# Review of Scientific Material Relevant to the Occurrence, Ecosystem Role, and Tested Management Options for Mountain Goats in Olympic National Park

**Fulfillment of Contract #14-01-0001-99-C-05, U.S. Department of Interior**

Reed F. Noss, Russell Graham, Dale R. McCullough, Fred L. Ramsey,
Jennifer Seavey, Cathy Whitlock, and Michael P. Williams

May 30, 2000

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## TECHNICAL ABSTRACT

Current National Park Service policy states that "exotic species are those that occur in a given place as a result of direct or indirect, deliberate or accidental action by humans." In order to justify control or eradication, however, three conditions must be fulfilled: 1) the species must be demonstrated to be an exotic; 2) it must be documented to threaten park resources or public health; and 3) control must be prudent and feasible. We reviewed the scientific material relating to these three conditions with respect to the mountain goat (*Oreamnos americanus*) in Olympic National Park. Our search included primary literature, technical reports, agency documents, unpublished academic works, conference proceedings, commentaries and letters from interested individuals and organizations, and primary field data. We reviewed park documents (including photographs) and toured goat-inhabited portions of the park. Available evidence suggests the mountain goat has never been native to the Olympic Peninsula. Although negative evidence is not proof of absence, there is no evidence to refute the hypothesis that mountain goats never occurred in the Olympic Peninsula prior to their introduction in the 1920s. The paleoecologic and environmental history of the Peninsula make the probability low that mountain goats could have colonized the Peninsula naturally. On the other hand, available data are insufficient to establish that mountain goats are causing significant damage to vegetation, harming rare plant populations, or are otherwise having deleterious impacts on the natural ecosystem. This does not mean that significant impacts have not occurred, only that previous studies were incapable, by design, of separating the effects of goats from other variables. Finally, we find that control of mountain goats is prudent and feasible. Our study does not provide unambiguous support for implementing the National Park Service's exotics policy. The relative importance of the three criteria--non-native status, threat to park resources, and feasible and prudent control--must be determined at a policy level.

## NON-TECHNICAL SUMMARY

Exotic species, also known as non-native or introduced species, are a legitimate concern to managers of national parks and to conservationists generally. Conservation biologists consider exotic species second only to direct habitat destruction in magnitude of threat to rare species and biodiversity. In many cases these species out-compete native species or threaten them by such activities as grazing or trampling. Examples of this kind of damage can be found in many national parks. The current policy of the National Park Service states, "exotic species are those that occur in a given place as a result of direct or indirect, deliberate or accidental action by humans." The policy further states that "management of populations of exotic plant and animal species, up to and including eradication, will be undertaken wherever such species threaten park resources or public health and when control is prudent and feasible." Thus, in order to justify control or eradication, three conditions must be fulfilled: 1) the species must be demonstrated to be an exotic; 2) it must be documented to threaten park resources or public health; and 3) control of the species must be prudent and feasible.

The mountain goat (*Oreamnos americanus*) was introduced to Olympic National Park, Washington, in the 1920s. Scientists with the National Park Service, as well as many others, are concerned that the goats are causing damage to the vegetation of the alpine and subalpine landscape, and may threaten the existence of rare plants, some of which are found nowhere else but in the Olympic Mountains. The National Park Service has determined that all three conditions--non-native status, threat to park resources, and feasible and prudent control--are met in this case, and is considering what control measures to implement for the goat. Some outside critics, however, have cast doubt on all three conditions and argued that more research is needed before decisions are made regarding management of the mountain goats. Our team of scientists was called in to review the scientific evidence that bears on these questions.

We reviewed the scientific material, including published and unpublished literature that relates to the three conditions of the National Park Service's exotic species policy, with respect to the mountain goat in Olympic National Park. Our search was comprehensive, including articles published in refereed scientific journals, agency technical reports, agency internal documents, unpublished academic works (e.g., theses), conference proceedings, industry-sponsored research reports, commentaries and letters from interested individuals and organizations, and, where possible, the primary field data from which the literature was derived. We reviewed national park documents (including photographs) and took a helicopter tour of goat-inhabited portions of the park.

With respect to the first condition, we find that the preponderance of evidence supports the view that the mountain goat has never been native to the Olympic Peninsula. Although negative evidence is not proof of absence, there is no evidence to refute the hypothesis that mountain goats never occurred in the Olympic Peninsula prior to their introduction in the 1920s. The environmental history of the Peninsula over the last tens of thousands of years makes the probability relatively low that mountain goats could have colonized the Peninsula naturally. With respect to the second condition, we find that scientific evidence available at

this time is insufficient to establish that the activities of mountain goats are causing significant damage to vegetation, leading to declines in populations of rare plants, or are otherwise having negative impacts on the natural ecosystem. This does not mean that significant impacts have not occurred, only that previous studies were incapable by their design of separating the effects of goats from other variables, such as the effects of weather. Finally, with respect to the third condition, our team finds that control of mountain goats in Olympic National Park would be prudent and feasible.

In conclusion, our study does not provide unambiguous support for implementing the National Park Service's exotics policy in this instance. The relative importance of the three criteria--non-native status, threat to park resources, and feasible and prudent control--must be determined at a policy level. This is a decision that goes beyond science.

# INTRODUCTION

In 1916 the National Park Service (NPS) was created and given authority to manage the national parks and monuments of the United States. The agency's mission was stated clearly, if somewhat contradictorily: "to conserve the scenery and the natural and historic objects and wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (quoted in Wright and Mattson 1996). To achieve this mission, the NPS must be able to recognize and mitigate threats to the natural ecosystems and native species of the parks. These threats are numerous and vary in kind and intensity among the parks. The most pervasive threats in national parks, and wilderness areas generally, are recreation, livestock, mining (including abandoned mines), fire (including fire suppression), exotic species, water projects, atmospheric pollution, and activities on adjacent lands (Cole 1994).

Exotic (alien, introduced) species are a major threat, not only to parks, but to virtually all kinds of natural ecosystems. Although natural communities are dynamic, with species changing their distributions over time in response to climate change, plate tectonics, and other factors, the pace of change imposed by human-assisted introductions of species is much faster than natural rates. Conservation biologists today overwhelmingly recognize exotic species as second only to direct habitat destruction in magnitude of impacts to native biodiversity. For example, alien species threaten some 49% of all imperiled species in the United States, including 47% of imperiled vertebrates, 27% of imperiled invertebrates, and 57% of imperiled plants (Wilcove et al. 1998). Nevertheless, only recently have scientists and conservationists acknowledged exotic species as a major threat to biodiversity. Heretofore, biologists assumed that the effects of exotics were mostly limited to disturbed habitats. Charles Elton, in an influential early book on biological invasions, proposed that disturbed habitats, because they have fewer or less vigorous native species, possess less "biotic resistance" to invaders (Elton 1958). This view has since been largely discredited, in favor of the idea that the specific characteristics and interactions of invading and indigenous species determine the outcome of invasions (Simberloff 1997). Globally, and in contrast to Elton's prediction, the relationship between degree of invasion and native species richness is positive (Lonsdale 1999). Nature reserves are less invaded by exotics than nonreserves, but the degree of invasion in reserves increases with the number of human visitors (Lonsdale 1999).

Most studies of biotic invasions have focused on exotic plants because the number of exotic plant species in most regions far surpasses the number of exotic animals. Nevertheless, introduced animals sometimes have enormous impacts on native ecosystems. Exotic mammalian herbivores are considered some of the most destructive of all introduced species, especially when they are introduced to islands with no history of herbivory by large animals. Among the characteristics of communities altered by exotic mammalian herbivores are lowered plant biomass, reduced primary production, lowered species diversity, potential extinctions, and decreased stability (Coblentz 1978, 1990). Again, such impacts are best documented for true islands, although it is plausible that island-like habitats (e.g., alpine ecosystems) could show similar effects from introduced herbivores.

A 1980 report to Congress from the NPS identified 602 perceived threats from alien species to natural resources in the parks (National Park Service 1980). Among these threats are the apparent impacts of mountain goats (*Oreamnos americanus*) in Olympic National Park. The NPS has followed the general principle espoused in the Leopold Report (Leopold et al. 1963) that the biota of the parks should "...be limited to native plants and animals." Because the present population of mountain goats in the Olympic National Park is known to have descended from individuals captured in Canada and Alaska and released into the park in the 1920s, the goat is considered by the NPS an exotic species (Houston et al. 1994b). Current NPS policy states that "exotic species are those that occur in a given place as a result of direct or indirect, deliberate or accidental action by humans," and does not include intentional restorations of native species (National Park Service 1988).

Current NPS policy (National Park Service 1988) further states that "management of populations of exotic plant and animal species, up to and including eradication, will be undertaken wherever such species threaten park resources or public health and when control is prudent and feasible." Draft (summer 1999) new policy language is essentially identical on this issue. This policy might appear to conflict with the 1938 Olympic National Park Act, wherein (Sec. 3) it is stated that "all hunting or the killing, wounding, or capturing at any time of any wild bird or animal, except dangerous animals when it is necessary to prevent them from destroying human lives or inflicting personal injury, is prohibited within the limits of the park..." This section of the legislation also states that "the Secretary of the Interior shall make and publish such general rules and regulations as he may deem necessary and proper for the management and care of the park and for the protection of the property therein, especially for the preservation from injury or spoliation of all timber, mineral deposits, natural curiosities, or wonderful objects within the park, and for the protection of the animals and birds in the park from capture or destruction..." Hence, the legislation establishing Olympic National Park is ambiguous on the mountain goat issue and the exotics issue generally. Whereas it prohibits killing and protects animals from capture, it also authorizes the Secretary of Interior to make and publish general rules and regulations, which presumably could include rules authorizing the control of exotics. Furthermore, protection of "natural curiosities, or wonderful objects" certainly could include protection of native plants from damage by exotic animals.

Given the documented and potential impacts from exotic organisms, in parks and elsewhere, eradication or control of these species in the parks would seem non-controversial. A number of factors come into play, however, when decisions are made about management of exotics. Most importantly, under a literal interpretation of current NPS policy, three conditions must be met to justify control or eradication of a species:

1) The species must occur there, directly or indirectly, as a result of human actions, either deliberate or accidental. That is, its status as an exotic species must be beyond reasonable doubt.

2) The species must be documented to threaten park resources or public health.

3) Control of the species must be prudent and feasible.

In the case of the mountain goat in Olympic National Park, the NPS has determined that all three of these conditions are met (e.g., Scheffer 1993, Houston et al. 1994b). Hence, by these criteria, control and possibly complete eradication of the goats are warranted. Some outside critics, however, have cast doubt on all three conditions and argued that more research is needed before decisions are made regarding management of the park's mountain goats (e.g., Anunsen and Anunsen 1993, Lyman 1988, 1998). Moreover, the goat is charismatic and popular with many park visitors and other members of the public. Some of these people have expressed outrage over any killing or even harassment of goats in the park. Hence, the topic of goat control has become enormously controversial. Although previous NPS scientists and independent reviewers have considered these issues, this report constitutes the most exhaustive independent review, to date, of the evidence relating to the native versus non-native status of the mountain goat in the Olympics and the impacts of goats on the ecosystem. These were the "two key issues" identified in our contract with the U.S. Department of Interior (USDI). We also review current information on the feasibility of control efforts for goats in the Olympics, although this topic (especially contraception) has been addressed more thoroughly by previous reviewers. In keeping with the scope of work in our contract, our fundamental purpose is to evaluate "the adequacy and findings of all research relevant to the management of mountain goats at Olympic National Park."

Although settling the issues of nativeness and impacts of mountain goats in the Olympics once and for all might be desirable from a policy perspective, no single report can accomplish that. Science is a process of accumulating incremental knowledge, punctuated from time to time by new discoveries and, rarely, by radical changes in theories and paradigms. Our report can only address the information available at this point in time. We underscore that our review was of the "scientific material," both published and unpublished, relevant to the mountain goat issue in the Olympics. Thus, we focused our attention on issues involving the natural sciences and did not consider legal, political, social, ethical, or esthetic issues. We recognize, however, that such issues will not fade into the background upon the emergence of a scientific review.

## OBJECTIVES AND METHODS

Our methodology was devised to fulfill the request of the USDI by providing a thorough, independent, and unbiased critique of scientific materials relevant to the status, ecological role, and tested management options for mountain goats in Olympic National Park. (Refer to Section C, Scope of Work, of the Final Contract, #14-01-0001-99-C-05.) We initially identified five key issues or questions from the Scope of Work as topics to focus on in our report, and to guide our search and evaluation of the literature:

1. Whether mountain goats are native to the Olympic Peninsula. To address this question we assessed the quality, reliability, accuracy, and reproducibility of all historic and scientific evidence available to determine if mountain goats reached the Olympics prior to the twentieth

century. We identified the most likely time periods during which mountain goats could have colonized the Olympics. On the basis of available information, we provided our best professional judgments on whether mountain goats are native or exotic to Olympic National Park.

2. How several major periods of glaciation and subsequent postglacial events influenced the biogeography and ecology of the Olympic Peninsula. To address this issue, we reviewed the literature on the paleoecologic and environmental history of the Olympic Peninsula. This issue is closely linked to issue #1, as the paleoecologic and environmental history of the Peninsula determined potential opportunities for colonization by mountain goats.

3. How mountain goats currently interact with and affect other physical and biological entities and processes in Olympic National Park. This question considers the mountain goat's role and activities in the ecosystem.

4. The nature and magnitude of impacts by goats, if any, on the components and processes of naturally evolving park ecosystems. This question is a refinement of issue #3, and considers whether the activities of the mountain goat pose a threat to any components of the Olympic National Park ecosystem. Hence, this question relates to the NPS policy consideration of whether the goat is documented to threaten park resources or public health, which according to current policy, is generally necessary to justify control or eradication.

5. Whether mountain goats are interfering with natural processes or systems, with the perpetuation of natural features or native species, or with the protection of endangered, threatened, or unique species. This is a more specific restatement of issue #4.

Because of close similarities in topic, our discussion in this report combines issues #1 and #2 and issues #3, #4, and #5. These groupings correspond to the policy considerations of whether a species is exotic, whether it threatens park resources, and whether it can be controlled prudently and feasibly, respectively.

## Review Team

We assembled a team of senior professionals with expertise and experience well suited for addressing the five issues stated above (see Appendix 1, Qualifications, Experience, and Affiliations of Key Personnel). No team member had publicly expressed a position on the issues of nativeness or impacts of Olympic mountain goats prior to this review. Briefly, the duties of the team members were as follows:

Dr. Reed Noss, as chief reviewer and editor, was responsible for overseeing the project and evaluating team members' contributions, in addition to personally reviewing much of the project literature. His primary tasks were summarizing the state of knowledge for each key issue and synthesizing and editing the results into a complete and comprehensive review

document. He wrote the abstract, non-technical summary, introduction, methods, discussion, and conclusions sections of this report.

Dr. Russell Graham was selected for his expertise in zooarcheology and vertebrate paleoecology. He was added to the team after the other team members first met and determined that this area of expertise was essential. His summary report focuses on the extent and quality of evidence supporting the existence of mountain goats in Olympic National Park prior to the introduction in the 1920s.

Dr. Dale McCullough was given more technical review responsibilities than any other team member, as a reflection of his expertise in several areas related to this review. He reviewed studies relating to mountain goat ecology, herbivory, dispersal, and population dynamics in Olympic National Park and elsewhere. His summary report includes an evaluation of the extent and quality of knowledge about the population status of mountain goats, their history in Olympic National Park, their effect on physical and biological entities and processes, and tested management options.

Dr. Fred Ramsey was selected for his expertise in statistics related to the natural sciences. His primary contribution to this project was to guide the review of the experimental design and statistical methods used in studies relating to mountain goat population biology, dispersal, herbivory and other impacts, and studies of botany and plant ecology. He evaluated the statistical validity of the results of key studies, including the strength and power of results, focusing on the questions of whether the goat is native to the Olympic Peninsula, the population sizes of goats, and whether goats are having significant impacts on native vegetation and flora.

Ms. Jennifer Seavey, a wildlife ecologist and ornithologist, coordinated this project. She contributed to reviews of scientific material related to plant species distributions and population status, impacts of herbivory on plant species, population and dispersal of mountain goats in the Olympic Peninsula, and other topics. Her primary role was conducting database and other bibliographic searches, obtaining materials for review, compiling the bibliographic database for the review, preliminary categorization of review items, disseminating review materials to team members, and compiling review results for final synthesis.

Dr. Cathy Whitlock is an authority on the paleoecology of the Pacific Northwest. Her primary contribution to this project was a review of studies related to the paleoecology of the Olympic Peninsula. She reviewed how the several major periods of glaciation and subsequent postglacial natural events and human activities influenced the evolution and development of the modern natural biogeography and ecology of the Olympic Peninsula. She also guided the review of the biogeographical arguments concerning whether mountain goats are native to Olympic National Park. Her summary evaluated the extent and quality of knowledge about the biogeography and paleoecology of the Olympic Peninsula and the history of mountain goats in Olympic National Park.

Dr. Mike Williams is a botanist and plant ecologist who has worked many years in the Pacific Northwest. His primary contribution to this project was a review of studies related to botany, plant ecology, herbivory, and effects of mountain goats on endemic, threatened, and endangered plants in the Olympic National Park. He summarized the extent and quality of knowledge about the effects of mountain goats on botanical resources in Olympic National Park.

Team members worked mostly independently during the course of this study. Semi-independent evaluation of the literature was desired to reduce biases and the potential influences of persuasion and "group think." Team members, however, were encouraged to contact other members when they had questions related to the other's area of expertise. Three face-to-face meetings of the team (but none with all members present) were held during the study, in addition to phone conferences, email, and other correspondence. Draft reports of team members were circulated among the group, but not for formal review.

## Literature Search and Evaluation

We performed a comprehensive search of the published and unpublished literature related to the five issues summarized above. The literature searched included primary (refereed) literature, agency technical reports, agency internal documents, unpublished academic works (e.g., theses), conference proceedings, industry-sponsored research reports, commentaries and letters from interested individuals and organizations, and, where possible, the primary field data from which the literature was derived. The NPS, Fund for Animals, The Humane Society of the United States, Dr. Lee Lyman, The Washington Native Plant Society, The Olympic Park Associates, and other key players in the Olympic mountain goat controversy were asked to provide relevant literature to the team. Team members provided lists of important references and bibliographies from their areas of expertise. We conducted exhaustive searches of digital databases of primary literature, government documents, and other ecological information, using all pertinent search engines. The Science Citation Index (SCI) was used to locate recent work that referenced materials in our preliminary reference list. Literature searches and reviews were conducted primarily at the University of Washington, Oregon State University, and the Conservation Biology Institute. Inter-library loans were used to obtain documents not present in these libraries or from other sources.

Team members were provided with copies of all literature relevant to their areas of expertise and to their tasks in this review. One or more of the team members examined a total of 806 documents, with 626 documents considered potentially relevant and actually reviewed. All references were added to a bibliography using ProCite version 4.0, with the assistance of Biblio-Link II.

Team members were provided with literature review forms, with instructions to fill out one form for each reference found to be generally relevant to the issues considered or otherwise of interest (Fig. 1). Team members assigned each reference to categories of type of material and of which of the five issues (see above) the reference addressed. Each reference was graded on

a scale of 1-5 in terms of technical merit, strength of results, relevance, and overall score. Team members also were encouraged to provide additional comments on each reference (see Fig. 1).

<u>**Olympic Mountain Goat Review- Literature Review Form**</u>

Lead Reviewer:________________________

Citation:__________________________________________________________________________
______________________________________________________________________________________
______________________________________________________________

Juried Publication?:____________________________

Types of material (check one):
___ Original Analysis
___ Critique of prior work
___ Synthesis of prior work
___ Commentaries, editorials, and historical documents

Paper Topic (Check one or more):
___ Whether Mt goats are native to ONP
___ Paleoecological and historical evolution of ONP, as it relates to Mt goats
___ Ecological role of Mt goats in ONP
___ Nature and magnitude of goat impacts on native species and natural systems
___ Whether Mt goats are interfering with natural processes or systems in ONP
___ Sufficiency of tested management options

Grade each:
___Technical merit (1 weak- 5 strong, NA)
___Strength of results (1 weak- 5 strong, NA)
___Relevance (1 not- 5 critical, NA)
___Overall Score (sum of above)

Comments:_______________________________________________________________________
______________________________________________________________________________________
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Figure 1. Literature Review Form. Each reviewer filled out one form for each reference found to be generally relevant to the issues considered or otherwise of interest.

## On-Site Examination

The entire team, except Drs. Fred Ramsey and Russ Graham, met on August 15-16, 1999 in Port Angeles, Washington. At this meeting the team had the opportunity to examine Olympic National Park documents that are limited to viewing at park headquarters, for example the "before and after" photographs of goat habitat and a variety of historic materials. The team also inspected mountain goat habitat and goats within the Olympic National Park by helicopter (cloud conditions prevented landing). We also were able to ask specific questions of Olympic National Park staff in relation to their areas of expertise and the research conducted in the park.

## Individual Reports

Each team member, with the exception of the team leader (Noss) and the team coordinator (Seavey), summarized his/her review in a report submitted to the team leader (see RESULTS: TEAM MEMBERS' REPORTS section). The reports summarize the extent and relevance of information available, its overall merit, and the strength of results for each of the issues examined by the team member. Team members were instructed to provide their best professional opinions on each issue they evaluated, for example, whether the available data support the notion that the mountain goat is exotic to the Olympic Peninsula and whether the goats are threatening park resources through their activities. The team leader was given the responsibility of integrating, editing, and synthesizing the individual reports into a summary statement for each of the issues considered.

# RESULTS: TEAM MEMBERS' REPORTS

The following reports represent the individual contributions of each team member, except the team leader and team coordinator. Our goal was not to achieve consensus on every issue, but rather to provide our individual, best professional judgments. The team leader synthesized these reports into a brief statement concerning the state of knowledge and the collective judgment of the group for each of the five issues examined (see DISCUSSION).

## Report of Dale McCullough

### *Is the mountain goat native to the Olympic Peninsula?*

No one questions that the current mountain goat (*Oreamnos americanus*) population on the Olympic Peninsula traces to introductions by humans in 1925 to 1929. The arguments concern whether or not they were native originally. The term "native" causes all sorts of definitional problems. Native when, for how long; in prehistory, or the Holocene, or the Pleistocene?

Lyman (1988, 1994, 1998) has been the most persistent critic of the Park Service's claims that mountain goats are not native. Others have sided with him on the issue, but contributed little in a substantive way to the examination of evidence beyond the critiques of Lyman.

In this section I make 3 points:

1. There is no credible evidence that mountain goats have ever occurred on the Olympic Peninsula.
2. The geological record is such that dispersal of mountain goats from the Cascade Range across the broad glacial, water bodies, glacial out-wash plains, lowlands lacking in rocky outcrops, and forested habitats to the Olympic Peninsula would have been extremely unlikely.
3. The proposal of Lyman (1988) that occurrence of mountain goats on the Olympic Peninsula about 13,000 years before present is justification for maintaining a population introduced by humans has little foundation in ecological or evolutionary terms.

The major documents examining the original status of mountain goats on the Olympic Peninsula are the reviews of historical evidence by Schultz (1994), ethnographic evidence by Shalk (1993), and zoogeography by Houston et al. (1994a). The reviews of Schultz (1994) and Shalk (1993) are professional, thorough, balanced, and convincing that mountain goats were not present on the Olympic Peninsula. It is more than a little indicative of the quality of these reviews that nine independent reviewers, who were chosen by an array of scholarly societies, were in virtually unanimous agreement with this assessment. Total unanimity in a group of academic experts working independently is a rather rare occurrence. Among the reviewers, the same telling points are made again and again: 1) numerous highly qualified scientific expeditions did search actively for mountain goats in appropriate habitat without finding a sign; 2) the two literature reports that goats were present were published in soft sources, and not based on first hand information; 3) the ethnographic record showed no mountain goat remains other than those that could easily be related to trade; 4) the distribution of wool dogs coincided with the absence of mountain goats; and 5) oral traditions of native peoples stated that there were no mountain goats on the Olympic Peninsula. These reviewers were also unanimous in their conclusion that the proposals of Lyman (1988) that mountain goats did occur on the Olympic Peninsula were lacking in credible evidence.

Given the heat of the controversy over the native status of the mountain goat in the present Olympic National Park, it is surprising that so little solid evidence has been marshaled for the view that they were native. The "evidence" available boils down to two things. First, three historical reports, one a newspaper article, one in National Geographic Magazine, a popular, non-reviewed source, and one in Forest and Stream, a hunting and adventure magazine that can make little claim to scientific credibility. Schultz (1994) explored these reports, and pointed out that they were not first hand accounts, and suffered from a number of deficiencies. One of them (Fannin and Grinnell 1890) reports that a Mr. L. L. Bales wrote to them that goats were "...abundant in the Oympian Range mountains..." but on the same page they report that mountain goats were found in the Sierra Nevada of California. On the face of it, the Sierra Nevada report would seem to be about as solid as a historical account could be. Captain

Charles E. Bendire, an Army officer and naturalist reported seeing mountain goats there in three winters, and that he shot one, and a friend of his shot no less than five. We know that the mountain goat did not occur in the Sierra Nevada. These animals were females from an isolated population of bighorn sheep (*Ovis canadensis*) that shows genetic differentiation from other bighorns (Bleich et al. 1996) and which are grayer and lighter in color and adapted to steep rocky terrain usually characteristic of mountain goats (McCullough and Schneegas 1966). It is notable that bighorn sheep, presumably rams, were killed and reported as well. This detailed report by apparently credible observers of mountain goats in the Sierra Nevada is a cautionary tale, and underlines the need to be skeptical of historical records that may well be mistaken.

Second, there is the report of Reagan (1917) of remains in archeological middens at La Push Village on the coast of the Olympic Peninsula. He stated, "Bones (it may well be that Reagan was including horns as "bones") of animals identified: elk, big horn, mountain goat[2], black bear, *Putorius*, species?, black-tailed deer, wild cat, beaver, raccoon and otter." Footnote 2 noted, "The latter two are found usually only in the ladle form of the horns. Spoons fashioned from horns are common trade items, so it cannot be inferred that they were produced at the site." No one has seriously proposed that the bighorn sheep occurred on the Olympic Peninsula. However, if horn ladles of mountain goats are considered evidence of occurrence of mountain goats on the Olympic Peninsula, the big horn sheep ladles should similarly indicate that they occurred on the Olympic Peninsula as well. Furthermore, the wording is such that it is hard to tell if Reagan was referring specifically to the La Push site or the region more generally.

Another piece of historical evidence not available to Lyman is a photograph of a mountain goat female and young taken by Paul Richardson between 1908 and 1915 recently added to the Olympic National Park archives. Richardson was a professional photographer and hunter who made photographs into picture postcards. At present there are no negatives or journals supporting these photos, some of which are clearly labeled as taken on the Olympic Peninsula. Others are labeled as from Alaska and other sites. This picture is the only one containing a mountain goat, and it is unlabeled as to locality. It shows paste marks on the reverse side, which suggests that it previously was in an album. The marks could not be matched up with albums that contained exclusively pictures from the Olympic Peninsula. By criteria of the image itself, it does not appear to have been taken on the Olympic Peninsula. The forests in the picture appear to be lowland forests, whereas the best mountain goat habitats on the Peninsula are in sub-alpine and alpine areas. It is a summer picture from the appearance of the herbaceous vegetation, and on the Peninsula, goat use of forested areas is primarily in the winter time when they retreat from snow to lower elevations. Finally, there are at least four clearly logged stumps in the picture of what appears to be Douglas fir. In none of the many pictures in the collection that are labeled as from the Olympic Peninsula, or the pictures in the album only from the Olympic Peninsula are there any logged stumps. It seems most likely that this picture of goats was taken in coastal British Columbia or Alaska (*editor's note: other team members who viewed this photograph suggested the Cascade Range as another possible locality*).

The review of the geology and zoogeography of the Olympic peninsula by Houston et al. (1994b) is less detailed and more subject to criticism than the works of Schultz (1994) and Schalk (1993). The nine outside reviewers selected by scholarly societies were less enthusiastic of this work, which generally is less thorough than the other two. Similarly, Lyman's criticisms, particularly about the comparison of the number of species occurring on other glacial refugia along the coast, were more telling. Houston et al. (1994b) were less meticulous about details than they might have been, given that their work was almost surely to come under severe scrutiny by critics of park policies. Still, Lyman's critique dealt with technical matters (the number count of species), rather than the major point Houston et al. (1994b) were making, that the fauna on the peninsula was depauperate and isolated. Even with Lyman's corrections, the conclusion that the flora and fauna of the Olympic Peninsula, like that of other glacial refugia, was depauperate compared to that of the Cascade Range still is valid.

Lyman's questioning of the objectivity of these authors is fair enough as scientific argument. But by using that standard, he opens the question of his own objectivity, and he did not serve his case by stating, "...I was more intent on figuring out a way to get goats into the Olympics" (Houston 1995). This statement erodes his claims to impartiality that are prevalent in his book about the controversy (Lyman 1998).

Several outside reviewers granted Lyman's point that the deeper record of the late Pleistocene-early Holocene was essentially lacking because the steep, erosion-prone landscape occupied by mountain goats is not conducive to formation of fossil deposits. However, his proposal that mountain goats may have been on the Olympic Peninsula about 17,000 to 13,000 years before present (YBP) and, therefore, in the meantime the National Park Service should treat the mountain goat as a native until such evidence is found stretches the connection beyond all logic. Surely if such fossil evidence existed, it would have to be taken into account in the evaluation of the question of native status, much as earlier occurrence of equids in North America was brought forward as one argument in the status of burros in Grand Canyon. But fossil goat evidence does not exist on the Olympic Peninsula. Fossil remains of bison and caribou dating from between 12,000 and 9,000 YBP were reported from the peninsula by Peterson, et al. (1983). Should these be considered native? Should mastodons (Gustafson et al. 1979)? Furthermore, the same hypothesis put forward for mountain goats by Lyman could be put forward for equids, camelids, probocidians, antilocaprids, and any other taxa known from the Pleistocene or early Holocene fossil record. By the same logic should not these taxa be re-established in order to reconstruct the "native" fauna? One would hope not--for the reasons discussed in greater detail below.

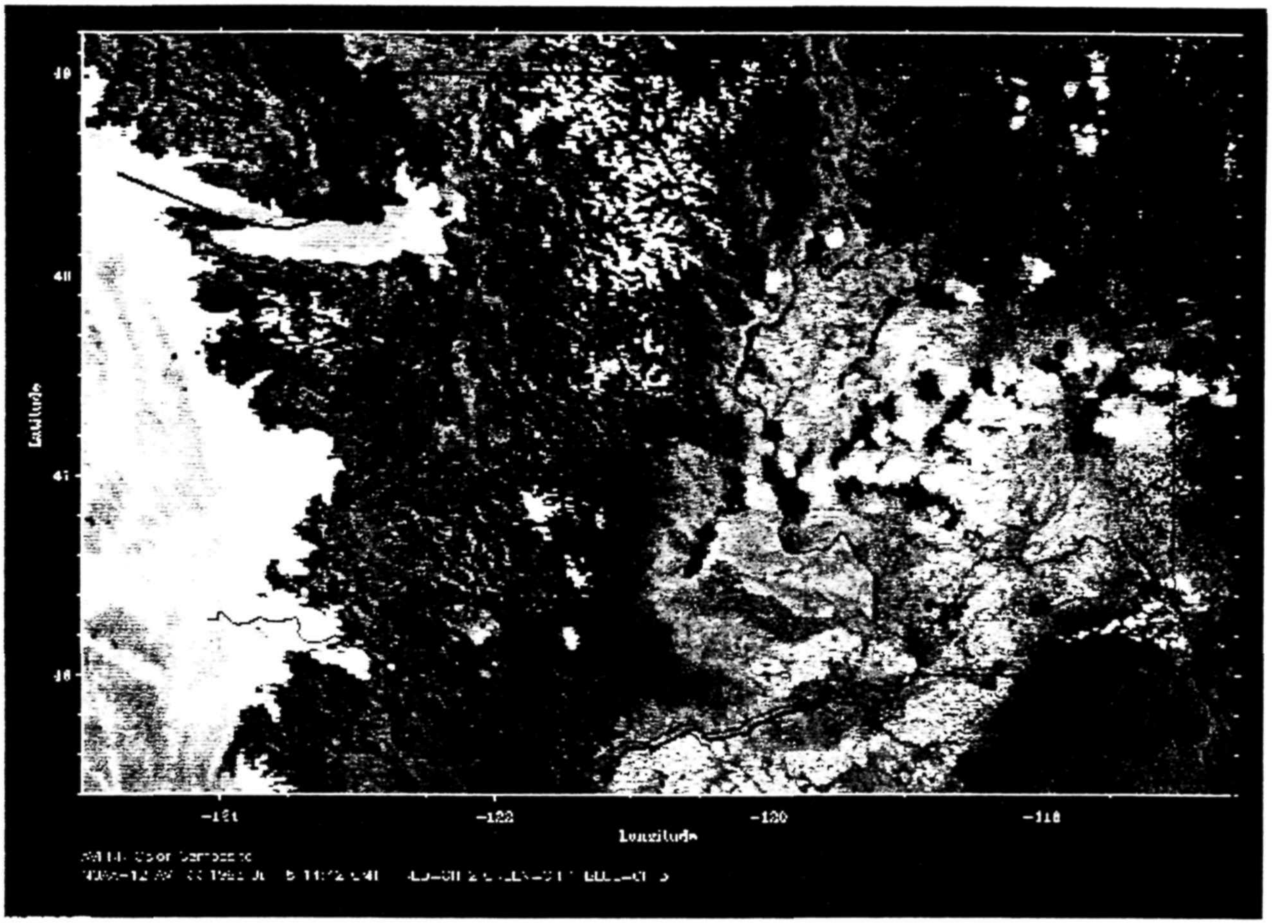
To reach the Olympic Mountains, Lyman (1988) proposed that mountain goats crossed the Puget Lowlands around 17,000 and 13,000 YBP. There is little doubt that mountain goats shifted southward at least as far as northern California during the southern advance of glaciers, but even Lyman's review of the evidence shows that there are no records known from anywhere west of the Cascade cordillera. Lyman argued that the habitat was suitable on the Olympic Peninsula during this time. He discusses vegetation and climate in ice-free areas (i.e., the gap between continental and alpine ice) on the Olympic Peninsula. However, his

emphasis on grasses and shrubs in this area does not apply very well to the pollen record for the intervening area that mountain goats would had to have crossed from the nearest population in the Cascade Mountains. According to Barnosky et al. (1987), grasses and shrubs began to decline in the Puget Trough and Pacific Lowlands shortly after 17,000 YBP, and by 15,000 YBP the vegetation became more forested. Of course, mountain goats can use forests, especially in winter although evergreen foliage is usually much lower in quality than more preferred forages. Also, the pattern of vegetation is more variable in mountainous regions where rain shadows, exposure, etc. influence vegetation, and these variables may well have created some habitat suitable for mountain goats. But the major expanse to be crossed in the Puget Lowlands was predominated by vegetation not very favorable for mountain goats for the last 15,000 years. The Puget Trough was a dry valley during the Evans Creek Stade (25,000-17,000 YBP), but the Cordilleran ice sheet advanced southward from 15,000 to 13,000 YBP during the Vashon Stade (Whitlock, this report). To cross this expanse earlier in time when it was dry, goats would have had to cross alpine vegetation in the absence of forested concealment cover from predators. To cross later, goats would have had to either negotiate through forests (Barnosky 1984, Barnosky et al. 1987), or cross on islands of vegetation (which may have occurred on the glaciers themselves) in a stepping-stone fashion. Neither route is impossible, but both are improbable.

