entering the job market until the end of this decade.

In spite of the careful analyses described above, at the end of this decade no exact picture of the number of Ph.D.'s needed at the end of the decade has been generated to date. However, as our society becomes more and more dependent upon technology, it would be unwise to reduce significantly the technical manpower that will be available at the end of this decade. One course of action might be to maintain the level of fellowships and traineeships at some predetermined level for the next several years. The problem is somewhat complicated by the fact that direct support of graduate students by traineeships and fellowships is provided to only one-sixth of all the students supported. Hence, the funding of this one channel of support does not determine the entire picture. Nevertheless, during a period of financial stability for both the universities and the graduate students, several important changes could take place. The adjustment of the new federal agencies to their roles in solving societal problems will become more clearly defined, and their programs for achieving these goals will become better developed. The universities, on the other hand, need time to focus on the solutions to their own internal problems of organization. The difficulties of establishing interdisciplinary degree programs to provide broad training in the techniques of synthesizing practical solutions to real problems must be surmounted. This will be especially difficult for institutions that have used the traditional approach of analytic and theoretical solutions to idealized situations as their prime standard of excellence. It will take time to reeducate and reorient significant portions of the university community to a new set of operational techniques and methods.

Conclusion

In the discussion above, two steps toward a national policy for academic science have been proposed. The first suggests a budgetary policy that would stabilize the total amount of federal money made available to the universities and colleges for R & D. The second suggests a temporary freeze on the level of direct support for graduate students in science and engineering.

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Ecosystems of National Parks

National parks are unique in seeking to limit man to nonconsumptive uses of the land.

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The primary purpose of the National Park Service in administering natural areas is to maintain an area's ecosystem in as nearly pristine a condition as possible (*1*). This means that ecological processes, including plant succession and the natural regulation of animal numbers, should be permitted to proceed as they did under pristine conditions, and that modern man must be restricted to generally nonconsumptive uses of these areas.

These deceptively simple, and seemingly naive, ideas require explanation. Few of our parks are completely self-contained ecological units, and their problems have been repeatedly cataloged (*2–5*). These areas have obviously been affected by modern man's overall disturbance of the biosphere, as well as by his more specific disturbances, including elimination and introduction of species, designation of artificial park boundaries, and suppression of natural biotic processes. I will not minimize these problems: an Everglades without water or with a jetport would be a travesty. I contend that, despite man's intrusions into the ecology of national parks, the pristine ecosystem relations in many of them are comparatively intact or have some reasonable potential for being restored. This sounds incongruous, since visitors to several of these areas number in the millions annually. However, it is necessary to recognize that the uses

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man makes of these parks are largely nondisruptive and nonconsumptive; that is, man does not supply or divert significant amounts of materials and energy to or from the park ecosystem, and he is not a significant part of the food chain. There are exceptions in almost every park to the concept of nonconsumptive land use, but I think it can be shown that the objectives for natural areas are realistic and that national parks illustrate a type of land use that makes it appropriate to recognize a unique park ecosystem.

Research and Management in the Park Ecosystem

The maintenance of a natural park ecosystem requires a unique approach to research and management. Unlike other forms of land management, management of a park ecosystem generally involves preventing or compensating for man's altering of natural ecological relations.

Effective management is aided by a research program that provides information which is interpreted in light of park objectives. Much of the research in parks is directed toward documenting pristine conditions and processes, determining the completeness of park ecosystems, and developing management procedures to maintain or restore the ecosystem. A complete ecosystem, as the term is used here, would have both cycling of materials and energy pathways comparable to those in pristine conditions. Lack of ecological completeness may take a variety of forms, for example, unnatural reduction or elimination of predator populations or a park's having only a portion of the historical range of a migratory species —a problem common to mountain parks with ungulate populations and parks with a diverse avifauna. Recognition of this problem is by no means new (*2, 6*); putting it into the context of the ecosystem and trying to evaluate and compensate for incompleteness is comparatively new (*3–5, 7, 8*). A goal of many research plans is to describe the park ecosystem in more quantitative terms. This is being done by concentrating research on key relations in a given park's ecosystem, with the hope that, through them, we may understand the whole.

