. Cres. Shoreline, Ripar.	1.60	1.64		x	x							x			
Med	Amphibians	2.44	2.82						x			x			x	
	River Ecosyst.-Habitat, LWD	2.44	2.45						x				x			
	Downed Trees(Rivers, Coast)	1.80	1.82										x			

	Small Watershed Processes	2.33	1.91								x	x				
	Wetland Obligate Plants	2.25	1.82									x				
	Wetland Grasses	1.57	1.36	x								x				
	Wetlands	2.20	2.00					x				x	x			
	Bald Eagles	2.19	2.36	x									x			x
	Lk. Crescent Trophic Status	1.93	2.00		x										x	
	Rare Plants at Lk. Ozette	1.88	2.30		x				x							
	Aquatic Invertebrates - FW	1.88	2.36								x					
	Harlequin Ducks	1.78	2.00								x					
	Subalpine/ Upper Montane															
High	Exotic Plants	2.56	2.55					x				x			x	
Med	Endemic Alpine Plants	2.47	2.36					x								
	Alpine Lakes	2.43	2.27		x	x		x								
	Mountain Goats	2.25	2.54												x	
	Subalpine Forests/Ecosystms	2.20	2.18		x				x							
	High Elev. Plant Communities	2.13	1.91		x											
	Hurricane Ridge Deer	1.94	1.09		x				x							
	Olympic Marmot	1.88	1.73				x		x			x			x	
	Meadow Survey	1.56	1.09											x		
	Miscellaneous															
High	Inventory Species Composit.	2.69	1.73									x				
	Activity on Outside Lands	2.50	2.36			x										
Med	Wildlife Habitat Use Pattern	2.06	1.72		x											
	Impact of Monitoring on Monitored Resources	2.00	1.36		x											

Appendix B. Environmental and man-caused stressors potentially affecting park resources, as identified by park staff at Olympic National Park Monitoring Workshop, February, 1997.

Priority	Category of Reason	Specific Concern
Physical Resources		
High:	Climate Change	
Med:	Climate Change	
Forest Ecosystems		
High:	External Forces & Policies -	Development outside ONP Exposed boundary Forest fragmentation outside ONP
	Exotic/Alien Species -	Habitat change caused by non-native species Exotic plants and animals
	Park Policies/Visitors -	Fire suppression Human trampling of vegetation
	Commercial & Consumptive Use -	Hunting
Med:	Commercial & Consumptive Use -	Illegal harvest of animals & plants Legal consumptive uses Firewood collection
	Park Policies/Visitors -	Potential reintroduction of wolves & fishers Habituation of animals to people Hazard tree program Park management effects on wilderness
	External Forces & Policies -	Logging Habitat loss in winter range of migratory birds Encroachment of ungulate habitat Effect of hunting ban on cougars
	Known to be Changing -	Less anadromous fish for bears Population decline of bats & migratory birds
Low:	Commercial & Consumptive Use -	Commercial use of cedar, beargrass, pacific yew (potential)
	Known to be Changing -	Immigration of porcupines
Riparian/Aquatic Ecosystems		
High:	Exotic/Alien Species -	Exotic mussel species Displacement of native flora
	External Forces & Policies -	Hatchery impacts

Med:	Commercial & Consumptive Use -	Consumptive use of fish & wetland grasses Poaching
	Park Policies/Visitors -	Human use/recreation at Lake Crescent Effect of visitors on rare plants at Lake Ozette
	External Forces & Policies -	Hatcheries Hybridization of Lake Crescent endemic fish Lake Crescent human residents
	Known to be Changing -	Global decline of amphibians Declining fish runs Siltation at Lake Ozette

Subalpine/Upper Montane

Med:	Park Policies/Visitors -	Fire suppression Human impacts & interactions for plants & animals Habitat modification for Hurricane Ridge deer
	Exotic/Alien Species -	Mountain goats Introduced fish
	Known to be Changing -	Regional declines in marmot populations Forest succession
	External Forces & Policies -	Air pollution

Miscellaneous

High:	External Forces & Policies -	Land-use practices outside park
Med:	Park Policies/Visitors -	Human impacts Impacts of research activity

Appendix C. Resources of concern to ONP staff as indicated by votes for top-five topics.

