means and prognosticate the future with some accuracy. Yet here we enter the third great arena of ethical discussion, passing beyond the benefits of science and the certain risks to the nebulous realm of quandaries. Man must choose goals, and a choice of goals involves us in weighing values—even whole systems of values. The scientist cannot make the choice of goals for his people, and neither can he measure and weigh values with accuracy and objectivity. There is nonetheless an important duty he must perform, because he and he alone may see clearly enough the nature of the alternative choices, including laissez faire, which is no less a choice than any other. It is the social duty and function of the scientist in this arena of discussion to inform and to demand of the people, and of their leaders too, a discussion and consideration of all those impending problems that grow out of scientific discovery and the amplification of human power. Science is no longer—can never be again—the ivory tower of the recluse, the refuge of the asocial man. Science has found its social basis and has eagerly grasped for social support, and it has thereby acquired social responsibilities and a realization of its own fundamental ethical principles. The scientist is a man, through his science doing good and evil to other men, and receiving from them blame and praise, recrimination and money. Science is not only to know, it is to do, and in the doing it has found its soul.

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Preserving Vegetation in Parks and Wilderness

This fragile natural resource is endangered by the lack of trained specialists and the lack of clear objectives.

Edward C. Stone

Federal efforts to preserve natural vegetation go back to 1872, when Yellowstone National Park was carved out of the public domain; state efforts go back to 1885, when the New York Adirondack Forest Preserve was established (*1*). All efforts, however, have been largely unsuccessful because of a failure to appreciate fully that vegetation is a living, dynamic complex and cannot be preserved in the sense in which a building or an archeological site can be preserved. Even the most uniform vegetation is a mosaic created by local variations in the environment and by prior events such as fire, drought, and insect infestation. When a mature plant dies, hundreds of seedlings spring up to take its place, some or all of which may be of different species. Which seedlings survive, and for how long, depends upon their relative growth potential, what effect the dead plant had on its environment before it died, and what kind of environment resulted when it died. Vegetation can only be preserved by controlling the complicated successional forces that have created it and that, if unchecked, will in turn destroy it.

The very efforts made to preserve a natural system of vegetation may bring on unplanned and undesired changes in it. That steps taken to preserve animal wildlife may have this effect is well known to the general public. By 1930 there were overpopulations of elk and bison in Yellowstone National Park, of mule deer in Zion National Park, and of deer and elk in Rocky Mountain National Park, all brought about by control of predators in and around the parks (*2*). Recognition of the problem led to a reconsideration of these practices, and today, although hampered by a lack of basic data and a restrictive budget, specialists in wildlife preservation are employed in the national parks to plan and apply sounder regulatory methods. While not so dramatic and not so widely publicized as imbalances in wildlife populations, drastic changes in the composition of many of the plant communities in the national parks have occurred during the last 50 years under fire-protection policies and heavy concentrations of use. In a number of cases these changes have progressed so far that even the once dominant plants in a wide variety of plant communities have been replaced, and now trees and shrubs occupy slopes and meadows once clothed in grass and sedge (*3*).

There are two federal agencies largely responsible for the management of national wildlands, each by charter concerned with conservation of this resource but each with different primary objectives. The Forest Service was organized in 1905 within the Department of Agriculture to manage the forest reserves—later renamed national forests—to secure favorable watershed conditions and to furnish a continuous supply of timber. Shortly thereafter, however, the Forest Service recognized

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that recreation was an important use of these areas compatible with its other uses, and began developing the recreational facilities that now serve 125 million visitors a year. Some 15 years later it recognized the need for wilderness reserves, and by appropriate administrative action over the next several years set aside almost 12 million acres for this purpose. Subsequently both of these administrative decisions have been sanctioned by congressional action (*4*).

The Park Service was organized in 1916 within the Department of the Interior to bring together under one administrative head a number of independent national parks formerly administered by several federal departments. It was specifically charged with preserving on these lands plant and animal life, and geological and archeological features of national value, for the enjoyment of the public. Vegetation preservation thus constitutes a minor part of the Forest Service's responsibilities but a major part of the Park Service's responsibilities.