Evaluation and restoration of natural factors that shaped the vegetation (the producer level of ecosystems) are under way in many areas. Continued protection of the vegetation from the influences of man is all the "management" that is required in some areas. In others, the restoration of natural processes requires more active management. Natural fires have helped shape the vegetation of many areas, and their influence is being restored in the form of prescribed burns and by allowing naturally occurring fires to burn. The 7000-acre pinelands in Everglades National Park represent a fire-maintained forest of southern slash pine (*Pinus elliottii*). Prescribed burns have been carried out since 1958, and their effects have been documented (*9*). This program will be continued on a routine management basis. Fire also maintained the red fir (*Abies magnifica*) forests of Sequoia and Kings Canyon national parks (*10*). Prescribed burning was done on an experimental basis in these fir forests, and now naturally occurring fires above 8000 feet in the Middle Fork of the Kings River are being allowed to run their course. Fires also burned at 20- to 25-year intervals in the groves of sequoias (*Sequoia gigantea*) in these parks (*11*). Restoration of natural fires presents a problem in the sequoia groves. Past suppression has resulted in an accumulation of fuels and the development of an understory vegetation. Experimental prescribed burns and mechanical removal of accumulated fuels are being tried in these areas. The management goals are to reduce this unnatural fire hazard, restore a natural process, and provide a suitable habitat for sequoia reproduction (*10*). Plans to "restore" natural fires in the parks of the Rocky Mountains are in various stages of discussion.

The periodic attacks of certain of the native herbivorous insects upon susceptible trees in park ecosystems has no doubt occurred for millennia. Attempts at "control" are not compatible with the objectives of natural areas, and the deaths of susceptible trees by native insects should be recognized as a natural process. The mountain pine beetle (*Dendroctonus monticolae*) is responding to favorable environmental conditions in portions of Yellowstone National Park and is attacking stands of lodgepole pine (*Pinus contorta*). No attempts at control are being considered (*12*).

The maintenance of representative populations of native ungulates in natural areas requires an appraisal of ecosystem completeness. In the parks of the Rocky Mountains, ecological incompleteness may result from having the historic winter ranges of wild ungulates outside park boundaries. Under these conditions, populations are managed by public hunting that is carried on outside the park boundaries (*3, 7*).

Ungulate populations that are yearlong residents on ecologically complete ranges are of considerably more interest. An hypothesis being tested on some of these populations that occur in periodically severe environments is that they may not need artificial regulation; that is, the park ecosystem is complete enough to ensure that the numbers of these animals are regulated naturally. Four specific examples are given.

1) A study of the moose (*Alces alces*) population in Grand Teton National Park has shown that regulation of numbers occurs primarily through periodic winter mortality and by reduction in successful births after severe winters, complemented by the emigration of subadults (*13*). Regulation has also resulted from short-term fluctuations in the conditions of the willow (*Salix* spp.) forage sources on winter range areas. These fluctuations have not caused permanent deterioration of plants or adverse effects upon other faunal species.

2) An elk (*Cervus canadensis*) population of about 1000 animals lives yearlong in the Madison, Firehole, and Gibbon river areas of Yellowstone Park (*7, 14*). Regulation appears to result from rigorous winters and limitations on food supplies, with the complementary actions of predators, parasites, and disease. The elk provide food for a population of grizzly bears (*Ursus arctos*), a remnant group of gray wolves (*Canis lupus*) (*15*), and a variety of smaller predators and scavengers.