Furthermore, Lyman fails to mention rock outcrops, the key habitat element for all mountain goat populations that defines their range and niche throughout their distribution. Rock outcrops are necessary for goats to escape pursuit by predators, and no goat is found for long very far from rock outcrops. The approximate distribution of good mountain goat habitat is shown in Fig. 2. Rock outcrops, that could serve as stepping stones to move across this expanse, are absent in the Puget Lowlands. Even if viewed without consideration of any significant topography between the intervening area, rock outcrops as stepping-stones are lacking. The most prominent intervening uplands are the Black Hills near Olympia that rise to about 810 m. They are mostly gentle, and are completely lacking in exposed rock outcrops (Tom Pock and Doug Magoon, Washington Department of Natural Resources, 1999, pers. commun.). At the time of the ice retreat (starting about 14,500 YBP), these hills were isolated between two outwash rivers the size of the current Columbia River. Other scattered hills in the Puget lowlands are below 200 m. Furthermore, the intervening area is characterized by lowlands which are laced with rivers and other water bodies. There may have been a window in time about 18,000-13,000 YBP when a favorable mix of open and forest patches may have been present. Earlier the habitat would have been too open (Heusser 1983), and later too closed (Barnosky et al. 1987) to be suitable for passage of mountain goats. It is hard to see how goats could have effectively crossed this expanse which, if measured from current suitable goat habitat in the Cascade Range to similar habitat in the Olympic Mountains (as indicated by modern occupation by goats), would involve a distance of about 130 km.

Houston et al. (1994a) stated that the Puget Lowlands are not an absolute barrier, but rather a filter to mountain goat dispersal. Of course, there are virtually no absolutes in biological science. Nevertheless, the issue is probabilities. Although even the most extraordinary event may occur rarely, it is not likely in the ordinary course of zoogeography. Working against the establishment of a viable population is the fact that most long-distant dispersal is by young

# *Satellite Image of Washington*




Click on image for full size view

NOAA-12 satellite, 1996 Jul 08 14:42 UT
Color composite. AVHRR channels 2, 1, and 3 are red, green, and blue

Index of available AVHRR images for Washington
Understanding the images
Index of states

Fig. 2. Color composite satellite image of Washington. The unshaded yellow areas show high mountain rocky areas suitable as prime mountain goat habitat. The yellow areas with shadows on the right hand part of the image are clouds, as are the greenish areas over the coast on the left hand edge. NOAA-12 satellite, 8 July 1996 (http://fermi.jhuapl.edu/states/avhrr/WA_213.n12.96jul08_1442.html).

males, and successful colonization requires the concurrent dispersal of both sexes (Stevens 1983) and successful reproduction in the new area. Most mountain goats disperse as individuals; these are unlikely to follow the same pathways through a broad, mainly flat inhospitable lowland where they are not funneled by topography, end up in the same area over 100 km away, and be successful in breeding. The resulting probabilities have to be derived by multiplying a series of independent probabilities, so that the likelihood of colonization becomes extremely small. Following the introduction of mountain goats to the Olympic Peninsula in 1925-29, even with passage through good habitat, it still took males about 25 years to reach the opposite (southern) limit of the habitat, and typically around another ten years before colonization by females (Houston, et al. 1994c).

Finally, I do not agree with Lyman that mountain goats should be considered native if they could be established to have been on the Olympic Peninsula some thousands of years ago. Only if Europeans drove goats to extinction within recorded historic times would there be a sound case for their reintroduction.

## *Mountain goat demography*

Given the great difficulty in studying a dispersed animal in remote and rugged habitat, the demographic and behavioral research on the Olympic Park goats is impressive. It is surely the best single study of mountain goats ever done. The marking program achieved an exceptional sample size under the conditions in the park. Census methods have evolved over time, and recent helicopter censuses have relatively narrow confidence limits. Furthermore, demographic data are backed up by considerable behavioral information that puts the results into a larger context.

In the following review I make the following points.

1. The Olympic Peninsula mountain goat population is probably not a true metapopulation because of the high exchange of individuals between habitat patches.
2. The Klahhane Ridge subpopulation has different demographics than other subpopulations for reasons besides time since colonization.
3. The most parsimonious explanation for the contradictions in population growth rate and impact of the goat removal program is that the helicopter census in 1983 was erroneously high.
4. The recent helicopter counts are precise and useful for detecting trends. Their accuracy is uncertain.

Houston et al. (1994d) used the term "metapopulation" to describe the Olympic Peninsula goat population, but in the archaic sense of Andrewatha and Birch (1954) as simply being a spatially structured population. A more modern formulation of the metapopulation concept was developed by the early 1990s (Gilpin and Hanski 1991), and it has been further refined since that time (McCullough 1996, Hanski and Gilpin 1997). In the modern view, the important feature of a metapopulation is not just a spatial structure across isolated habitat patches, but

also that dispersal of individuals between patches is sufficiently infrequent that the separate patches have nearly independent demographics. Furthermore, at least some of the patches are small enough to suffer local extinctions, which are countered by periodic recolonizations through dispersal of animals from other patches. So long as the colonization rate exceeds the extinction rate, the metapopulation can remain viable over time even though any (or all) local populations may be unstable.

The Olympic Peninsula satisfies part of the metapopulation concept--that the goat habitat is distributed in spatially discrete patches--but fails the requirement that the patches be characterized by largely independent demographies. Both natural history and modeling show that if animal movement between patches is very frequent, the population will behave demographically as a continuous population, despite spatial structuring. This seems to best describe the conditions of mountain goats in Olympic National Park.

A great amount of movement between good habitat patches and substantial dispersal (i.e., unidirectional movement) were revealed by marking and radio telemetry (Stevens 1983). Ungulate biologists have long presumed that mountain goats, given their patchily distributed habitat, were more prone to movement between isolated patches of habitat than most ungulates. Still, the amount of movement documented on the Olympic Peninsula (Stevens 1983) is impressive. Common occurrence of given individuals in more than one patch showed that the home range of many goats consisted of more than one patch.

Furthermore, the concept of a metapopulation calls for a matrix between patches that is inhospitable, dangerous and, thus, difficult to cross or survive in. The matrix between prime habitat patches for Olympic mountain goats is probably more mixed, containing some small favorable spots, and overall being not severely detrimental to survival. Thus, crossing between patches is not so hazardous, although probably more risky than remaining in a given patch. Still, the balance of finding mates, quality food, and other resources may outweigh the costs of sharing a crowded range with conspecifics, and risk of moving between patches.

Although the Olympic goats do not satisfy the strict definition--in the modern sense--of a metapopulation, this concept is useful for a context to understand the spatial elements of their demography. For example, Stevens (1983) reported that dispersal was density dependent, and resulted in a net export of individuals from the high density Klahhane Ridge subpopulation to other subpopulations. Although she did not test this conclusion statistically, a quick chi-squared test of her data on movement of marked individuals (for the Klahhane subpopulation, 22 dispersed, 108 non-dispersed; for the combined other subpopulations 2 dispersed, 86 non-dispersed) showed the difference to be significant at $P < 0.001$. Thus, the difference in behavior between the Klahhane Ridge and other subpopulations was statistically different, with the Klahhane Ridge animals much more likely to disperse permanently to other areas. It can not be demonstrated that the density of goats on Klahhane Ridge was the cause, but it was correlated with other comparative data gathered by Stevens, as well as generally consistent with the literature on ungulate movements (McCullough 1985).

In a metapopulation context, this situation would be viewed as a mainland-island model. The "mainland," Klahhane Ridge, was a relatively large population (at the time, before population reduction) that produced an excess of individuals that, on average, suffered detriments from population density, such as lowered individual growth and reproductive rates (Stevens 1983). Thus, there was increased pressure to disperse, particularly among young animals and those in low social positions that suffered the greatest detriment due to their lack of ability to compete for limited resources. In a natural selection sense, the cost-benefit ratio of staying at home versus looking for better conditions elsewhere was shifted in the direction of moving elsewhere. The "islands" were the other subpopulations that were smaller, in some cases more isolated, and generally had higher individual growth rates and reproductive rates (Stevens 1983). The island subpopulations were at lower density, had less competition for available resources, and consequently, were under less pressure to disperse.

Why did the other subpopulations not develop demographics similar to those of Klahhane Ridge? There seem to be several possible--not mutually exclusive—explanations: 1) they were colonized too recently, and have not had a long enough time to reach carrying capacity; 2) they are too small, and are inherently unstable, as is often the case with small populations. They are maintained--i.e., "rescued" (Brown and Kodric-Brown 1972)--by continuing influx of new individuals from the mainland subpopulation. In a larger context, this is known as source-sink dynamics (Pulliam 1988); and, 3) they may have had high subadult and adult mortality rates that offset good phenotypic individual condition and high reproductive rates.

The time-since-colonization hypothesis can not be rejected. Studies by Stevens (1983) were done between 1977 and 1979, whereas the colonization of many of the subpopulations (with the notable exception of those in the Mount Constance area) other than Klahhane Ridge were thought to have occurred in the late 1960s and early 1970s (Moorhead and Stevens 1982). Because Mount Constance was combined with the other subpopulations for comparing demography and animal growth, on average, time could be an important factor. Ten or fewer years is a short time to expect new populations of mountain goats to explore and adapt to local conditions, and reach population equilibrium with local resources.

The second hypothesis about small populations also can not be entirely rejected, particularly during the time of Stevens' (1983) studies. Many subpopulations were in the process of being established, and a considerable number of goats were dispersing from the Klahhane Ridge mainland population. Over four years, 22 out of 130 marked animals dispersed, and if this is raised to Stevens' estimate of 181 goats in the Klahhane subpopulation, an estimated 31 goats dispersed over the study, or about 8 per year. This estimate would be biased to the low side, because most goats disperse as young animals, so older goats available to be captured for marking would be biased towards non-dispersers. There is considerably more doubt if small population size, per se, is a problem at the present time. First, about 20 years have passed, and if equilibrium among the various subpopulations was going to be reached, it should have been achieved by this time. Additionally, the Klahhane Ridge subpopulation was substantially reduced (virtually eliminated) in the 1980s, and that population is not functioning as a mainland population any longer. Consequently, dispersal to or from Klahhane Ridge (and possible source-sink dynamics in the system) is probably no greater than for other

subpopulations. Second, as noted above, the subpopulations are not closed, and the matrix between subpopulations is not uniformly inimical. This means that demographic units are broader and less bounded than the mapped subpopulation areas, so they are not as small as the patches of favorable habitat would suggest. Third, the last three helicopter censuses have been conducted in more-or-less the same manner, and there doesn't seem to have been much change in the numbers and distribution of subpopulations (Happe et al. 1997). What changes that were made in the census routine have been directed to optimizing the sampling scheme rather than in adapting to shifts in mountain goat usage. That the censuses of goats have remained nearly the same since 1990 (broadly overlapping confidence limits) suggests that small population sizes are not leading to an obvious decline of subpopulations, or the total population. This may be because all subpopulations have had comparable success over this period, or, alternatively, that different dynamics of the separate subpopulations are being dampened for the total by movement between subpopulation areas.

One is left with the conclusion that if the Klahhane Ridge subpopulation was subsidizing the other subpopulations in the late 1970s, it no longer is doing so. Furthermore, if the other subpopulations were dependent on the Klahhane Ridge subpopulation for viability in earlier times, they no longer are. Despite the decoupling, one is further left with the impression that there was a fundamental difference between Klahhane Ridge and the other subpopulations. Numerous researchers have commented that Klahhane Ridge was the best habitat, and this may have been more than simply a matter of larger size. It may have been qualitatively better, or the juxtaposition of habitat elements may have been more favorable. Equal amounts and quality of resources may be expressed as different carrying capacities depending on their distributions.

Finally, the role of salt can not be dismissed as contributing importantly to the quality of Klahhane Ridge for mountain goats. Salt is a limited commodity in high demand in spring and early summer for mountain goats (Hebert and Cowan 1971), and many other ungulate species in areas where relatively high rainfall leaches salts from the soil. In early observations, Moorhead (1977, 1981) remarked how salt put out purposefully for goats, and human urine were attracting goats to Klahhane Ridge. Particularly telling was the "experimental" placing of salt on U.S. National Forest lands adjacent to Olympic National Park (Henderson 1984). The fact that goats were attracted to, and had pronounced impacts on the local soils and vegetation in only one year was ample demonstration of the drawing power of salt. Perhaps if other areas had been salted similarly to Klahhane Ridge, they may have proven to be similarly attractive, reached comparable goat densities, and shown corresponding density-dependent declines in animal growth and reproduction.

One demographic question involves the similarity of the time series of population estimates for mountain goats on the Olympic Peninsula (Fig. 3), and the ungulate eruptive population model of Caughley (1970). This model traces back to Leopold (1943), and has had considerable acceptance in the field. It is further interesting that the species that Caughley (1970) studied was the Himalayan thar (*Hemitragus jemlahicus*), which was introduced to New Zealand, a species with biology similar to mountain goats and a history not that different from the introduction of goats to the Olympic Peninsula.

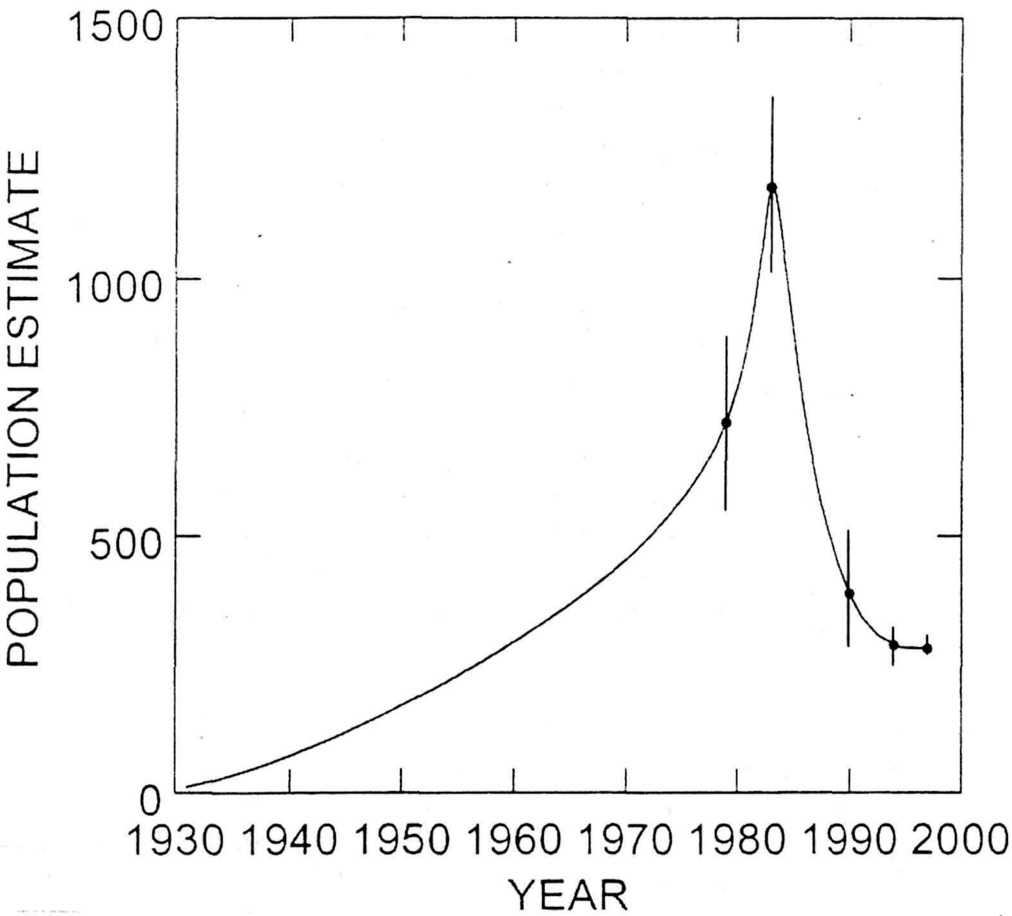



Fig. 3. Population estimates of mountain goats on the Olympic Peninsula over time. The 1979 estimate is the midpoint and upper and lower estimates of Stevens (1983), and the following estimates were from helicopter censuses with mean and 95% confidence estimates (Happe et al. 1997). Note the unusually high rate of increase indicated between 1979 and 1983.

The eruptive model suggests that an ungulate introduced to a new environment will grow rapidly (with little or no density dependence) until it overshoots the carrying capacity of the environment. Because the environment would not support this number, the population would then die off and decline to an equilibrium population size that is controlled by density dependence at a level substantially below the peak number. If this model applied to the mountain goat population on the Olympic Peninsula, the population trajectory observed would have matched the expected, including the current apparent stability at a number well below the peak numbers. Steven (1983) documented a number of apparently individual and population level density-dependent responses, which would be consistent with an overshoot. Consequently, the overshoot would have occurred with either the unadjusted 1983 helicopter estimate, or an estimate reduced to be consistent with other estimates (see below).

Although the eruptive model of ungulate populations is widely accepted, it is actually supported by little empirical evidence (McCullough 1997). In fact, there are a growing number of documented ungulate population cases that do not conform to the eruptive model. Nevertheless, the eruptive model should be kept in mind for Olympic Peninsula goats because if it applies, the recent relative stability of goat numbers may continue because the model proposes that the population reduced its own carrying capacity during the overshoot of the original carrying capacity. Note that this stability apparently occurred despite the fact that winter conditions have become generally milder since 1970 (see below). Otherwise the apparent equilibrium is temporary, and a buildup of numbers due to reduced density would be likely in the future. Given that even if mountain goats are eliminated in Olympic National Park, they will continue on adjacent Forest Service lands, the population behavior--and whether the population is showing a more permanent reduction in carrying capacity--will remain an important consideration.

The current helicopter surveys of the mountain goat population have been refined to the point where they are--from all indications--giving better estimates. The error bars are quite narrow, given all of the difficulties with these kinds of censuses. In terms of accuracy, the weak link is the correction factor used to account for animals that were present, but not observed in the helicopter samples. The use of 66% efficiency is based on very little data. Also, it may change over time with environmental conditions, light conditions at the time of the counts, population density, etc. For example, higher populations may be more clumped, and groups of goats may be seen more readily than singletons. Therefore, a greater proportion of the population may be observed in high than in low populations. These variables will not be reflected in the error bars because a constant correction factor is applied. Thus, the time series of helicopter estimates should be viewed as measures of trend, whereas the absolute number of goats should be treated with caution until further work on the correction factor is done. This could be done through radio telemetry so goats present and missed could be used with a mark-resight model to estimate the missed fraction.

Lyman (1998:28ff) has questioned the reliability of the peak estimate of mountain goat populations reported by the Park Service. The helicopter census estimate of 1,175 reported for 1983 comes in for particular criticism. This one point estimate, obviously, shows the greatest discrepancy from the long-term time series of population estimates. Lyman is probably correct

in his claims that this one point was the one that clinched the Park Service's conclusion that the mountain goat population in Olympic National Park was growing out of control, and that drastic measures had to be taken as quickly as possible. Their logic was basically sound. If the previous numbers of goats studied by Stevens (1983) were already causing negative impacts on the soils and vegetation, this substantially greater number would be devastating.

In retrospect, it appears that the 1983 population estimate was probably too high. For example, the population growth from introduction (1930, about 12 goats) to the mean of the 1979 estimate (719 goats) (Stevens 1983) gives a growth rate (r-bar) of 0.085. For the population to have subsequently increased from 719 to 1,175 by 1983, the growth rate would have to have been 0.123, or 31% greater. An increase in population growth rate does not seem tenable in view of the reported negative impacts of goats on their environment (Pfitsch 1981, Pike 1981, Reid 1983, Stevens 1983), and the apparent density-dependent reduction in kid recruitment beginning in 1980 (Houston et al. 1994d:Fig. 26) at Klahhane Ridge. At the time, this was the largest population. Furthermore, another substantial population at Baldy Ridge had already been in decline since the 1960s. As a consequence of changes in two of the major subpopulations, a decline in growth rate of the overall population would have been expected.

If the 1983 estimate is adjusted downward by about 300 to 400 individuals, the inconsistencies--with the longer time series of estimates and the known removals--largely disappear. The growth rate is more consistent with that shown up to the time of Stevens' study, and the removals reduce the population to the size range indicated by subsequent helicopter census estimates. That the downward adjustment of the 1983 estimate removes the discrepancies, however, does not prove that the 1983 estimate is wrong. Whether it is wrong or not can never be known for sure. Animal censuses are enormously difficult under the conditions of the Olympic Peninsula. Independent verification is virtually impossible. We will never know the real number. Sampling will always be necessary, and thus, we will always be required to deal with probabilities. Even the probabilities we derive are suspect, for they depend on the strict adherence to sampling assumptions--assumptions that are almost impossible to achieve under field conditions of weather, landscape, and equipment. The best we can hope for is approximation of the assumptions. Also, it is easy to forget just what statistical probabilities mean, and how misleading they may be in practice (Johnson 1999).

I do not agree with Lyman (1998) that the Park Service intentionally inflated the estimate in order to support their goat management policies. The estimates have to be viewed in the time frame when they were obtained. All mountain goat population estimates before the 1979 estimate (Stevens 1983) were "guestimates" based on unsystematic field observations, and no controlled sampling. They are very unreliable. Even the number of mountain goats that initiated the population is uncertain, for there is no record if any of the first four goats introduced in 1925 survived, and the numbers and composition of subsequent introductions are inconsistent. The 1979 study (Stevens 1983) was the first to systematically estimate mountain goat numbers. This consisted of mark-resight estimates of the Klahhane Ridge subpopulation, and was based on extensive experience doing field work on mountain goats and ground counts of other subpopulations. It is not possible to quantify probabilities if sampling is not conducted according to specified protocols; yet, one should not undervalue sound natural history work. It

is typical that ground counts by experienced workers on familiar ground exceed by appreciable numbers the comparable sample counts. Correction factors on sample counts are usually the weak link. Usually a single correction factor is used, or there is great variance in correlations with environmental variables in more complex correction procedures.

When the 1983 helicopter census was taken, there was little prior experience with that approach in Olympic National Park, and helicopter censuses were in their early stages everywhere. When a number implausibly larger than Steven's estimate--given goat reproductive rates--was obtained, it was reasonable to assume that her estimate was incorrect, and too low, because it was not as systematic, or based on as specified and diligently followed a protocol as the helicopter census. There was no other basis to judge which estimate--or both for that matter--was in error. There were no other data points with which to compare. Concluding that the Park Service may have judged wrongly is the luxury of hindsight.

The known number of goats removed in the control program is the only absolutely known number in the demographic data set. As such, it deserves greater emphasis in the consideration of discrepancies between population estimates made by Stevens (1983) and those based on helicopter samples. The helicopter estimates of 1990, 1994, and 1997 (Happe et al. 1997) had the benefit of refinement based on previous experience, and implementation of progressively more rigorous controls, both in sampling design and efficiency of equipment. The confidence intervals are impressively narrow for ungulate estimation, which speaks to precision, if not accuracy. Accuracy still suffers from the weak link in the approach, the correction factor applied to adjust for missed animals.

Parsimony, as a way of reaching conclusions, is not infallible. It simply determines the fewest steps of logic that are necessary to explain an outcome. In fact, the simplest answer may not be the correct answer. Nevertheless, in the question of the high population estimate in 1983, some statistical properties come into play. If a complex explanation involves integration of a sequence of independent variables, then the variance of each of those variables is multiplied. These multiplicative steps quickly expand the confidence bounds to enormous levels. In short, the probability of being wrong is very great.

The most parsimonious explanation for the 1983 helicopter population estimate is that it is too high. Simple modeling applying the rate of increase from 1930 to 1979 (r-bar = 0.085) to the midpoint estimate of 719 goats (Stevens 1983) and the known goat removals (Houston et al. 1994b:195) does not reduce the population. In fact, it continues to increase with Park Service removals, even with hunter kills outside the park added as well (Fig. 4). Lowering the 1983 estimate appropriately will make it consistent with the 1979 estimate (Stevens 1983), and with the known removals and subsequent helicopter population estimates in 1990, 1994, and 1997. Only one logical step is required. Thus, in Fig. 4, if the 1990 helicopter mean estimate (389 goats) is calculated backwards to find out what initial population was consistent with a 0.085 rate of increase and the known total removals and hunter kills, an estimate of 589 is derived for 1981, the first year of removals. This is a minimum estimate, of course, and doesn't include any variation in population growth rate, or any other source of adult mortality. Still, it shows that no increase in the population estimated by the 1979 estimate (Stevens 1983) is

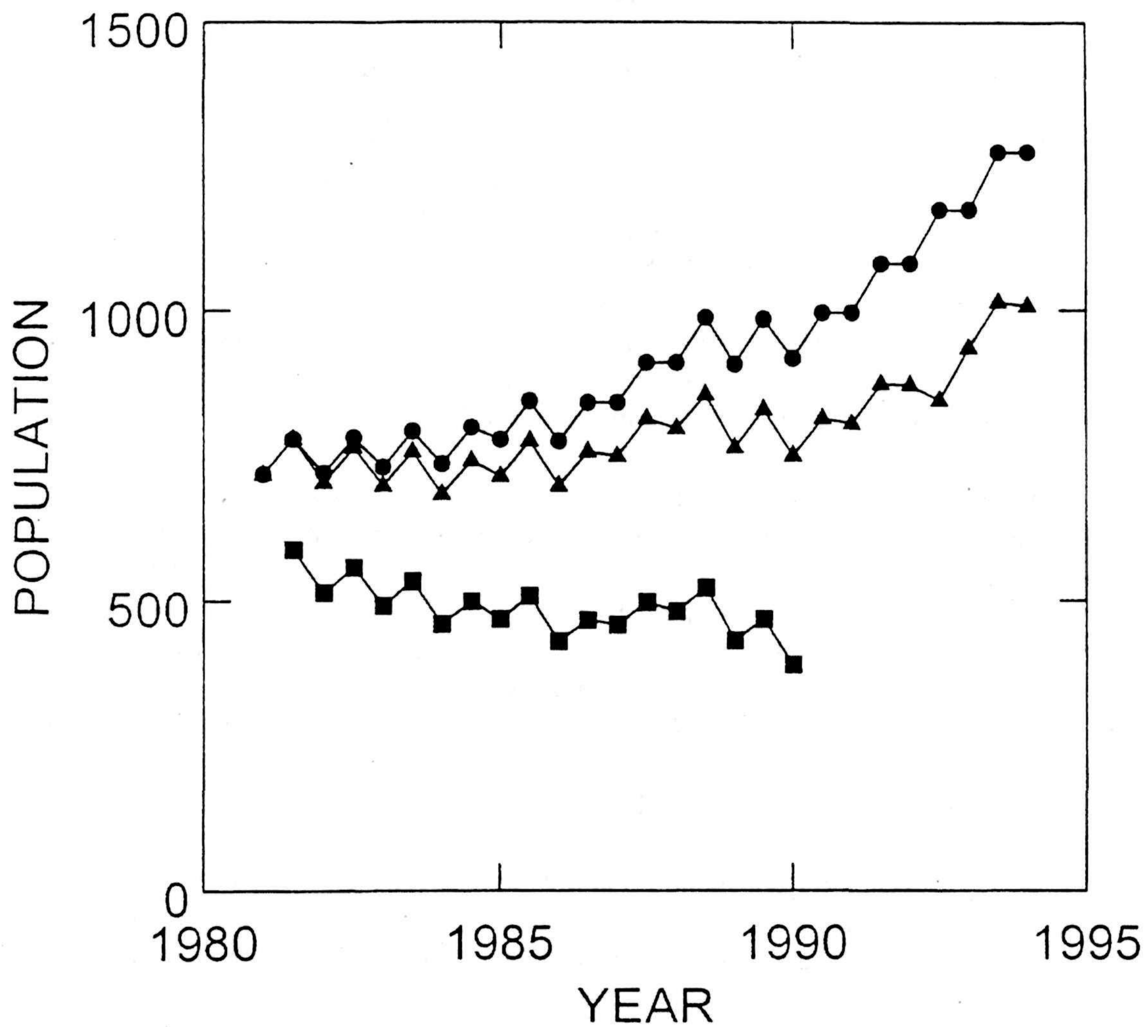



Fig. 4. Population projections made on the basis of known removals and hunter kills on the Olympic Peninsula. Circles are a projection based on starting population of 719, the midpoint of Stevens' (1983) estimates, a rate of increase of 0.085, and the known Park Service removals. Triangles use the same parameters, but include both known Park Service removals and hunter kills (Rolf Johnson, Washington Department of Fish and Wildlife, 1999, personal communication). Note that neither projection results in a decline in the population from Stevens' midpoint estimate. Squares represent a backwards projection from the 1990 helicopter mean census of 389 mountain goats with the known removals and kills and a rate of increase of 0.085. An estimate of 589 in 1981 is projected. See text for further explanation.

necessary to support the known removals and hunter kills. Thus, an initial population in the park at the start of removals in the range of 700 to 800 is indicated.

Conversely, if the 1983 estimate is assumed to be approximately correct, it requires (assumption 1) that the Stevens estimate be too low, and/or (possibly assumption 2) that the population achieved an incredible increase between the time of the 1979 estimate (Stevens 1983) and the 1983 helicopter census. Furthermore, there had to be significant mortality other than the known removal for the 1983 helicopter estimate to be consistent with the subsequent helicopter estimates. Houston et al. (1994c) proposed that the difference in mortality could be accounted for by a combination of death of dependent kids of female mountain goats removed in the control program (assumption 3), and winter mortality (assumption 4). These would seem to be independent variables, and require separate logical steps. Thus, the explanation for the 1983 helicopter estimate being correct would require a minimum of three, and possibly four steps.

The first one (or two) steps, the relationship between the 1979 estimate (Stevens 1983) and the 1983 helicopter estimate was discussed earlier. What is the evidence for the other sources of mortality proposed in assumptions three and four? There is no direct evidence for either. Houston et al. (1991) stated that kids of all 67 females removed in the control operations may have died. It is almost certain that some kid mortality occurred due to orphaning. But the females were removed over some time, so the kids were of variable ages when orphaned, and surely this influenced their probability of survival. Mountain goat kids on Klahhane Ridge begin feeding on vegetation by two weeks of age, and are nutritionally largely independent of the female by four weeks (Hutchins 1984). The mortality of kids may trace more to lack of experience than nutritional stress, and it would seem that orphaned kids could compensate for lack of experience by joining female and young groups in nursery groups (Stevens 1983:24, Hutchins 1984:87). Studies of mountain goats elsewhere suggest that survival of orphaned kids is routine (as reviewed by Hutchins 1984:183). The actual fate of the orphaned kids will never be known, but the assumption that they all died seems improbable. There seems to be no way to derive a reasonable estimate of this source of mortality. In addition, if it could be determined, the relative value would have to be judged against the normal background kid mortality. For Klahhane Ridge based on changes in adult female to kid ratios, Stevens (1983) estimated annual kid mortality for 1977 to 1980 to range from 32 to 60%, and based on known individuals, Hutchins (1984) reported summer mortality of 27% in 1981. Background kid mortality is already encompassed in the population estimates on each side of 1983, and so the relative effect of kid mortality would be less than the absolute value.

The proposed high winter mortality is based on the observation that the snowfall in the winters of 1976 to 1981 (Stevens 1983) was substantially less than that in 1982 and following (Houston et al. 1994b). In the complete absence of data on winter mortality, it is impossible to say either that it did or did not occur. Winter mortality of mountain goats is an almost unmentioned topic in the literature on Olympic National Park. Stevens (1983), who conducted the most thorough field investigations by far, hardly mentions winter mortality. She reported known mortality of only 10 goats in six years, none of which was attributed to winter severity. This may be because of the aforementioned mild winters during the period of her study.

Although there is no data on winter mortality, there are data on winter severity as expressed by snow water equivalents at the end of April (Olympic National Park records, ftp://ftp.wa.nres.usda.gov/pub/snow/data/historic/snow/clall.txt.) The longest record is for Deer Park, which goes back to 1949 (N = 43 years); the records for Cox Valley (N = 31 years) and Hurricane Ridge (N = 37 years) are shorter (Fig. 5). There was a significant correlation between the time series for all three areas (Deer Park and Cox Valley, $R^2 = 0.81$, $P < 0.001$; Deer Park and Hurricane Ridge $R^2 = 0.86$, $P < 0.001$, Cox Valley and Hurricane Ridge $R^2 = 0.89$, $P < 0.001$).

Houston et al.' s (1994c) claim that the winters were more severe after Steven's (1983) study, and the start of removals of goats from the park is true for only two years. In fact, the trend for all three survey areas is significantly downward (Deer Park, $R^2 = 0.51$, $P < 0.001$; Cox Valley, $R^2 = 0.17$, $P < 0.001$; Hurricane Ridge, $R^2 = 0.36$, $P < 0.001$). Thus, the winters on average have grown progressively milder over the record, and particularly since 1970 (Fig 5). This would argue against winter mortality being more than an incidental factor in the discrepancy between the 1983 helicopter count and subsequent statistics.

In summary, therefore, winter mortality might have been high in more severe winters, but this suggestion is entirely hypothetical, and not supported by a historical record of winter die-off in hard winters. Perhaps mountain goats can merely move further down slope in response to snow depth. On balance, the dependence on unsupported assumptions and complicated logic required to support the reliability of the 1983 helicopter estimate suggests the more parsimonious alternative that this estimate was too high.

## *Impact of mountain goats on vegetation*

Studies of the effects of mountain goat feeding and trampling on plants are the most difficult part of the Olympic National Park research record to understand and evaluate. This is partly due to the complexity of these interactions, but more so to the lack of clear research design, consistency, and often, frustratingly confused presentation.

In the discussion below I make the following points.

1. Attribution of plant responses to the activity of goats is handicapped by a lack of baseline data from before goats were present.
2. Gravity, snow slipping, freezing and thawing, and wind are the major factors on these rocky, steep habitats, and they override and obscure the impact of goats.
3. Heterogeneity is extreme on a micro scale due to topography, climate, fire, and biotic relationships. These variables, plus the influences of salting, human activities, and grazing by other herbivores complicates the design of sampling schemes.
4. Comparison of Klahhane Ridge with other areas is not valid because the latter are not appropriate control areas.