The Forest Service has moved ahead rapidly in meeting its responsibilities as watershed and timber manager and purveyor of recreation facilities. It has been able to do so for a number of reasons. From its inception it was able to staff its key administrative posts with men trained for the job of managing forests for watershed and timber; it could draw upon a wealth of European experience, and it had an excellent research staff engaged in developing workable silvicultural techniques, based upon sound understanding of ecology, for use by its foresters operating in the field. In its minor role as vegetation-preservation manager of 12 million acres of wilderness, the Forest Service has yet to do much of anything.

The Park Service has moved slowly in its major role, that of preservation manager, although it has successfully operated the land under its control for the enjoyment of the public. When established, the Park Service, unlike the Forest Service, had no ready source of professional help to which it could turn. There was no such thing as a vegetation specialist versed in preservation management—that is, a vegetation-preservation manager. Furthermore, administrators could not rely upon European experience for guidance, because there was none. Nor could they turn to a research staff for developing the necessary management techniques, because again there was none. To make matters even more difficult, they were forced almost from the beginning to fight a rear-guard action with private companies and government agencies that wanted to open park lands for mining, hunting, water impoundment behind massive dams, logging, and other commercial activities. Thus administrative energies and funds were all but exhausted in maintaining existing park boundaries; and the problem of preserving a variety of undescribed ecosystems, in which changes at the time were not well advanced or readily apparent to the untrained eye, was largely solved as far as the administrator was concerned once an efficient fire-control system had been established, livestock excluded, and insect epidemics brought under control. This does not imply that the Park Service has failed to attract competent biologists to its professional staff and that there has been no effort to stem the successional tide; this is not true. Characteristically, however, individuals in the Park Service who have been trained as biologists have been called upon more for protective and interpretive service than for specialized management of the vegetation complex, because overall park policies have not until recently included the concept of vegetation management except in the narrow aspects of fire, insect, and disease control.

In 1963, public attention was drawn to this state of affairs in the national parks by a report of a committee appointed by the National Academy of Sciences at the request of Secretary of the Interior Udall to aid in "the planning and organizing of an expanded research program of natural history re-