3) The elk and mule deer (*Odocoileus hemionus*) populations in the Middle Fork of the Flathead River drainage in Glacier National Park appear to be naturally regulated (*16*). Rates of reproduction of both species have been low. Population stability over the past 20 years has resulted from low mortality, balanced against low recruitment. The availability of winter yarding sites in coniferous forests probably determines carrying capacity. Differences in winter yarding areas and forage preferences appeared to reduce interspecific competition and permitted coexistence of both species.

4) A population of 100 to 300 bison

(*Bison bison*) has annually wintered in the Pelican Valley of Yellowstone Park since establishment of the park in 1872 (*17*). This population has been subjected to reduction in numbers by man only twice after having been poached to near-extermination about 1902. It is considered to be naturally regulated. Regulation has been accomplished by the effects of average and even mild winters on mortality and reproduction. This has resulted in long periods of near stability. Increases during particularly favorable periods have been offset by periodically more severe winters. Short-term occupancy of thermal areas during periods of extremely adverse conditions may permit survival of biologically essential components of the population.

Certain tentative conclusions may be drawn from these examples, since several of these populations appear to have characteristics in common (*14*). Realized annual recruitment to the population is low. Range conditions fluctuate, and some areas appear to be periodically "overgrazed," in terms of the usual criteria. Ungulates participate in plant successional processes and may be capable of reducing or eliminating remnant vegetation types that are no longer a number-limiting food source. Large predators represent only one of a complex of regulatory factors on ungulates and may have been overrated as a major control in harsh environments (*18*). However, it is still difficult to generalize upon the effects of predation (*19*). Once the existence of natural regulation has been determined from intensive research, the "management" of these ungulate populations will consist of monitoring population characteristics and habitat conditions.

This approach to the management of vegetation and native ungulates illustrates the uniqueness of park ecosystems. It follows that the criteria used in forestry or range and wildlife management, where vegetation and wildlife are harvested as a crop, do not necessarily apply to national parks. For example, having an elk population with a low rate of reproduction on ranges that appear temporarily overgrazed may be poor game management, but it is excellent management of a park ecosystem, as long as it is essentially natural. It is self-evident that the usual concept of "waste" (*20*) does not apply in parks; that is, the death of trees and ungulates is necessary to maintain ecological relationships.

Managing Man

Providing for the educational and esthetic enjoyment of man, while maintaining pristine ecological relationships, represents the greatest challenge in the management of natural areas. In broadest terms, man affects natural ecosystems by altering biogeochemical cycles and by quantitatively or qualitatively altering energy pathways. This latter influence includes such things as supplying energy to or diverting it from the system, altering the distribution and abundance of native species, and introducing exotic species.

Overnight camping, regarded as traditional and compatible with park objectives, is permitted under current policies (*21*). However, a natural ecosystem can absorb only a small number of these facilities, and the larger complexes (including lodges, housing areas, and so forth) have effects that extend beyond their immediate boundaries. For example, the disposal of sewage from such areas could alter energy pathways, as well as nitrate and phosphate cycles. The disposal of nearly 7000 tons of garbage annually within Yellowstone Park represents a substantial energy input and has contributed to management problems by altering the natural distribution of the grizzly bear (*22*).

Effects of the input of materials and energy into the ecosystem may be modified temporarily by refined treatments that prevent, or at least alter the form of, the input (*23*). This is being done in several areas. Management programs for the grizzly bear call for elimination of garbage as a food source, plus such related steps as increased campground sanitation and protection, and, perhaps, eventual removal of these complexes from prime bear habitat (*22, 24*).

To effectively resolve these conflicts with park ecosystems, major complexes should eventually be moved to at least the periphery of—and better still, outside—natural areas. The concept of maintaining large overnight facilities was developed in the early decades of this century, when modes of transportation were slower and population centers were further from parks (*4*). However, in this day of rapid transportation, there seems to be little real need for maintaining such facilities in the heart of a natural area.