Resource	ONP Staff	RM Staff	Item Total	Ctgry Tot
Old-Growth Forest Dynamics	7	4	11	29
Lowland Old-Growth Ecosystems	4	3	7	
Old-Growth Obligate Species	0	5	5	
Forest Biodiversity & Succession	4	0	4	
Forest Health	1	1	2	
Anadromous Fish	4	9	13	13
T & E Species	6	7	13	13
Climate Data	6	5	11	11
Ungulate Populations	0	1	1	10
Elk Populations	4	4	8	
East-side Elk	1	0	1	
Migratory Fauna (Elk & Salmon)	5	2	7	7
Riparian Forest Dyn./Fluvial Process	3	4	7	7
Exotic Plants	4	2	6	6
Subalpine Forests/Ecosystems	2	0	2	5
High-Elevation Plant Communities	2	0	2	
Endemic Alpine Plants	1	0	1	
Amphibians	2	2	4	4
Exotic Fauna	2	2	4	4
Water Quality (lakes, rivers, precip.)	4	0	4	4
Air Quality	2	1	3	3
Inventory of Species	3	0	3	3
Land Use & Activity Outside Park	3	0	3	3
Mountain Goats	1	2	3	3
Native Fish	3	0	3	3
Forest Fungi & Decay Processes	2	0	2	3
Forest Floor Fungi & Mycorrhizae	1	0	1	
Neotropical Birds	2	0	2	3
Migratory Birds	0	1	1	
Alpine Lakes	1	1	2	2
Black Bear	2	0	2	2
Endemic Animals & Plants	1	1	2	2
Inventory of Meadows	2	0	2	2
Natural Disturbance	2	0	2	2
Predator Diversity & Range	2	0	2	2
Wilderness	1	0	1	2
Wilderness Campgrounds	1	0	1	

Beargrass	1	0	1	1
Cedar	1	0	1	1
Developed-Area Old-Growth	1	0	1	1
Downed Trees in Rivers & Coast	1	0	1	1
Forest Canopy: lichens, moss, etc.	1	0	1	1
Glaciers	1	0	1	1
Hurricane Ridge Deer	1	0	1	1
Murrelet Habitat Use	1	0	1	1
Rare Plants at Lake Ozette	1	0	1	1
River Ecosystems	1	0	1	1
Small Watershed Processes	1	0	1	1
Wetlands	1	0	1	1
Wolves & Fishers	1	0	1	1

Appendix D. Potential resource monitoring projects in Olympic National Park recommended by state, federal, tribal, and private resource managers on the Olympic Peninsula.

Lowland Forest Ecosystems

1. Baseline studies of forest processes, composition, and function in unmanaged lowland old-growth forests for comparison to a wide range of forest management intensities and prescriptions.

2. Trends in 'species of concern' and late-successional old-growth wildlife species in unmanaged forest landscapes

3. Describe habitat use and colonization patterns of old-growth dependent wildlife species to help define the range of stand ages and structural characteristics that meet their requirements,

4. Conduct retrospective studies of forest development following natural disturbances to identify objectives for managing secondary forest succession following logging,

5. Monitor trends in special forest products (e.g., mosses, epiphytes, fungi)

6. Monitor wildlife species distributions to refine understanding of species habitat requirements

7. Monitor northern spotted owl nest sites for fecundity as baseline for comparison to managed forests,

8. Monitor neo-tropical migrant birds as baseline for comparison to managed forests.

9. Create a common data base for northern spotted owl and marbled murrellet monitoring.

10. Establish permanent reference plots to monitor changes in forest structure and biodiversity.

Aquatic/Riparian Ecosystems

1. Monitor abundance of streamside vertebrates (mammals, birds, amphibians) in perrenial and intermettent streams for comparison to managed forests. Opportunity exists to expand existing monitoring program (USFS-PNW) to include unmanaged reference sites in Olympic National Park.

2. Monitor physical properties (e.g., water quality, channel morphology, large woody debris, mass-wasting frequency) of permanent reference watershed(s).

3. Monitor recovery of a watershed after natural disturbance (e.g., burn)

4. Monitor permanent reference plots established at headwaters of streams and seeps.

5. Monitor amphibians as bioindicators.

6. Pair watersheds inside and outside park and monitor watershed characteristics in managed and unmanaged settings.

7. Monitor effects of non-fish-bearing streams on fish downstream.

8. Describe riparian communities as function of riparian vegetation width, including strips wider than is available on managed lands.

9. Monitor riparian processes and functions in unmanaged watersheds.

Coastal Ecosystems

1. Expand concept of a watershed to include the nearshore environment. Specifically, compare sedimentation from natural and managed watersheds on nearshore organisms, e.g., kelp.
2. Monitor intertidal communities.

Miscellaneous

1. Describe social values of pristine systems in a way that can be compared to managed systems of varying intensity.

2. Research is needed on most effective measurements of system health.

3. Describe natural variation in salmonid and forest resources so that management effects can be distinguished from natural variation.