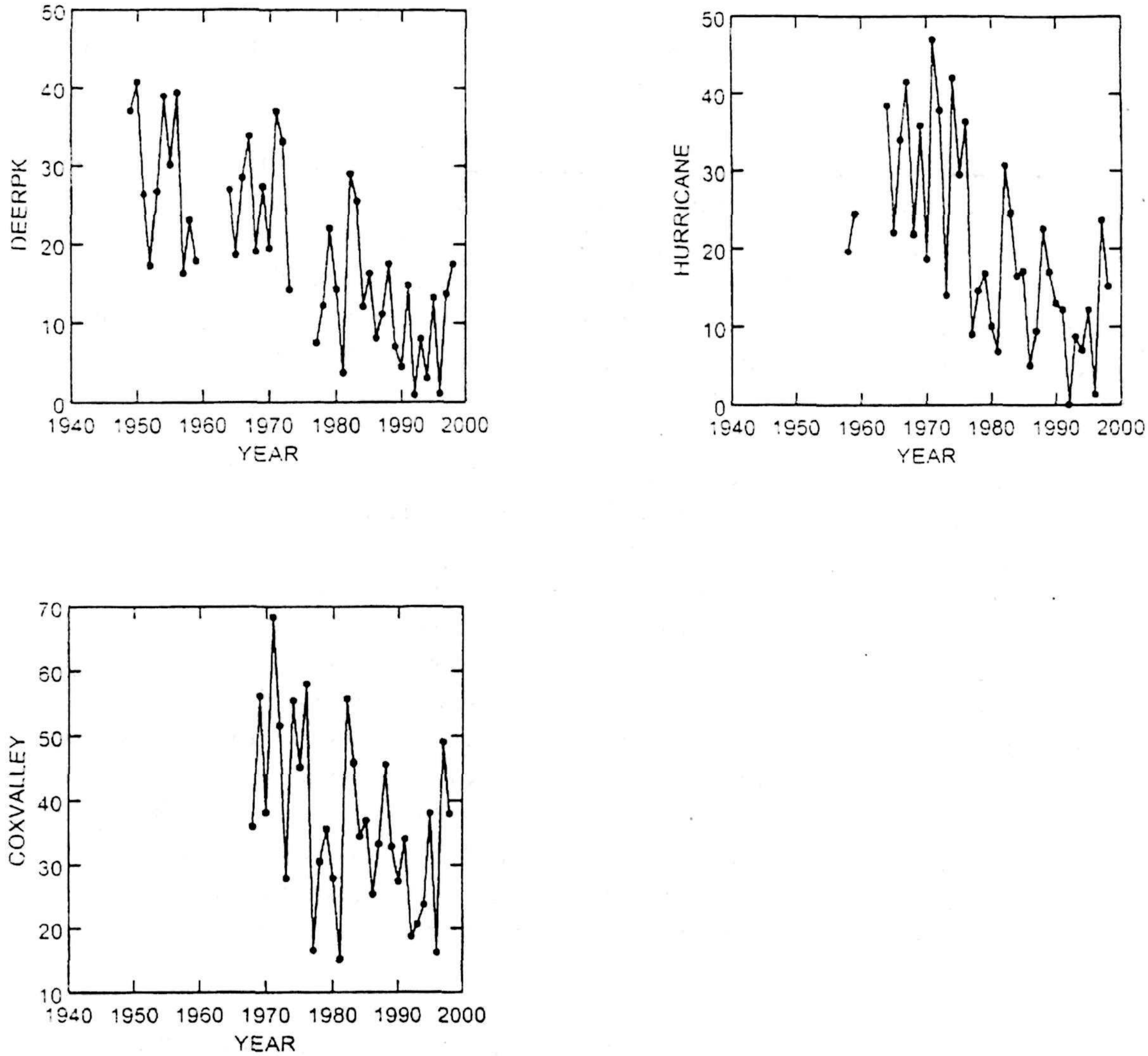



Fig. 5. Snow water equivalents at the end of April on three snow survey courses on the Olympic Peninsula, Deer Park, Hurricane Ridge, and Cox Valley (ftp://ftp.wa.nrcs.usda.gov/pub/snow/data/historic/snow/clall.txt) used to indicate winter severity. Snow water equivalents were significantly correlated between the three areas ($P < 0.001$) and all three show a significant downward trend over time ($P < 0.001$).

5. It is axiomatic that mountain goats are having some impact on the vegetation and soils, but the vegetation work reviewed here is not adequate to sort out what is due to goats and what to other variables, even on a relative scale.

Prime mountain goat habitat is extreme. It is a salient characteristic of the species. They select the rockiest, steepest terrain, which is naturally unstable independent of the activity of goats. Because such areas are located in the highest parts of mountain ranges, climate also is extreme. Gravity, freezing and thawing, and other forces are responsible for continually shifting substrates and little soil formation. Plant populations are in a continuous state of flux and occurrence of wildfires further complicates the picture. The consequent heterogeneity is extreme. Goats are simply one more disturbance factor that interacts with all of the rest.

Ideally, natural factors would have been studied in the absence of goats (prior to arrival) so subsequent data could be compared to derive the additional effects of goats. This is not possible at this time. Two approaches have been used instead. One is a comparative approach, using subpopulations with low goat density to compare with the high goat density of Klahhane Ridge. This approach suffers from the several areas not being comparable beyond a superficial level, as will be explored below. The second approach was the use of exclosures, which theoretically should have been a powerful way to reveal the impact of goats by their sudden exclusion from some areas, and continued grazing on others. Unfortunately, the study design of exclosure research was not very good, and was further weakened by false starts with exclosures that were too small, inconsistent application of methods, poor matching of paired treatment and control plots, and inadequate replication. Ultimately, variables could not be separated, and the design lacked statistical power. These workers are not unique in this regard. Grazing exclosure studies, in general, have been characterized by poor design.

Great heterogeneity of the alpine environment, and especially mountain goat habitat, has plagued both study approaches. Vegetation units are too small and patchy to stratify very effectively, and any defined stratum of reasonable size (as in the vegetation communities described by Pfitsch et al. 1983) has such high variance that the number of replications required to sample it becomes prohibitive. The alternative is to be selective of sites to compare for grazing impacts, and not attempt to characterize the larger landscape. In this design one can isolate what impacts goats are having on small plots, but at the cost of losing generality. The choices come down to pursuing generality at the requirement of tremendous replication or seeking selectivity at the expense of generality. Many of the vegetation studies reviewed here failed to deal with this distinction, and inadvertently fell out somewhere in between--thus doing neither very well.

First, consider the comparative approach between Klahhane Ridge with high goat density and other areas (such as Tyler Peak) with low goat density. Many of the problems have been outlined by Reid (1983:26-29). Despite the difficulties, this is the best vegetation work, mostly done by a series of graduate students at the University of Washington (Pfitsch 1981, Pike 1981, Reid 1983). Limitations of this research are acknowledged by these authors, and they are circumspect about what can be concluded about the separate impact of mountain goats versus other grazers, human impacts and natural processes--climate and geologic processes.

Still, I think they over-emphasize the comparability between sites. This is most clearly revealed in Pike (1981). In searching this paper, one finds that although Klahhane Ridge (treatment area) and Tyler Peak (control area) may have similar elevations, Klahhane Ridge has an average exposure of 212 degrees whereas Tyler Peak is 190 degrees. The more western exposure of Klahhane Ridge would be expected to be hotter and drier. Slope of the study site on Klahhane Ridge was 30 degrees and Tyler 24 degrees, an important difference when applied to angles approaching the angle of repose in unstable substrate materials. One would ordinarily expect that erosion would be greater, more bare substrate would be exposed, plant cover would be less, and species composition shifted in favor of disturbance species on Klahhane Ridge. Klahhane Ridge is further west (and therefore less affected by the rain shadow than Tyler Peak: snow-melt was later and water content was greater at Klahhane Ridge (although snow surveys were rather far from either site, 5 and 10 km, respectively, so that this comparison may not be valid). Different abundances of grazers suggest different habitat characteristics: at Klahhane Ridge deer were fewer, mountain beaver and marmots more, and only percentages of snowshoe hares were similar.

Finally, and most telling because it is cumulative over very long time periods, is the occurrence of Alaska cypress (*Chamaecyparis nootkatensis*) at Klahhane Ridge, and lodgepole pine (*Pinus contorta*) at Tyler Peak. These differences are consistent with a more mesic environment at Klahhane Ridge, and more extreme environmental conditions than Tyler Peak independent of mountain goats. Indeed, the low number of mountain goats at Tyler Peak may be due to these differences, rather than the impact of goats being responsible for the differences--i.e., the goat is a response variable rather than a driving variable.

In view of the lack of appropriate matched sites, exclosure studies take on a greater importance. The exclosure studies reported here, however, are lacking in rigor. Exclosures varied in size (some being far too small) and length of time monitored since erection. Methods were inconsistent and poorly designed. As noted earlier, this is typical of exclosure studies, most of which were established to monitor trends without recognizing that monitoring requires equal attention to design as does research.

The logic of exclosures seems not to have been followed. Essentially they are a factorial experiment with exposed versus exclosed on one axis, and grazing on the other. Grazing may have levels (which most of these studies had), or only one level in which case it is a paired plot study. The number of replications per cell needs to go up in proportion to the heterogeneity of the sample population, and all sites need to be selected at random (in the strict, rather than haphazard sense) to achieve generality with power. This design usually is not feasible under field conditions like Olympic National Park because of the logistics of getting materials into the rugged backcountry and the amount of labor to construct them. Also, because of human use of the park, it is desirable to minimize the number of artificial structures.

A minimal study involves paired plots, which give up generality in order to detect changes on given sites--usually some that have a high likelihood of revealing change. In this approach it is not possible to assess the larger consequence of grazing. It can not even be inferred because

inferential statistics requires that the population of interest be sampled. Only subjective judgment is available to relate the results obtained from selected plots to the whole. For paired plots to be valid, even within the confined inferential context, they must be carefully matched, and the one selected for exclosure picked by a random procedure. Because of heterogeneity, no two plots are going to be exactly the same. Still, pre-treatment assessment by the same methods to be applied after the exclosure is constructed is one way to establish the similarity of the plots. If they are not highly similar, it is not valid to attribute changes following exclosure to the grazing animal. If other grazing animals do not have equal access to both of the paired plots, the attribution to any differences of one of them is complicated by the failure to exclude the effects of the other.

The exclosure studies at Olympic National Park suffered multiple deficiencies, and the design was never explicitly stated in statistical terms, including the satisfaction of the assumptions of the models to be applied. Too many objectives were attempted, so that none were done well. The descriptions of methods are complex, convoluted, and difficult to understand. One is left with the impression that yes, mountain goats almost certainly had some impact on vegetation in the unenclosed plots (most people would concede that without any study) but that it is impossible from these studies to sort the relative effects of mountain goats from other variables. First, background environmental change in these highly unstable environments is very great. As Pike (1981) notes, "Snow creep and other downward movement is a considerable force on these slopes. Unstable, highly stressed habitats make seedling establishment extremely difficult" (p. 124), and "Steel exclosure posts were bent 20-30 degrees during the 1979-80 winter by snow creep" (p. 144).

Many, if not most of the changes in the exclosure studies could be due to these environmental forces. Reid (1983:26) notes that Pfitsch and Bliss (1984) attributed recovery of *Festuca idahoensis* to mountain goat exclusion, but "...accumulating evidence showing later-lying snow and thus a period of increased soil moisture inside the 1976 exclosures may also partially explain this pattern." Furthermore, consider the plant composition changes reported by Schreiner (1986) in which total vascular plant cover is lowest on low grazing plots and highest on moderate plots. If goats were the driving variable, plant cover should have been lowest on high grazing plots, highest on low grazing plots, and intermediate on moderate grazing plots. Similarly, when palatability of plant species were sorted into preferred, avoided, or neutral, the greatest relative change was in the neutral species (Schreiner 1986), again suggesting that environmental forces are of greater magnitude than grazing in their impact on these plant communities. Even the conclusions about the impact of mountain goats on Idaho fescue and *Carex spectabilis*, the most preferred plants, is compromised by the concurrent influence of other grazing animals.

It is axiomatic that grazing by mountain goats is having some impact on the vegetation of Olympic National Park. But the plant studies reviewed here are not sufficient to assign a statistically defensible magnitude to those impacts attributable to mountain goats, versus those due to other variables. Grazing effects may be of minor importance anyway, since most of the plant researchers have concluded that trampling, wallowing, and other direct mechanical

effects of mountain goats are more detrimental to the vegetation than grazing per se (e.g., Pike 1981, Pfitsch et al. 1983).

Comparison of photos from times before goats were present (or abundant) with recent repeats is another means by which mountain goat impacts on the vegetation are presented. Many of the photos are too indistinct to judge. Those in Shreiner and Burger (1994), I presume, were selected from the larger set on the basis that they showed goat impacts more clearly. Nevertheless, I had a hard time distinguishing many of the differences noted in the captions. Other differences to my eye between the photos were not remarked on. Some apparent differences may not be real because the paired photos were taken at different times after snowmelt (so seasonal effects may be reflected), or with different lighting. Furthermore, the differences may be attributable to natural causes or to other grazers. Lyman (1998) argues that the same matched pairs of photographs have had caption changes that shifted over time from more guarded interpretations to ones that are more damning of the impact of goats. Whether intentional or not, such does seem to be the case in some of the examples he presents. In any event, the photographs clear enough to be made out are weak evidence about impact of goats on vegetation.

### *Impact of mountain goats through trailing, trampling, and wallowing*

Studies of the impact of mountain goats on soils have characteristics similar to those of vegetation. The unstable environment and high heterogeneity make determining the influences of goats versus other factors very difficult. The points made in the following section are virtually the same as those at the beginning of the vegetation review section, so they are not repeated here.

Most authors, including both university-based researchers and park scientists, agree that the major impact on the environment is direct disturbance on the substrate. This would seem to be prima facie evidence that mountain goat trailing and wallowing, in combination with unstable 30 degree slopes is devastating to the soils. Reid (1983) noted that erosion was worst in the early and late seasons when needle ice, snowmelt, and rainfall are greatest, and this is when goats made most use of south-facing meadows where goat wallows are concentrated. Still, that correlation in time makes it difficult to sort out the effects of a naturally harsh environment versus the effects of goats. The general tenor of these presentations is that goat activities cause erosion in what would otherwise be stable slopes. But how can one determine that erosion is not an on-going process to which goats further contribute? Is it 80% natural and 20% goat activity, or the reverse, or what?

Other things about the impact of goats on the substrate are troubling. For example, studies following given known and mapped wallows are not followed through on. Why aren't such studies, which would seem most definitive, completed (Pfitsch et al. 1983)? Pfitsch et al. (1983) mention that mapping the boundaries of the wallows is difficult. Why? One would think that if goat wallowing were so pervasive and damaging, the edges would be fairly easily demarcated. Or, are the effects more ephemeral and obscured by succession? Is there

evidence that the large blowout area on Klahhane Ridge was initiated by goats and amplified by wind, or was the reverse true? What is the documentation for the estimate of 40 tons of soil lost from one wallow (Lyman 1998)? This quantity was frequently quoted in the various materials reviewed, but no citation was ever given. Nor did I find a study that seemed to warrant such an estimate. E. Schreiner (Olympic National Park biologist, 1999, personal communication) stated that this estimate came from estimating the size of the "pit" created by goat activities, multiplied by the weight of the soil presumed to be there before the disturbance.

What is the role of anthropogenic influences of salting and urination? Apparently until about 1983 the Park Service purposefully put out salt to attract goats to where they could be captured by rope foot snares or observed easily by park visitors, and urine of visitors contributed further to the problem. It is curious that the early reports of Moorhead (1977, 1981) referred to a human salting and urination problem, rather than a goat wallowing problem, that the Park Service needed to address. Why was further work not done on the influence of salting, length of time the residue attracted goats, and other studies that would help distinguish natural behavior of goats versus artificial concentration and consumption of soil induced by salting? This question seems particularly relevant in view of the demonstration of Henderson (1984) that salting altered goat use and goats produced impacts on soils and vegetation in one year.

Finally, the evidence suggests that the areas heavily impacted by goats are localized. It is obvious that goats are influencing soils to some extent. However, the degree of such impacts are not clear in the face of the widespread erosion due to natural causes on extreme slopes and in the face of disturbances due to snow movement, water flow, and an array of other mammalian effects.

## *Conclusions about mountain goat impacts*

There is little doubt that mountain goats are having some impact on the soils and vegetation of Olympic National Park. The question is how much impact, and is the contention of the Park Service that it is unacceptably high sustainable by scientific evidence? Several critics of the Park Service maintain that the scientific evidence is weak, and compromised by the attempts of the Park Service to justify an unsupportable policy of mountain goat eradication from the Park.

I conclude that the research on vegetation and stability of substrates is not adequate to separate the effects of mountain goats from those due to natural processes, other grazing animals, or humans. In the large picture, topography and climate are the predominant forces in these systems. Vegetation slows and redirects those processes to some degree. Grazing by goats and other animals and disturbance by humans influences the system indirectly by altering vegetation, and directly by disturbing substrates. Gravity, rainfall, freezing and thawing, fire, and snow sliding do the rest. Sorting out the influence of one variable, goats, from other sources of disturbance, and assigning the cascading effects of that disturbance is a daunting task.

In fairness to the researchers in Olympic National Park, it needs to be emphasized that the questions addressed are inherently complex, and complicated by numerous interconnections. One could hardly pick a much more difficult environment in which to design good research than the high peaks of the Olympic Peninsula. But, unfortunately for these researchers, they did not have the luxury of selecting a study site--the mountain goats did that for them. The goal of all research is to control most variables so the influence of one or two variables will be revealed. There is very high variance in all ecological systems, and the extreme conditions of topography and climate of Olympic National Park exacerbates the problem. Because the researchers could not control most of the variables, they were dependent on nature to present a useful experiment over space and time. Typically, nature is not sympathetic to human aspirations.

These inherent difficulties are made worse by the logistic problems of reaching remote study sites, transporting materials and living necessities, and attempting to avoid further disturbance of the system by research activities. Status as a national park imposes another set of constraints in that all manipulations need to be kept to a minimum. Visitors want to see and photograph mountain goats without eartags or collars in their natural environment that--given past anthropogenic influences--is more an illusion than reality. Wilderness in the lower 48 states largely has been tamed, but that does not take away from the importance to visitors of the sense that they are connecting with unadulterated nature.

The research conducted in Olympic National Park, considered as a whole, is as good as research done elsewhere under similar conditions and constraints. A fair proportion has been subjected to peer review. It must be kept in mind that all field research is subject to shortcomings to a greater or lesser degree. Published papers vary in quality, but none are perfect. All papers are subject to questions of adequacy of design and fairness of conclusions. Given that science is a relative instead of absolute process, authors are given a certain amount of license in the area of interpretation--usually termed the "discussion." The quality of the original design is an important area for debate, for it sets the limits on the strength of the test and the limits to inference from the results.

## Report of Cathy Whitlock

### *Paleoecologic and environmental history of the Olympic Peninsula*

This review was undertaken to address the question of whether present populations of mountain goats (*Oreamnos americanus*) in Olympic National Park are exotic and, thus, a component of the ecosystem that has no historical precedence. The information that I examined included site-specific reports, review papers on environmental history, and previous reports and correspondence specifically addressing the mountain goat status in Olympic National Park. Lyman (1998, 1988) hypothesizes that mountain goats could have dispersed to the Olympic Peninsula during the last glaciation and a population could have persisted there up to historic time (Lyman 1988). If true, mountain goats would have to be considered part of the

native fauna. My analysis of this hypothesis and its plausibility is based on my understanding of the glacial history of western Washington (Crandell 1964, 1965; Carson 1970; Thorson 1980; Waitt and Thorson 1983; Booth 1987; Easterbrook 1992; Thackray 1996;), the vegetation history of western Washington (Heusser 1977, 1983; Tsukada et al. 1981; Barnosky 1984; Barnosky et al. 1987; Cwynar 1987; Whitlock 1992; McLachlan and Brubaker 1995; Brubaker and McLachlan 1996; Gavin and Brubaker 1998), and the climate history of the Pacific Northwest (Barnosky et al. 1987; Thompson et al. 1993). Much of this literature has been accurately summarized by Houston and Schreiner (1994d). In all cases, the ages are presented as radiocarbon years before present (yr BP).

**Conditions during the Fraser Glaciation**

The Pacific Northwest has experienced multiple glaciations in the last 2 million years, although the extent of ice cover on the Olympic Peninsula is well known only for the last few glaciations. Ice cover during the last glaciation, the Fraser Glaciation (ca. 25,000-10,000 yr BP; Crandell 1965; Waitt and Thorson 1983), was not as great as in previous periods, probably because earlier glacial advances occurred when the climate was cool and wet (Thackray 1996). The climate during the last glacial maximum was cold and dry (Thompson et al. 1993).

The Fraser Glaciation in western Washington featured three distinct ice advances. The greatest alpine advances in the Olympic Mountains and Cascade Range occurred during the Evans Creek Stade (ca. 25,000-17,000 yr BP). This period coincided with the time of maximum ice-sheet development in the Northern Hemisphere, but the Cordilleran ice sheet was relatively small in size and confined to the Coast Range of British Columbia. Lowered sea level during this period extended the coastline some 30-50 km farther west, and the marine embayment of Puget Sound was not present; thus the Puget Trough was a dry valley. The Cordilleran ice sheet advanced into Washington State after 18,000 yr BP and reached its maximum during the Vashon Stade (ca. 15,000-13,500 yr BP). At its maximum, ice lobes occupied the northern and central Puget Trough and the present-day Strait of Juan de Fuca (Waitt and Thorson 1983). Alpine glaciers retreated upvalley during the Vashon Stade, and the valleys of the Cascade Range and Olympic Mountains supported glacially dammed lakes. The interfluves at middle and lower elevation also were unglaciated at this time. The primary drainage of the Puget lobe was south and westward down the Chehalis River valley (Thorson 1980). The Puget lobe reached its maximum position south of Olympia Washington at ca. 14,500 yr BP and began to recede almost immediately. The glacier had retreated to Canada by ca. 13,000 to 12,500 yr BP. A final advance of Cordilleran ice to the International Boundary occurred during the Sumas Stade (ca. 11,500-10,500 yr BP) (Easterbrook 1992).

Pollen data from the western Olympic Peninsula (Heusser 1977, 1983) indicate that the lowlands were covered by tundra parkland during the Evans Creek Stade. Upper treeline was lowered as much as 1000 m, allowing the spread of alpine and subalpine communities to low elevations. Along the Pacific slope, spruce, pine, mountain hemlock, and western hemlock formed communities that resembled the subalpine zone of the Olympic Mountains today. In

the Puget Trough, subalpine communities included Engelmann spruce, lodgepole pine, and subalpine fir. The closest analogue for these communities is the modern subalpine parkland of the northern Rocky Mountains (Barnosky et al. 1987). Paleoclimate reconstructions from the Puget Trough suggest that the climate was 5-7 °C cooler than today and annual precipitation was 1000 mm less during the Evans Creek Stade (Whitlock 1992). On the west side of the Olympic Peninsula, conditions were cold, but probably more humid than in the Puget Trough.

During the Vashon Stade, temperate species, including alder, pine, hemlock, and spruce, started to expand in the western Olympic Peninsula (Heusser 1977, 1983). In the Puget Trough, the flora shifted toward more mesophytic taxa, including mountain hemlock and Sitka spruce (Barnosky 1984). Based on comparisons with modern pollen assemblages, the vegetation in the Puget Trough resembled present-day high-elevation communities in the western Cascade Range and eastern Olympic Peninsula. Temperature estimates based on pollen data suggest that the mean annual temperature was 2-6 °C below present, and precipitation was at present levels (Thompson et al. 1993). The advance of Cordilleran ice and the change in vegetation during the Vashon Stade were likely related to the northward shift of the jet stream between 18,000 and 12,000 yr BP. This change in atmospheric circulation would have brought winter precipitation to southwestern British Columbia and Washington and created warmer and wetter conditions than occurred during the Evans Creek Stade (Thompson et al. 1993).

With retreat of Cordilleran ice after ca. 13,500 yr BP, the Puget Trough was invaded first by lodgepole pine, a taxon which can disperse rapidly and grow on poorly-developed soil (Whitlock 1992). Between 12,000 and 10,000 yr BP, lodgepole was joined by Sitka spruce, Douglas-fir, and western hemlock to form a closed forest. The presence of these taxa suggests that significant warming had occurred in the region following the Vashon Stade. In the rainshadow region of the northeastern Olympic Peninsula, open communities of herbs and shrubs were present between ca. 12,000 and 10,000 yr BP (Peterson et al. 1983). The Manis Mastodon site in this region supported an open woodland fauna that included mastodon, caribou, bison, black bear, and muskrat, but not mountain goat (Gustafson et al. 1979). Its location in the rainshadow of the Olympic Mountains and the coarse-textured outwash soils may partially explain the openness of the late-glacial vegetation. In the southern Puget Trough, vegetation changes associated with warming were first registered at 11,200 yr BP, when a mixture of high-elevation and low-elevation species grew together in closed forest (Barnosky 1984). After ca. 10,000 yr BP, additional warming allowed temperate conifers to expand at low elevations and restricted montane species to higher elevations.

**Holocene Environments**

The Holocene Epoch is the geologic interval that spans the last ca. 10,000 years. The warmest, effectively driest period of the last 120,000 years occurred in the early Holocene, from ca. 10,000-5000 yr BP. Summer drought was more severe than today, probably as a result of greater-than-present summer insolation and a strengthened northeastern Pacific subtropical high pressure system (Barnosky et al. 1987; Thompson et al. 1993). These

conditions led to more-frequent fires than at present in western Washington (Cwynar 1987; Gavin and Brubaker, unpublished data, 1999). Pollen data from the western and northeastern Olympic Peninsula indicate an expansion of Douglas-fir, bracken fern, and red alder (Heusser 1977; Brubaker and McLachlan 1996). At higher elevations in the northeastern Olympic Mountains, Sitka alder, fir, and Alaska cedar were present (Brubaker and McLachlan 1996). Early-Holocene forests in the Puget Trough featured more Douglas-fir, red alder, and bracken fern than today (Barnosky et al. 1987; Whitlock 1992; McLachlan and Brubaker 1995), and local prairies were expanded in the central Puget Trough (Tsukada et al. 1981). A mosaic of forest types probably existed in the lowlands as a result of the fire regime (Cwynar 1987): Alder and bracken fern were widespread in early successional forests, Douglas-fir was dominant in the intermediate stages, and western hemlock and spruce comprised the late-successional forests. Paleoecologic records from the Coast Range of British Columbia suggest that upper treeline was higher during the early Holocene, and the alpine zone was consequently smaller than at present (Clague and Mathewes 1989; Pellatt and Mathewes 1998). Estimates from the southeastern Coast Range indicate an upward shift of 60 m and possibly >130 m elevation (Clague and Mathewes 1989).

In the late Holocene, after ca. 6000-5000 yr BP, pollen records from all elevations indicate a shift towards wet-loving taxa. The change in vegetation is attributed to the onset of cool humid conditions that developed as summer insolation decreased to present levels (Whitlock 1992). At low elevations, an increase in western red cedar in the Olympic Peninsula began at ca. 7000 yr BP. Cedar spread northward into the northern Puget Trough by ca. 6000-5000 yr BP, and the central coast of British Columbia by ca. 4000 yr BP (Hebda and Mathewes 1984). In the lowlands of the Olympic Peninsula and Puget Trough, the spread of western red cedar was accompanied, or followed by, an increase in western hemlock and Sitka spruce between ca. 6000-4000 yr BP (McLachlan and Brubaker 1995; Cwynar 1987; Whitlock 1992). Western white pine also became locally abundant, and prairies in the central Puget Trough decreased from their early Holocene size. At high elevations in the northeastern Olympic Peninsula, the modern forest and climate developed at ca. 3000 yr BP (Brubaker and McLachlan 1996). The Slab Camp site, located in the montane zone, suggests closed forests after 5000 yr BP (Gallison 1994). At middle elevations on Mount Rainier, the present vegetation and cool conditions were established in the last 3500 years (Dunwiddie 1986). The shifts in vegetation correlate well with the timing of glacial advances between ca. 3500 and 2200 yr BP on Mount Rainier (Crandell and Miller 1974), and presumably in the Olympic Mountains as well.

Pollen data from the northeastern side of the Olympic Mountains suggest that the present mosaic of subalpine parkland and meadow was established at ca. 6000 yr BP (Gavin and Brubaker 1998). This particular study showed changes in the composition of subalpine meadow communities that implied variations in late Holocene climate. For example, an increase in *Polygonum bistortoides*-type pollen was explained as evidence of wetter-than-present summers during the Medieval Warm Period (ca. 1200-700 yr BP). The establishment of *Carex*-dominated community between ca. 500-1000 yr BP occurred during the Little Ice Age (Gavin and Brubaker 1998). The Little Ice Age also led to glacier advances on the highest peaks of the Olympic Mountains (Heusser 1957). The end of the Little Ice Age is evidenced

by the retreat of these glaciers in the 20th century (Spicer 1986). In addition, historic photographs from Olympic National Park show an upward shift in treeline and a closing of subalpine forests following the end of this cold period (Houston et al. 1994b).

## *Implications for the Mountain Goat Issue in ONP*

A native species, as defined by the National Park Service, is one whose presence is not the result of direct or indirect human action (Houston et al. 1994b). Despite a reasonably intensive search, no fossil or historical evidence has been discovered to indicate the presence of mountain goats on the Olympic Peninsula prior to their introduction in the 1920s. Therefore, it is unlikely that mountain goats were part of the native fauna.

On the other hand, the hypothesis that mountain goats could have been present on the Olympic Peninsula in prehistoric times (Lyman 1988, 1998) cannot be refuted by the absence of fossil evidence. The optimal period for goat colonization would have been during the Evans Creek Stade (25,000-18,000 yr BP), when the climate was unusually cold and dry and the lowlands were unglaciated. Extensive parkland vegetation at low and middle elevations would have provided habitat for mountain goats to extend their range into the Olympic Mountains from the north, south, or east. We know from the fossil record that the extinct *Oreamnos harringtoni* extended into the southern Rockies and Southwest during Pleistocene glacial periods (Lyman 1998). Inasmuch as this biogeographic shift would have forced mountain goats to cross major mountain ranges, valleys, and river systems, the Puget Trough during Evans Creek time was probably not a significant barrier.

During most of the late Quaternary, the Olympic Mountains were isolated from the Cascade Range and the rest of the Coast Range by ice, forest, and water. When the Cordilleran ice sheet extended into Washington State (18,000-13,000 yr BP; Easterbrook 1992), the opportunities for colonization probably were reduced. At its glacial maximum, the ice sheet dammed valleys in the Cascade Range and Olympic Mountains, creating large ice-marginal lakes. Spill-over from these lakes cut steep channels along the Cascade and Olympic fronts (Crandell 1965; Thorson 1980. These features may have been barriers to faunal dispersal along the eastern and northern margins of the Peninsula. The Puget lobe drained southwestward to the Chehalis River valley and westward to the Pacific Ocean (Booth 1987). This meltwater could have blocked a southern corridor to the Olympic Mountains as well. It is possible, nonetheless, that mountain goats crossed these barriers or traversed the ice sheet itself to reach the Olympic Peninsula, but again there is no corroborating evidence.

Following the retreat of Cordilleran ice, seawater entered the deglaciated Strait of Juan de Fuca and the Puget Trough (Easterbrook 1992), creating a new potential barrier for mountain goat movement. This marine incursion would have blocked passage along the eastern and northern margin. After ca. 13,500 yr BP and especially after ca. 10,000 yr BP, the climate warmed sufficiently for the development of forest at low elevations. Closed vegetation may have hindered dispersal of mountain goats into the Olympic Peninsula from the south.

The subalpine and alpine zones in the Olympic Mountains have been truly isolated from that of adjacent mountains for the last 10,000 years. This alpine "island" was smallest during the early Holocene (ca. 10,000-6000 yr BP), when climate was warmer and treeline was higher than present. In the last ca. 6000 years, the alpine/subalpine region has changed little from its present extent. If closed forest is an impediment to goat dispersal, then goats probably did not arrive during the Holocene or previous interglaciations. It should be noted, however, that introduced goats were released in closed forest near Lake Crescent and managed to move to high elevations (Houston et al. 1994b). Mountain goats in Olympic National Park also travel to lower forested elevations to escape severe winter conditions (Houston et al. 1994b). So, forests may not pose a significant barrier for mountain goat dispersal.

A report by Schalk (1993) on the archeology and ethnography makes a strong case that mountain goats were not present on the Olympic Peninsula. A few concerns raised by the report, however, still apply to the interpretation of archeological record from the Olympic Peninsula: First, the number of archeological sites is relatively small, and the bones recovered thus far cannot be considered a comprehensive record of faunal composition (Grayson 1981). Second, most sites are coastal and far from goat summer range; this reduces the possibility of finding their bones in most sites. Archeological reconnaissance of high-elevation areas is underway, and to date neither mountain goat bones nor hunting structures of the type associated with mountain goats elsewhere have been found (P. Gleeson, Olympic National Park researcher,1999, personal communication). It is unlikely that bones will be preserved in these high-elevation areas of shallow soil and active solifluction; however, the few cave/rock shelters in the Park may preserve faunal remains and should be explored thoroughly. Small unidentified bone fragments have been found in preliminary excavations from one rockshelter (P. Gleeson, Olympic National Park researcher, 1999, personal communication). Third, nearly all the sites are late Holocene (i.e., the last 5000 years) in age, and most are less than 1000 years old. This age range does not span periods when subalpine habitats, preferred by mountain goats, were more widespread. I am aware of two old sites: the Manis Mastodon site (Gustafson et al. 1979) of late-glacial age and the Slab Camp archeological site (Gallison 1994) of early Holocene age. Neither contained remains of mountain goat.

Schalk (1993) considered most of the archeological records from the Olympic Peninsula and Lyman (1998) examined additional sites. Mountain goat bones were absent from all sites, with the possible exception of horn ladles recovered at LaPush Village (Reagan 1917). The spoons were fashioned from big horn sheep or mountain goat according to Reagan. It is not clear whether the account (actually a footnote) refers to artifacts collected specifically at the LaPush site or whether it was a more general observation. Such ladles were widely traded among coastal tribes (Schalk 1993). The California Academy of Sciences, which represents one of the institutions that may house some of Reagan's collections, currently has no goat horn ladles from the Olympic Peninsula in their collection. They do, however, have horn ladles from Vancouver Island (Russell Harman, Anthropology Department, 1999, personal communication). Later excavations at LaPush did not yield mountain goat remains, and the fact that horns usually decompose in coastal archeological sites casts some uncertainty on the identification. Schalk (1993) also doubted the accuracy of other faunal identifications in

Reagan (1917). Thus, there are several questions about the Reagan (1917) report that weaken its credibility as an account of prehistoric mountain goats on the Olympic Peninsula.

A review of ethnographic documents indicated that mountain goats were not part of the Olympic fauna in the 1800s (Schalk 1993). Coastal tribes obtained mountain goat wool and horns through an extensive trade network, and the goat materials found on the Peninsula were probably trade items from the Cascade Range and the Coast Range of British Columbia and southeast Alaska. Dogs were kept by the Quinault, Quileute, Makah, Klallam, and Twana peoples as a source of wool, which further suggests that goats were not locally available. Schalk (1993) found it significant that mountain goats were not part of the folklore, mythology, or decorative art. If mountain goats were hunted in the Olympic Mountains, he expected to find a description or reference in local ethnographic accounts.

An examination of historical documents also concluded that mountain goats were probably not present on the Olympic Peninsula from the 1750s to early 1900s (Schultz 1993). Scientific expeditions of the 1880s and 1890s that passed through areas of suitable habitat did not report mountain goats. Naturalists, biologists, and longtime local residents who spent considerable time hiking the Olympic Mountains also reported no mountain goats. Lyman (1993) and Anunsen and Anunsen (1995), however, point to three accounts of goats on the Peninsula: (a) a reference in the 1896 National Geographic by S.C. Gilman; (b) an 1890 Seattle Press article, which describes the Press Expedition; and (c) an article by Fannin and Grinnell in 1890 that places "white goats" in the Olympic Mountains. Schultz (1994) discounted the validity of these sources because they lacked observational detail. The accounts are secondary reports that did not provide information on the circumstances, location, or date of a goat sighting. Moreover, the reports contain other apparent inaccuracies. The Gilman (1896) account described the presence of partridge, which is not found on the Olympic Peninsula. The reference to a goat (but not specifically mountain goat) in the Seattle Press article occurred in a summary article, but goats were not mentioned in either of the explorers' daily journals (Schultz 1994). The same newspaper article also referred to the presence of chicken. (Lyman (1998) suggests that partridge and chicken in these accounts may have been native grouse.) Fannin and Grinnell (1890) offered a general description of mountain goat occurrence, but erroneously placed mountain goats in southern California and Colorado (Schultz, Olympic National Park researcher, 1999, personal communication). In addition, the reference in Fannin and Grinnell (1890) to goats in the Olympic Peninsula is indirect and does not offer specific locations. The absence of goat sightings during more extensive scientific expeditions tends to support the view that goat populations were not present in historic time prior to their introduction in the 1920s.