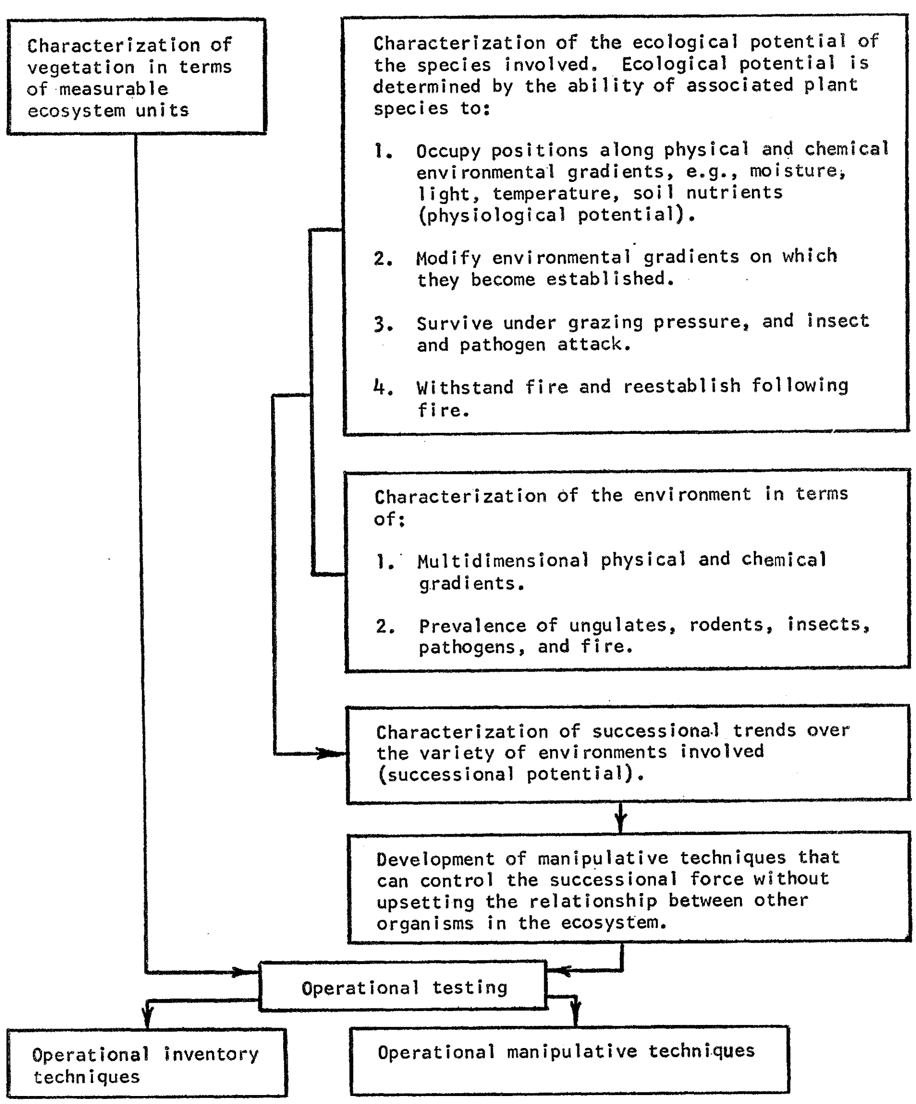

Fig. 1. Information required to develop manipulative techniques for vegetation preservation.

search by the National Park Service." The committee presented "the pressing need for research in the national parks by citing specific examples in which degradation or deterioration has occurred because research on which proper management operations should have been based was not carried out in time; because the results of research known to operational management were not implemented; or because the research staff was not consulted before action was taken" (*5*). The report stresses the need to develop, by means of extensive research, the ecological basis for managing the preservation of both plant and animal life in the ecosystems involved. "It is inconceivable," the authors remark, "that property so unique and valuable as the national parks, used by such a large number of people, and regarded internationally as one of the finest examples of our national spirit should not be provided adequately with competent research scientists in natural history as elementary insurance for the preservation and best use of the parks." This is an excellent, long overdue report, exhaustive in its treatment of research needs, but it did not in my opinion focus strongly enough on the need for professional vegetation specialists at the operational level, specialists who will be responsible for carrying out the manipulative steps recommended by the research staff, much as the Forest Service's professional foresters carry out the cutting practices recommended by its research staff.

The various state agencies that administer park and forest preserves with preservation as the stated objective have come into existence at different times in response to different pressures and differ widely in the composition of their administrative staffs. All engage in protection of some kind, but none, as far as I can ascertain, is involved in manipulative procedures to preserve the integrity of specific types of vegetation. Some ecological research is under way, but again there are no professional vegetation specialists available to carry out the manipulative program that will come out of this research.

Fig. 2. Coast redwood is physiologically attuned to periodic inundation and is provoked by the accompanying deposition of silt to regenerate a new, possibly more active, feeder-root system. Large amounts of organic matter incorporated in the silt can be fatal, however, and the vegetation-preservation manager must be ready to test for this condition and remove these silt deposits quickly if necessary. What steps he will need to take once upstream flood-control measures have altered this peculiar environment are not yet clear.

The Objectives of Preservation

Since vegetation is never static, preservation must consist, in effect, of managing change. Consequently, it is necessary to determine exactly what the objective is, and thereby to determine how much change, and what kind, can be tolerated.

One of the most common objectives is to keep park lands green or, in the arid West, green and golden. Fire protection is considered the principal means to this end. The fact that vegetation protected from fire may change completely in a relatively short period has rarely been considered, because administrators and the public have not appreciated that this can happen.

Probably the next most common objective is the preservation of certain favored dominant species within the vegetative complex. When this is the objective, the fact that certain successional stages may be fast disappearing and that the overall vegetative structure may be changing within rather broad limits is usually ignored, as long as the dominants remain dominant and the general appearance of the landscape is not altered. Change that does not interfere with the effective display of the dominant species has, in general, been acceptable. Preservation of the redwood tree, for example, has been the sole objective in the world-famous string of redwood parks that extends from south of San Francisco to the Oregon border. Consequently, change among associated species has been ignored.