4. Prepare a list of research sites within the park that have long-term data sets (including UW research sites).

Appendix E. Endemic fauna and flora of the Olympic Peninsula.

Taxa		Source
Vertebrates		
Mammals		
Olympic marmot	*Marmota olympus*	Hall 1981
Olympic yellow-pine chipmunk	*Tamias amoenus caurinus*[a]	Hall 1981
Olympic snow mole	*Scapanus townsendii olympicus*	Johnson & Yates 1980
Olympic Mazama pocket gopher	*Thomomys mazama melanops*	Hall 1981
Olympic ermine	*Mustela erminea olympica*	Hall 1981
Amphibians		
Olympic torrent salamander	*Rhyacotriton olympicus*	Good & Wake 1992
Fish		
Olympic mud minnow	*Novumbra hubbsi*[b]	Wydoski and Whitney 1979
"Beardslee" rainbow trout	*Oncorhynchus mykiss irideus*[c] (lacustrine form)	R. Behnke 1992 pers. comm.
"Crescenti" cutthroat trout	*Oncorhynchus clarki clarki*[c] (lacustrine form)	R. Behnke 1992 pers. comm.
Invertebrates		
Insects		
(Lepidoptera - butterflies and moths)		
Olympic arctic[d]	*Oeneis chryxus valerata*	Burdick 1957
Hulbirt's skipper	*Hesperia comma hulbirti*	Lindsey 1939
(Orthoptera - grasshoppers)		
Olympic grasshopper	*Nisquallia olympica*	Rehn 1952
(Coleoptera - beetles)		
Mann's gazelle beetle	*Nebria danmanni*	Kavanaugh 1981
Quileute gazelle beetle	*Nebria acuta quileute*	Kavanaugh 1979
Sylvan gazelle beetle[d]	*Nebria meanyi sylvatica*	Kavanaugh 1979
Johnson's snail eater[d]	*Scaphinotus johnsoni*	Van Dyke 1924
Tiger beetle	*Cicindela bellissima frechini*	Leffler 1979a
Millipedes		
Millipede[d]	*Tubaphe levii*	Causey 1954
Molluscs		
Arionid slug	*Hemphillia dromedarius*	Branson 1972
Arionid jumping slug	*Hemphillia burringtoni*	Pilsbry and Vanatta 1948
Vascular Plants		
Pink sandverbena[d]	*Abronia umbellata acutulata*	Kartesz & Kartesz 1980
Olympic Mt. milkvetch	*Astragalus australis var. olympicus*	Isely 1983
Piper's bellflower	*Campanula piperi*	Kartesz & Kartesz 1980
Flett's fleabane	*Erigeron flettii*	Kartesz & Kartesz 1980

Table 1. (continued)

Vascular plants (continued)		
Thompson's wandering fleabane	*Erigeron peregrinus peregrinus var. thompsonii*[e]	Kartesz & Kartesz 1980
Henderson's rock spirea	*Petrophytum hendersonii*	Kartesz & Kartesz 1980
Webster's senecio	*Senecio neowebsteri*	Kartesz & Kartesz 1980
Olympic Mt. synthyris	*Synthyris pinnatifida var. lanuginosa*	Kartesz & Kartesz 1980
Flett's violet	*Viola flettii*	Kartesz & Kartesz 1980
Olympic aster[d]	*Aster paucicapitatus*	Kartesz & Kartesz 1980
Magenta paintbrush[d]	*Castilleja parviflora var. olympica*	Kartesz & Kartesz 1980
Lance-leaf springbeauty[d]	*Claytonia lanceolata var. pacifica*	McNeill 1972
Blood-red pedicularis[d]	*Pedicularis bracteosa var. atrosanguinea*	Kartesz & Kartesz 1980
Tisch's saxifrage[d]	*Saxifraga tischii*	Skelly 1988
Cryptogams		
Liverwort[d]	*Porella roellii forma crispata*	Hong 1987

[a] Trinomials indicate subspecies.
[b] Occurs south to Chehalis River.
[c] Formerly considered a distinct species; currently considered a lake-adapted form of the subspecies.
[d] Also occurs on Vancouver Island.
[e] Not found in Olympic National Park.

Appendix F. Potential effects of stressors to park resources of management concern at 4 levels of biological organization: landscape, community/ecosystem, population/species, and organismal.