In conclusion, mountain goats could have reached the Olympic Peninsula during the last glacial maximum, taking advantage of the changes in climate, vegetation, and hydrology that occurred then. There is no evidence that they did, however, and the scenario remains speculation only. The paleoecologic record also suggests that high-elevation environments would have been suitable for mountain goats through the Holocene, and, assuming they got there, it is not clear why a population did not survive to historic time. Lyman (1988) argues that, at best, one can conclude only that mountain goats were *probably* not present in prehistoric time, and thus their

exotic status today can never be proven with certainty. This statement is true, of course, but a comprehensive review over the last decade has produced no data to suggest that these animals have had a long history on the Olympic Peninsula. The few controversial accounts (e.g., Reagan 1917; Gilman 1896; and Barnes 1890; Fannin and Grinnell 1890) are problematic and not convincing. The preponderance of information suggests that (1) *Oreamnos americanus* was not native to the Olympic Peninsula, and (2) the release of goats in the 1920s introduced a new large herbivore to the alpine ecosystem.

## Report of Russ Graham

### *Hypothesis*

It is virtually impossible to prove that mountain goats never occurred on the Olympic Peninsula because proof of this hypothesis would be based on negative, rather than positive, evidence. Lack of evidence could result for a variety of reasons (poor sampling, undiscovered records, or even destruction of records) which may be independent of either the absence or presence of mountain goats. Therefore, the only refutable hypothesis is: *Mountain goats never occurred (or did not occur at specific times) on the Olympic Peninsula.*

### *Criteria for Refutation*

To refute the above hypothesis it is mandatory to have thoroughly documented evidence that mountain goats did occur on the Olympic Peninsula at one time. The best evidence would be a specimen that was collected at a specific time in the past. Documentation should include preservation of the specimen in a public repository with photographs or illustrations, and written accounts with maps and drawings. This type of documentation could come from a specimen of a living animal collected in historic times or it could be a paleontological/zooarcheological specimen recovered by excavation. Another strong form of evidence would be a written document with photographs or illustrations by a credible source (a person familiar with mountain goats) which could be a scientist, explorer, or casual traveler.

Anecdotal reports in newspapers, especially without photographs and other pertinent data, are of questionable utility. Photographs and personal accounts are also of low quality unless they are substantiated by information identifying the photographer or narrator, location and time of the photograph, and authenticity of the photograph (an original). Ethnographic accounts would be of interest but they can not be viewed as direct evidence for the presence of the animal. Stories and myths should be weighted the same as anecdotal newspaper accounts or stories told about other mythical creatures. Ethnographic materials like bone tools, effigies, skins, etc. could be transported by humans and therefore do not necessarily denote the point of origin.

## *The Evidence*

To date, I believe that there is no evidence to refute the hypothesis that mountain goats never inhabited the Olympic Peninsula. Lyman (1998) reached the same conclusion after reviewing all materials available to him. Furthermore, I have reviewed the FAUNMAP database (Faunmap Working Group 1994) which records archeological and paleontological sites in the contiguous 48 states of the US with mammal remains for the last 40,000 years. It did not contain any records of mountain goats on the Olympic Peninsula.

One equivocal case is the report in a footnote by Reagan (1917:16) of ladles made of mountain goat and bighorn sheep (*Ovis canadensis*) horns from middens at the La Push Village Site. Although Reagan refers to them as made from horns, these types of ladles are generally made from horn sheath and not the boney horn core. Horn core sheath does not normally preserve well over long periods of time. Reagan does not indicate how many of these objects were recovered or from where in the site they were found; and he does not illustrate them. Attempts to find these specimens in collections at various institutions associated with Reagan, especially the California and Utah Academy of Sciences, have been futile (Jennifer Seavey, Michael P. Williams Consulting, Inc., September 7, 1999, personal communication). The California Academy does have horn sheath ladles in their collections but they are from British Columbia.

Finally, the context of these specimens at La Push is questionable. La Push is located on the coast of the Olympic Peninsula, clearly not a typical environment for mountain goats. Therefore it must be surmised that the animals were killed elsewhere. It is possible that the goats could have been taken on the Olympic Peninsula at higher elevations and brought to the coastal site. Huelsbeck's (1983) analysis of more than 250,000 mammal bones from the Ozette Site, another coastal culture, indicated that their subsistence was primarily from marine resources with little emphasis on land mammals. In fact, he believed that even deer and elk were processed at kill sites and only selective remains returned to the village.

However, it is just as likely that the specimens were derived through trade or warfare and not from mountain goats from the Olympic Peninsula. For example, Reagan (1917:12) indicates that enemies of the La Push Villagers were killed and that their remains and materials were discarded at the cave-burial place at La Push. Furthermore, he notes that "The stone implements found [at the cave-burial place] are made from stone that is not found in the region and must have been brought there in implement form by the person with whom it was interred." The fate of the mountain goat and bighorn sheep ladles could have been the same as the extraneous stone tools. Further credence is leant to this idea by the presence of bighorn sheep ladles since bighorn sheep are also not known from the Olympic Mountains.

More recently, Duncan (1977) conducted test excavations at the La Push site and did not report the remains of mountain goat. Her report was a preliminary interim report but she (p. 9) did note the occurrence of northern fur seal (*Callorhinus ursinus*), and California sea lion (*Zallophus californicus*). She used vernacular names to list other taxa like whale, sea birds, mallard, beaver, elk, and fish. Interestingly, she did note the absence of harbor seal.

Therefore, she would have more than likely reported any mountain goat remains if they had been found or recognized.

There are other archeological and paleontological sites known from the Olympic Peninsula but the absence of mountain goat remains (negative evidence) is not evidence for the absence of mountain goats. Lack of mountain goat remains from fossil sites could result from location of sites in environments not inhabited by mountain goats. The Manis Mastodon site (Gustafson et al. 1979) contains remains of late Pleistocene mammals, including several extirpated taxa, but its location in the lowlands would tend to preclude the presence of mountain goat habitats. Finally, absence of mountain goat fossils could be due to the lack of high altitude paleontological and archeological sites. Furthermore, the predominance of volcanic rocks instead of cave forming carbonate rocks (limestones, dolomite, etc.) significantly reduces the probability of recovering a fossil record from higher elevations. High elevation sites also are characterized by erosion rather than deposition and are, therefore, not conducive to fossil preservation.

I have not included comments on photographs, mountaineering expeditions, newspaper accounts, or scientific surveys since they have been adequately reviewed by McCullough (this report). My comments would be redundant.

## *Biogeographic Models*

Biogeographic models do not provide definitive evidence for the existence of taxa in specific regions. Instead, these models can provide a probability statement about the likelihood of taxa dispersing to various areas at certain times. Lyman (1998:149-201) provides a good review of the application of biogeographic models and the Quaternary biology of mountain goats to the potential existence of mountain goats on the Olympic Peninsula. McCullough (this report) and Whitlock (this report) provide further discussion of this issue with regards to past environments and mountain goat habitat and behavior. I believe that biogeographic models have little relevance to the issue, although they are quite interesting for deriving refutable hypotheses. In fact, as stated by Lyman (1998:196), "The evidence presented here [with regards to biogeographic models in his book] is, at best, indirect. It does not unequivocally indicate that mountain goats were present on the Olympic Mountains prior to the 1925 transplant. The only evidence that will provide such an indication must come from the fossil [/archeological] record." Obviously, historical records as discussed in the section on *Criteria for Refutation* would also apply.

## *Conclusion*

*There is no direct evidence to refute the hypothesis that mountain goats never occupied the Olympic Peninsula.*

## Report of Mike Williams

### *Introduction*

This review is directed towards the plant ecology studies conducted by the National Park Service (NPS) to determine if mountain goat populations (*Oreamnos americanus*) were having adverse impacts to the natural resources of Olympic National Park. These impacts can be divided into two classes: 1) on the alpine and subalpine vegetation of the Olympic Mountains and 2) on rare and imperiled plant species. These studies were necessary in that, assuming that the mountain goat is an exotic species to the Olympic National Park, National Park Service policy requires that adverse impacts from exotic species be documented prior to their removal from the park or other control efforts (National Park Service 1988).

The following discussion represents my professional opinion, based on my review of materials I have been provided during the course of the team's review of relevant documents. The use of the term "relevant" within this section applies to those documents I specifically found to be relevant to my particular area of expertise, plant ecology. This term as used within this section may or may not be appropriate for the relevance of such documents to other team members and their specific written opinions.

I also have limited my discussion to the impact studies on the vegetation and rare plants and have not addressed the faunal, archeological and historical evidence of goat occurrence, as this is outside my area of expertise.

### *Methods*

I have reviewed documents listed on the project bibliography that are relevant to my specific discipline. I have examined all of those that in my professional opinion were relevant to my area of expertise. Outside sources were examined as appropriate and I have requested any such outside sources be added to the project bibliography.

I also have participated in interviews with park service staff at the headquarters building in Port Angeles on 16-17 August 1999. Those NPS staff present for the interviews included E. Schreiner, D. Houston, R. Olson, P. Gleason, S. Schultz, and K. Hoffman. I also attended the helicopter tour of the park on 16 August 1999. The tour guide was Rich Olson of the NPS staff. There was abundant cloud cover over much of the high country of the park during the tour. Our route concentrated around Mt. Dana, over Enchanted Valley, E. Fork of the Quinault, Piro's Spire, Mt. Constance, Mt. Deception, Mt. Mystery, Mt. Claywood and Hayden Pass, and Sentinel Peak.

## *Results*

I find that the NPS staff has attempted in the past to study the impact of mountain goats on vegetation and rare plants with a wide variety of studies and approaches. I did not find any attempt by the NPS staff to prevent examination of any document or to influence my review in any way. Their comments during interviews and the tour were technically based and appropriate briefings for such a review. Their past studies, while extensive, have been limited in some years due to funding shortfalls, and most recently by curtailment of most field work pending the outcome of the review of the decisions and management recommendations reached during the EIS process. All in all, I think they have made a thorough and commendable effort to document what impacts, if any, mountain goats are having on NPS resources.

### Alpine and Subalpine Vegetation Impact Studies

The impact studies began as far back as the early 1970s and have continued up to the present time, in part. A monograph summarizing the findings up to the 1993 field season was published in 1994 (Houston et al. 1994b). It includes a number of papers dealing with mountain goat biology, history of occurrence, and studies following activity of mountain goats in relation to alpine vegetation and populations of rare, endemic plants.

A photographic series of comparisons (Schreiner and Burger, 1994 in Chapter 11, Houston et al. 1994b) offers inconclusive findings for changes in vegetation cover considering the highly variable phenology and cover of alpine landscapes and problems associated with replicate and consistent photography. In examining these series, I find that the plant phenology is often not well discussed. Many of the apparent differences between years could be attributed to phenological differences, related to climate, and not differences in cover resulting from goat grazing. In looking at the photoseries along with the climatic data (i.e., snowpack and precipitation data for the years examined), my impression is that climate may have had a more substantial effect than the goats. In such comparisons, "effective dates of the growing season" should be developed and used as the criterion to match photos rather than a calendar date. The comparable photographs must be taken to match exactly the shadowing and time of day of the originals. It is not clear that this is the case in the photographs I examined.

In one photo (Plate 1), a bare slope was identified in a 1915-20s photo, yet no discussion as to other processes that initiate alpine bare slopes was presented besides goat impact. Obviously, assuming the goats are not native, this bare slope was created prior to goat establishment. The frequency of fire in the 1900s, for example, also may be related to disturbances within the alpine and subalpine, which may have even exceeded goat impacts. Kuramoto and Bliss (1970) note that the lack of snowpack can result in soil stripping during the winter storm periods. I have personally observed "blow outs" in these snow-free areas during intense early winter storms in years with low or late snowpack in the subalpine zone of the Sierra Nevada of eastern California, and I am certain such events occur in the Olympic Mountains.

The precipitation and snowmelt differences also should be examined in relation to the specific years and the time of the season. In Plate 9a, an 11-year difference is compared, but the time of year of the high goat population photo is also 15 days earlier in a vegetation zone with a very short growing season (< 90 days). This photographic difference could be related to phenology and a lower snowpack in the later photo (Hurricane Snow Course Data: 1970 snow depth on April 24 was 55 inches with a 18.6 water equivalent; 1981 snow depth was 19 inches with a water equivalent of 6.8 inches; ftp://ftp.wa.nrcs.usda.gov/pub/snow/data/historic/snow/). Reduced snowpack in 1981 (35% of the 1970 snowpack) and insulating cover could have affected the vegetation between these two years. In the next figure (Plate 9b), which shows two photos differing in their respective years by five days, the authors comment that the differences may be due to phenology, yet this point is not made on any other photoseries, even though others have considerably more separation in time. Kuramoto and Bliss (1970) emphasized that depth of snowpack determines the time of initiation and duration of the growing season. Any photographic analysis should include with each comparison details of the snowpack and time of melt off. This also should be based on as local a data set as possible due to considerable differences in snowpack within the Olympic Mountains (Houston et al. 1994b).

The NPS should use such photo comparisons cautiously. Many of the changes supposedly seen in the photo series were attributed to mountain goats. One statement clearly reflects this potential bias: "Modifications of vegetation and soils by mountain goats were visible even though goat effects were superimposed on those driven by climate, fire and humans." After examining the photo series both in the monograph (Houston et al. 1994b) and at the NPS office, I cannot concur, because the patterns do not seem so clear-cut. Some of the photos are taken at different times of the day, such that shadowing differences complicate the ability to discern vegetation differences. The expansion of forest in much of the subalpine (see Plate 1 and 2) since the turn of the century can be attributed to changes in climate (Franklin et al. 1971; C. Whitlock, University of Oregon Paleoecologist, 1999, personal communication), but other processes may have been at work in these areas which may have provided additional disturbances, including changing frequency of fires and possibly increased disturbance from aboriginal use for late-summer food harvests. Separating out the mountain goat landform impacts from those promoted by other causes, in my opinion, is not easily done using simple photographic comparisons.

The actual impact to the vegetation from grazing is clear in the immediate area of wallows, where all vegetation is removed. It is interesting that the wallows are frequently abandoned and new wallows used (E. Schreiner, Olympic National Park biologist, 1999, personal communication). Color slides shown to the team at the NPS office on 16 August 1999 showed fairly rapid (< 5 yrs.) recolonization of abandoned wallows and trails by alpine plants. However, the actual adverse impact to the alpine and subalpine landscape has not been clearly shown. Pfitsch and Bliss (1984) state that "Despite the high densities of mountain goats on Klahhane Ridge, indications of severe damage to their habitat by overgrazing, such as the prevalence of unpalatable species, are lacking." They continued, "While wallows are common and the composition of plant communities is changed in their immediate vicinity...the wallows do not appreciably reduce the amount of forage available to the goats." This

statement is supported by the earlier work of Pfistch et al. (1983) and Reid (1983). Certain shifts in dominant plant species were observed, but this would not necessarily be deemed damage to vegetation by most ecologists. Bell and Bliss (1973) also did not observe an overall detrimental effect of mountain goats on the alpine vegetation of the Olympic Mountains.

Little clear evidence is offered that mountain goat grazing has severely impacted the subalpine and alpine landscape. Much of the disturbance can be tied to physical processes, not to mountain goats solely. Even some of the wallow areas may be initiated by other factors (Houston et al. 1994b), although most of the smaller wallows can be tied to the goats. The areal extent of the active wallows is not obvious in the NPS reports. How the presence of these wallows and other goat-related disturbances affect the vegetation is not clear. In fact, Pfitsch and Bliss (1984) comment that the results of a 5-year study at Klahhane Ridge using exclosures "...supports the idea that these subalpine plant communities are structured primarily by the severity of the physical environment, with competitive interactions playing a minor role." I would concur based on the examination of much of the findings presented in the work to date.

### Impacts to Rare Plants

The obvious message in rare plant population trend data, both in the Olympic National Park and elsewhere, is that clear patterns in plant populations from grazing impacts and other activities of herbivores are difficult to determine. Rare plants often are found in areas with abundant native grazers; moreover, rarity alone does not indicate that a species is endangered. Many species have evolved with grazing; the presence of grazing within their habitats does not necessarily indicate a threat. In fact, many species of plants are aided in dispersal by grazers, and grazers actually can diversify the habitat, allowing for colonization of rare species, which do not compete well, in closed vegetation. The same may be said with respect to responses of plants to the wallows created by goats. Polley and Wallace (1986) found that grassland species diversity increased in association with buffalo wallows due to increased microsite heterogeneity.

The NPS staff have stated clearly (Schreiner et al. 1994, Chapter 12, Rare Plants, in Houston et al. 1994b) that "the extent of herbivory by mountain goats on rare plants was difficult to assess because so few rare taxa occurred in plots." This being the case, finding statistical significance in changes in shoot density of rare, geophytic plants in a highly disturbed landscape like the alpine and subalpine zones, may be a poor indicator of population status. I found no clear trends in any of the studies of rare plants with regard to detrimental impacts clearly attributable to mountain goats, outside of wallows created on top of existing plants. That these impacts lessen the performance of the plant populations is questionable.

Schreiner et al. 1994 (in Houston et al. 1994b, Chapter 12) admit that their findings are inconclusive. I would concur, based on their studies specifically looking at "damage" to herbaceous perennials, which, in the case of geophytes, often are capable of surviving such injury and may even receive stimuli to produce more below-ground apical meristems from such

"damage." High variability within the vegetation-forming processes typical of alpine areas complicates the interpretation of analyses in these systems (Del Moral 1983). Specific habitat occurrences of a number of rare species (e.g., rock crevices) do not seem to have been evaluated in the studies by Schreiner et al. 1994, likely due to the considerable difficulty in replicate sampling of rarely occurring species in highly variable terrain.

More specific discussion is offered on *Astragalus australis* Lam. var. *olympicus* Isley, a herbaceous perennial (Houston et al. 1994b). [This species also is known in the literature as *Astragalus cottonii* Jones]. This genus *Astragalus* has evolved with grazing or other forms of surface disturbance, and most of the species are geophytes or cryptophytes, that is, plant species with the root crown or caudex protected beneath the soil surface (Barneby 1964). The Olympic Mountains milk-vetch has a caudex buried 2-7 cm below the surface (Barneby 1964). One can assume that some type of biotic wallow or wallow-like formation likely occurred in the postglacial habitat of *Astragalus australis* var. *olympicus*, considering the diversity of postglacial fauna prior to extinctions. I believe it is difficult to say that wallowing or disturbances like wallows directly reduce the overall populations of *Astragalus*. This genus of plants is often associated with disturbances (personal observations). It is known to occur on scree and talus slopes and is restricted to the Olympic Mountains on NPS land in the alpine and subalpine areas (Barneby 1964; Buckingham, 1981; Schreiner et al. 1994).

Buckingham (1981) observes no predation on *Astragalus* (as *A. cottonii*) even though goat tracks were observed in the population in the vicinity of Hurricane Hill. This report goes on to state that "With goats, deer, rabbits and marmots on the sites, it would appear that *Astragalus* is generally avoided by the larger animals." In fact, Pfitsch and Bliss (1984) and Pfistch et al. (1983) list *A. australis* var. *olympicus* as a non-selected forage species by mountain goats. This appears to be substantiated in other reports such as those of Kaye (1989) and Buckingham (1981), although death of four plants by goats is reported by Schreiner et al (1994).

Kaye (1989) finds that plant decline of *Astragalus* in permanent trend plots occurred but the cause is unknown. He goes on to state that "the infrequent and sporadic nature of these goat disturbances in *Astragalus australis* var. *olympicus* populations, however, makes goat impact an unlikely explanation for recent population declines, especially at Hurricane Hill where goat impact was consistently low. *A. australis* var. *olympicus* was probably rare in the Olympic Mountains before mountain goats were introduced." (pp. 89-90).

The difficulty in equating damage to individual plants with impacts to a plant population is considerable, especially in highly-perturbed habitats such as those seen in the alpine and subalpine zones. Germination and seedling establishment can be highly variable and microsite-specific. In later studies (Schreiner et al. 1994, p. 181) seedling establishment of *Astragalus* was shown to have been considerable in some years with survival into the next year, yet it is not clear at what levels of goat activity the seedlings were observed. Non-seedling plants did not show clear trends in relation to goat removal. One site (Blue Mountain-NE) with low goat populations did not appear to vary from a site with higher goat populations (Hurricane Hill), although the figures do not show error bars. Plant mortality is also vague as presented in Schreiner et al. (1994). Plant death is not clearly explained; it seemed that E. Schreiner

(Olympic National Park biologist, 1999, personal communication) was suggesting that in some years the plant was "gone" and then in subsequent years it "came back." I would have to presume that the plant was still alive and resprouted from an existing crown. This plant could not then be considered "dead." This observation would not reflect a change in the populations. I have had similar observations in rare *Astragalus* populations in the Intermountain West, where intense grazing pressure by domestic cattle often does not result in the death of plants, but rather a loss in above-ground shoots in one growing season. With reduced grazing in subsequent years, the existing crown resprouts.

Some limited studies have continued or were initiated by NPS staff to follow population dynamics of *Astragalus australis* var. *olympicus* (E. Schreiner, Olympic National Park biologist, 1999, personal communication) up to the present, but these data were not yet available in written form. The observed trend was that in exclosures or in areas with reduced goat populations, for the most part, populations of *Astragalus* increased. However, in one case the populations of the milk-vetch declined last year after two years of increased abundance (E. Schreiner, Olympic National Park bioloigst, 1999, personal communication). We were not provided these data, but such a trend is what I would expect from my own experience with exclosures elsewhere. The expected increase in abundance inside the exclosure is not observed. This may be the result of rapid expansion of other species, typically dominants within the exclosure, or other factors. The point is that exclosures, while seemingly a simple solution to grazing impacts, may bring about unexpected results in the rare species populations.

NPS studies to date have focused on plant cover decline with goat population increases, but plant cover can not always be equated with fecundity and reproductive success (Harper 1977). Their studies (Pfitsch et al. 1983, p. 106) state that flowers and fruit of *Campanula piperi* were higher in number at Klahhane Ridge plants, where the goat populations were greatest. Pike concludes by stating: "Based on the results of this study, it is not evident that these species are seriously impacted by mountain goat grazing, except where soils are removed around rock masses," and "...This is not to say that all three species receive little impact by goat grazing, only that there is no clear evidence of plant population reduction as a result of high goat density."

## *Discussion*

Alpine vegetation is characterized as developing under intense disturbance regimes (Billings 1974, Bliss 1971, Bliss 1985). With extremes of diurnal and seasonal temperatures, seasonal precipitation differences, extreme winds and storm effects in the alpine and subalpine zones, the resulting vegetation's composition and pattern are tightly linked to the physical conditions of the microsite (Kuramoto and Bliss 1970). Trends in vegetation in such environments associated with ungulates such as the mountain goat have to be evaluated carefully and over long time intervals.

The complexity of the system is exemplified by the difficulty in conducting research in these environments. Field plots can be difficult to place in a randomized fashion due to shallow soils, rock outcrops, presence of snowpack fields, and other microsite factors. Locating study plots to overlap rare plants can be exceedingly difficult considering the plant's rarity and patchiness (Houston et al. 1994b). Seasonal variability and snowpack-induced patchiness confounds resampling on a regular basis. In 1999 in the Olympic Peninsula, a snowpack 300% larger than the previous year has prevented any sampling consistent with the sampling periods in previous years (E. Schreiner, Olympic National Park biologist, 1999, personal communication).

Exclosures (typically fencing and wire frames) can introduce considerable error into a study; hence, extreme care must be taken if they are to be employed appropriately. Exclosures can affect snowpack accumulation, temperature, shading, animal activity patterns, and nutrient status. Size of the exclosures is often critical to obtaining statistically significant data. Moreover, the cost of building exclosures in the alpine zone and the difficulty in maintaining them beyond one season can severely limit the ability of a researcher to employ them and receive a reasonable assurance of statistical validity. Long-term studies must follow exclosures to determine if the species intended to be protected by such means might actually fare better outside the exclosure. This has been my personal observation in numerous exclosure studies in the Intermountain West, where growth by other species, typically dominants inside the exclosure, was such that the rare species were found in relatively greater abundance outside the exclosure than inside the exclosure.

I would urge the NPS to use caution in stating that populations of *Astragalus australis* var. *olympicus* are adversely impacted by mountain goat grazing and trampling. Wallowing clearly removes plants in the wallows, although the long-term heterogeneity provided by the wallowing over the landscape may actually benefit seedling establishment by this species on the abandoned wallows. I concur with Schreiner et al. 1994 (in Houston et al. 1994b) that considerably more study is required to determine population trends of rare plant species in reduced mountain goat areas. However, until such studies are conducted, definitive statements linking mountain goat abundance to declining populations or vigor of rare species are unfounded.

One particular concern I had in examining the documents was the comment made in the monograph (Schreiner et al. 1994, p. 184.), which stated "Even though we were unable to quantify the risk mountain goats pose to the persistence of rare plant populations, it is clear that mountain goats do affect and kill individual plants through grazing, wallowing, and trampling." This statement is misleading, as grazing and trampling alone have not been shown to kill these plants, although certainly these activities may "affect" the rare species. The draft EIS has taken this farther by stating, "Goats damage and kill milk-vetch plants by eating them, trampling them, and wallowing on them." This statement is attributed directly to the monograph (Houston et al. 1994b). The placement of this statement in the EIS makes the problem appear much more severe than has actually been shown and certainly implies that grazing and trampling by goats kill plants. As I have discussed above, this may not be the case. This statement in the EIS should be revised to follow closely the scientific studies and

should be precisely written to avoid any misunderstandings. Grazing and trampling have not been shown to kill the *Astragalus* plants by the studies I have examined.

### *Research Recommendations*

Continue and expand long-term population trend studies of *Astragalus australis* var. *olympicus* to include annual variation of plant cover in relation to snowpack. Detailed population studies are needed to determine if the presence of mountain goats may actually benefit this species by seed dispersal and gut scarification and possible manuring benefits. Additional years following the exclosure studies should be sampled to determine trends within the exclosures. The results commented on by E. Schreiner to the team on 16 August 1999 regarding a decline in an *Astragalus* population within an exclosure should be written up and made available to management and the EIS staff. Review of impacts from the exclosures themselves and feasibility of developing appropriate sized exclosures should be made. Other control areas should be developed and compared with exclosure studies.

Develop large-scale vegetation mapping to include analyses of recolonization of abandoned wallows and trails, and the areal extent of active vs. abandoned wallows and trails.

Provide a greater database of vegetation response to snowmelt and snowpack accumulation to understand the heterogeneity within the alpine/subalpine zone microsites with varying climate regime. Such work is necessary to clearly associate declines in vegetative cover with the presence and abundance of mountain goats. Without such studies the annual climatic variation typical of any alpine zone overwhelms other causes of variation in cover of dominant or rare species of plants.

In future work, the NPS should clarify what is meant by "damage." It needs to be clearly presented how grazing damage affects the plant population's fecundity to the point the population has actually been harmed. For example, has there been a study that shows conclusively that *Astragalus* produces fewer seed and/or growing points when grazed by mountain goats beyond the first year of study? To date, I do not believe there has been such a study. Plant death should be assumed only when individual root crowns are actually found to be dead.

Additional climate-related studies should be conducted in the goat and non-goat areas to look at solifluction and formation of bare areas such as "blow outs" in years of low snow cover with or without goats.

## Report of Fred Ramsey

### *Are mountain goats native to the Olympic Peninsula?*

The evidence against native populations in the recent past--say the last several centuries--was summarized well in Susan Schultz's Appendix B to The Draft Environmental Impact Statement (National Park Service 1995). The case against her conclusion was best explained by Anunsen and Anunsen (1993). There is an additional plethora of other documents addressing the issue, but most offer nothing but recapitulation and argumentation.

Very little evidence supports the existence of a native population. On the other hand, the evidence denying it is not overwhelming. The appended timeline (Fig. 6), based on Schultz, shows that most of the referenced explorations occurred after 1875. Four occurred before 1880, with one--the first: Spanish Coastal Exploration of 1790-92--reporting mountain goats from the peninsula. Schultz's attempts to discredit this reference were damaging but not convincing. The evidence offered by Schultz would not, in my opinion, defeat a scenario in which a small native population is put under duress and possibly exterminated in the mid-to-late nineteenth century by predators forced inland by human encroachment onto the peninsula.

If goats were native, should there be skeletal evidence? Stevens states that "Mountain goats are particularly elusive after death for animals of their size. This is a result of ruggedness of the terrain they inhabit and the action of scavengers, snow, rain, small mammals and bacteria. All of the above can act quickly in a damp wilderness." (Stevens et al. 1979, p. 46). In a study of 43 radio-collared mountain goats in southeast Alaska, six deaths were observed with five being the result of avalanches (Schoen and Kirchoff 1982). Both documents comment that time on the winter range, which represents at least half of a goat's existence, is when most of the mortality occurs and is spent at lower elevations. Lyman (1998) also argues that very little effort has been expended searching for goat remains in the places where they most likely would be found.

In short, the evidence is weak both ways. Though the evidence favors no native population's existence, park personnel who act on that being fact should give some thought to their possible response to someone coming in with skeletal remains, after all the existing goats have been removed.

## *Are mountain goats likely to exterminate native vegetation?*

Considerable effort has been given to studying how mountain goat herbivory and wallowing affects the vegetative structure of various plant communities. I am aware that studies of biological and ecological systems are a difficult task. However, my opinion is that their efforts were largely ineffectual.

The kinds of studies to which I refer here are typically those reported by Schreiner (1984,1986, 1987, and 1989), by Pfitsch (1981), and by Driver et al. (1978, 1979). Permanent plots were established and monitored, some with no controls whatsoever. Some plots were paired with exclosures on one of the pairs with the other being a control. Before and after pictures were examined. There is no suggestion that the plots were selected in any way that would be representative of a wider range of situations. There is no mention of the simple device of flipping a coin to randomize the choice of which receives the exclosure. In an

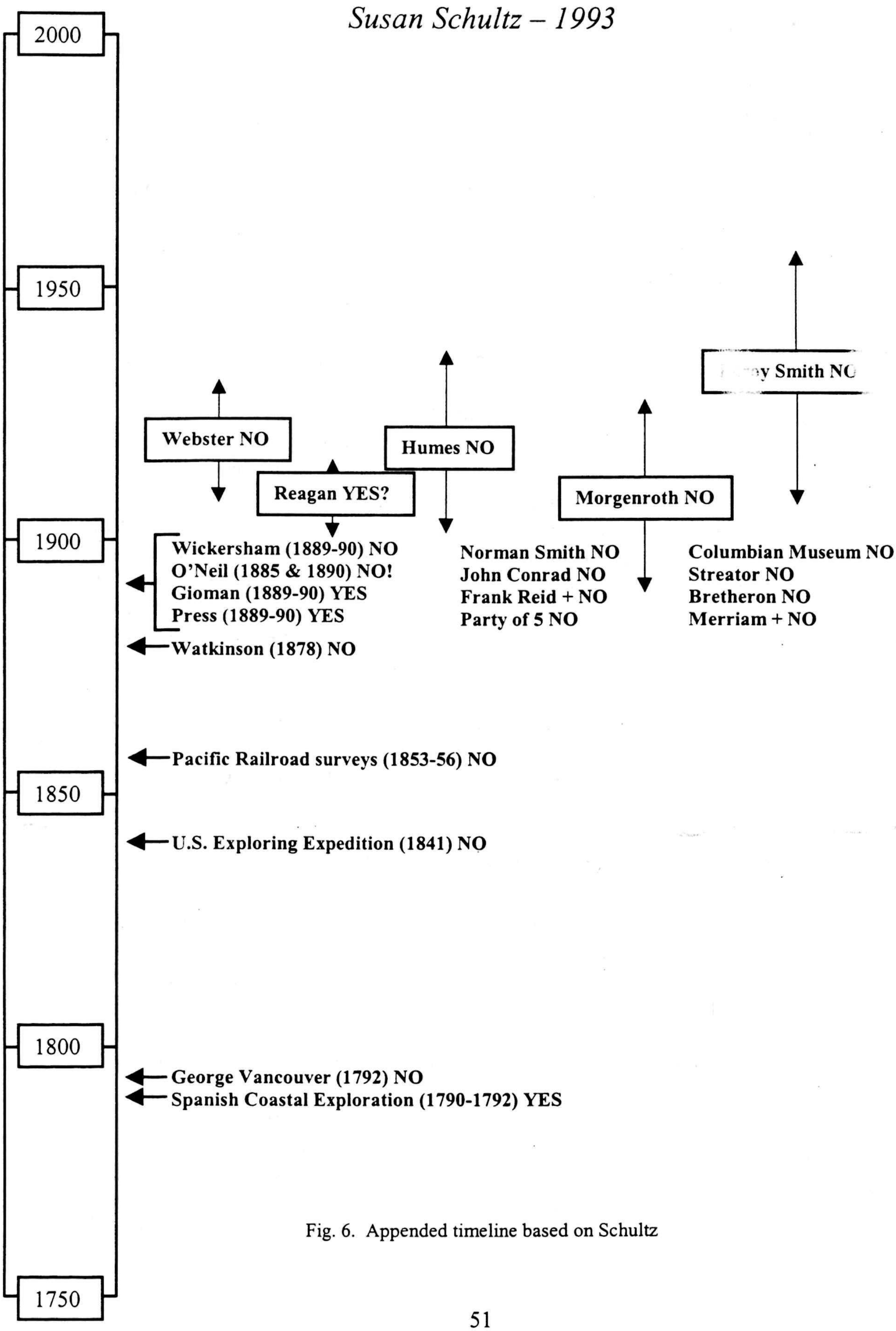



Fig. 6. Appended timeline based on Schultz

attempt to conjure evidentiary information, these investigators subsample the plots and analyze the results as though each subsample was an independent case.

This is bad science at its worst. Yet the difficult-game excuse cannot be used. In Schreiner's (1974) Master's Thesis, he reported the results of a study of human trampling that was designed as an actual randomized experiment. This 1974 document is the earliest of his reports, so he was clearly aware of the design principles that should have been used in his later studies.

Mountain goats may indeed pose a serious threat to sensitive native plants. It is unfortunate that none of these studies were capable--by their design--of determining the extent of the threat.

## *How many goats are there?*

Estimating the numbers of animals in the park may be the most difficult task faced by ONP researchers. It is a notorious statistical problem to estimate population sizes under the best of conditions. Researchers working in this area must consider how detectability varies with terrain, weather, time of year, observer, etc., whether animals are detected in groups or individually, whether prior detection influences current detection, whether animals react strongly to the presence of observers, and on and on.

Mountain goats in ONP are not an ideal subject for censusing. Many of the problems listed here are certainly present in mountain goat estimation. Yet little was done by these researchers to study or correct for them. The researchers adopted a simple methodology based on mark/recapture estimation, and they unquestioningly applied it. This may not necessarily have produced estimates that are far off the mark, however, since the procedures do possess a certain degree of robustness.

Measuring uncertainty is particularly difficult, and here the researchers have clearly overstated the strength of their results. To see how, one must go back to Houston's 1983 report (Houston et al. 1983), in which they used an "index-manipulation-index" (IMI) method to estimate the amount of undercounting by aerial surveys. An aerial count was made in early 1983. Then a known number of goats were removed. Finally another aerial count was made. The reduction in counts divided by the known reduction in population size was used to estimate the fraction of the populations which is counted in an aerial survey. Some 52 goats were removed. With 132.5 counted initially (average of two counts on consecutive mornings) and 99 counted after removal, the drop in numbers was 33.5. The known drop being 52, the fraction observed was 33.5/52, or 0.64. Doing this for three consecutive years resulted in 0.66.

This is an estimate. No uncertainty was attached to it in the report. If one ignores the possibility that the detectability factor may change systematically from year to year and from early to late surveying, a reasonable level of uncertainty for the estimate is that the true value lies somewhere between 0.54 and 0.80.

After this report, all subsequent attempts to estimate populations sizes have used the 0.66 factor as though it were as immutable as 3.14159 [Pi]. Researchers have commented harshly on the sizes of confidence intervals, and they have taken steps to reduce them. But the true situation is that these confidence intervals do not reflect an uncertainty in the 0.66 number.