A less common but still popular objective is the preservation of particular successional stages. Most often this objective has reflected a desire to preserve a piece of virgin forest or native grassland and generally has involved a *climax* phase of vegetation, that is, a condition of dynamic equilibrium in which species composition remains more or less constant. On occasion, however, there has been a strong desire to preserve a particular *subclimax* phase, such as Douglas fir on the Olympic Peninsula, red pine in the Lake States, and Caribbean pine in the Everglades, where successional change may be proceeding rapidly. In support of this type of preservation, a committee appointed by Secretary Udall to

Fig. 3. Fire and browsing by deer (see trees in left foreground) have been important in the creation and maintenance of grass prairies in the redwood–Douglas fir forest along the north coast of California. The vegetation-preservation manager can use fire but is not dependent upon it to maintain this open, park-like intermingling of grassy glades and trees. A variety of selective herbicides—none of which enter the biotic food chain—is available and can be used effectively in conjunction with either spot burning or mowing.

review wildlife-management practices in the national parks has recently recommended that certain successional stages be re-created and maintained in order to present "vignettes" of early America to the park visitor (*6*). The ease with which various successional sequences can be maintained varies with the area and the type of vegetation involved. Consequently, preservation may not be as cheaply achieved in one area as in another. Provided he is aware of this, the park manager can select appropriate areas and achieve his objectives with a minimum effort.

A closely associated objective is that of slowing succession. Supporters of this objective argue that it is futile to try to stop succession, that if it can be slowed sufficiently a vegetation mosaic containing most of the successional stages could be maintained, and that such a mosaic is what we should strive for in the national parks. Certainly the degree of preservation desired is always an important consideration. Succession can often be slowed for only a few cents per acre, while costs of stopping succession can run to several hundred dollars per acre.

Today, many wilderness supporters argue that we should leave large areas of vegetation alone to change as they may; that man should keep his hands off and let nature run its course, unimpeded by controls against fire, insect, and disease. When pressed on the point of fire control, however, proponents of this policy have usually agreed that some fire control is reasonable, provided it does not interfere with the occurrence of natural fire. Accordingly, lightning fires would be allowed to run unchecked, and if the aboriginal arsonist were alive today he would not be discouraged because he would be a part of the natural environment. Paradoxically, fire started by a careless camper would be dealt with vigorously.

On most of the areas that might be affected by such a program, succession is extremely slow and, because of extensive areas of exposed rock, wildfires soon burn themselves out. With sufficient control of human use these areas will change little in the next 100 or even 200 years, and this is probably what most proponents of a hands-off policy visualize. There are other areas, however, where the understory is now very dense and highly inflammable throughout much of the year and not in the condition that prevailed when the areas were set aside. Uncontrolled wildfire would be catastrophic. Thus, in the absence of fire control, vegetation in one area would be maintained more or less as it is today for many years to come, while in another area it might be violently changed within the next few years.

Compatibility of Objectives

Many preservationists consider management per se to be an unwarranted interference with nature by man. This need not be true. Management consists merely of those actions that are necessary to achieve one or more objectives, whatever they may be, even if the objective is "no management." Management dealing with vegetation may be intensive or extensive, depending upon the objectives, but unless the objectives are thoroughly outlined effective management is impossible. Because vegetation preservation may be only one of several objectives, all must be carefully considered together to determine whether they are compatible. Intensive public use may be compatible with a general policy of keeping certain park lands green, but may be incompatible with a specific policy of preserving dominant species or particular stages in a successional sequence. Probably incompatible objectives are much more widespread in current efforts to preserve vegetation than is generally recognized, because change in vegetation can proceed for many years without detection by the public or even by the park administrator responsible for its preservation.

Research on Vegetation Preservation

The National Academy of Sciences Advisory Committee, in reviewing the research program of the National Park Service, "was shocked to learn that for the year 1962 the research staff (including the chief naturalist and fieldmen in natural history) was limited to ten people and that the Service budget for national history research was $28,-000—about the cost of one campground comfort station" (*5*). If we consider only the magnitude of the research job required to support a realistic vegetation-preservation program, it is easy to understand why the committee was shocked. A million-dollar annual budget and a staff of several hundred scientists, with several times as many supporting personnel, are needed. The Yellowstone National Park staff, for example, has indicated (5) that the research required to support its vegetation-preservation program would entail an analysis of the current climatic trends; a detailed soil survey; and analyses of the vegetative mosaic and the factors creating it; successional patterns in the various biotic communities; the interrelationships of plants and animals, particularly dominant species like ungulates; variations of current ecological conditions from the original; the factors that have caused these deviations; the practicability of re-creating original ecological conditions where ecological damage or deterioration, for instance, soil loss, has occurred; and the direct effect of visitors on important natural features. Thus, dealing effectively with the problem of vegetation preservation in this one park, only one of 31 national parks, will require a dozen or more scientists—climatologists, pedologists, and ecologists of various specializations—with a supporting staff of perhaps a hundred or more.