Concern/Question	Landscape Scale	Comm./Ecosyst.	Popn./Species	Organismal
Atmospheric Changes: Is atmospheric composition changing and if so, is it affecting plants & animals?	Shifts in geographic variability of atmospheric composition Spatial distn. & intensity of pollution related plant lesions Changes in composition of ppt.	Changes in nutrient cycling, esp. soil processes (including CO_2 and N) Changes in community composition as growth rates/competitive intereactions change	Changes in abundance & demographics of air pollution sensitive species (e.g., lichens, amphibians) Changes in competitive interactions due to changes in growth	Changes in growth & viability of air pollution-sensitive species Changes in tree physiology (annual growth, phenology, etc.) Growth rates vs. CO_2
Fire Suppression: Does fire suppression alter the structure, composition and habitat quality of forests and wildlife populations?	Changes in forest structure (e.g., age distn., species distn. & dominance, patch freq., structure and turnover) Shifts in seasonal distn. of water yield	Changes in canopy structure including woody debris Changes in plant community structure	Changes in relative abundance of guilds of organisms defined by canopy layer occupancy (e.g., canopy dwelling birds, epiphytes)	
Insularization: Are park wildlife and plant populations or communities affected by forest fragmentation beyond park boundaries?	Changes in: Composition & structure of landscapes adjacent of park (i.e., proportions of patch types, patch size, indices of fragmentation, configuration, juxtaposition) Patterns of species distn. relative to park boundary Scale, frequency & intensity of natural disturbances along gradients away from park boundary	Diversity of species & guilds on park boundary vs. interior Forest community structure on park boundary vs. interior Proportions of native/non-native species on park boundary vs. interior	Abundance of focal species relative to park boundary (eg., NSO, MaMu, corvids, exotics) Demographic rates of focal species relative to park boundary (NSO dispersal, neotropical bird productivity and nesting success)	Allelic diversity of rare or focal species (is population fitness stable?) (E.g., NSO, rare plants and animals) Increased abundance of exotic herbivores e.g., slugs

Climate Change: Is climate changing in amount and seasonal pattern of climate variables and is this affecting habitat distribution?	Shifts in elevational gradients of climate variables (e.g., temp., snow course) Temporal shifts in climate variables (e.g., first & last frost, fuel moisture course, ppt.) Changes in freq. & size of disturbances Changes in stream flow amt., timing, glacial flour, temp.	Shifts in composition and structure of under- and overstory vegetation Changes in substrate temperature, esp. water and unshaded surfaces Changes in availability of soil moisture and nutrients	Changes in comparative physiological response of tree species Changes in duration of resource availability (quality and amount) for wildlife, esp. herbivores Increased incidence of insect/disease attacks	Changes in plant physiology (e.g., annual growth, phenology of growth, length of growth period) Changes in sporocarp production, quantity and timing
Consumptive Use: Are park wildlife and plant populations or communities affected by consumptive uses inside or outside the park?	Effects of legal harvests of elk outside park on sex-age structure inside the park	Lasting shifts in community composition Domino effects of sporocarp harvest on tree growth, fungal mycelia, mineral cycling, rare taxa, favored taxa for harvest (e.g., matsutake)	Shifts in patterns of abundance and distribution of harvested plant species (salal, moss) in relation to access (distance from trail) Effect of number, sex and age of illegal harvest of large mammals (bear, elk) on remaining populations Potential extinctions Long-term effects on sporocarp production (shitake, chantrelle, etc.) of harvest and associated trampling	Physiological effects from reduced sporocarp abundance Genetic alterations resulting from fruiting body removal and illegal harvest of large ungulates (e.g., trophy elk)

Disease: Are park wildlife and plant populations or communities affected by disease?	Loss of major patch types, e.g. 5-needle pines	Shifts in forest community structure due to white pine blister rust Secondary effects of blister rust on nutcrackers Changes in communitiy composition and species abundance	Extinction of 5-needle pines Decline of deer populations with new unidentified exotic disease Effect on fisher recovery of mustelid diseases Effects of balsam woolley aphids on true firs	Loss of fungi associated with pine taxa
Visitors/Facilities & Roads: Are visitors and campground facilities affecting vegetation, soils, and wildlife of ONP?	Occupation and disruption of 'critical habitats' - i.e., what proportions of particular habitat types or vegetation communites are affected by visitors and campgrounds? Transport of exotic organisms - i.e., vectors	Disruption of animal populations - high or low abundances (i.e., lots more mice out there, or loss of communities) Human disturbance providing sites for exotic organisms Physical site changes - erosion, vegetation loss, etc. Corridors/avenues of travel by exotics	Adverse effects on rare/special taxa - direct/indirect Facilitation effects from extra food sources	