In summary, my opinion is that the confidence intervals accompanying population estimates are wildly optimistic. Uncertainty about 0.66 is just one instance of variability not considered.

## DISCUSSION

The team members' individual reports, offered above, although providing somewhat different perspectives of the issues examined, converge on a number of common themes. We all agree that the available data are imperfect and incapable of providing absolutely conclusive answers to the key questions posed in this review. Such is the nature of science under any conditions. In the case of the mountain goat in the Olympic Mountains, scientific uncertainty is compounded by the extreme and highly variable nature of the alpine environment, the difficulty of conducting properly replicated studies in such an environment, the poor conditions for preservation of fossil materials, inadequate funding for research, and other challenges. Despite these difficulties, team members arrived at similar conclusions for most of the issues examined. We agree that the available evidence supports reasonably definitive conclusions. The following is a summary of the team's responses to the five fundamental questions (lumped into two main issues) posed earlier.

<u>1. Whether mountain goats are native to the Olympic Peninsula; and 2. How several major periods of glaciation and subsequent postglacial events influenced the biogeography and ecology of the Olympic Peninsula.</u>

The consensus of our team is that the preponderance of evidence supports the view that the mountain goat has never been native to the Olympic Peninsula. Although negative evidence is not proof of absence (Lyman 1998), there is no direct evidence to refute the testable hypothesis that mountain goats never occurred in the Olympic Peninsula prior to their introduction in the 1920s. Furthermore, given the paleoecologic and environmental history of the Olympic Peninsula, our team considers the probability relatively low that goats could have colonized the Peninsula at some time in the past.

McCullough, Whitlock, Ramsey, and Graham, in their reports (above) considered the question of whether the mountain goat is native to the Peninsula. Noss also considered this question, though not in a separate report. The reviews by McCullough and Whitlock of the paleoecological and historical evidence are detailed, and these two reviewers suggest that the goat should be considered an exotic species in the Olympics. We believe that the available scientific evidence that bears on this issue is reasonably thorough, although more work searching for faunal and archeological remains in appropriate habitats (e.g., caves, potential goat wintering sites) would be helpful. Although we agree with Lyman (1998) that the review of geology and zoogeography by Houston et al. (1994b) is (in McCullough's words) not as

"meticulous about details" as it should have been, the main points made by Houston et al. (1994b) about glacial history and about the Olympics being depauperate in fauna compared to the Cascade Range, are valid. For reasons mentioned in McCullough's review, Lyman's (1988) proposal that mountain goats could have colonized the Olympic Peninsula by crossing the Puget Lowlands around 17,000-13,000 BP does not have much support. Indeed, as pointed out in Whitlock's review, conditions for dispersal of goats to the Olympic Peninsula were potentially most favorable during the Evans Creek Stade (ca. 25,000-17,000 yr BP). Still, because of lack of rock outcrops and other key features of mountain goat habitat in the potential dispersal zone, we consider colonization of the Peninsula by mountain goats at any time unlikely.

Whitlock provides a succinct but thorough review of the paleoecologic and environmental history of the Olympic Peninsula. The series of glaciations over the past 2 million years (i.e., the Quaternary Period) has had marked influences on the Peninsula's landforms, biogeographic history, and present-day biota. The Olympic Mountains were isolated by ice, forest, and water during most of the Quaternary. As noted, the Evans Creek Stade of 25,000-18,000 years ago appears to be the period of minimal isolation. Pollen evidence suggests that the lowlands of the Peninsula were covered by tundra parkland during the Evans Creek Stade, the time of greatest alpine advances in the Olympic and Cascade ranges. Upper treeline was as much as 1000 m lower than today. With sea level lower during this period, the western coastline extended 30-50 m beyond today's, and the Puget Trough was a dry valley. The lowlands were unglaciated. Nevertheless, no evidence exists for mountain goats in the Olympics during the Evans Creek Stade or any other period. Opportunities for colonization by mountain goats were probably reduced 18,000-13,000 years ago, when the Cordilleran ice sheet extended into Washington state. Following the retreat of the Cordilleran ice, seawater entered the Puget Trough, continuing the isolation. A wide stretch of forest in the lowlands outside the Trough would have made colonization of the Peninsula by mountain goats from the south extremely unlikely, albeit goats are known to cross narrower stretches of closed forest (e.g., the goats introduced to the Peninsula were released in closed forest, and goats use closed forest in winter).

McCullough and Whitlock both note that the historical "evidence" supporting presence of mountain goats prior to the releases in the 1920s is extremely weak. Their reviews support the earlier conclusions of Schultz (1994) that the sources reporting presence of mountain goats in the Olympics are not credible. McCullough also mentions the recently located photograph of a female mountain goat and young, taken by Paul Richardson between 1908 and 1915. All of our team, except Graham and Ramsey, were able to study this original photograph. As McCullough notes, there is no evidence to suggest this photograph was taken in the Olympics, and several aspects of the habitat suggest it was taken elsewhere. Finally, if mountain goats were present on the Olympic Peninsula prior to the twentieth century, it is extremely curious that they do not appear in the folklore, mythology, or art of the native peoples, even though mountain goat horns are known to have been widely traded. Most of us consider the ethnographic evidence (as reviewed by Schalk 1993) a powerful argument for the absence of a population of mountain goats on the Peninsula prior to the introductions in the 1920s.

The review by Russ Graham brings out the important point that, because faunas change continually over time as species respond individualistically to environmental change in accordance with their tolerance limits, an arbitrary time line (say, 300 years in the past) for considering a species native or exotic lacks a scientific basis. The instability of communities makes it difficult to determine what is an invader. Although the NPS may draw the line for nativeness at 300 years ago, some scientists draw it at the late Pleistocene. Therefore, Graham suggests that "consideration should be given to ecosystem processes and not just lists of species that were present or absent at some arbitrary time."

After giving these caveats, Graham addresses the refutable hypothesis that "mountain goats never occurred (or did not occur at specific times) on the Olympic Peninsula." He discusses the criteria for refutation of this hypothesis, noting that the best evidence would be a well-documented specimen collected at a specific time in the past. He dismisses anecdotal reports and ethnographic accounts as indirect evidence, at best, noting that bone tools, effigies, skins, and other materials are often transported by humans and do not denote the point of origin. He suggests that biogeographic models, while interesting and useful for generating testable hypotheses, have little relevance to the question of nativeness, as they do not provide definitive evidence. He reviewed the FAUNMAP database (Faunmap Working Group 1994), which contains archeological and paleontological records of mammals for the last 40,000 years, and found that it contains no records of mountain goats from the Olympic Peninsula. Graham agrees with the other reviewers (e.g., see McCullough's review) that the brief account by Reagan (1917) of ladles made from horns of mountain goat and bighorn sheep, found at the La Push Village site, are equivocal. These horn ladles probably originated elsewhere. Therefore, Graham concludes that "there is no direct evidence to refute the hypothesis that mountain goats never occupied the Olympic Peninsula." None of the museums contacted (Washington State University, Makah Museum, University of Washington, California Academy of Sciences, University of Utah, and Kansas Academy of Science) had any information on ladles made of mountain goat parts and attributed to the Olympic Peninsula.

Ramsey's review is not enthusiastic about the quality of the evidence on either side of the native/exotic question. Ramsey suggests that "very little evidence supports the existence of a native population. On the other hand, the evidence denying it is not overwhelming." He notes that little effort has been expended searching for goat remains on their winter range, where remains might most likely be found (as pointed out by Lyman 1998). Acknowledging that the evidence is weak both ways, Ramsey concludes that "though the evidence favors no native population's existence, park personnel who act on that being fact should give some thought to their possible response to someone coming in with skeletal remains, after all the existing goats have been removed."

A verified find of mountain goat remains (other than traded items) on the Peninsula, dated prior to the 1920s, would falsify the hypothesis that mountain goats never occurred there. But such a find would not necessarily resolve the exotic species policy issue. As McCullough points out, the mastodon, caribou, and bison are all known from the Olympic Peninsula 9,000 or more years ago. Should these species be considered native? The general consensus of our team is as follows: The pre-European settlement scene that is usually considered a standard for

national parks (e.g., Leopold et al. 1963), although imperfect as a guide to what might naturally occur in the parks today or be sustained in the future, is nevertheless a more appropriate model than the Pleistocene, when conditions generally were more different from today's. Hence, we believe that the only evidence of mountain goats on the Peninsula that would indisputably verify their status as a native species would be remains from the last several centuries, prior to the introductions of the 1920s. Seeking out such possible remains should be a priority for research, but we would be surprised if any such remains are found.

3. How mountain goats currently interact with and affect other physical and biological entities and processes in Olympic National Park; 4. The nature and magnitude of impacts by goats, if any, on the components and processes of naturally evolving park ecosystems, and 5. Whether mountain goats are interfering with natural processes or systems, with the perpetuation of natural features or native species, or with the protection of endangered, threatened, or unique species.

For removal of mountain goats to be justified under the National Park Service's policy on exotics, they must not only be shown to be introduced, they must be shown to threaten park resources or public health. The reviewers on our team who explored this issue (McCullough, Williams, Ramsey, Noss) are in general agreement that the data available at this time are insufficient to establish that mountain goats are causing significant damage to vegetation, harming rare plants at a population level, or otherwise having deleterious impacts on the natural components and processes of the ecosystems they inhabit. We came to this conclusion reluctantly, as some of the plants in question are endemic to the Olympics, whereas the mountain goat that might threaten them is almost certainly exotic there and known to be common elsewhere. The endemics of the Olympics are irreplaceable; the mountain goat is not.

Crucial to the consideration of impacts is the question of how large goat populations have been and might become in the future. McCullough examines this question at length in his review. He concludes that the Olympic Peninsula population of mountain goats is not a true metapopulation because of the high interchange of individuals among habitat patches. The contradictions between the calculated population growth rate and the impacts of the goat removal program are most parsimoniously resolved by concluding that the 1983 population estimate, based on helicopter surveys, was erroneously high. McCullough also notes that helicopter censuses are useful for measures of trend, but cannot provide accurate estimates of population size because of problems with the correction factor. Similarly, Ramsey recognizes that "it is a notorious statistical problem to estimate population sizes under the best of conditions." Ramsey notes that the NPS researchers "adopted a simple methodology based on mark/recapture estimation, and they unquestioningly applied it." He concludes that use of the 0.66 correction factor is not well justified and that the "confidence intervals accompanying population estimates are wildly optimistic." Our team finds that the methods used to estimate goat populations were inadequate. We find no evidence, however, to support the charges of Lyman (1998) that the NPS intentionally inflated population estimates in order to justify their proposed goat management program.

Williams, the botanist and plant ecologist on our team, reviewed the studies of mountain goat impacts in Olympic National Park and points out other factors that might be responsible for the patterns observed and attributed by NPS scientists to goats. Williams describes why the photographic comparisons are imperfect and inconclusive. He stresses the importance of timing photography to the phenology of plants, which can differ tremendously within seasons in different years. McCullough makes very similar comments in his review, noting that "many of the photos are too indistinct to judge" and that "some apparent differences may not be real because the paired photos were taken at different times after snowmelt." Other team members (Noss, Whitlock) who viewed these same, original photographs at Olympic National Park concur with Williams' and McCullough's assessment.

With respect to the studies of rare plants and results of exclosure studies, Williams points out that apparent damage to plants at an individual level does not necessarily translate to impacts at population or community levels. One of the endemic plants, *Astragalus australis* var. *olympicus*, for example, is well adapted to grazing and physical disturbance. Individual plants assumed by Olympic National Park staff to be dead probably were not dead at all, but persisting below the surface. (This species has a root crown buried and protected 2-7 cm below the soil surface.) Although wallowing by goats removes plants from the immediate area of the wallows, Williams notes that "the long-term heterogeneity provided by the wallowing over the landscape may actually benefit seedling establishment."

Earlier, Kaye (1989) concluded that "the infrequent and sporadic nature of these goat disturbances in *Astragalus australis* var. *olympicus* populations...makes goat impact an unlikely explanation for recent population declines..." Similarly, Pike (1993) found that flowers and fruits of another of the endemic plant species, *Campanula piperi*, were higher in areas of highest goat densities. With respect to the rare plants generally, Pike (1993) stated "it is not evident that these species are seriously impacted by mountain goat grazing, except where soils are removed around rock masses." Indeed, none of the most detailed studies of goat impacts on rare plants were able to document substantial impacts of goats. Hence, Williams concluded that he "found no clear trends in any of the studies of rare plants with regard to detrimental impacts clearly attributable to mountain goats, outside of wallows created on top of existing plants. That these impacts lessen the performance of the plant populations is questionable."

McCullough echoes Williams' concerns about exclosures and other methods used by NPS researchers to study potential impacts of goats on rare plants and vegetation. Williams and McCullough agree that the design of the exclosure studies makes them incapable of providing reliable information about impacts to rare plants and other ecosystem components. As McCullough explains in detail in his review, the alternate approach of comparisons between sites with and without goats, also used by NPS researchers, is also unreliable. The basic principles of experimental design appear to have been ignored in both classes of studies. Ramsey's review is blunt on this point: "This is bad science at its worst." The concluding comments of McCullough and Ramsey on the experimental design issue are remarkably similar. McCullough: "One is left with the impression that yes, mountain goats almost certainly had some impact on vegetation...but that it is impossible from these studies to sort the

relative effects of mountain goats from other variables," and "I conclude that the research on vegetation and stability of substrates is not adequate to separate the effects of mountain goats from those due to natural processes, other grazing animals, or humans." Ramsey: "Mountain goats may indeed pose a serious threat to sensitive native plants. It is unfortunate that none of these studies were capable--by their design--of determining the extent of the threat."

Therefore, our findings contradict a number of statements made by the NPS regarding the impacts of goats. We find no support for the strong, definitive conclusions of previous NPS documents, such as the Environmental Assessment (National Park Service 1987; p. 8) which stated: "Mountain goats are causing significant changes in the vegetation patterns and soils throughout the alpine zones of Olympic National Park...If no action is taken to control or eliminate them, the changes will continue and result in permanent alteration of Olympic's alpine ecosystem." Again, we find no substantial evidence of anything but localized and ephemeral impacts. This does not mean that more severe and extensive impacts have not occurred, but rather that studies have not been able to document them with statistical confidence. Similarly, we cannot agree with a number of statements from the Draft Environmental Impact Statement (National Park Service 1995), such as "Mountain goats cause significant impacts to native ecosystems of Olympic National Park" (p. 3), or "Threats to 33 known rare/endemic plant taxa from goat trailing, wallowing, and grazing include risks to individual plants, subpopulations, and populations" (p. 8). We suggest that the statement "Park managers are concerned that introduced goats could drive some rare, endemic plants to extinction at Olympic" is unnecessarily alarmist.

We do not mean to impugn Olympic National Park researchers with these statements. Williams comments that "all in all, I think they (the researchers) have made a thorough and commendable effort to document what impacts, if any, mountain goats are having on NPS resources." McCullough remarks that "the research conducted in Olympic National Park, considered as a whole, is as good as research done elsewhere under similar conditions and constraints."

In conclusion, our team agrees that potential impacts to rare plants, vegetation, and ecosystem processes from an exotic herbivore should rightly be a primary concern of the NPS. Nevertheless, studies to date have not established that mountain goats are causing substantial damage to plants at the population or community levels, that they are interfering significantly with natural ecological processes, or that their presence otherwise threatens park resources. This absence of well-documented impacts is, as noted, largely a consequence of inadequate experimental design.

Another possible explanation for the lack of documented impacts on plants is that the impacts of goats truly are dwarfed in comparison with the effects of the physical environment. The alpine and subalpine landscape of Olympics appears to be, fundamentally, a physically-driven ecosystem, not a biologically-driven ecosystem. Pfitsch and Bliss (1984) noted that "these subalpine communities are structured primarily by the severity of the physical environment, with competitive interactions playing a minor role." As acknowledged by McCullough and Williams in their reviews, rain, snow, freeze-and-thaw cycles, wind, slope instability, and

other physical processes overwhelm the effects of biotic factors on vegetation. The flora and fauna of the high Olympics have adapted through natural selection to this dynamic, stressful environment and may be relatively immune to the effects of grazing and other disturbances by herbivores, whether native or exotic, unless the densities of those animals are extraordinarily high. Whether mountain goats have ever been so abundant, or are likely to become so in the future, to cause impacts to the vegetation above and beyond the effects of the natural disturbance regime, is a question available data do not permit us to answer.

The feasibility of tested management options for goats in Olympic National Park.

If the USDI determines through the EIS process that the impacts of the mountain goat, which almost certainly is an exotic species in the Olympic Peninsula, are substantial enough to warrant control, the next policy question is whether control is prudent and feasible. Our team believes that this issue has been addressed rather thoroughly in the past. The data on which to base a decision about control are generally adequate. For example, five scientists were asked in 1992 to evaluate the potential for contraceptives to eliminate or control mountain goats in the park. Although the panel felt contraceptives had some value for control of mountain goats, the only feasible option for eliminating mountain goats from the park is lethal shooting. Another review of the applicability of non-lethal methods for control of mountain goats was conducted in 1994, employing the original five scientists and four additional reviewers, which included Dr. McCullough. Although reviewers disagreed somewhat about the potential of non-lethal methods to control goats, all nine reviewers agreed that non-lethal methods would not eliminate goats from the park.

## CONCLUSIONS

We recognize that our findings do not provide unambiguous support for implementing the NPS exotics policy in the case of the mountain goat in Olympic National Park. Whereas we agree with the NPS that the goat is almost certainly an exotic species by any definition, we cannot agree with the statements in the DEIS (National Park Service 1995) and other NPS documents that the goats are causing significant impacts to the native vegetation and rare plants. Although it is certain that the goats are having some impact (i.e., any large animal would), substantial and harmful impacts at the population, community, and ecosystem levels have not been established.

We recommend that the USDI and NPS consider its exotics policy carefully and determine whether all three criteria--non-native status, threat to park resources, and feasible and prudent control--must be firmly established before a decision about control of mountain goats in Olympic National Park is made. This is a policy question, not a scientific one. If, indeed, all three conditions must be fulfilled in order to implement a management program, then we suggest that further research with improved experimental design be conducted to test hypotheses about impacts to the natural ecosystem and its components.

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APPENDIX I: SCIENTIFIC REVIEW TEAM MEMBERS

# 1.0 Qualifications, Experience and Affiliations of Key Personnel

## 1.1 **Reed Noss**

### *1.1.1 Specialty*

Dr. Noss is a world renowned wildlife ecologist and conservation biologist. His primary interests are in conservation biology, biogeography, landscape ecology, land-use planning, nature reserve design, ecosystem management, field ornithology, forest and rangeland wildlife relationships, biological inventory and monitoring, natural history, teaching, and writing. He is a very well respected technical reviewer. Dr. Noss was editor-in-chief for the journal *Conservation Biology* from 1993-1997 and has worked on numerous advisory panels and technical review projects. He is currently President and Chief Scientist for Conservation Science, Inc. and President of the Society for Conservation Biology.

### *1.1.2 Role in the Project*

Dr. Noss was the chief reviewer for this project. His duties included reviewing and evaluating the technical merit, strength of results and breadth of conclusions of the review documents. His primary task was to summarize the state of knowledge for each key issue and synthesize the results into a complete and comprehensive review document.

### *1.1.3 Curriculum Vitae*

**Reed Frederick Noss, Ph.D.**
Ecologist and Conservation Biologist

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***Summary***

Primary interests and talents are in conservation biology, biogeography, landscape ecology, land-use planning, nature reserve design, ecosystem management, field ornithology, forest and rangeland wildlife relationships, biological inventory and monitoring, natural history, teaching, and writing.

Education includes a B.S. in Biology and Health Education, graduate work in Environmental Education, a M.S. in Ecology (University of Tennessee), and a Ph.D. in Wildlife Ecology (University of Florida).

Employment experience includes field biological research, animal and plant population surveys, conservation and land-use planning, environmental assessment and review, land management, natural history interpretation, supervision, administration, writing, editing, and teaching.

***Personal***

Born June 23, 1952, Dayton, Ohio (citizen of U.S.A.)
Married, three children
Excellent physical condition

***Employment***

August 1999-present. **Chief Scientist**. Conservation Science, Inc. (CSI). Corvallis, Oregon

August 1990-present. **International Consultant and Lecturer in Conservation Biology.** Corvallis, Oregon

1997-present. **Courtesy Professor**, Department of Forest Science, Oregon State University, Corvallis, Oregon (this is a non-salaried position)

1994-present. **Courtesy Associate Professor,** Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon (this is a non-salaried position)

1989-present. **Adjunct Professor**, The Union Institute, University of Cincinnati, Cincinnati, Ohio (this is a non-salaried position)

August 1997-August 1999. **Chief Scientist,** The Conservation Biology Institute. Corvallis, Oregon

1993-1997. **Editor**, *Conservation Biology*. Society for Conservation Biology. Oregon State University, Department of Fisheries and Wildlife, Corvallis, Oregon
1991-1997. **Research Associate**, Stanford University, Center for Conservation Biology

1991-1996. **Research Scientist**, University of Idaho, College of Forestry (half-time appointment, National Biological Service; on leave Sept. 1993-May 1996 as a Pew Scholar in Conservation)

1992-1996. **Science Director**, The Wildlands Project (supported by Pew Scholars Award in Conservation and the Environment)

1989-1994. **Courtesy Assistant Professor,** Department of Fisheries and Wildlife, Oregon State University

1988-1990. **Biodiversity Project Leader,** U.S. Environmental Protection Agency, Environmental Research Lab, Corvallis, Oregon

1984-1988. **President and Ecologist,** Landscape Ecosystems (consulting firm), Gainesville, Florida

1987-1988. **Staff Ecologist**, KBN Engineering & Applied Sciences, Inc., Gainesville, Florida

1988. **Adjunct Faculty**, Santa Fe Community College, Gainesville, Florida (Biology Instructor)

1987. **Associate Faculty**, School for Field Studies, Beverly, Massachusetts (taught field ecology course in San Juan Mountains of Colorado)

1984-1987. **Graduate Research Assistant,** University of Florida, Gainesville, FL

1983-1984. **Managed Area Specialist**, Florida Natural Areas Inventory, The Nature Conservancy, Tallahassee, FL

1981-1983. **Ecologist**, Ohio Natural Heritage Program, Ohio Dept. of Natural Resources, Division of Natural Areas & Preserves, Columbus, Ohio

1980-1981. **Naturalist**, Ohio Dept. of Natural Resources, Div. of Parks & Recreation

1979. **Field Biologist;** contracts included: (1) survey of herpetofauna in proposed state natural areas for Tennessee Natural Heritage Program; (2) survey of gray bat maternity colonies in Kentucky for U.S. Fish & Wildlife Service

1977-1979. **Graduate Teaching Assistant**, University of Tennessee (Knoxville); taught General Biology and General Ecology

1978. **Ecological Consultant in Nicaragua**. Land-use and national park planning

1972-1977. **Environmental Education**, several jobs: (1) Science Director for youth camp in Ontario (3 summers); (2) Teacher-naturalist at Glen Helen Outdoor Education Center, Antioch College (1 year); (3) Naturalist for youth camp in Ohio (1 summer); (4) Naturalist for Ohio Historical Society at Cedar Bog State Preserve (2.5 years, part-time)

***Education***

1988. Ph.D. Department of Wildlife & Range Sciences, School of Forest Resources & Conservation, University of Florida. Cumulative GPA = 4.00

1979. M.S. Graduate Program in Ecology, University of Tennessee, Knoxville. Cumulative GPA = 3.96
1975-1976. Graduate School of Education, Antioch College, Yellow Springs, Ohio. 15 graduate hours in outdoor education

1975. B.S. School of Education, University of Dayton, Ohio. Final GPA = 3.78

***Honors and Awards***

1984-1987. Graduate Research Award, School of Forest Resources and Conservation, University of Florida

1985. Annual Research Award, Florida Ornithological Society

1986. Annual Research Award, Alachua Audubon Society

1986. Annual Research Award, Frank M. Chapman Memorial Fund, American Museum of Natural History

1986. Annual Research Award, Josselyn Van Tyne Memorial Fund, American Ornithologists' Union

1987. President's Recognition Award, University of Florida

1988. Environmental Publication Award, National Wildlife Federation

1993-1996. Pew Scholars Award in Conservation and the Environment

1995. Conservation Community Award for Outstanding Achievement in the Field of Publications, Natural Resources Council of America (for book, *Saving Nature's Legacy*)

1995. Edward T. LaRoe III Memorial Award of the Society for Conservation Biology. This is the highest award of the Society, given for outstanding achievement in translating the principles of conservation biology to policy and management

*Avocations*

Karate (6th degree black belt and master instructor, Hayashi-ha Shito-ryu), kobudo (ancient Okinawan weaponry), tai chi chu'an, hatha yoga, birding, natural history, hiking and backpacking, nature photography, music

*Professional Society Memberships*

Society for Conservation Biology
The Natural Areas Association
Ecological Society of America
American Institute of Biological Sciences
Society for Ecological Restoration and Management

*Recent Professional Appointments*

1999-2001. President, Society for Conservation Biology

1992-present. Member, Board of Governors, Society for Conservation Biology

1992-present. Member, Board of Directors, The Cenozoic Society (Wild Earth magazine)

1990-present. Member, State of Oregon Habitat Conservation Trust Fund Board (appointed by the President of the Oregon Senate)

1999-present. Scientific Fellow, Wildlife Conservation Society

1997-present. Member, Advisory Board, Korea Peace Bioreserves Project

1996-present. Science Advisor, World Resources Institute

1992-present. Member, Advisory Board, The Ecoforestry Institute

1992-present. Member, Scientific Advisory Board, Conservation International and Ecotrust

1993-present. Member, Advisory Board, Oregon Natural Desert Association

1994-present. Member, Science Advisory Board, Defenders of Wildlife

1991-1996, 1999. Member, Board of Directors, The Wildlands Project

1993-1996. Member, Board of Directors, Natural Areas Association

1993. Member, Old-growth Ecosystem Panel for Northwest Forest Ecosystem Team advising President Clinton on forest management options

1993-1996. Member, Committee on the Scientific Basis for Ecosystem Management, Ecological Society of America

1994-1996. Member, Ad Hoc Committee to Revise Criteria for Selection of Biosphere Reserves, USMAB, U.S. Department of State

1989-1991. Participant, Keystone Center National Policy Dialogue on Biological Diversity

1990-1991. Member, World Wildlife Fund Advisory Committee on Habitat Conservation Plans

1989-present. Member, Advisory Board, Northwest Ecosystem Alliance

1991-1994. Member, Southern California Coastal Sage Scrub Scientific Review Panel (appointed by Governor of California)

1991-present. Member, Board of Editors, Conservation Biology

1988-1993. Subject Matter Editor for Landscape Ecology, Board of Editors, The Natural Areas Journal

1991-present. Science Editor, Wild Earth

1984-present. Peer reviewer for Conservation Biology, Biological Conservation, Ecology, Ecological Applications, Journal of Wildlife Management, The Natural Areas Journal, BioScience, The Environmental Professional, Trends in Ecology and Evolution and others

***Personal and Professional References***

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Dr. Gary Meffe, Editor, *Conservation Biology*, Department of Wildlife Ecology and Conservation, Newins-Ziegler 303, Box 110430, University of Florida, Gainesville, FL 32667, (352) 846-0557, meffe@gnv.ifas.ufl.edu

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## *PUBLICATIONS*

### *Publication Summary*

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| Refereed Journal Articles: 33 | Other Articles: 49 |
| Book Chapters: 43 | Technical Reports: 24 |
| Books: 4 | Symposium Proceedings: 11 |
| Papers and Books in Review: 3 | **Total**: 167 |

Noss, R.F. 1980. Caving for gray bats in Kentucky. The Explorer 22(4): 22-27.

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Cristoffer, C., R.F. Noss, and J.F. Eisenberg. 1985. Report No. 3. On the captive breeding and reintroduction of the Florida panther into suitable habitats. Report to Florida Game & Fresh Water Fish Commission, Tallahassee, FL.

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Sawyer, J.O., S.C. Sillett, W.J. Libby, T.E. Dawson, J.H. Popenoe, D.L. Largent, R. Van Pelt, S.D. Viers, Jr., R.F. Noss, D.A. Thornburgh, and P. del Tredici. 1999. Redwood trees, communities, and ecosystems: a closer look. In R. Noss, ed. The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. Island Press, Washington, DC.

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Carroll, C., W. J. Zielinski, and R.F. Noss. 1999. Using presence-absence data to build and test spatial habitat models for the fisher in the Klamath region, USA. Conservation Biology in press.

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Noss, R.F. In press. Sustaining ecological integrity. Global Bioethics:

Noss, R.F. In press. Roadside ecosystems. In B.L. Harper-Lore, M. Wilson, and D. Jacobovitz, eds. Roadside use of native plants. U.S. Department of Transportation, Federal Highway Administration. Washington, DC.

Noss, R.F. In press. Protecting western rangelands. Sierra.

Noss, R.F. In press. Wilderness biology and conservation: future directions. In D. Cole and S. McCool, eds. Wilderness Science in a Time of Change. USDA Forest Service, Missoula, MT.

Pimentel, D., L. Westra, and R. Noss, editors. In press. Ecological Integrity in the Modern World? Island Press, Washington, DC.

Noss, R.F. In review. Can urban areas have ecological integrity? The role of connectivity. Landscape Architecture.

Carroll, C., R.F. Noss, and P.C. Paquet. In review. Carnivores as focal species for conservation planning in the Rocky Mountains. Ecological Applications.

Noss, R. In review. A reserve design for the Klamath-Siskiyou ecoregion. Wild Earth.

## 1.2 **Dale McCullough**

### *1.2.1 Specialty*

Dr. McCullough is one of the world's leading experts on ungulate ecology. He has over 35 years of professional experience research experience in the areas of wildlife biology, conservation ecology and wildlife management. He has held the A. Starker Leopold Endowed Chair at UC Berkeley from 1985 to the present. Dr. McCullough has participated in numerous national and international research projects and committees. He has experience working with a number of ungulate species, including white-tailed deer, mule deer, bison, wild burros, wild horses, American elk, bighorn sheep and others.

### *1.2.2 Role in the Project*

Dale McCullough's primary contribution to this project was the review of studies relating to mountain goat ecology, herbivory, dispersal, population dynamics, management and control in Olympic National Park and elsewhere. Dr. McCullough's role also included a review of the tested management options for goat control. He prepared a summary of the extent and quality of knowledge about the population status of mountain goats, their history in Olympic National Park, their effect on physical and biological entities and processes, and the control options tested by the Park management.

### 1.2.3 *Curriculum Vitae*


**Dale Richard McCullough, Ph.D.**
Professor of Wildlife Biology

Department of Environmental Science, Policy, and Management
Ecosystem Sciences Division
Mail Address: 151 Hilgard Hall
University of California
Berkeley, CA 94720-3110
Office: 3 Mulford Hall
Laboratory: 5 Mulford Hall
Telephone and fax: 510-642-8462
Laboratory phone: 510-643-2922
Alternate faxs: 510-643-3490, 510-643-5098
E-mail: mcculla@nature.berkeley.edu
Webpage: http://www.CNR.Berkeley.edu/departments/espm/facultyinfo/frame/faculty.htm


Date and Place of Birth: 5 December 1933, Sioux Falls, South Dakota
Married Karen, 3 children, divorced
Married Yvette, 2 children

Education:
B.S. (Wildlife Management) South Dakota State University, 1957
M.S. (Wildlife Management) Oregon State University, 1960
Ph.D. (Zoology) University of California, Berkeley, 1966

Employment:
Graduate Assistant, Oregon Cooperative Wildlife Research Unit, 1958-60

General Assistant, Pacific Cooperative Water Pollution and Fisheries Research Laboratory, Summer, 1960
Curatorial Assistant, Museum of Vertebrate Zoology, University of California, Berkeley, 1960-62
Summer Biologist, Arctic Health Research Center, Cape Thompson, Alaska,
AEC Project Chariot (terrestrial nesting birds), Summer, 1961
Teaching Assistant, University of California, Berkeley, 1962-63
Field Investigator, Museum of Vertebrate Zoology, University of California, Berkeley, 1963-65
Acting Assistant Professor, University of California, Berkeley, 1965-66
Assistant Professor, University of Michigan, 1966-69
Associate Professor, 1969-74
Chairman, Resource Ecology Program, 1971-72, 1974
Professor, 1974-79
Professor, University of California, Berkeley, 1980-present
A. Starker Leopold Endowed Chair, 1985-present
Vice-chairman, Department of Forestry and Resource Management, 1986-1990

Teaching:
Courses taught: Wildlife Ecology, Wildlife Management, Natural Resource Management, Big Game Management, Range Management, Animal Behavior, Population Dynamics, American Game Birds and Mammals, Case Histories in Wildlife Management, numerous graduate seminars and group and individual studies.

Master of Science degrees completed under my direction, 40
University of Michigan, 22; University of California, Berkeley, 18
Ph.D. degrees completed under my direction, 17
University of Michigan, 10; University of California, Berkeley, 7

Grants and Contracts
National Science Foundation, 6
National Park Service, 2
Bureau of Land Management, 3
California Department of Fish and Game, 4
McIntire-Stennis Program, 12
National Rifle Association, 4
Wildlife Management Institute, 1
Welder Wildlife Refuge, 2
World Wildlife Fund, 2
California State Parks, 1
Michigan Department of Natural Resources, 3
San Francisco SPCA, 2
Australian CSIRO, 1
Taiwan National Research Council, 1
Division of Agriculture and Natural Resources 1
Boone and Crockett Club 1
Mule Deer Foundation 1
Pacific Rim Program 1
National Academy of Sciences 1
Numerous other stipends and grants-in-aid

Consulting:
City of Los Angeles, Dept. Water and Power
Bureau of Land Management
National Park Service
U.S. Fish and Wildlife Service
Bureau of Reclamation
Smithsonian Institution

Department of the Army, Fort Hunter Liggett, Fort Ord
Department of the Interior, Interagency Grizzly Bear Research Team
Dye Creek Ranch
Laguna Ranch
Jasper Ridge Reserve, Stanford University
California Dept. Parks and Recreation
California Dept. Fish and Game
San Francisco SPCA
Conway Ranch
Hokkaido, Japan Government
Academia Sinica, Taiwan, R. O. C.