The Forest Service has not as yet committed its research staff to studying the overall problems of vegetation preservation, but much of what its silviculture and range-management researchers have discovered over the last 35 years is directly applicable. Both the silviculturist and the range manager, like the vegetation-preservation manager, are interested in successional processes and their control. The distinction lies in the end products desired and the tools that can be used to obtain them. The silviculturist is interested in the amount and quality of timber produced. He selects trees to this end and in the process completely alters the structure of the vegetation units involved. His imprint in the form of skid trails, neatly sawn stumps, and extraction roads is everywhere apparent. The range manager is interested in the weight and quality of beef or mutton that vegetation produces. He uses his animals, through rotational grazing schemes of various kinds, to control plant succession. Except for the presence of domestic animals, fences, and occasional scars of a disc harrow on a reseeded, overgrazed range, his mark is not apparent and the structure of the vegetation units involved may not be greatly altered.

What is most needed to get a full-scale vegetation-preservation research program underway by the Forest Service is an administrative decision to do so. Only a few shifts in research emphasis at key points within the present research program, along with a relatively modest augmentation of the basic research staff, are needed. Once embarked upon such a program, the Forest Service soon would be able to develop suitable operational techniques for preserving vegetation on the 12 million acres of wilderness that are its responsibility.

All the state parks involved in vegetation preservation need research support, but few are receiving it. The State Division of Beaches and Parks in California, for example, has an annual support budget of $10,000,000 and is responsible for vegetation preservation on more than 600,000 acres. The size of the individual parks varies from a few hundred to several thousand acres, and the type of vegetation to be preserved varies through cactus and scrub on the Mohave Desert, oak woodland in the Central Valley, mixed conifers in the Sierra, and redwoods along the North Coast. Its annual research budget amounts to only $28,000. A third of this is being spent on a crash program to develop recommendations for preserving redwood groves along the Eel River which are subjected to periodic flooding and to more than 500,000 visitors annually. The rest is being spent by the interpretive-services section. Nothing is being spent on research to determine how the variety of vegetation types that occur in the other parks in the state should be maintained.

The type of information required to develop manipulative techniques for the preservation of vegetation is summarized in Fig. 1. Some of this information, obtained through the efforts of university-based scientists, their graduate students, and Forest Service re-

Fig. 4. Big cone spruce, shown against the sky line, is not a fire-resistant species but has survived in the chaparral of Southern California because of natural firebreaks created by shallow soils and the regular occurrence of widespread fires in the past. Today these natural firebreaks are overgrown and no longer offer protection. The vegetation-preservation manager must reestablish these firebreaks if stands of big cone spruce are to be preserved.