Angling, as it is currently practiced in most natural areas, is a consumptive use of a natural ecosystem and may cause substantial alteration of energy pathways. Angling is considered a traditional, albeit controversial, use of parks. Some people hold that angling represents an anachronism with present pressures and that it should be eliminated (*4*); others hold that fish populations should be fully exploited and supplemented by stocking waters with fish raised in a hatchery. Angling in some form will no doubt be continued in the foreseeable future. However, the practice of stocking waters with hatchery fish, solely to maintain angling, has no place within a natural area. Furthermore, I consider maximum sustained yields to anglers to be too disruptive of ecosystem relations. Various races of native cutthroat trout (*Salmo clarkii*) still occur in the parks of the Rocky Mountains, although their distribution outside the parks has been greatly reduced.

Management objectives within these natural areas are to maintain wild populations of these and other native fishes in the aquatic ecosystems and to provide "quality angling" (*25*). "Quality angling" stresses the recreational aspects of angling: fish may be caught and released, but comparatively few, if any, are intentionally killed. This approach to the management of wild fish is being tested in several areas.

Sightseeing, which is considered a nonconsumptive use of parks, may also alter energy pathways unless it is regulated. For example, visitors have so damaged certain accessible areas of the fragile alpine tundra of Rocky Mountain National Park that initial recovery from trampling may require decades; complete recovery, centuries (*26*). This alteration was aggravated by such consumptive acts as picking flowers and removing stones. Management actions that may help correct the situation include channeling visitor activities by developing well-routed and maintained trails, relocating parking areas, and developing a visitor education program to explain the nature of tundra ecosystems.

These examples of the influence of man on natural ecosystems illustrate something of the conflicts facing park managers. Despite these conflicts, it appears to be feasible to maintain natural relations—if it is recognized that park ecosystems have a finite capacity for absorbing certain of man's disruptive and consumptive influences. This capacity has been reached in many areas.

Interpretation of the Park Ecosystem

The explanation of natural phenomena to the park visitor is another function of the National Park Service. Interpretation includes exhibits at museums, visitor information centers, and along roadsides; hikes and evening programs conducted by Park Service personnel; and self-guiding trails and auto tours. In addition, most areas offer a variety of publications that explain features of the park.

Visitor interest in these facilities and activities appears to be high. Nearly 20 percent of the 2.4 million summer visitors to Grand Teton Park in 1969 used visitor centers and attended more formal programs (*27*). Over 50 percent of the visitors to Yellowstone National Park during 1970 visited at least one of the six visitor centers, and about 10 percent attended one or more evening programs or nature walks (*28*). During the past several years, interpreters have used the ecosystem concept as a vehicle for communicating an understanding of park philosophy. Museum exhibits and brochures describe in laymen's terms the park ecosystem and objectives in managing natural areas. A skilled interpreter can build an entire program around a park's ecosystem.

A quality environment does not yet rank high as a national priority, despite current public interest in ecological problems. The National Park Service has an opportunity to contribute to the promotion of an environmental ethic that extends beyond park ecosystems to those of outside areas, and to such problems as environmental degradation and rates of human population increase. This opportunity is being used, and hopefully more emphasis will be placed on environmental problems in future interpretive programs. The contrast between the ecosystem of an unpolluted river in a park and a river such as the Thames [where perhaps one-half of the energy input is from sewage and detritus (*29*)] might be enlightening to many visitors.

Summary

The preservation and maintenance of natural park ecosystems, with modern man's being restricted to generally nonconsumptive uses of the park, represents one end of a spectrum of land use that extends through exploitation of natural ecosystems to the development of simplified agricultural ecosystems. Criteria for management of a park ecosystem must, of necessity, differ from criteria for other uses of land, since park management involves preventing or compensating for the influence of man. The objectives for natural areas appear to be ecologically feasible if it is recognized that these areas have a finite capacity for absorbing man's consumptive and disruptive influences. The interpretation of ecosystems to park visitors provides an opportunity to contribute to an environmental ethic that extends beyond the park environment.

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