<u>Local, National, and International Committees and Activities</u>

Member, Wildlife Society, National Meetings Committee; Role of the Society Committee
Member, National Academy of Sciences - National Research Council Yellowstone Grizzly Bear Review Committee
Member, International Biological Program, Terrestrial Production Program, Several Eastern Deciduous Biome Planning Committees
Sabbatical Leave, data analysis of George Reserve deer herd, done at the University of California with NSF funding (1972-73)
Member, National Academy of Sciences/National Research Council, Task force on Wildlife and Fisheries Issues (1981)
Member, two NSF Grant Review Panels, Physiological and Population Ecology and Psychobiology
Reviewer, National Academy of Sciences/National Research Council Committee Report on Wild Horses and Burros
Reviewer, Ecology, American Naturalist, Journal of Wildlife Management, Wildlife Monographs, Wildlife Society Bulletin, Journal of Mammalogy, Nature, many others
Member, Editorial Board, Addison/Wesley Biological Conservation Series
Member, Workshop on the Status of the porpoise populations impacted by tuna fishing, National Marine Fisheries Service (1980)
Member, Workshop on the Status of fur seal population, National Marine Fisheries Service (1983)
Member, Modeling Committee for the Yellowstone Grizzly Bear, U.S. Department of the Interior (1980-82)
Member, International Union for the Conservation of Nature, Survival Service Commission, Threatened Deer Committee (1975-present)
Appointed Research Conservationist, Museum of Vertebrate Zoology, UCB (1981-present)
Instructor, two Wildlife Society Short Courses for upgrading professionals;
Instructor, Deer Management Short Courses or special presentations, Michigan Department of Natural Resources, California Department of Fish and Game, Nevada Fish and Game, Colorado Division of Wildlife, British Columbia Division of Wildlife, Western States Deer Group Workshop, Great Lakes Deer Group Workshop
Sabbatical Leave, 16 months in Australia to conduct a field study of three species of kangaroos of the outback in New South Wales with sponsorship of CSIRO (1985-86)
Member, National Academy of Sciences/National Research Council Committee on Wild Horses and Burros (1988-90)
Member, Wildlife Society Committee on Management of Wildlife in National Parks
Member, Savannah River Ecology Laboratory workshop on dynamics of deer populations
Editorial board member, <u>Deer of China</u>
Member, study group, Hokkaido, Japan, management of deer and conservation of brown bears in Hokkaido (1990)
Member, deer specialist group, Hokkaido, Japan, deer management for damage control
Consultant, Japanese Transportation Department, Hokkaido, Japan, sika deer accident prevention on Japanese highways (1992)
Consultant, Death Valley National Monument, bighorn sheep management
Sabbatical leave, 12 months in Taiwan to study the Reeve's muntjac (1992-93)

Chair, Scientific Panel to review control of tule elk at Point Reyes National Seashore
Participant, Workshop on contraception to control deer populations, sponsored by Philadelphia Zoo
Member, Review Team, Wildlife Habitat Management, Tongass National Forest, 1993-94
Editorial Board, Zoological Studies, Academia Sinica, Taipei, Taiwan
Consultant, Yangmingshan National Park, Taipei, Taiwan, sika deer recovery plan
P. I., National Academy of Sciences, Brucellosis in the Greater Yellowstone Area (1997)

International Research Experience:
Costa Rica
Taiwan (Republic of China)
Mexico
Australia

Countries Visited To Observe National Parks and Game Reserves

| | |
|---|---|
| England | Canada |
| Scotland | Zimbabwe |
| Japan | Botswana |
| Malaysia | Tanzania |
| Nepal | Kenya |
| New Zealand | Thailand |
| Mainland China | Mexico |

Honors
1971 Choice Magazine (Amer. Libr. Assoc.). "Outstanding academic book" for The Tule Elk.
1981 Wildlife Society, "Outstanding Book of the Year" for the George Reserve Deer Herd.
1981 Named "Distinguished Alumnus", South Dakota State University.
1981 Appointed Research Conservationist, Museum of Vertebrate Zoology, U. C. Berkeley.
1984 Invited to give the Charles Hanson Memorial Lecture, Arizona State University.
1984 Invited to give the Fredrick Barkalow Memorial Lecture, North Carolina State University.
1985 Named to an endowed chair, The A. Starker Leopold Distinguished Professor of Wildlife Biology, University of California, Berkeley.
1986 Invited to give the Paul L. Errington Memorial Lecture as part of the Aldo Leopold Centennial Celebration, Iowa State University.
1991 Reappointed to A. Starker Leopold endowed chair.
1993 Invited to give plenary lecture, International Union of Game Biologists Congress, Halifax, Nova Scotia
1994 Wildlife Society, "Outstanding Book Award, Editorship" (with R. H. Barrett) for Wildlife 2001: Populations.
1994 Named distinguished alumnus, Oregon State University.
1996 Reappointed to A. Starker Leopold endowed chair.
1997 Wildlife Society, "Outstanding Book of the Year Award, Editorship" for Metapopulations and Wildlife Conservation.

Publications
A 1. McCullough, D. R. 1964. Relationship of weather to migratory movements of blacktailed deer. Ecology 45(2):249-256.

A 2. McCullough, D. R. 1965. Sex characteristics of black-tailed deer hooves. Journal of Wildlife Management 29(1):210-212.

A 3. McCullough, D. R. 1965. Elk deposit on the San Francisco Peninsula. Journal of Mammalogy 46(2):347-348.

A 4. McCullough, D. R. 1966. A preliminary report on a model for range and big game management. Transactions of the California-Nevada Section of the Wildlife Society 13:55-60.

A 5. McCullough, D. R, and Edward R. Schneegas. 1966. Winter observations on the Sierra Nevada bighorn sheep. California Fish and Game 52(2):68-84.

A 6. McCullough, D. R. 1967. The probable affinities of a wolf captured near Woodlake, California. California Fish and Game 53(2):146-153.

A 7. Croon, G. W., D. R. McCullough, C. E. Olson, Jr., and L. M. Queal. 1968. Infrared scanning techniques for big game censusing. Journal of Wildlife Management 32(4):751-759.

A 8. McCullough, D. R. 1969. The tule elk: its history, behavior, and ecology. University of California Publication in Zoology, Vol. 88, University of California Press, Berkeley and Los Angeles. 209 pp.

B 9. McCullough, D. R., C. E. Olson, Jr., and L. M. Queal. 1969. Large animal censusing by thermal mapping -- a progress report. Pages 138-147 *in* P. L. Johnson, editor. Remote sensing in ecology. University of Georgia Press, Athens.

B 10. McCullough, D. R. 1970. Secondary production in birds and mammals. Pages 107-130 *in* D. L. Reichle, editor. Ecological studies: analysis and synthesis, Vol. 1. Springer-Verlag, New York.

F 11. McCullough, D. R. 1970. Review of the world of the American elk, by Joe Van Wormer. Journal of Wildlife Management 34(3):664-665.

E 12. McCullough, D. R. 1971. The tule elk: its history, behavior, and ecology. Library Reprint Series, University of California Press, Berkeley and Los Angeles. 209 pp. (Reprint in hard cover of reference 8.)

F 13. McCullough, D. R. 1974. Status of larger mammals in Taiwan. Taiwan Tourism Board, Taipei, Taiwan. 36 pp.

F 14. Cowan, I. McT., D. G. Chapman, R. S. Hoffmann, D. R. McCullough, G. A. Swanson, and R. B. Weeden. 1974. Report of the committee on the Yellowstone grizzlies. National Academy of Sciences. 61 pp.

A 15. McCullough, D. R. 1975. Modification of the Clover deer trap. California Fish and Game 61(4):242-244.

A 16. Feist, J. D., and D. R. McCullough. 1975. Reproduction in feral horses. Journal of Reproduction and Fertility, Supplement 23:13-18.

F 17. McCullough, D. R. 1976. Review of Whitetail deer: a year's cycle, by Curtis S. Stadtfeld. Michigan Academician 9(4):487-488.

A 18. Feist, J. D., and D. R. McCullough. 1976. Behavior patterns and communication in feral horses. Zeitschrift für Tierpsychology 41:337-371.

A 19. Allen, R. E., and D. R. McCullough. 1976. Deer-car accidents in southern Michigan. Journal of Wildlife Management 40(2):317-325.

A 20. Hirth, D. H., and D. R. McCullough. 1977. Alarm signals in ungulates, with special references to white-tailed deer. American Naturalist 111:31-42.

B 21. McCullough, D. R. 1978. Case history of the tule elk. Pages 302-317 *in* Threatened Deer, International Union for the Conservation of Nature.

B 22. McCullough, D. R. 1978. Essential data required on population structure and dynamics in field studies of threatened herbivores. Pages 173-184 *in* Threatened Deer, International Union for the Conservation of Nature.

E 23. McCullough, D. R. 1979. The George Reserve deer herd: population ecology of a K-selected species. University of Michigan Press. 271 pp.

F 24. McCullough, D. R. 1979. Review of the African Buffalo, by A. R. E. Sinclair. Journal of Mammalogy 60:438-439.

B 25. McCullough, D. R. 1981. Population dynamics of the Yellowstone grizzly bear. Pages 173-196 *in* C. W. Fowler and T. Smith, editors. Dynamics of large mammal populations. John Wiley and Sons, N.Y., N.Y.

A 26. McCullough, D. R. 1982. Behavior, bears, and humans. Wildlife Society Bulletin. 10(1):27-33.

A 27. McCullough, D. R. 1982. White-tailed deer pellet group weights. Journal of Wildlife Management 46(3):829-832.

A 28. McCullough, D. R. 1982. Antler characteristics of George Reserve white-tailed deer. Journal of Wildlife Management 46(3):821-826.

A 29. McCullough, D. R. 1982. Evaluation of night spotlighting as a deer study technique. Journal of Wildlife Management 46(4):963-973.

A 30. McCullough, D. R. 1982. Population growth rate of the George Reserve deer herd. Journal of Wildlife Management 46(4):1079-1083.

F 31. McCullough, D. R. 1982. Review of Elk of North America: Ecology and Management. J. W. Thomas and D. E. Toweill, editors. Journal Forestry 80(12):794.

A 32. McCullough, D. R., and W. J. Carmen. 1982. Management goals for deer hunter satisfaction. Wildlife Society Bulletin 10(1):49-52.

A 33. McCullough, D. R. 1983a. Rate of increase of white-tailed deer on the George Reserve: a response. Journal of Wildlife Management 47(4):1248-1250.

F 34. McCullough, D. R. 1983b. Review of Red deer: behavior and ecology of two sexes, by T. H. Clutton-Brock, F. E. Guinness, and S. D. Albon. Ecology 64:966.

F 35. McCullough, D. R. 1983c. In memoriam: A. Starker Leopold. California Monthly, Oct. 1983:32.

A 36. McCullough, D. R., and D. E. Ullrey. 1983. Proximate mineral and gross energy composition of white-tailed deer. Journal of Wildlife Management 47:(2):430-441.

F 37. McCullough, D. R. 1984a. Review of Study and management of large mammals, by T. Riney. Journal of Wildlife Management 48(3):666-667.

B 38. McCullough, D. R. 1984b. Lessons from the George Reserve. Pages 307-339 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Wildlife Management Institute, Washington, D. C., and Stackpole Company, Harrisburg, PA.

A 39. Hargis, C. D., and D. R. McCullough. 1984. Winter diet and habitat selection of marten in Yosemite National Park. Journal of Wildlife Management 48(1):140-146.

A 40. O'Bryan, M. K., and D. R. McCullough. 1985. Survival of black-tailed deer following relocation in California. Journal of Wildlife Management 49(1):115-119.

B 41. McCullough, D. R. 1985a. Long range movements of large mammals. Pages 444-465 *in* M. J. Rankin, editor. Migration: mechanisms and adaptive significance. Contributions in Marine Science, Univ. Texas.

A 42. McCullough, D. R. 1985b. Variables influencing food habits of George Reserve white-tailed deer. Journal of Mammalogy 66:682-692.

F 43. Dasmann, R. F., D. R. McCullough, W. W. Middlekauff, W. C. Russell, D. E. Teeguarden, and H. J. Vaux. 1985. In memoriam. A. Starker Leopold. University of California, Academic Senate.

A 44. McCullough, D. R., and D. E. Ullrey. 1985. Chemical composition and gross energy of deer forage plants on the George Reserve. Michigan Agricultural Experiment Station Research Report 465. 19 pp.

A 45. McCullough, D. R., and P. Beier. 1986. Upper vs. lower molars from cementum annuli age determination. Journal of Wildlife Management 50(4):705-706.

B 46. McCullough, D. R. 1987. North American deer ecology: fifty years later. Pages 115-122 *in* M. Schnepf, editor. Aldo Leopold: the man and his legacy. American Soil Conservation Society, Ankeny, Iowa.

A 47. McCullough, D. R., and D. J. Case. 1987. White-tailed deer forage on alewives. Journal of Mammalogy 68(1):195-197.

A 48. McCullough, D. R. 1987. Interpretations of the Craigheads' data on Yellowstone grizzly bear populations, and its relevance to current research and management. International Conference Bear Research and Management 6:21-32.

B 49. McCullough, D. R. 1987. The theory and management of Odocoileus populations. Pages 535-549 *in* C. Wemmer, editor. Biology and management of the cervidae. Research Symposia of the National Zoological Park. Smithsonian Institution Press.

A 50. Case, D. J., and D. R. McCullough. 1987. The white-tailed deer of North Manitou Island. Hilgardia 55(9):1-57.

F 51. McCullough, D. R. 1988. Resolution of respect: A. Starker Leopold, 1913-1983. Bulletin of the Ecological Society of America 69(1):21-23.

F 52. McCullough, D. R. 1988. Strategies of deer management. Pages 109-117 *in* I. Hatter and H. Langin, editors. Proceedings of the deer management workshop, Wildlife Branch, Ministry of Environment and Parks, Victoria, B.C., Canada.

F 53. McCullough, D. R. 1988. Kangaroos in the land of drought and plenty: review of Caughley, G., Shepherd, N., and Short, J., 1987, Kangaroos: their ecology and management in the sheep rangelands of Australia, Cambridge University Press. Ecology 69(4):1311-1312.

A 54. McCullough, D. R., and D. H. Hirth. 1988. Evaluation of the Petersen-Lincoln estimator for a white-tailed deer population. Journal of Wildlife Management 52(3):534-544.

A 55. Beier, P., and D. R. McCullough. 1988. Motion-sensitive radio collars for estimating white-tailed deer activity. Journal of Wildlife Management 51(1):11-13.

F 56. McCullough, D. R. 1989. Report on a review of management of bighorn sheep in Death Valley National Monument. Death Valley National Monument, California. 78 pp.

A 57. McCullough, D. R., D. H. Hirth, and S. J. Newhouse. 1989. Resource partitioning between sexes in white-tailed deer. Journal of Wildlife Management 53(2):277-283.

A 58. Beier, P., and D. R. McCullough. 1990. Factors influencing white-tailed deer activity patterns and habitat use. Wildlife Monographs 109:1-51.

A 59. McCullough, D. R. 1990. Detecting density dependence: filtering the baby from the bathwater. Transactions of the North American Wildlife Conference 55:534-543.

A 60. McCullough, D. R., D. S. Pine, D. L. Whitmore, T. M. Mansfield, and R. H. Decker. 1990. Linked sex harvest strategy for big game management with a test case on black-tailed deer. Wildlife Monographs 112:1-41.

B 61. McCullough, D. R. 1990. Deer conservation and management in the U.S.A. Pages 150-154 *in* I. Ohtaishi, K. Kaji, and T. Mano, editors. Proceedings of the Deer and Bear Management Symposium, Hokkaido 1990, Wildlife Information Center, Sapporo, Hokkaido, Japan. (translated into Japanese by H. Ono, pp. 55-59).

B 62. McCullough, D. R. 1990. Population dynamics and wildlife management. Pages 183-186 *in* I. Ohtaishi, K. Kaji, and T. Mano, editors. Proceedings of the Deer and Bear Management Symposium, Hokkaido 1990, Wildlife Information Center, Sapporo, Hokkaido, Japan. (translated into Japanese by T. Yabe, pp. 107-111).

A 63. Beier, P., and D. R. McCullough. 1991. Influence of sex and weather on white-tailed deer activity patterns. (abstract) Applied Animal Behaviour Science 29:507-508.

B 64. McCullough, D. R. 1991. Management of wildlife population dynamics for exploitation and non-consumptive use. Pages 125-128 *in* Maruyama, et al., editors. Wildlife conservation: present trends and perspectives for the 21st century. Japan Wildlife Research Center, Tokyo, Japan.

B 65. McCullough, D. R. 1991. Refuges and zoning to control exploitation of hunted wildlife. Pages 9-21 *in* Y-S Lin, and K. H. Chang, editors. Proceedings of the first international symposium on wildlife conservation, Republic of China. Council on Agriculture, Taipei, Republic of China.

F 66. McCullough, D. R., F. W. Weckerly, P. I. Garcia, and R. Evett. 1991. Development of reliable herd composition counts and population estimates for deer in coastal California. Contract Report FG 9521, California Dept. of Fish and Game, Sacramento, California. 110 pp.

F 67. Wagner, F. H., J. Berger, D. R. McCullough, J. W. Menke, E. S. Murray, B. W. Pickett, U. S. Seal, and M. Sharpe. 1991. Wild horse populations: field studies in genetics and fertility. National Academy Press, Washington, D. C. 42 pp.

B 68. McCullough, D. R. 1992. Introduction. Pages 1-9 *in* D. R. McCullough and R. H. Barrett (eds.). Wildlife 2001: Populations. Elsevier Science Publishers, Ltd., London, England. 1163 pp.

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E 70. McCullough, D. R., and R. H. Barrett, editors. 1992. Wildlife 2001: Populations. Elsevier Science Publishers, Ltd., London, England. 1163 pp.

F 71. Gallagher, J. F., and D. R. McCullough. 1992. Deer response to the 1987 wild fires and subsequent timber harvest practices, Klamath National Forest. Report to California Dept. of Fish and Game, Contract No. FG-8610. 51 pp.

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F 73. McCullough, D. R., R. A. Garrott, J. F. Kirkpatrick, E. D. Plotka, K. D. Ralls, and E. T. Thorne. 1993. Report of the scientific panel on control of tule elk on Point Reyes National Seashore. Point Reyes National Seashore, California. 42 pp.

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A 77. McCullough, D. R., F. W. Weckerly, P. I. Garcia, and R. Evett. 1994. Sources of inaccuracy in black-tailed deer herd composition counts. Journal of Wildlife Management 58:(2):320-330.

A 78. Massey, B. N., F. W. Weckerly, C. E. Vaughn, and D. R. McCullough. 1994. Correlations between fecal nitrogen and diet composition in free-ranging black-tailed deer. Southwestern Naturalist 39(2):165-170.

D 79. McCullough, D.R., J. Fischer, and J. Ballou. 1994. A recovered metapopulation: the tule elk. (abstract) First Annual Conference of the Wildlife Society, Albuquerque, New Mexico.

D 80. Gogan, P. G. P. and D. R. McCullough. 1994. History of the tule elk at Point Reyes National Seashore. (abstract) First Annual Conference of The Wildlife Society, Albuquerque, New Mexico.

A 81. McCullough, D. R. 1994. Importance of population data in forest management planning. The Forest Chronicle 70(5):633-537.

F 82. McCullough, D. R. 1994. Tongass National Forest land management plan: scientific review. Pages 109-122 *in* A. R. Kiester and C. Eckhardt, Review of wildlife management and conservation biology on the Tongass National Forest: A synthesis with recommendations. Pacific Northwest Research Station, USDA Forest Service, Corvallis, Oregon.

B 83. Mayer, K. E., J. E. DiDonato, and D. R. McCullough. 1995. California urban deer management: two case studies. Pages 51-57 *in* Urban deer: a manageable resource? J. B. McAninch and L. P. Hanson, editors. Proceedings of the 1993 Symposium of the North Central Section of The Wildlife Society.

F 84. Wagner, F. H., R. Foresta, R. B. Gill, D. R. McCullough, M. R. Pelton, W. F. Porter, and H. Salwasser. 1995. Wildlife policies in the U.S. National Parks. Island Press, Covelo, CA. 242 pp.

D 85. King, G. M., D. R. McCullough, E. E. Hanson, and G. A. Sargeant. 1995. Habitat characteristics of northern spotted owls in the managed forests of the Yakima Indian Reservation, eastern Washington. (abstract) Second Annual Conference of The Wildlife Society, Portland, Oregon.

D 86. Neale, J. C. C., B. N. Sacks, M. M. Jaeger, and D. R. McCullough. 1995. Comparative use of space and habitat by sympatric predators in Mendocino County, California. (abstract) Second Annual Conference of The Wildlife Society, Portland, Oregon.

D 87. Sacks, B. N., J. C. C. Neale, M. Jaeger, and D. McCullough. 1995. Fine- and coarse-scale space use patterns by coyotes in Mendocino County, California, with an "i" towards "y." (abstract) Second Annual Conference of The Wildlife Society, Portland, Oregon.

A 88. McCullough, D. R. 1996. Spatially structured populations and harvest theory. Journal of Wildlife Management 60:1-9.

E 89. McCullough, D. R. (editor) 1996. Metapopulations and wildlife conservation. Island Press, Covelo, California. 432 pp.

B 90. McCullough, D. R. 1996. Introduction. Pages 1-10 *in* Metapopulations and wildlife conservation, D. R. McCullough, editor. Island Press, Covelo, California.

A 91. McCullough, D. R. 1996. Failure of the tooth cementum aging technique with reduced population density of deer. Wildlife Society Bulletin 24(4):722-724.

B 92. McCullough, D. R., J. K. Fischer, and J. D. Ballou. 1996. From bottleneck to metapopulation: recovery of the tule elk in California. Pages 375-403 *in* Metapopulations and wildlife conservation, D. R. McCullough, editor. Island Press, Covelo, California.

B 93. McCullough, D. R. 1996. Demography and management of wild populations by reproductive intervention. Pages 119-132 *In* Contraception in Wildlife, Book 1. Proceedings of a symposium held November 1987, Philadelphia, PA. P. N. Cohn, E. D. Plotka, and U.S. Seal, editors. Edwin Mellen Press, Lewiston, NY.

F 94. Severinghaus, L. L., and D. R. McCullough. 1996. A comprehensive review of the sika deer restoration program in Taiwan. Report to Yangmingshan National Park, Taipei, Taiwan, R. O. C. (Chinese and English) 128 pp.

D 95. Neale, J. C. C., B. N. Sacks, M. M. Jaeger, and D. R. McCullough. 1996. Resource use by sympatric bobcats and coyotes in northern California. (abstract) Third Annual Conference of The Wildlife Society, Cincinnati, Ohio.

D 96. Sacks, B. N., J. C. C. Neale, M. M. Jaeger, and D. R. McCullough. 1996. Ecology of coyotes in a sheep ranching environment. (abstract) Third Annual Conference of The Wildlife Society, Cincinnati, Ohio.

D 97. McCullough, D. R. 1997. Density dependence, productivity, and the window of opportunity for linked-sex harvest strategy. (abstract) Western States and Provinces Deer and Elk Workshop, Rio Rico, Arizona.

D 98. McCullough, D. R. 1997. Drive counts of tule elk at Point Reyes National Seashore, California. (abstract) Western States and Provinces Deer and Elk Workshop, Rio Rico, Arizona.

B 99. McCullough, D. R. 1997. Irruptive behavior in ungulates. Pages 69-98 *in* Ecology of deer populations. W. J. McShea, H. B. Underwood, and J. H. Rappole, editors. Smithsonian Institution Press, Washington, D. C

A 100. McCullough, D. R., K. W. Jennings, N. B. Gates, B. G. Elliott, and J. E. DiDonato. 1997. Overabundant deer populations in California. Wildlife Society Bulletin 25: in press.

D 101. Blejwas, K., M. M. Jaeger, and D. R. McCullough. 1997. Turnover, territories and sheep depredations in an exploited coyote population. (abstract) Annual Meeting of the Western Section of the Wildlife Society , San Diego, California.

D 102. Neale, J. C. C., B. N. Sacks, M. M. Jaeger, and D. R. McCullough. 1997. Overlap and partitioning of space and resources by bobcats and coyotes in Northern California. (abstract) Annual Meeting of the Western Section of the Wildlife Society, San Diego, California.

D 103. Sacks, B. N., J. C. C. Neale, M. M. Jaeger, and D. R. McCullough. 1997. Ecology of coyotes in relation to depredation and control on a California sheep ranch. (abstract) Annual Meeting of the Western Section of the Wildlife Society, San Diego, California.

D 104. McCullouogh, D. R. 1997. Ecological realities of predator management. (abstract) Annual Meeting of the Wildlife Society, Snowmass, Colorado.

D 105. McCullough, D. R., P. Beier, and D. H. Hirth. 1997. Fine-scale sexual segregation in white-tailed deer. (abstract) Annual Meeting of the Wildlife Society, Snowmass, Colorado.

D 106. Blejwas, K. M., M. M. Jaeger, and D. R. McCullough. 1997. Reducing coyote predation on livestock through selective control. (abstract) Annual Meeting of the Wildlife Society, Snowmass, Colorado.

D 107. McCullough, D. R. 1998. Density dependence and life-history strategies of ungulates. (abstract) Annual Meeting of the American Society of Mammalogists, Blacksburg, Virginia, Abstract Number 147.

D 108. Chevelle, N. F., D. R. McCullough, and L. R. Paulson. 1998. Brucellosis in the Greater Yellowstone Area. National Academy Press, Washington, D. C.

A 109. Conner, M. M., M. M. Jaeger, T. J. Weller, and D. R. McCullough. 1998. Effect of coyote removal on sheep depredation in northern California. Journal of Wildlife Management 62:690-699.

A 110. Neale, J. C. C., B. N. Sacks, M. M. Jaeger, and D. R. McCullough. 1998. A comparison of bobcat and coyote predation on lambs in north-coastal California. Journal of Wildlife Management 62:700-706.

B 111. McCullough, D. R. In press. Mule Deer. *In* The complete book of North American mammals, D. E. Wilson, editor. Smithsonian Institution Press, Washington, D. C.

A 112. McCullough, D. R. In press. Drive counts of tule elk at Point Reyes National Seashore, California. Proceedings of the Western States Deer and Elk Workshop, Rio Rico, Arizona.

## 1.3 **Cathy Whitlock**

### *1.3.1 Specialty*

Dr. Whitlock is an internationally respected paleoecologist. Her expertise lies in the areas of paleoenvironmental reconstruction, the paleoecology of the Pacific Northwest, Quaternary vegetation and climate and climatic variability through the Cenozoic. She is an expert on the evolution and change of Pacific Northwest ecological systems during the Pleistocene and Holocene.

### *1.3.2 Role in the Project*

Dr. Whitlock's primary contribution to this project was the review of studies relating to the paleoecology of the Olympic Peninsula. She guided the review of how the several major periods of glaciation and subsequent postglacial natural events and human activities influenced the evolution and development of the modern natural biogeography and ecology of the Olympic Peninsula. She also assisted the review of the biogeographical arguments related to whether mountain goats are native to Olympic National Park. She prepared a summary of the extent and quality of knowledge about the biogeography and paleoecolgoy of the Olympic Peninsula and the history of mountain goats in Olympic National Park.

### *1.3.3 Curriculum Vitae*

**CATHY LYNN WHITLOCK**
Professor of Paleoecology

Department of Geography
University of Oregon
Eugene, Oregon 97403 U.S.A
SSN: 118-42-0626
office: (541) 346-4566; fax: (541) 346-2067
e-mail: whitlock@oregon.uoregon.edu

EDUCATION

| | | |
|---|---|---|
| B.A. | 1975 | Colorado College, (Geology, magna cum laude) |
| M.S. | 1979 | University of Washington (Geological Sciences) |
| Ph.D. | 1983 | University of Washington (Geological Sciences) |

RESEARCH INTERESTS

Quaternary environmental change
Vegetation, fire, and climate history of the northwestern U.S.
Climatic variability through the Cenozoic
Data-model comparison of past climatic change

TEACHING INTERESTS

Introduction to biogeography, plant geography
Paleoecology and paleoclimatology
Quaternary pollen and plant macrofossil analysis
Cenozoic vegetation history, environments, and climates

POSITIONS

| | |
|---|---|
| currently | Full Professor, Department of Geography, University of Oregon<br>Adjunct Professor, Department of Geosciences, University of Oregon<br>Adjunct Professor, Department of Geology and Earth Sciences, University of Pittsburgh<br>Research Associate, Section of Paleobotany, Carnegie Institute Museum of Natural History<br>Consultant, Conservation Biology Institute |
| 1996-1997 | Visiting Professor, College of Oceanic and Atmospheric Sciences, Oregon State University and Visiting Scientist at USDA Forest Service, Pacific Northwest Station, Corvallis |
| 1993-1995 | Consultant, Golder Associates, Inc., Seattle |
| 1990-1994 | Associate Professor, Department of Geography, University of Oregon |
| 1988-1990 | Assistant Professor, Department of Geology and Planetary Sciences, University of Pittsburgh. |
| 1987 | Adjunct Assistant Professor, Department of Geology and Planetary Sciences, University of Pittsburgh<br>Invited Visiting Scientist, Academia Sinica Institute of Vertebrate Paleontology and Paleoanthropology, Beijing<br>Consultant, BWIP paleoclimate evaluation of the Columbia Basin, Rockwell Hanford Operation, Richland |
| 1984-1990 | Assistant Curator-in-Charge, Section of Paleobotany, Carnegie Museum of Natural History, Pittsburgh |
| 1983-1984 | Visiting Research Fellow, Department of Botany, Trinity College, Dublin, Ireland |
| 1981-1982 | Research Assistant, Limnological Research Center, University of Minnesota |
| 1980-1981 | Research Assistant, Quaternary Research Center, University of Washington<br>Consultant, pollen biostratigraphy of Jackson Hole, Wyoming. U.S. Bureau of Reclamation |
| 1979-1980 | Teaching Assistant, Department of Geological Sciences, University of Washington |
| 1978-1983 | Graduate Research Fellow, National Science Foundation |
| 1978 | Consultant, peat stratigraphy of the Puget Lowland. Roger Lowe and Associates, Seattle |
| 1977 | Field Assistant, Conservation Division, U.S. Geological Survey |
| 1976 | Thomas J. Watson Fellow |
| 1975 | Field Assistant, Geological Division, U.S. Geological Survey |
| 1974 | Laboratory Assistant, Pollen Laboratory, U.S. Geological Survey |

GRANTS, CONTRACTS, AND AWARDS

| | |
|---|---|
| 1999-2003 | National Science Foundation (Earth Systems History): Early- versus late-Holocene drought variation in the Northern Rocky Mountains |
| 1999-2004 | USDA Forest Service: Sensitivity of Klamath forests to climate change |
| 1998-2003 | USDA Forest Service: Vegetation and fire history of the Cascade Range |
| 1997-2001 | National Science Foundation (Geography): Climate-fire-ecosytem linkages on decadal-to-millenial time scales in the Northern Rocky Mountains |
| 1997-1998 | InterAmerican Institute Phase I: Fire and climate linkages in the Americas (T.T. Veblen, PI). |
| 1997 | National Science Foundation (Climate Dynamics) and InterAmerican Institute: Workshop on Charcoal Methods to Reconstruct Past Fires (Eugene, Oregon, 1-8 June) |
| 1996-2001 | National Science Foundation (Climate Dynamics): Heinrich-scale climate events in western North America and the Northeast Pacific? Testing Possible Mechanisms |
| 1996-1999 | US Geological Survey: Modern pollen rain studies in the Pacific Northwest |
| 1996-1997 | UW-National Park Service: Fire history of Trail Lake, southeastern Yellowstone National Park |
| 1995-1999 | USDA. Forest Service: Fire history of the Klamath Mountains, northern California |
| 1994-1997 | National Science Foundation (Climate Dynamics): Response of the Pacific Northwest to large-scale changes in climate during the last 150,000 years. |
| 1993-1998 | USDA Forest Service: Long-term fire history of the Oregon Coast Range |
| 1993-1997 | National Park Service: Paleoecology of the Yellowstone Lake basin. |
| 1995-1996 | Consultant, State of Montana Historical Society |

1993-1994 National Science Foundation (Geography): Dissertation Improvement Grant for Sarah Millspaugh; postglacial fire history in Yellowstone National Park

1992-1993 National Science Foundation (Systematic Biology): A multidisciplinary study of evolution of the diatom *Stephanodiscus yellowstonensis*: paleontology, molecular biology, expermental morphology (E.C. Theriot, PI).

National Institute for Global Environmental Change (Western Regional Center): Potential magnitude and rate of future vegetation change in the western United States in response to global warming [with P.J. Bartlein]

1991-1993 Golder Associates, Inc.: Paleoclimatic history of Carp Lake Washington.

1990-1994 UW-NPS Research Grant: Postglacial fire frequency and its relation to long-term vegetational and climatic changes in Yellowstone Park

1989-1992 National Science Foundation (Climate Dynamics): Regional climatic response in the northwestern U.S. to changing boundary conditions during deglaciation

1988-1989 UW-NPS Research Grant, National Park Service: Late Quaternary vegetational and climatic history of the Yellowstone/Grand Teton region

M. Graham Netting Research Grant, Carnegie Museum of Natural History: Postglacial fire frequency and its relation to long-term vegetational and climatic changes in Yellowstone Park

1988 National Science Foundation (Climate Dynamics): COHMAP--Cooperative Holocene Mapping Project

National Science Foundation Grant (Systematic Biology): Barstovian mammals in the Rocky Mountains and mid-Miocene biogeography: Case study from Chalk Cliffs, Montana (A.D. Barnosky, principal investigator); two years

Pennsylvania Historical and Museum Commission: Development of exhibit-related educational programs and publications.

1987-1988 National Science Foundation Grant (Ecology): Collaborative research on the postglacial history of the northern Great Plains

1986 National Science Foundation Grant (Earth Science Equipment): Acquisition of Computerized Image Analysis System (with M.R. Dawson and J.L. Carter)

UW-NPS Research Grant, National Park Service: Postglacial vegetation and climate of Grand Teton National Park and vicinity

UW-NPS Research Grant, National Park Service: The relationship between climate and sedimentation rates in small lakes and ponds (with H.E. Wright, Jr., D.R. Engstrom, and S.C. Fritz); two years

Pennsylvania Historical and Museum Commission: Renovation of Paleobotany exhibits and collections; two years

M. Graham Netting Research Grant, Carnegie Museum of Natural History: Paleoecology of the American West; two years.

1985 UW-NPS Research Grant, National Park Service: Postglacial vegetation and climate of Jackson Hole and the Pinyon Peak Highlands, Wyoming

Pennsylvania Historical and Museum Commission: Renovation and Curation of Paleobotany Collections

M. Graham Netting Research Grant, Carnegie Museum of Natural History: Late Quaternary paleoecology of the American West

1984 M. Graham Netting Research Grant, Carnegie Museum of Natural History: Middle to late Quaternary biota from the Trout Cave area, Pendleton Co., West Virginia (with A.D. Barnosky)

National Science Foundation grant (Ecology): Postglacial vegetation and climate of the northern Great Plains (to H.E. Wright, Jr.)

1983 NATO Postdoctoral Fellowship, Trinity College, Dublin

1982 Travel grants to XI INQUA Congress, Moscow. National Research Council and University of Washington

1981 National Science Foundation Dissertation Improvement Grant: Vegetation and climate history of southwestern Washington

| | |
|---|---|
| | Robert K. Fahnestock Award in Geomorphology, Geological Society of America |
| | Sigma Xi, grant-in-aid |
| | Geological Society of America, grant-in-aid |
| 1980 | Scholarship, English-speaking Union |
| 1978-1983 | National Science Foundation Graduate Fellowship (three nonconsecutive years) |
| 1977-1982 | Corporation Fund Grant, Department of Geological Sciences, University of Washington |
| 1977 | National Science Foundation Graduate Fellowship, honorable mention |
| 1976 | Thomas J. Watson Fellowship |
| 1975 | Outstanding senior, Rocky Mountain Association of Geologists |
| 1972-1975 | Dean's List, Colorado College |
| 1971 | National Merit Award of Commendation |

## PROFESSIONAL SOCIETY MEMBERSHIPS

Phi Beta Kappa
Sigma Xi
Geological Society of America
American Quaternary Association
Irish Quaternary Association
American Association of Stratigraphic Palynologists
Association of American Geographers
American Association for the Advancement of Science

## PROFESSIONAL SERVICE

| | |
|---|---|
| current | President-elect, American Quaternary Association (1998-2000); President (2000-2002) |
| | Editorial Board, *Geology* |
| | Editorial Board, *Review of Palaeobotany and Palynology* |
| | AAAS Executive Committee (American Association for the Advancement of Science, Pacific Division) |
| | PEP1: Paleoclimates of the Americas Program Committee |
| | Steering Committee: Bioregional Atlas Series of the Pacific Northwest, Ecotrust. |
| | Board Member of the Biogeography Specialty Group, Assoc. of American Geographers |
| | Western North American Coordinator for the NOAA National Geophysical Data Center, Global Paleovegetation Data Base |
| | Scientific Review Panel on Status of Mountain Goats in Olympic National Park, Conservation Biology Institute |
| 1998-1999 | AAG Biogeography Specialty Group, Student Paper Competition Organizer and Judge |
| 1996 | Organizer "Last interglacial-glacial cycle" symposium, International Palynology Conference, Houston. |
| | AMIGO (America's Interhemisphere Geo-Biosphere Organization), Paleoecology and fire history group |
| 1995-1998 | Steering Committee, PAGES Pep I; Western North America |
| 1994-1998 | Participant in Biome 6000 Projectl IGBP sponsored project. |
| 1994 | Program Co-chair, Biennial meeting of the American Quaternary Association |
| 1993-1995 | Review Panel, National Science Foundation Geologic Record of Global Change Program |
| 1991-1996 | Advisory Board, North American Pollen Data Base |
| | Advisory Board, Denver Natural History Museum |
| | Holocene Commission, International Quaternary Union |
| 1990-1994 | Elected Councilor, American Quaternary Association |

RECENT INVITED PRESENTATIONS

1999 Chair, AAG Panel Discussion on Ecosystem Management, Honolulu.
Ecological Society of America: Paleoecology and Ecosystem Management Symposium
Yellowstone National Park Biennial Science Conference
Geological Society of America, Fire records Symposium

1998 AGU Chapman Conference: Causes of Millennial Scale Climate Change
Wildlife Society: Fire history studies
Yellowstone National Park: 125th Anniversary Symposium
University of Montreal Center for Global Change
Environmental Protection Agency
Oregon State University
Paleoclimates of the Americas, Merida
Association of American Geographers
Biennial meeting of the American Quaternary Association
Lane County Natural History Society

1997 University of Wyoming
Oregon State University
USDA Forest Science Lab
InterAmerican Institute Workshop, Silver Falls
Geological Society of America, invited symposium

PUBLICATIONS IN PEER-REVIEW JOURNALS, PROCEEDINGS, AND BOOKS

in press

Whitlock, C., and Millspaugh, S.H. Holocene vegetation and fire history of the Greater Yellowstone Ecosystem; with emphasis on the Yellowstone Lake region. In Human Settlement of the Foothill-Mountain Environments Proceedings of the Rocky Mountain Anthropology Conference in Jackson WY, Sept. 30-Oct. 2, 1993.