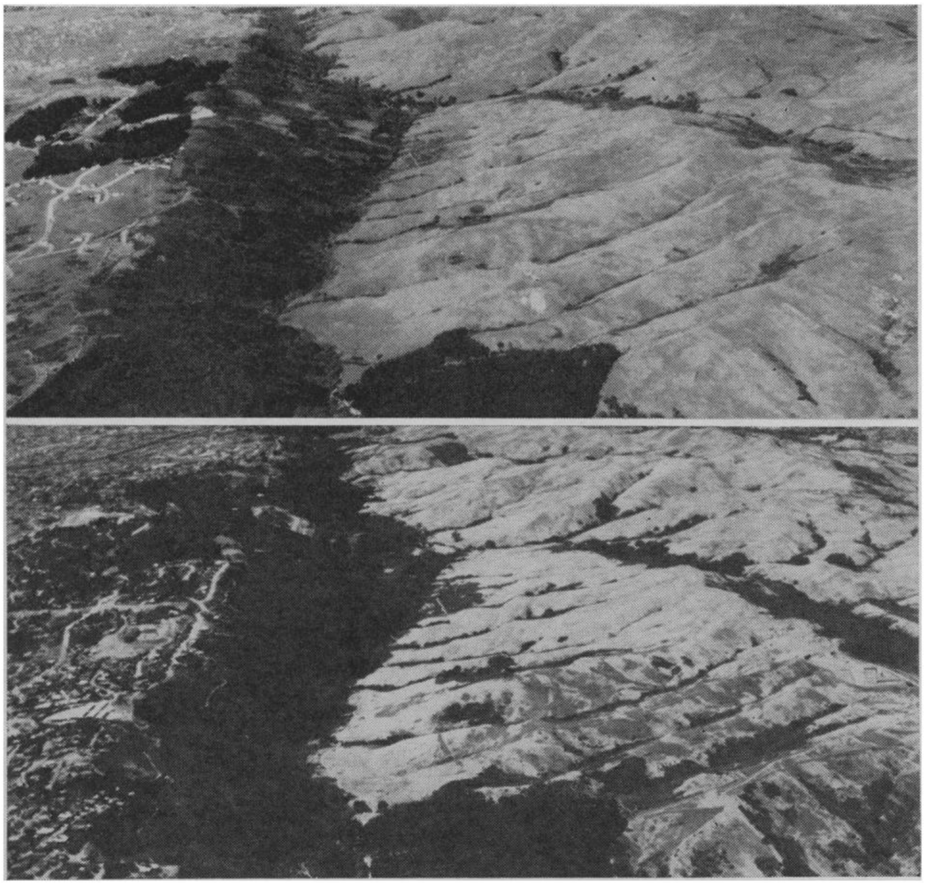

Fig. 5. Top aerial photograph was taken shortly before the grass-covered slopes in the right foreground were purchased by a local park district and cattle were excluded. Bottom aerial photograph was taken early in 1965—35 years later—and shows the extent to which brush has replaced grass within the park boundaries. If the grass cover is to be preserved, the vegetation-preservation manager must remove the brush and take steps to keep it out. Fire as a tool has been ruled out by local smog-control officials. Introducing cattle is difficult because of the number of youth groups using the area. Bulldozers, herbicides, and mowing machines appear to be the alternative tools available.

searchers, is already available for certain types of vegetation. Rarely, however, will this information be complete from a vegetation-preservation viewpoint, partly because preservation has not generally been the objective of the studies, but mostly because studies of plant succession in this country have closely followed an approach developed by the well-known ecologist F. E. Clements (*7*). Clements was convinced that successional sequences, which involve changes with time, can be determined by observing changes in vegetative patterns in space, and through his persuasive pen he was able to convince others that this was feasible. The major difficulty encountered in this approach has been that the only method of evaluating the accuracy of a researcher's estimate of successional trends, that is, his first approximation, has been to wait and see.

Where short-lived grasses and herbs have been involved and reestablishment of a dynamic equilibrium following disturbance has been rapid, the Clementsian approach has been reasonably effective. Researchers have been able to modify their first approximation through several subsequent approximations, improving the accuracy of their estimate each time. This is the approach that largely has been used by range-management researchers. Recently, however, they also have experienced its limitations and have begun to turn to detailed environmental analyses and growth-performance studies under controlled environments.

Where long-lived plants have been involved and reestablishment of a dynamic equilibrium following disturbance has been slow and will not be reached for another hundred years or so, first approximations based on Clements' approach are often little better than educated guesses. In dealing with vegetation of this type a more sophisticated analysis of the ecological potential and the relative magnitude of the environmental factors involved will be required (see Fig. 1). Studies of comparative growth performance of associated species in controlled environments along the lines suggested by Hellmers (*8*), and environmental-gradient analyses along the lines suggested by Whittaker (*9*), Bakuzis (*10*), and Waring and Major (*11*), are essential.

Specialists in Vegetation-Preservation Management

The National Academy of Sciences Advisory Committee (*5*) points out briefly that the Park Service has applied research in a piecemeal fashion and has "failed to insure the implementation of the results of research in operational management." The committee concludes with the comment that "Reports and recommendations on the subject will remain futile unless and until the National Park Service itself becomes research-minded and is prepared to support research and to apply its findings." That the "implementation of the results of research" calls for experts on the management of vegetation has as yet not been recognized. Even preservation-oriented conservationists, who are the backbone of the leading conservation groups in this country, have been slow to perceive this. Many of them still regard vegetation much as they do their own gardens and are quick to suggest how a particular vegetative cover can best be preserved, whether it be in the local nature reserve, in a state park dominated by 1000-year-old redwood trees, or in an untrammeled wilderness.

Obviously the decision as to what should be preserved cannot be left entirely to the specialist. The concerned public, although amateurs in vegetation preservation, must be heard and heeded. But at the same time a realistic assessment must be made of what can be achieved at costs commensurate with public interest, and this depends upon a knowledge of various alternatives and the relative cost and feasibility of achieving each one. Only the vegetation specialist can furnish this kind of information.

The vegetation-preservation specialist must be trained in management, must possess a thorough knowledge of ecology, must be experienced in assessing the relative growth potential of each species in the vegetative mosaic, must be experienced in the use of various manipulative techniques, and must understand research methods. Today there are few men so qualified. There is an impressive number of competent plant ecologists scattered throughout related professions who are oriented toward management, but there are relatively few who have had experience in a detailed assessment of the environmental complex, and even fewer who have had experience in manipulative techniques.

The vegetation-preservation specialist will not replace the research ecologist and to a large extent will be dependent upon him. He must be competent to understand research, to evaluate research findings in terms of his management function, and to translate research into manipulative techniques particularly suited to the specific vegetation he must manage. These manipulative techniques must be based on an understanding of the ecology of the vegetation in question; if such information is not available and ecologists are not employed to develop it, the preservation specialist will be forced to forego his primary responsibility and to spend his time collecting basic ecological data.

Because success in the field of vegetation preservation requires several—usually many—years to evaluate, the vegetation-preservation specialist often will operate in an atmosphere in which unsubstantiated opinions are forcefully urged. Many fire enthusiasts, for example, are convinced that fire protection should be curtailed, and do not recognize that merely because fire control has led to some undesired effects it does not necessarily follow that fire control should be abandoned or prescribed burning introduced. Involved is the whole process of recognizing the management objective, evaluating the ecological forces in play, identifying the conditions which must be achieved to develop the desired vegetation response, and, finally, evaluating all the possible ways of moving toward those conditions economically and with a minimum of unwanted side effects. In all of this the vegetation-preservation specialist will need a fine sense of perspective.

Little can be accomplished in the field of vegetation-preservation management until a source of competently trained specialists has been developed—and perhaps not until considerable numbers of these specialists have infiltrated the various responsible administrative bodies. How can we develop such a source? At the moment I can see only one solution: Ask those universities that have strong programs both in ecology and in land management, for example, those with forestry and range-management curricula, to take on the job. It should be possible to train these specialists by means of a 2-year graduate program, provided it is preceded by an undergraduate degree with a proper emphasis on basic biology and is followed by an appropriate period of apprenticeship. Several universities could readily meet this challenge, provided financial support were assured. The question that remains to be answered is: How soon will the universities that have staffs capable of carrying out this graduate program be asked to join in creating this new profession?

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NEWS AND COMMENT

Chemistry: A "Little Science" Would Like a Little More Money

There is a saying among lawyers, If you have a strong case, pound on the facts, otherwise pound on the table. In recent years, as various scientific disciplines have turned out studies to justify their designs on the federal treasury, there has been a good deal of table pounding.

Last week the chemists produced their study, *Chemistry: Opportunities and Needs*,* a 222-page document, nearly 2 years in the works, which, in the science-study genre, sets a mark for careful data collection and humble advocacy. Inevitably the chemists arrive at the conclusion that needs are unfulfilled and opportunities are wasting. But chemistry is a relatively inexpensive brand of research, and, as wish lists go in this business, they are talking about "little science."

Chemistry, the report acknowledges, has overflown disciplinary boundaries, and it is not easy to identify all the places where chemistry is practiced. But, working with the definition that, in universities, chemistry is what takes place in chemistry and joint chemistry-biochemistry departments, the report concludes that last year the federal government provided less than $60 million of the $90 million spent, outside of construction costs, in the direct support of these departments. Over the past decade the federal contribution has annually grown by 15 percent. The chemists would like to see the federal growth rate stepped up to 25 percent for 3 or 4 years, principally to buy new instruments and computer time, so that by 1968 the direct federal contribution would be $120 million. (In 1964, the report calculates, university chemistry

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