Whitlock, C. The paleoecologic record in Chapter 2: What managers ought to know about the ecology and dynamics of the Coast Range. In *Forest and Stream Management in the Oregon Coast Range* (S. Hobbs, J. Hayes, R. Johnson, G. Reeves, T. Spies, and J. Tappeiner, editors). Oregon State University Press, Corvallis.

Whitlock, C., Sarna-Wojcicki, A.M., Bartlein, P.J., and Nickmann, R.J. Vegetation history and tephrostratigraphy at Carp Lake, Southwestern Washignton, U.S.A. *Palaeogeography, Palaeoclimatology, and Palaeoecology*..

Kershaw, A.P., and Whitlock, C. (editors). Paleoecological records of the last glacial/interglacial cycle: patterns and causes of change. Special issue of *Palaeogeography, Palaeoclimatology, and Palaeoecology.*

Mohr, J.A., Whitlock, C., and Skinner, C.N. Postglacial vegetation and fire history, eastern Klamath Mountains, California. *The Holocene.*

Submitted

Whitlock, C., and Markgraf, V. Paleoecologic comparison of the temperate forests of western North America and South America. In *Disruptions and Variability in Ecosystems Processes and Patterns* (G.A. Bradshaw, P. Alaback, and H. Mooney, eds). Springer Verlag.

Whitlock, C., and Knox, M.A. Prehistoric Burning in the Pacific Northwest. In: Fires in Western Wilderness. (T.R. Vale, ed.)

Whitlock, C. Markgraf, V., Ashworth, A., Bartlein, P. Temperate Coast Regions in North America and SouthAmerica during the LGM and early Holocene. In *Paleoclimates of the Americas* (V. Markgraf, ed.) Academic Press.

Whitlock, C., Reasoner, M.A., and Key, C.J. Paleoenviromental History of the Rocky Mountain region during the last 20,000 years. In *Rocky Mountain Futures: An Ecological Perspective* (J.A. Barron, D. Fagre, R. Hauer, eds.)

Whitlock, C., and Anderson, R.S. Methods and interpretation of fire history reconstructions based on sediment records from lakes and wetlands. In *Fire and Climatic Change in the Americas* (T.W. Swetnam, G. Montenegro, and T.T. Veblen,eds.)

Millspaugh, S.H., Whitlock, C., and Bartlein, P.J. Variations in fire frequency and climate over the last 17,000 years in central Yellowstone National Park. *Geology*.

Millspaugh, S.H. and Whitlock C. Postglacial fire, vegetation, and climate history of the Yellowstone-Lamar and Central Plateau provinces, Yellowstone National Park. In *After the Fires: The Ecology of Change in Yellowstone National Park* (L. Wallace, ed.). Yale University Press.

Moss, M.L., Peteet, D.M., Whitlock, C. Mid-Holocene Culture and Climate on the Northwest Coast of NorthAmerica. *Annals of the Carnegie Museum*.

Blinnikov, M. Busacca, A., and Whitlock, C. A new 100,000-year phytolith record from the Columbia Basin, Washington, USA. Proceedings of the International Phytolith Congress, Aix en Provence.

Wimberly, M.C., Spies, T.A., Long, C.J., and Whitlock, C. Variability in the amount of old forests in the Oregon Coast Range: historic patterns and their implications for forest management. *Conservation Biology*.

Alaback, P., Veblen, T.T., Whitlock, C., Lara, A., Kitzberger, and Villalba, R. Climatic and anthropogenic influences on fire regimes in temperate forest ecosystems in western North and South America. In *Disruptions and Variability in Ecosystems Processes and Patterns* (G.A. Bradshaw, P. Alaback, and H. Mooney, eds). Springer Verlag.

1999 Whitlock, C., and Grigg, L.D. Paleoecological Evidence of Milankovitch and Sub-Milankovitch Climate Variations in the Western U.S. during the late Quaternary. In *Mechanisms of millennial-scale global climate change* (R.S. Webb and P.U. Clark, editors). AGU Geophysical Monograph 112.

1998 Grigg, L.D., and Whitlock, C. Late-glacial climate and vegetation changes in western Oregon. *Quaternary Research* 49: 287-298.

Long, C.J., Whitlock, C., Bartlein, P.J., Millspaugh, S.H. A 9000-year fire history from the Oregon Coast Range, based on a high-resolution charcoal study. *Canadian Journal of Forest Research* 28: 774-787.

Bartlein, P.J., Anderson, P.M., Anderson, K.H., Edwards, M.E., Thompson, R.S., Webb, R.S., Webb, T. III, and Whitlock, C. Paleoclimate simulations for North America over the past 21,000 years: features of simulated climate and comparisons with paleoenvironmental data. *Quaternary Science Reviews* 17, 549-585.

MacDonald, G.M., Cwynar, L.C., and Whitlock, C. The late-Quaternary history of pines in northern North America. In *Ecology and Biogeography of Pinus* (D.M. Richardson, ed.), pp. 122-136. Cambridge University Press, Cambridge, UK.

1997 Whitlock, C., and Bartlein, P.J. Vegetation and climate change in northwest America during the past 125 kyr. *Nature* 388: 57-61.

Bartlein, P. J., Whitlock, C., and Shafer, S. Future climate in the Yellowstone National Park region and its potential impact on vegetation. *Conservation Biology* 11: 782-792.

Whitlock, C., Bradbury, J.P., and Millspaugh, S.H. Controls on charcoal distribution in lake sediments: case studies from Yellowstone National Park and Northwestern Minnesota. In *Sediment Records of Biomass Burning and Global Change* (J.S. Clark, H. Cachier, J.G. Goldhammer, and B.J. Stocks, eds). Springer Verlag.

Hebda, R. J., and Whitlock, C. Environmental history of the coastal temperate rainforest of northwest North America. In *The Rain Forests of Home: Profile of a North American Bioregion* (P.K. Schoonmaker, B. von Hagen, and E.C. Wolf, eds), pp. 227-254. Island Press, Washington, DC

1996 Whitlock, C., and Millspaugh, S.H. Testing assumptions of fire history studies: an examination of modern charcoal accumulation in Yellowstone National Park. *The Holocene* 6: 7-15.

1995 Whitlock, C., Bartlein, P.J., and Van Norman, K.J. Stability of Holocene climate regimes in the Yellowstone region. *Quaternary Research* 43, 433-436.

Whitlock, C. The history of *Larix occidentalis* during the last 20,000 years of environmental change in Ecology and management of *Larix* forests. U.S. Department of Agriculture Forest Service, Intermountain Research Station General Technical Report GTR-INT-319. pp. 83-90.

Whitlock, C. Review of "Mountains and Plains: the Ecology of Wyoming Landscapes" by Dennis H. Knight. *Yellowstone Science* 3, 15-16..

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1994 Whitlock, C. Long-term vegetational response to climatic change and edaphic conditions in Yellowstone National Park. In *Plants and Their Environments: Proceedings of the First Biennial Scientific Conference on the Greater Yellowstone Ecosystem.* National Park Service Technical Report NPS/NRYELL/NRTR, 301-304.

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1993 Whitlock, C. Postglacial vegetation and climate of Grand Teton and southern Yellowstone National Parks. *Ecological Monographs* 63: 173-198.

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1992 Whitlock, C. Vegetational and climatic history of the Pacific Northwest during the last 20,000 years: Implications for understanding present-day biodiversity. *The Northwest Environmental Journal* 8: 5-28.

Janssens, J.A., Hansen, B.C.S., Glaser, P.H., and Whitlock, C. Development of a raised-bog complex in northern Minnesota. In *Patterned peatlands of northern Minnesota* (H.E. Wright, Jr., B. Coffin, and N. Aasing, eds) pp. 189-222. University of Minnesota Press, Minneapolis.

1991 Engstrom, D.R., Whitlock, C., Fritz, S.C., and Wright, H.E., Jr. Recent environmental changes inferred from the sediments of small lakes in Yellowstone's Northern Range. *Journal of Palaeolimnology 5:* 139-174.

Whitlock, C., Fritz, S.C., and Engstrom, D.R. A prehistoric perspective on Yellowstone's Northern Range. In *The Greater Yellowstone Ecosystem: Redefining America's Wilderness Heritage* (R.B. Keiter and M.S. Boyce, eds), pp. 289-305. Yale University Press.

Whitlock, C. Paleoecology Review of "Plant Community History: Long-term Changes in Plant Distribution and Diversity" and "After the Ice Age: the Return of Life to Glaciated North America". *Trends in Ecology and Evolution 6:* 341-342.

1990 Whitlock, C. and Dawson, M.R. Pollen and vertebrates of the Early Haughton Formation, Devon Island, Arctic Canada. *Arctic 43,* 324-330.

Whitlock, C. Review of Packrat Middens; the last 40,000 years of biotic change (J.L. Betancourt, T.R. VanDevender, and P.S. Martin, eds; University of Arizona Press). *Science 250,* 1021-1022.

Whitlock, C. Late-Quaternary vegetational and climatic history of the Yellowstone/Grand Teton region. Final Report to the University of Wyoming-National Park Service Research Center. 27 pp.

Prior to 1990, I published under my then-married name, Cathy Barnosky

1989 Barnosky, C.W. Postglacial vegetation and climate in the northwestern Great Plains of Montana. *Quaternary Research 31,* 57-73.

Wright, H.E., Jr., Barnosky, C.W., Engstrom, D.R., and Fritz, S.C. Limnological and environmental changesinferred from the sediments of small lakes in the Northern Range of

Yellowstone National Park. Final report to the University of Wyoming-National Park Service Research Center.

1988 Barnosky, C.W. A late-glacial and postglacial pollen record from the Dingle Peninsula, County Kerry, southwestern Ireland. *Proceedings of the Royal Irish Academy,* 88B, 23-27.

Barnosky, A.D., Barnosky, C.W., Nickmann, R.J., Ashworth, A.C., Schwert, D.P., and Lantz, S.W. Late Quaternary paleoecology at the Newton Site, Bradford Co., northeastern Pennsylvania: *Mammuthus columbi*, palynology and fossil insects. In *Proceedings of the Smith Symposium: Late Pleistocene and early Holocene paleoecology and archaeology of the eastern Great Lakes region* (R.S. Laub, D.W. Steadman, and N.G. Miller, Editors). pp. 173-184. *Bulletin of the Buffalo Society of Natural Sciences 33*.

COHMAP Members. Climatic Changes of the last 18,000 years: Observations and model simulations. *Science* 241, 1043-1052.

1987 Barnosky, C.W. Response of vegetation to climatic changes of different duration in the late Neogene. *Trends in Ecology and Evolution* 2, 247-250.

Omar, G., Johnson, K.R., Hickey, L.J., Robertson, P.B., Dawson, M.R., and Barnosky, C.W. Fission-track dating of Haughton Astrobleme and included biota, Devon Island, Northwest Territory, Canada. *Science* 237, 1603-1605.

Barnosky, C.W., Grimm, E.C., and Wright, H.E., Jr. A review of the postglacial history of the northern Great Plains. *Annals of Carnegie Museum* 56, 259-273.

Barnosky, C.W., Anderson, P.M., and Bartlein, P.J. The northwestern U.S. during deglaciation: vegetational history and paleoclimatic implications. In *North America and Adjacent Oceans During the Last Deglaciation* (W.F. Ruddiman and H.E. Wright, Jr., eds.), pp. 289-321. The Geology of North America, vol. K-3. Geological Society of America, Boulder.

1985 Barnosky, C.W. Late-Quaternary vegetation history near Battle Ground Lake, southern Puget Trough, Washington. *Geological Society of America Bulletin* 96, :263-271.

Barnosky, C.W. A record of late-Quaternary vegetation from the southwestern Columbia Basin, Washington. *Quaternary Research* 23, 109-122.

Barnosky, C.W. Book review: "An Atlas of Past and Present Pollen for Europe: 0 - 13000 Years Ago" by B. Huntley and H.J.B. Birks (Cambridge University Press). *Quaternary Research* 24, 133-135.

Janssens, J.A., and Barnosky, C.W. Late-Pleistocene and early-Holocene bryophytes from Battle Ground Lake, Washington, U.S.A. *Review of Palaeobotany and Palynology* 46, 97-116.

1984 Barnosky, C.W. Late Miocene vegetational and climatic variations inferred from a pollen record in northwest Wyoming. *Science* 223, 49-51.

Barnosky, C.W. Late Pleistocene and early Holocene environmental history of southwestern Washington State, U.S.A. *Canadian Journal of Earth Sciences* 21, 619-629.

Wright, H.E., Jr., and Barnosky, C.W. (editors). *Late Quaternary Environments of the Soviet Union.* University of Minnesota Press, Minneapolis.

Wright, H.E., Jr., and Barnosky, C.W. Introduction. *In*: *Late Quaternary Environments of the Soviet Union* (A.A. Velichko, H.E. Wright, Jr., and C.W. Barnosky, eds.). University of Minnesota Press, Minneapolis.

Dean, W.E., Bradbury, J.P., Anderson, R.Y. and Barnosky, C.W. The variability of Holocene climate change: evidence from varved lake sediments. *Science* 226, 1191-1194.

1983 Barnosky, C.W. Late-Quaternary vegetational and climatic history of southwestern Washington. Ph.D. Dissertation, University of Washington.

Martin, J.E., Barnosky, A.D., and Barnosky, C.W. Fauna and flora associated with the West Richland mammoth from the Pleistocene Touchet Formation in south-central Washington. *Research Reports of the Burke Memorial Museum No. 3*, 1-61.

Oldfield, F., Barnosky, C., Leopold, E., and Smith, J. Mineral magnetic studies of lake sediments--a brief review. In *Paleolimnology* (J. Merilainen, P. Huttonen, and R.W. Battarbee, eds.), pp. 37-44. W. Junk Publishers, The Hague.

1981 Barnosky, C.W. A record of late Quaternary vegetation from Davis Lake, southern Puget Lowland, Washington. *Quaternary Research* 16, 221-239.

1979 Barnosky, C.W. Late Quaternary vegetation history of the southern Puget Lowland: a long record from Davis Lake, Washington. M.S. thesis, Department of Geological Sciences, University of Washington.

1978 Edson, G.M., and Barnosky, C.W. Lithologic and geophysical logs of holes drilled in the Willow Springs Quadrangle, Emery and Sevier counties, Utah. *U.S. Geological survey Open-file Report* 77-866.

COURSES TAUGHT AT UNIVERSITY OF OREGON

Geog. 101: The Natural Environment (1990-1997 alternate years)
Geog. 323: Biogeography (1990, 1991, 1992, 1994, 1997-1999)
Geog. 423, 523: Advanced Biogeography (1997, 1999)
Geog. 430, 530: Quaternary Environments (1990-1994, 1997-1999)
Geog. 431, 531: Quaternary Vegetation History (1991, 1993, 1995, 1997)
Geog. 607: Seminar: Quaternary of Pacific Northwest (1991, 1997)
Geog. 607: Seminar: Disturbance History and Environmental Change (1994)

MAJOR ADVISOR ON GRADUATE COMMITTEES

L. Berkeley M.A. (in progress), Geography
M. Blinnikov Ph.D. (8/99), Geography
C. BrilesM.A. (in progress), Geography
A. Brunelle-Daines Ph.D. (in progress), Geography
H. Friefeld Ph.D. (6/99), Geography
K. Hakala Ph.D. (in progress), Univ. Pittsburgh, Department of Earth and Planetary Sciences
J. Gardner M.A. (8/99), Geography
L. Grigg M.A. (12/96), Geography; Ph.D. (in progress), Geography
M. Knox M.A. (in progress), Geography; Ph.D. (in progress), Geography
C. Long M.A. (3/96), Geography
S. Millspaugh M.S. (8/91), Univ. Pittsburgh, Department of Earth and Planetary Sciences; Ph.D. (12/97), Geography
T. Minckely M.A. (12/98), Geography
J. Mohr M.A. (12/97), Geography

| | |
|---|---|
| C. Pearl | M.A. (6/99), Environmental Studies |
| M. Power | Ph.D. (in progress), Geography |
| D. Sea | M.S. (12/93), Department of Geological Sciences |
| B. Sherrod | M.S. (12/90), Univ. Pittsburgh, Department of Earth and Planetary Sciences |
| A. Tattersall | M.S. (6/99), Interdisciplinary Studies |
| M. Worona | M.S. (6/93), Department of Geological Sciences |

DEPARTMENTAL SERVICE

| | |
|---|---|
| 2000-2003 | Department Head |
| 1999- | Undergraduate Program Director |
| | Faculty Search Committee |
| | Graduate Admission Committee |
| | Department Seminar Series |
| | Tenure and Promotion Committee |
| 1997-1998 | Trussell Family Scholarship Committee |
| 1993-1995 | Graduate Program Director |
| 1994-1995 | Faculty Search Committee |
| 1994 | Department Seminar Series |
| 1992-1993 | Charitable Fund Drive Chair |
| 1991-1993 | Trussell Family Scholarship Committee Chair |
| 1990-1993 | Library Representative |
| 1990-1991 | Graduate Admissions Committee |

UNIVERSITY SERVICE

| | |
|---|---|
| 1998-1999 | University Senate |
| 1994-1997 | University Senate |
| 1993-1999 | Environmental Studies Advisory Committee |
| 1993-1994 | Faculty Search Committee for Vice President for Academic Affairs |
| 1991-1992 | Strategic Plan Action Team on Infrastructure and Technical Support |
| | Out-of-State Travel Committee (CAS) |
| 1990-1999 | General Sciences Advisory Committee |

## 1.4 **Fred Ramsey**

### 1.4.1 Specialty

Dr. Ramsey's specialty is the application of statistics to biological research. He has particular interests and abilities in statistical ecology. Dr. Ramsey is a leading expert in the use of statistics in population studies, wildlife habitat relationships and wildlife surveys. He has worked as the chief statistician for the Micronesian Forest Bird Survey and the Hawaiian Forest Bird Survey. He has received several prestigious awards including the Distinguished Statistical Ecologist Award, from the International Congress of Ecology.

### *1.4.2 Role in the Project*

Dr. Ramsey's primary contribution to this project was be to guide the review of the statistical methods used in studies relating to mountain goat population, dispersal, herbivory and other impacts and studies of botany and plant ecology. He prepared evaluations of the statistical validity the results of key studies and described the strength and power of important results.

### *1.4.3 Curriculum Vitae*

**Fred Lawrence Ramsey, Ph. D.**
Statistician

EDUCATION

Doctor of Philosophy, Iowa State University. 1964
Major: Statistics
Minor: Mathematics, Economics.
Thesis: Effects of trend elimination on tests for time series.

Master of Science, Iowa State University. 1963
Major: Statistics
Minor: Mathematics, Economics.
Thesis: Fiducial prediction in location and scale families.

Bachelor of Arts Degree, University of Oregon. 1961.
Major fields: Mathematics, Economics, Philosophy.

Post-Doctoral Fellow, Johns Hopkins University. 1965-66.
Major field: Statistics.

## PROFESSIONAL EXPERIENCE

Oregon State University; Corvallis, Oregon
Professor of Statistics; 1986- present.

Murdoch University; Perth, Western Australia
Visiting Scholar; August, 1997 - March, 1998.

Oregon Health Sciences University; Portland, Oregon
Research Consultant, Department of Neurosurgery; 1989-93.

University of Wollongong. Wollongong, New South Wales, Australia
Visiting Professor; 1985-86.

U.S. Fish & Wildlife Service, Environmental Services Office; Honolulu, Hawaii
Chief Statistician for Micronesian Forest Bird Survey; 1981-86.

U.S. Fish & Wildlife Service, Endangered Species Program; Patuxent, Maryland
Chief Statistician for Hawaiian Forest Bird Survey; 1977-86.

Oregon State University; Corvallis, Oregon
Associate Professor of Statistics; 1973-1986.

University of Copenhagen; Copenhagen, Denmark.
Visiting Lecturer; 1972-73.

Oregon State University; Corvallis, Oregon
Assistant Professor of Statistics; 1966-72.

Goddard Space Flight Center; Greenbelt, Maryland.
Statistician; 1965.

Iowa State University; Ames, Iowa
Assistant Professor of Statistics; 1964.

Bonneville Power Administration; Portland, Oregon.
Mathematician; 1962.

## AWARDS

Fellow of the American Statistical Association, 1996.
Distinguished Statistical Ecologist Award; International Congress of Ecology, 1994.
Outstanding Monograph Award; The Wildlife Society, 1987.
Elected Member of the International Statistical Institute, 1984.
Special Achievement Award; U.S. Fish & Wildlife Service, 1982.
OSSSO Teaching Award; Oregon State University, 1975.
Snedecor Award in Statistics; Iowa State University, 1964.
De Cou Prize in Mathematics; University of Oregon, 1961.

## ORGANIZATIONS

American Statistical Association (ASA)
The Biometric Society
International Statistical Institute

NATIONAL AND INTERNATIONAL COMMITTEES AND PROFESSIONAL ACTIVITIES

ASA Committee on Environmental Monitoring and Assessment; 1996.
Visiting Lecturer; Committee of Presidents of Statistical Societies (COPSS); 1884-96.
Editorial Board, *Journal of Environmental and Ecological Statistics*; 1992 - present.
Snedecor Award Committee, representing American Statistical Association; 1993.
Associate Editor, *Biometrics*; 1989-94.
Committee on Statistics in Wildlife and Fisheries Research, Biometrics Section,
American Statistical Association; 1979 -
Environmental Protection Agency Review Panels; 1984 and 1987.
Aquatic and Terrestrial E.P.A. Review Committee (ASA); 1984-5.
Steering Committee, International Symposium on "Estimating the Numbers of Terrestrial
Birds"; Asilomar, California; 1980.

PUBLICATIONS
[Order of authorship in parentheses]

Characteristics of forests at spotted owl nest sites in the Pacific Northwest. With K.T. Hershey and E.C.Meslow (3). *Journal of Wildlife Management* (to appear, 1998).

Detectability analysis in wildlife surveys, with application to sea turtle populations in the tropical Pacific ocean. With S. Beavers (2). *Journal of Wildlife Management* (to appear July, 1998).

Optimality of an unconditional estimator of population size. With K. Harrison (2). *Journal of Environmental and Ecological Statistics (*to appear, 1999).

Conditional and unconditional estimators of a population total. With V.M. Lesser (1). ). *Journal of Environmental and Ecological Statistics* **2**:181-190. 1995.

Differential permeability and quantitative MR imaging of a human lung carcinoma brain xenograft in the nude rat. With P.A. Barnett, S. Roman-Goldstein, C.I. McCormick, G. Sexton, J. Szumowski, and E.A. Neuwelt (3). *American Journal of Pathology* **146**(2):436-449. February, 1995.

The effect of blood-brain barrier disruption on intact and fragmented monoclonal antibody localization in intracerebral human carcinoma xenografts. With E.A. Neuwelt, P.A. Barnett, K.E. Hellstrom, and C.I. McCormick (6). *Journal of Nuclear Medicine* **35**(11):1831-41. November, 1994.

Habitat association studies in conjunction with adaptive cluster sampling. With R. Sjamsoe'oed (1). *Journal of Environmental and Ecological Statistics* **2**:1-21. 1994.

The impact of intracerebral tumor size and drub molecular weight on the need for blood-brain barrier disruption. With E.A. Neuwelt, P.A. Barnett, C.E. McCormick, and L.G. Remsen (5). *AmericanJournal of Pathology,* **1994.**

Effects of Gd-DTPA after osmotic BBB disruption in a rodent model: toxicity and MR findings. With S. Roman-Goldstein, P.A. Barnett, C.I. McCormick, J. Szumowski, E.M. Shannon, and E.A. Neuwelt (6). *Journal of Computer Assisted Tomography* **18**(5):731-36. 1994.

Osmotic blood-brain barrier disruption: CT and radionuclide imaging. With W. Roman-Goldstein, D.A. Clunie, J. Stevens, R. Hogan, J. Monard, and E.A. Neuwelt (6). *American Journal of Neuro-radiology* **15**:581-90. 1994.

Habitat association studies of the northern spotted owl, sage grouse, and flammulated owl. With M. McCracken, M. Drut, and J. Crawford (1). *Case Studies in Biometry, Ch. 10*. Ed: N. Lange et al.,International Biometric Society. John Wiley & Sons, N.Y. 1994.

Effects of behavioral stimuli on plasma interleukin-1 activity in humans at rest. With W.H. Keppel, D.H. Regan, S.H. Heffeneider, and S. McCoy (5). *Journal of Clinical Psychology* **49**(6):777-85. 1993.

Dexamethasone decreases the delivery of tumor-specific monoclonal antibody to both intracerebral and subcutaneous tumor xenografts. With E.A. Neuwelt, P.A. Barnett, I. Hellstrom, and C.I. McCormick (3). *Neurosurgery* **33**(3):478-84. 1993.

An adaptive procedure for sampling animal populations. With S.K. Thompson and G.A.F. Seber (2). *Biometrics* **48**(4):1195-1200. 1992.

Evaluation of a program to prevent head and spinal cord injuries: A comparison between middle school and high school. With A.E.C. Avolio and E.A. Neuwelt (2). *Neurosurgery* **31**:557-62. 1992.

Effect of gadopentetate dimeglumine administration after osmotic blood brain barrier disruption: toxicity and MR imaging findings. With S. Roman-Goldstein, P.A. Barnett, C.I. McCormick, M.J. Ball, and E.A. Neuwelt (5). *American Journal of Neuroradiology* **12**:885-90. 1991.

Primary CNS Lymphoma treated with osmotic blood-brain barrier disruption: prolonged survival andpreservation of cognitive function. With E.A. Neuwelt, D.L. Goldman, S.A. Dahlborg, J. Crossen, S. Roman-Goldstein, R. Braziel, and B. Dana (5). *Journal of Clinical Oncology* **9**(9):1580-90. 1991.

*Micronesian Forest Bird Survey, The Federated States: Pohnpei, Kosrae, Chu'uk, and Yap*. With J. Engbring (2). U.S. Fish & Wildlife Service, Office of Environmental Services, Honolulu,Hawaii. 312 pp. 1990.

Comments on a 'Saturation Index'. *Oecologia* **81**:569-70. *A 1986 Survey of the Forest Birds of American Samoa*. With J. Engbring (2). U.S. Fish & Wildlife Service, Office of Environmental Services, Honolulu, Hawaii. 145 pp. 1989.

On transect sampling to assess wildlife populations and marine resources. With K.E. Gates, G.P. Patil, and C. Taillie (1). In *Handbook of Statistics, vol. 6*. Eds.: P.R. Krishnaiah and C.R. Rao., N. Holland Publishing Co. 1988.

Dispersed and underdispersed dependencies. With B.M. Walker and R.C. Bell (2). *International Journalof Personal Psychology* **1**:68-80. 1988.

The Slug Trace. *The American Statistician* **42**:290. 1988.

Transect methods. Encyclopedia of Statistical Sciences, vol. 9. (pp. 309-12.) Eds.: S. Kotz and N.L.Johnson. John Wiley & Sons, Inc. N.Y. 1988.

Detectability functions in observing spatial point processes. With S.K. Thompson (2). *Biometrics* **43**:355-62. 1987.

Covariate adjustments of effective area in variable area wildlife surveys. With V.J. Wildman and J. Engbring (1). *Biometrics* **43**:1-11. 1987.

A fable of PCA. *The American Statistician* **40**:323-24. 1986.

*Pacific Islands Forest Bird Survey, 1982: Saipan, Tinian, Agiguan, and Rota*. With J. Engbring and V.J. Wildman (2). U.S. Fish & Wildlife Service, Office of Biological Services, Washington D.C. 1986.

Aquatic research review report: ASA Reviews of EPA-funded acid precipitation research. With G.P.Patil, W. Liggett, and W.K. Smith (3). *The American Statistician* **39**(4):254-259. 1985.

Surveys for monitoring changes and trends in renewable resources: forests and marine fisheries. With J. Bernard, W. Myers, J. Pearce, M. Sissenwine and W.K. Smith (4). The American Statistician 39(4):363-373. 1985.

*Distribution and abundance of the forest birds of Guam: results of a 1981 survey*. With J. Engbring (2).U.S. Fish & Wildlife Service, Office of Biological Services, Washington D.C. 54 pp. 1984.

Diet dissimilarity. With C.P. Marsh (1). *Biometrics* **40**:707-15. 1984.

Effects of abundant species on the ability of observers to make accurate counts of birds. With J.M. Scott (2). *The Auk* **98**:610-13. 1981.

Analysis of bird survey data using a modification of Emlen's method. With J.M. Scott (1). Estimating the Numbers of Terrestrial Birds. Eds.: C.J. Ralph and J.M. Scott. *Studies in Avian Biology* **6**:483-87 1981.

Tests of hearing ability. With J.M. Scott (1). Estimating the Numbers of Terrestrial Birds. Eds.: C.J. Ralph and J.M. Scott. *Studies in Avian Biology* **6**:341-45. 1981.

Length of count period as a possible source of bias in estimating bird numbers. With J.M. Scott (2). Estimating the Numbers of Terrestrial Birds. Eds.: C.J. Ralph and J.M. Scott. *Studies in Avian Biology* **6**:409-13. 1981.

Distance estimation as a variable in estimating bird numbers. With J.M. Scott and C.B. Kepler (2). Estimating the Numbers of Terrestrial Birds. Eds.: C.J. Ralph and J.M. Scott. *Studies in Avian Biology* **6**:334-40. 1981.

Avian surveys of large geographical areas: a systematic approach. With J.M. Scott and J.D. Jacobi (3).*Wildlife Society Bulletin* **9**. 1981.

Estimating population densities from variable circular plot surveys. With J.M. Scott (1). *Sampling Biological Populations*. Eds.: R.M. Cormack, G.P. Patil and D.S. Robson. StatisticalEcology, Vol S5. International Cooperative Publishing House. Fairland, Md. 1979.

Parametric models for line transect surveys. *Biometrika* **66**:505-12. 1979.
Statistical problems arising from surveys of rare and endangered forest birds. With J.M. Scott and R.T.Clark (1). *Proc. 42nd Session of the International Statistical Institute*. Manila, Philippines, 1979.

A bang-bang representation for 3x3 embeddable stochastic matrices. With S. Johansen (2). *Wahrscheinlichkeithstheorie, Gebiete* **47**:107-18. 1979.

A note on the small sample power functions for nonparametric tests of location in the double exponentialfamily. With W.J. Conover and O. Wehmanen (3). *Journal of the American Statistical Assn.* **73**:188-90. 1978.

Vertical distribution and migration of oceanic micronekton off Oregon. With W.G. Pearcy, E. Krygier,and R. Mesecar (4). *Deep Sea Research* **24**:223-45. 1977.

Probability distributions of breaking wave heights, emphasizing the utilization of the JONSWAP spectrum. With J.H. Nath (2). *Journal of Physical Oceanography* **6**:316-23. 1976.

Characterization of the partial autocorrelation function. *Annals of Statistics* **2**:1296-1301. 1974.

Particle concentrations over the oceans. With W.P. Elliott and R. Johnston (2). *Journal de ResearchesAtmospheriques* **VIII**:939-45. 1974.

The size distribution and inland penetration of sea-salt particles. With G.F. Rossknecht and W.P. Elliott (3). *Journal of Applied Meteorology* **12**. 1973.

A Bayesian approach to bioassay. *Biometrics* **28**:841-58. 1972.

Small sample power functions for nonparametric tests of location in the double exponential family. *Journal of the American Statistical Association* **66**. 1971.

Comments on cloud condensation nuclei from industrial sources and their apparent influence on precipitation in Washington State. With W.P. Elliott (2). *Journal of Atmospheric Sciences 27* 1970.

BOOKS AND MONOGRAPHS

*The Statistical Sleuth – A Course in Data Analysis*. With D.W. Schafer. Duxbury Press. 1997.

*Forest Bird Communities of the Hawaiian Islands: Their Dynamics, Ecology and Conservation*. WithJ.M. Scott, S. Mountainspring, and C.B. Kepler (3). Studies in Avian Biology, No. 9. 1986.

*Birding Oregon*. Published by the Audubon Society of Corvallis, Oregon. 1978. (Non-technical and not refereed.)

INVITED SPEAKER ADDRESSES

Workshops on the application of statistical methods in wildlife research.
    Curtin University, Perth Western Australia. November, 1997.
    The University of Queensland, Brisbane, Queensland, Australia. March, 1998.
    Gatton Agricultural College, Gatton, Queensland, Australia. March, 1998.
Marbled murrelet ocean survey conference. U.S. Fish & Wildlife Service. Barlow, Oregon, Nov. 1996.
American Statistical Assn., Montana Chapter Meetings. Butte, Montana. October, 1997.
Walla Walla College Mathematics Awareness Week, Keynote addresses. Walla Walla, WA. May, 1995.
American Statistical Assn., annual meetings. Toronto, Canada. August 1994.
International Statistical Institute. Bologna & Florence, Italy. August, 1993.
Biometric Society (WNAR) and Institute of Mathematical Statistics joint meetings. Honolulu, Hawaii June, 1988.
30th annual meeting of the Australian Mathematical Society, University of Western Australia, Perth Western Australia. May, 1986.
West Australian Statistical Society annual meetings. Perth, Western Australia. May, 1986.
Biometric Society (WNAR). San Luis Obispo, California. June, 1985.
Symposium on Estimating the Numbers of Terrestrial Birds (4 papers). Asilomar, California. Oct., 1980.
42nd Session of the International Statistical Institute. Manila, Philippines. December, 1979.
Second International Ecological Congress (4 papers). Parma, Italy. August, 1978.

PROFESSIONAL CONSULTANCIES

Multnomah County, Oregon
    Cooper v. Multnomah County et al.
    Statistical Consultant, 1996.
    Contact: Hele Rode, Assistant County Counsel

Willner & Associates, Attorneys at Law. Suite 303, 111 Front Avenue, Portland, OR 97204-3500
    Kapner, Wolfberg & Associates v. Kaiser Foundation Health Plan. Suit No. 94-1216-JE
    Statistical Consultant, 1995-6.
    Contact: Don S. Willner

U.S. Fish & Wildlife Service; P.O. Box 50167, Honolulu, Hawaii 96850
Analysis of 1982 and 1994 bird surveys from Rota and Tinian. 1995.
Contact: Michael Lusk

University of Idaho; Moscow, Idaho 83844
Hawaiian Bird Survey Statistical Workshop
Contact: Oz Garton

Smith & Pearson, Attorneys at Law. 905 Spaulding Building, 319 SW Washington, Portland, OR 97204
State of Oregon v. Jorge Mireles-Torres. 1994.
Statistical Consultant

U.S. Fish & Wildlife Service; P.O. Box 50167, Honolulu, Hawaii 96850
Wildlife survey workshop. Guam. 1994.
Contact: Ernest Kosaka

Conservation International. 1015 18th Street NW, Washington DC 20036
Zahamena Strict Nature Reserve Project, Madagascar. 1994-5
Statistical Consulant: Avian Survey and Monitoring Design
Contact: Fred Hannah

Willner & Zabinsky, Attorneys at Law. Suite 303, 111 Front Avenue, Portland, OR 97204-3500
Bromagem et al. v. Intel Corporation. 1993.
Statistical Consultant
Contact: Don Willner

City of Corvallis, Oregon; Public Works Department
Water Quality Analysis. 1993.
Statistical Consultant

Fruit Growers Supply Co., Fruit Growers Road, Hilt, California 96044
Habitat Association Evaluation for Siskiyou Mountain Salamander. 1993-present.
Statistical Consultant
Contact: Charles Brown

Oregon Department of Environmental Quality, Water Quality Division, Executive Building, 5th floor
811 SW 6th Avenue, Portland, Oregon 97204
Dioxin emission standard for paper mills. 1991.
Statistical Consultant

Oregon State University School of Forestry, FRM Project, DRS 031. Corvallis, Oregon 97331
Sampling plans for monitoring seed quality. 1991.
Statistical Consultant

Lane County Legal Aid Service, Inc., 376 East 11th Ave., Eugene, Oregon 97401-3246.
Sampling Disability Claims
Statistical Consultant

Pacific Power & Light Co., Pricing & Regulatory Affairs Division, 920 SW Sixth Ave., Portland, Oregon 97204
Sampling program for single phase meters. 1989-90.
Statistical Consultant

Gleaves, Swearingen, Larsen & Potter, Attorneys at Law. 975 Oak St., Eugene, OR 97401-3156
Bond, Batman & Greene v. Bohemia Inc.. 1989.
Statistical Consultant

Jolles, Sokol & Bernstein, Attorneys at Law. 721 SW Oak Street, Portland, Oregon 97205-3791
Bell v. First Interstate Bank. 1988.
Statistical Consultant

U.S. Environmental Protection Agency. Corvallis, Oregon
Multivariate analysis of National Lakes Survey. 1987.
Scientific Review Panel

Oregon Aqua Food, Inc. Springfield, Oregon
Straying rates of wild and hatchery Coho salmon. 1987.
Statistical Consultant

State of Oregon, Human Resources Division. Salem, Oregon
Food stamp issuance error rates. 1987.
Statistical Consultant

University of Arizona. Tucson, Arizona
Adjustment of salary disparities. 1984.
Statistical Consultant

ARCO Alaska. Anchorage, Alaska
Effects of pipeline placement on Caribou migration. 1980-83.
Statistical Consultant
Contact: Donald Keene

MAILING ADDRESSES

3550 NW Glenridge Place
Corvallis, Oregon 97330
ph: 541-753-3677

Department of Statistics
Oregon State University
Kidder 44
Corvallis, Oregon 97331-4606
ph: 541-737-1992
FAX: 541-737-3489
email: ramsey@stat.orst.edu

## 1.5 Mike Williams

### *1.5.1 Specialty*

Dr. Williams is a skilled botanist and plant ecologist. His expertise lies in the areas of vegetation surveys, endangered species monitoring and protection, plant population and community ecology and riparian-wetland ecology. He is experienced in the specific areas of alpine flora ecology and in rare plant dynamics through his work as both a research biologist and an environmental consultant.

### *1.5.2 Role in the Project*

Dr. Williams' primary contribution to this project was be the primary reviewer of studies relating to botany, plant ecology, herbivory and endemic, threatened and endangered plants in the Olympic National Park. He authored a summary of the extent and quality of knowledge about the effect of mountain goats on botanical resources in Olympic National Park

### *1.5.3 Curriculum Vitae*

**Michael P. Williams, Ph.D.**
Botanist and Plant Ecologist

Office:
Michael P. Williams Consulting, Inc.
P.O. Box 31669
Seattle, WA 98103-1669
PHONE: (206) 632-2384
FAX: (206) 623-3292

email: williamsconsult@seanet.com

***Summary***

Have worked as an ecological consultant since 1976. Specialties include riparian-wetland inventories and assessments, mitigation and monitoring designs, vegetation surveys, inventories of endangered, threatened, and sensitive plant species, population distributions and forest composition characterizations.

***EDUCATION***

Ph.D. Botany, emphasis Plant Ecology, University of Washington, Seattle, 1995.
M. S. Botany, University of Tennessee, Knoxville, 1980.
B. A. Botany, University of California, Santa Barbara, 1976.

***PROFESSIONAL HISTORY***

Principal and Senior Scientist, Michael P. Williams Consulting, Inc., 1988 to present.
Instructor for Vascular Plants of the Pacific Northwest Course, University of Washington, 1995.
Instructor for Snohomish County, Watershed Community Link Wetland Stewardship, 1997.
Instructor for King County Wetlands Short Course, Washington State Extension Service, 1995.
Research Associate II/Manager, University of California, Sagehen Creek Field Station, 1981 to 1985.

District Botanist, U.S.D.I. Bureau of Land Management, Winnemucca, NV, 1979-1981.
Scientist, E.G.& G., Inc., Nevada Test Site, Mercury, NV, 1976 to 1978.

### *HONORS*

Current Peer Reviewer for Conservation Biology, Madroño, and Northwest Science.
President of the Society for Ecological Restoration-Northwest Chapter (SER-NW) 1997-1998
*Astragalus yoder-williamsii* Barneby, Brittonia 32:30-32, 1980.
National Science Foundation Dissertation Improvement Grant, Fall 1986 through Fall 1988.
Sigma Xi Science Society, Elected as Member, 1985.
President of the Northern Nevada Native Plant Society, 1982-84.
Task Force Member, Urban Soil and Water Conservation, Society of Soil and Water Conservation.

### *RECENT SPECIALIZED TRAINING*

National Wetlands Training Institute, Hydric Soils and Hydrology, 1991.
Wetlands Monitoring Standards Workshop, Professional. Consultants of Snohomish Co., 1993.
Washington Growth Management Act and State Environmental Policy Act Interface Workshop, 1992.
Open Space Areas Workshop, WA Department of Ecology, Bremerton, WA, 1992.
Hydric Soils Workshop, Society of Consulting Soil Scientists, Portland, OR, 1993.
Wetlands Mitigation and Restoration Design Workshop, Seattle, WA, 1992.
Wetland Soil Geomorphology Workshop, 1994.
Natural Channel Design Principles and Applications, Nashville, TN, 1997.
Construction Site Erosion and Spill Control Certification Course, Washington Department of Transportation, 1998-2001.

### *SELECTED PUBLICATIONS*

(Used surname of Yoder-Williams from 1979 to 1989.)

Williams, M. P. 1995. Inhibition of conifer regeneration by an herbaceous perennial, Wyethia mollis. Ph.D. Dissertation, University of Washington, Seattle.

Williams, M. P. 1993. *Berberidaceae* [family treatment]. In D. Wilken and J. Hickman (eds.) The Jepson Flora. University of California Press, Berkeley.

Parker, V. T. and M. P. Yoder-Williams. 1989. Reduction of survival and growth of *Pinus jeffreyi* by an herbaceous perennial, *Wyethia mollis*, and montane chaparral. American Midland Naturalist 121:105-111.

Folt, C. L., M. J. Weaver, M. P. Yoder-Williams, and R. P. Howmiller. 1989. Field studies comparing growth and viability of a population of phototropic bacteria. Appl. and Env. Microbiology 55(1):78-85.

Erman, D.C., E. D. Andrews, and M. Yoder-Williams. 1988. Effects of winter floods on fishes in the Sierra Nevada. Can. J. Fish. Aquat. Sci. 45:2195-2200.

Raphael, M. G., M. L. Morrison, and M. P. Yoder-Williams. 1987. Breeding bird populations during twenty-five years of post-fire succession in the Sierra Nevada. Condor 89:614-626.

Yoder-Williams, M. P. and V. T. Parker. 1987. Allelopathic interference in the seedbed of *Pinus jeffreyi* in the Sierra Nevada, California. Canadian Journal of Forestry Research 17:991-994.

Morrison, M.L., M.F. Dedon, M.G. Raphael, and M.P. Yoder-Williams. 1986. Snag requirements of cavity nesting birds: Are the U.S.D.A. Forest Service Guidelines being met? Western Journal of Applied Forestry 1:38-40.

Morrison, M.L., M.F. Dedon, M.P. Yoder-Williams, and M.G. Raphael. 1986. Distribution and abundance of snags in the Sagehen Creek Basin, California. U.S.D.A. Pacific Southwest Forest and Range Experiment Station Res. Note PSW-389, 4p.

Yoder-Williams, M.P., M. Liverman, and K. With. 1985. Burned pine-forest, and mature pine-forest. In W.T. and A.C. Van Velzen (eds.), Forty-eighth breeding bird census. American Birds 39:114.

Morrison, M.L., M.P. Yoder-Williams, D.C. Erman, R.H. Barrett, M. White, and D.A. Airola. 1985. An annotated species list of vertebrates of the Sagehen Creek Basin, Nevada County, California. University of California Agricultural Experiment Station Special Publication, 16 p.

Yoder-Williams, M.P. and K. With. 1984. Burned pine-fir forest, and mature pine-fir forest. In W.T. and A.C. Van Velzen (eds.), Forty-seventh Breeding Bird Census. American Birds 38:91-92.

Morrison, M.L. and M.P. Yoder-Williams. 1984. Movement of Steller's Jays in western North America. North American Bird Bander 9:12-15.

Patterson, R. and M.P. Yoder-Williams. 1984. *Leptodactylon glabrum*, a new intermountain species of the Polemoniaceae. Systematic Botany 9:261-262.

Yoder-Williams, M.P. 1983. Burned pine-fir forest, and mature pine-fir forest. In W.T. and A.C. Van Velzen (eds.), Forty-sixth Breeding Bird Census. American Birds 37:89.

Yoder-Williams, M.P. 1982. Research natural areas and rare plants in Nevada, p. 89-95. In N.S. Van Pelt, (ed.), Research Natural Area Needs in Nevada and Utah: A First Estimate. The Nature Conservancy, San Francisco.

Yoder-Williams, M.P. 1980. Vernon Orlando Bailey (1864 - 1942): A self-taught biologist who became the Chief Naturalist for the U.S. Biological Survey. Mentzelia 5:2-4.

Williams, M.P. 1980. Studies of *Elymus mollis* directed towards its use in revegetation of maritime tundra. Masters thesis, University of Tennessee, Knoxville, 123 pp.

**PROFESSIONAL CERTIFICATIONS AND MEMBERSHIPS**

Master Bird Bander, U.S. Fish and Wildlife Service, 1981-1991.
California Botanical Society, 1975 to present.
Ecological Society of America, 1976 - 1978, 1980 to present.
Botanical Society of America, 1985 to present.
Northern Nevada Native Plant Society, 1978 to present.
California Native Plant Society, 1982 to present.
Sigma Xi, Full Member, 1985 to present.
Society for Ecological Restoration, 1992 to present.
Society of Wetland Scientists, 1990 to present.
Society for Conservation Biology, 1994 to present
Washington Native Plant Society, 1994 to present
Soil and Water Conservation Society, 1995 to present.
International Erosion Control Association, 1997

**PRESENTATIONS (last three years)**

Redefining the landscape in an agricultural economy. Landscape Connections: Working with Culture and Ecology to Restore the Inland Northwest. September 19 and 20, 1997. Washington State University, Pullman, Washington.

Inhibition of conifer regeneration by an herbaceous perennial, *Wyethia mollis*, in the eastern Sierra Nevada, California. 47th Annual Meeting of the American Institute of Biological Sciences/Botanical Society of America. August 4-8, 1996. University of Washington, Seattle, Washington.

Landscapes, ecology, ecosystems and restoration: working concepts. Session Organizer and Moderator. Symposium: The Role of Restoration in Ecosystem Management, Taking a Broader View, Society for Ecological Restoration, 1995 International Conference, University of Washington, September 14-16, 1995.

**Professional References**

1. Dr. Joseph Ammriati, Chair
   Department of Botany
   University of Washington
   Seattle, WA 98195

2. Dr. V. Thomas Parker
   Department of Biological Sciences
   San Francisco State Universtiy
   1600 Holloway Ave
   San Francisco, CA 94132

3. Dr. Harold Kleiforth
   Desert Research Institute
   Atmospheric Sciences
   P.O. Box 60220
   Reno, NV 89506

## 1.6 **Russell Graham**

### 1.6.1 *Specialty*

Dr. Graham is a distinguished paleoecologist. His primary interests focus on vertebrate paleoecology, especially in the distribution of vertebrate species during the Quaternary period. He presently is the Curator and Head of the Earth and Space Sciences division of the Denver Museum of Natural History.

### 1.6.2 *Role in the Project*

Dr. Graham's primary contribution to this project was the review of studies relating to the vertebrate paleoecology of the Olympic Peninsula. He was the lead reviewer of whether mountain goats are native to Olympic National Park. He prepared a summary of the extent and quality of knowledge about the probability and quality of evidence supporting the existence of mountain goats in Olympic National Park.

### 1.6.3 *Curriculum Vitae*

**Russell W. Graham, Ph. D.**
Paleontologist

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Curator and Head, Earth Sciences
Denver Museum of Natural History
2001 Colorado Blvd
Denver, CO 80205
Phone: 303 370-8363
FAX: 303 331-6492
e-mail: rgraham@dmnh.org

**PERSONAL**

| | |
|---|---|
| Birth Date: | May 28, 1947. |
| Birth Place: | Hammond, Indiana. |
| Citizenship: | USA. |

**EDUCATION**

1976 Ph.D., Geology, University of Texas at Austin.
1972 M.S., Geology, University of Iowa.
1969 B.S., Zoology, University of Iowa.

**EXPERIENCE**

1996- Curator and Head, Earth Sciences, Denver Museum of Natural History
1987-96 Curator and Head, Geology, Illinois State Museum, Springfield.
1981-86 Associate Curator, Illinois State Museum, Springfield.
1978-81 Research Associate, Illinois State Museum, Springfield.
1978 Consultant, Paleoindian Program, Smithsonian Institution, Washington, D.C.
1977-78 Assistant Professor, Geology, Indiana-Purdue University at Indianapolis, Indianapolis.

**PROFESSIONAL ORGANIZATIONS**

American Association for the Advancement of Science
Fellow
American Association of Archaeologists
American Quaternary Association
Paleobiological Councilor, 1992-96
Chairman of the 1996 Biennial Program
President-elect 1996-98
American Society of Mammalogists.
Association for Systematic Collections.
Sigma Xi
Chapter President, 1991-92.
Society of Vertebrate Paleontology
Regional Editor, 1986-Present

**HONORS**

Fellow AAAS
Participant in Smithsonian-Chinese Scientific Exchange Program, The Origin of Man in the New World, 1981 & 1982.
Postdoctoral Fellowship, Systematic and Evolutionary Biology, Smithsonian Institution, 1976-77.
F.L. Whitney Memorial Scholarship, University of Texas at Austin, 1974.
NSF-OTS Fellowship for Tropical Ecology, Universidad de Costa Rica, 1971.
NDEA Grant, University of Iowa, 1967-68.

**PUBLICATIONS**

Graham, R.W. and H.A. Semken, Jr.
1976 Paleoecological significance of the short-tailed shrew (genus *Blarina*) with a systematic discussion of *Blarina ozarkensis*. *Journal of Mammalogy* 57:433-439.

Graham, R.W.
1976 Late Wisconsin mammal faunas and environmental gradients of the eastern United States. *Paleobiology* 2:343-350.

Graham, R.W.
1979 Paleoclimates and late Pleistocene faunal provinces in North America. Pp. 49-69. **IN** *PreLlano Culture of the Americas: Paradoxes and Possibilities*, R.L. Humphrey and D.J. Stanford (eds.), Washington Anthropological Society, Washington, D.C.

Graham, R.W., C.V. Haynes, D.L. Johnson and M. Kay
1981 Kimmswick: A Clovis-mastodon association in eastern Missouri. *Science* 213:1115-1117.

Graham, R.W.
1981 Preliminary report on late Pleistocene vertebrates from the Selby and Dutton archeological/paleontological sites, Yuma County, Colorado. *Contributions to Geology University of Wyoming* 20:33-56.

King, F.B. and R.W. Graham
1981 Effects of ecological and paleoecological patterns on subsistence and paleoenvironmental reconstructions. *American Antiquity* 46:128-142.

Graham, R.W., J.A. Holman and P.W. Parmalee
1983 Taphonomy and paleoecology of the Christensen Bog mastodon bone bed, Hancock County, Indiana. *Illinois State Museum Reports of Investigations* 38.

Lundelius, E.L., Jr., R.W. Graham, E. Anderson, J.E. Guilday, J.A. Holman, D. Steadman and S.D. Webb
1983 Terrestrial vertebrate faunas. Pp. 311-353. **IN** *Late Quaternary Environments of the United States, Volume 1: The Late Pleistocene*, S.C. Porter (ed.), University of Minnesota Press, Minneapolis.

Graham, R.W.
1984 Paleoenvironmental implications of the late Quaternary distribution of the eastern chipmunk (*Tamias striatus*) in central Texas. *Quaternary Research* 21:111-114.

Graham, R.W. and E.L. Lundelius, Jr.
1984 Coevolutionary disequilibrium and Pleistocene extinctions. Pp. 223-249. **IN** *Quaternary Extinctions - A Prehistoric Revolution*, P.S. Martin and R.G. Klein (eds.), University of Arizona Press, Tucson.

Graham, R.W. and D.J. Stanford
1984 A report on karst studies in the People's Republic of China. *Speleological Society Bulletin* 45:79-81.

Graham, R.W.
1985 Diversity and community structure of the late Pleistocene mammal fauna of North America. *Acta Zoologica Fennica* 170:181-192.

Graham, R.W.
1985 Response of mammalian communities to environmental changes during the late Quaternary. Pp. 300-313. **IN** *Community Ecology*, J. Diamond and T.J. Case (eds.), Harper and Row, Publishers New York.

Graham, R.W. and M.A. Graham
1986 Vision Quests: an alternative hypothesis for signal fires along Seminole Canyon, Val Verde County, Texas. *Plains Anthropologist* 31:73-76.

Graham, R.W.
1986 Plant-animal interactions and Pleistocene extinctions. Pp. 131-154. **IN** *The Dynamics of Extinction*, D.K. Elliot (ed.), John Wiley and Sons, New York.

Graham, R.W.
1986 Taxonomy of North American mammoths. Pp. 165-169. **IN** *The Colby Mammoth Site - Taphonomy and Archaeology of a Clovis Kill in Northern Wyoming*, G.C. Frison and L.C. Todd (eds.), University of New Mexico Press, Albuquerque.

Bonnichsen, R., R.W. Graham, T. Geppert, J.S. Oliver, S.G. Oliver, D. Schnurrenberger, R. Stuckenrath, A. Tratebas and D.E. Young
1986 False Cougar and Shield Trap caves, Pryor Mountains, Montana. *National Geographic Research* 2:276-290.

Graham, R.W.
1986 Stratigraphy and taphonomy of faunal sequences at Barnhart, Missouri. Pp. 45-55. **IN** *Quaternary Records of Southwestern Illinois and Adjacent Missouri*. Field Guide No. 4, American Quaternary Association Ninth Biennial Meeting, Champaign.

Graham, R.W.
1986 Stratified cultural and faunal horizons at Kimmswick, Missouri. Pp. 56-67. **IN** *Quaternary Records of Southwestern Illinois and Adjacent Missouri*. Field Guide No. 4, American Quaternary Association Ninth Biennial Meeting, Champaign.

Graham, R.W., H.A. Semken, Jr. and M.A. Graham (eds.)
1987 *Late Quaternary Mammalian Biogeography and Environments of the Great Plains and Prairies.* Illinois State Museum Scientific Papers 22.

Graham, R.W.
1987 Late Quaternary mammalian faunas and paleoenvironments of the southwestern plains of the United States. Pp. 24-86. **IN** *Late Quaternary Mammalian Biogeography and Environments of the Great Plains and Prairies*, R.W. Graham, H.A. Semken, Jr. and M.A. Graham (eds.), Illinois State Museum Scientific Papers 22.

Graham, R.W. and H.A. Semken, Jr.
1987 Philosophy and procedures for paleoenvironmental studies of Quaternary mammalian faunas. Pp. 1-17. **IN** *Late Quaternary Mammalian Biogeography and Environments of the Great Plains and Prairies*, R.W. Graham, H.A. Semken, Jr. and M.A. Graham (eds.), Illinois State Museum Scientific Papers 22.

Graham, M.A., M.C. Wilson, and R.W. Graham
1987 Paleoenvironments and mammalian faunas of Montana, southern Alberta and southern Saskatchewan. P. 410-459. **IN** *Late Quaternary Mammalian Biogeography and Environments of the Great Plains and Prairies*, R.W. Graham, H.A. Semken, Jr. and M.A. Graham (eds.), Illinois State Museum Scientific Papers 22.

Semken, H.A., Jr. and R.W. Graham
1987 Summary: environmental analysis and plains archeology. Pp. 474-480. **IN** *Late Quaternary Mammalian Biogeography and Environments of the Great Plains and Prairies*, R.W. Graham, H.A. Semken, Jr. and M.A. Graham (eds.), Illinois State Museum Scientific Papers 22.

Wiant, M.D. and R.W. Graham
1987 Mapping Illinois' cultural and paleobiological resources. *Proceedings 1987 National Symposium on Mining, Hydrology, Sedimentology, and Reclamation*: 27-29.

Graham, R.W. and J.I. Mead
1987 Environmental fluctuations and evolution of mammalian faunas during the last deglaciation in North America. Pp. 371-402. **IN** *North America and Adjacent Oceans During the Last Deglaciation*, W.F. Ruddiman and H.E. Wright, Jr. (eds.), The Geology of North America, Geological Society of America, Volume K-3.

Graham, R.W. and M. Kay
1988 Taphonomic comparisons of cultural and noncultural faunal deposits at Kimmswick and Barnhart sites, Jefferson County, Missouri. Pp. 227-240. **IN** *Late Pleistocene and Early Holocene Paleoecology and Archeology of the Eastern Great Lakes Region*, R.S. Laub, N.G. Miller and D.W. Steadman (eds.), Buffalo Society of Natural Sciences 33.

Graham, R.W.
1988 Comment: the role of climatic change in the design of biological reserves: the paleobiological perspective for conservation biology. *Conservation Biology* 2:391-394.

Graham, R.W.
1990 Evolution of new ecosystems at the end of the Pleistocene. Pp. 54-60. **IN** *Megafauna and Man: Discovery of Americas Heartland*, L.D. Agenbroad, J.I. Mead and L.W. Nelson (eds.), The Mammoth Site of Hot Springs, South Dakota, Inc. Scientific Papers 1.

Graham, R.W. and E.C. Grimm
1990 Effects of global climatic change on the patterns of terrestrial biological communities. *Trends in Ecology and Evolution* 5:289-292.

Graham, M.A. and R.W. Graham
1990 Holocene records of *Martes pennanti* and *Martes americana* in Whiteside County, northwestern Illinois. *American Midland Naturalist* 124:81-92.

Graham, R.W.
1991 Variability in the size of North American Quaternary black bears (*Ursus americanus*) with the description of a fossil black bear from Bill Neff Cave, Virginia. Pp. 237-250. **IN** *Beamers, Bobwhites and Blue Points: A Tribute to Paul W. Parmalee.* J.R. Purdue, W.E. Klippel and B.W. Styles (eds.), Illinois State Museum Scientific Papers 23.

Hofman, J.L., L.C. Todd, R.W. Graham and F.B. King
1991 Howard Gully: A terminal Pleistocene record from southwestern Oklahoma. *Current Research in the Pleistocene* 8:33-36.

Graham, R.W.
1992 Late Pleistocene faunal changes as a guide to understanding effects of greenhouse warming on the mammalian fauna of North America. Pp. 76-87. **IN** *Global Warming and Biological Diversity*, R.L. Roberts and T. Lovejoy (eds.), Yale University Press, New Haven.

Graham, R.W.
1993 Processes of time-averaging in the terrestrial vertebrate record. Pp. 101-124. **IN** *Taphonomic Approaches to Time Resolution in Fossil Assemblages*, S.M. Kidwell and A. K. Behrensmeyer (eds.), Short Courses in Paleontology 6, The Paleontological Society, University of Tennessee, Knoxville.

Graham, R.W. and M.A. Graham
1994 The late Quaternary distribution of *Martes* in North America. Pp. 26-58. **IN** *The Biology and Conservation of Martens, Sables, and Fishers.* S.W. Buskirk, A.S. Harestoel, M.G. Raphael and R.A. Powell (eds.), Cornell University Press, Ithaca.

Miller, B.B., R.W. Graham, A.V. Morgan, W.D. McCoy, D.F. Palmer, A.J. Smith and J.J. Pilny
1994 A biota associated with Matuyama reversed sediments from west central Illinois. *Quaternary Research* 41:350-365.

Graham, M.A. and R.W. Graham
1994 Response of individual mammal species to past environmental change. *ARC/INFO Map Book* 1993:37.

Oliver, J.S., III and R.W. Graham
1994 A catastrophic kill of ice-trapped coots: time-averaging vs. scavenger specific disarticulation patterns. *Paleobiology* 20:229-244.

FAUNMAP Working Group (R.W. Graham and E.L. Lundelius, Jr., codirectors)
1994 FAUNMAP: a database documenting late Quaternary distributions of mammal species in the United States. *Illinois State Museum Scientific Papers* 25, Nos. 1 and 2.

Graham, R.W.
1996 Response of vertebrate animals to climate change. *Encyclopedia of Climate and Weather.* Oxford University Press, New York.

Graham, R.W., J.O. Farlow and J.E. Vandike
1996 Tracking ice age felids: identification of tracks of *Panthera atrox* from a cave in southern Missouri, USA. Pp. 331-345 IN *Morphology and Paleoecology of Late Cenozoic Mammals - Tributes to the Career of C.S. (Rufus) Churcher*, K. M. Stuart and K. L. Seymour (eds.), University of Toronto Press, Toronto.

Faunmap Working Group (Graham, R. W. and E. L. Lundelius, Jr. - codirectors)
1996. Spatial response of mammals to late Quaternary environmental fluctuations. Science 272:1601-1606.

Graham, R. W.
in press The Pleistocene terrestrial mammals fauna of North America. IN Evolution of Tertiary Mammals of North America, C. Janis, K. Scott, and L. Jacobs, (eds.), Cambridge University Press, Cambridge.

Semken, H. A., Jr. and R. W. Graham
1996. Paleoecologic and taphonomic patterns derived from correspondence analysis of zooarcheological and paleontological faunal samples, a case study from the North American prairie/forest ecotone. IN Neogene and Quaternary Mammals of the Palaearctic, A. Nadachowski and L. Werdelin, (eds.), *Acta Zoologica Cracoviensia* 39:477-490.

Graham, R. W.
1997. The spatial response of mammals to Quaternary climate changes. IN *Past and Future Rapid Environmental Changes: the Spatial and Evolutionary Responses of Terrestrial Biota*. B. Huntley, W. Cramer, A. V. Morgan, H. C. Prentice, and A. M. Solomon (eds.), NATO ASI Series 1: Global Environmental Change 47:153-162.

Munson, P.J. and R.W. Graham
in press Additional records of Pleistocene muskoxen from Indiana. *Indiana Academy of Science*.

## 1.7 **Jennifer Seavey**

### *1.7.1 Specialty*

Ms. Seavey's qualifications are in the areas of wildlife biology, population biology, ornithology, and wildlife policy. Her most current work focuses in the area of biological assessments of development and restoration projects in the Northwest. She is currently a Senior Biologist with Michael P. Williams Consulting, Inc. in Seattle, Washington.

### *1.7.2 Role in the Project*

Ms. Seavey contributed through searching out and obtaining scientific materials relevant to the occurrence, ecosystem role, and tested management options for mountain goats at Olympic National Park, Washington. Her primary role was in conducting database and other bibliographic searches, obtaining materials for review, compiling the bibliographic database for the review, preliminary categorization of review items, coordinating dissemination of review materials to team members and compiling review results for final synthesis.

### *1.7.3 Curriculum Vitae*

**Jennifer Seavey, M. S.**
Ecologist, Program Coordinator

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Michael P. Williams Consulting, Inc.
1000 Lenora St, Suite 510
Seattle, WA 98121
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**EDUCATION**

**University of Washington**, Seattle, WA (1997). M.S. Wildlife Sciences.
**Lewis and Clark College**, Portland, OR (1991). B.S. Major: Biology. Minor: Political Science.
**School for Field Studies**, North Queensland, Australia. (Spring 1990). Course Title: Biodiversity of Tropical Rainforest.
**Northfield Mt Hermon School**, Northfield, MA (1987). High School

**PROFESSIONAL EXPERIENCE**

**Senior Biologist**, Mike Williams Consulting Inc., Seattle, WA (May 1997- present). Wildlife ecology specialist. Planned and executed wildlife surveys. Analyzed and summarized findings in project assessment reports. Project coordinator for Olympic mountain goat assessment project.
**Board of Directors**, Cascade Conservation League, Seattle, WA (August 1998 - present). Nonprofit environmental conservation organization for the preservation of open space in Puget Sound.
**Research Assistant**, University of Washington, Seattle, WA (September 1997- August 1998). Hired to aid in development and data collection of common murre research in Oregon. Literature searches and population model exploration of common murre data.
**Teaching Associate**, University of Washington, Seattle, WA (January 1998- March 1998). Held faculty position in Biology Department to teach laboratory for Introductory Biology. Held office hours. Graded labs and exams.

**Teaching Assistant**, University of Washington, Seattle, WA (September 1996-August 1997). Taught laboratory for Introductory Biology. Held office hours. Graded labs and exams. Subjects covered: Botany and Ecology. Student evaluations available upon request.

**Environmental Consultant**, Cascade Conservation League, Seattle, WA (March 1997). Performed field survey and prepared report of avian diversity of a local wetland for litigation purposes.

**Director of OAKBIRD Project**, University of Washington, Seattle, WA (September 1994-May 1997). Conducted original Master's thesis research as well as general bird surveys. Managed field crew of four. Conducted point count censuses, nesting observations, and analysis of data.

**Teaching Assistant**, University of Washington, Seattle, WA (January 1996-March 1996). Taught two laboratories per week for Field Ornithology. Held office hours. Graded labs and exams.

**Field Biologist**, University of Washington, Seattle, WA (April 1994-September 1994). Performed point count bird censuses on both the eastern and western slopes of the Cascade Mountain range.

**Assistant Biological Technician**, U.S. Fish and Wildlife Service, National Ecological Research Center. Fort Collins, CO (April- June 1993). Surveyed shorebirds throughout the South Texas Gulf coast.

**Banding Director**, Manomet Bird Observatory- Belize Project (in collaboration with the Program for Belize). Belize, Central America (January-April 1993). Directed mist netting effort of rainforest avifauna using eighteen mobile mist nets. Trained and supervised Belizean field technicians.

**Banding Laboratory Supervisor**, Manomet Bird Observatory, Manomet, MA (October-January 1993). Supervised students and volunteers operating fifty mist nets daily. Acted as interpretive liaison to the public.

**Raptor Biologist**, Golden Gate Raptor Observatory, San Francisco, CA (August-October 1992). Performed daily count of raptor migration activity. Compiled and analyzed data. Trapped and banded raptors. Assisted in coordinating and training volunteer banders and counters.

**Avian Breeding Biology Researcher**, Point Reyes Bird Observatory, Stinson Beach, CA (March-August 1992). Tracked color banded birds. Mapped territories of breeding pairs. Located and monitored nests. Mist netted local and migratory birds. Conducted point counts.

**Environmental Education Director**, Backyard Bird Shop, Portland, OR (June 1991-March 1992). Designed and implemented environmental education programs for various age groups

**Naturalist**, Portland Audubon Society, Portland, OR (June 1991-August 1991). Planned and executed natural history programs. Represented the Society at public functions.

**Ornithological Research Assistant**, Dr. Don McKenzie, Lewis and Clark College, Portland, OR (January 1991-June 1991). Responsible for banding local and migratory bird populations, utilizing ten mobile mist nets.

**Field Biologist**, School for Field Studies, North Queensland, Australia (February 1990-May 1990). Conducted point count surveys. Compiled and analyzed data. Drafted manuscript of research.

## PUBLICATIONS

Seavey, J. "**Natural History of the Ash-throated Flycatcher in Washington State.**" In press. Washington Birds.

Seavey, J. "**Nest Site Selection and Nesting Success of the Ash-throated Flycatcher in Klickitat County, WA.**" Submitted to The Auk.

Seavey, J. "**Species Account : Ash-throated Flycatcher**" Chapter in press. Birds of Washington.

Seavey, J. and D. Hardesty. "**Breeding Bird Census: Disturbed Coastal Scrub B**" Journal of Field Ornithology Volume 64, 1993.

## INDEPENDENT RESEARCH

**"Urban Recreational Development and Avian impacts."** (proposal in prep) Research exploring recreational development of Seattle area wetlands and subsequent impacts of avian communities.

**"Nest site competition among Common Murres and Brandt Cormorants "** (April 1998-July 1998) A study of breeding ecology of the Common Murre and their interaction with Brandt's Cormorants.

**"Nest Site Selection and Nesting Success of the Ash-throated Flycatcher in Klickitat County, WA."** (September 1994-May 1997). A study of the nesting ecology and habitat selection of the Ash-throated Flycatcher. Master's thesis.

**"Natural History of Raptors on Sauvie Island, Oregon"** (March 1991-June 1991). Examines raptor populations on Sauvie Island, Oregon.

**"Use of Isolated and Adjacent Fragments or Regrowth Areas by Rainforest Birds in North Queensland, Australia."** (February 1990-May 1990). Explores habitat selection issues.

**PRESENTATIONS**

September 1999. Seattle City Parks Department. Course in current development: Park employee training in field ecology and restoration, focusing on ornithological resources.

August 1990. Invited Speaker. Washington Ornithological Society Annual Meeting. Presented life history of Ash-throated Flycatchers in Washington.

May 1999. Oak Woodland Symposium. Poster of Master's thesis research.

October 1998. Society for Ecological Restoration. Poster regarding avian issues in wetland mitigation.

June 1998. Guest Speaker - Marine Biology course at Oregon State University's Marine Science Center. Presented Common Murre ecology lecture.

May 1997. University of Washington Wildlife Seminar. Presented Master's thesis.

March 1997. Northwest Vertebrate Biology Conference. Invited to present Master's thesis.

Winter 1995. Washington State Department of Ecology Brown Bag Series. Presented ongoing Master's research.

Fall 1994. University of Washington Wildlife Seminar. Presented Master's thesis proposal.

October 1991. Oregon Academy of Sciences. Presented Australian research project.

**HONORS**

June 1997. Crary Award for Excellence in Introductory Biology Graduate Student Teaching. Presented by the Biology program at the University of Washington, Seattle, WA.

**REFERENCES**

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APPENDIX II: LITERATURE REVIEWED

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