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energy for the transport of Ca^{++} and CO_3^{--}, and (4) through the removal of crystal poisons such as phosphate ions.

These various hypotheses were tested by L. E. Duguay and D. L. Taylor in 1978, in the symbiosis involving *Archaias angulatus* and its symbiont *Chlamydomonas hedleyi* (Chlorophyceae). They have not been examined rigorously in associations involving diatoms. However, present information does suggest that diatom symbiosis is similar, and provides the same nutritional-physiological benefits. This assumption is supported by the work of R. Röttger (1972) and R. Röttger and W. H. Berger (1972) which clearly shows the enhancement of growth, reproduction, and calcium carbonate deposition in the foraminifer *Heterostegina depressa*. Assuming that the fundamental attributes of associations involving diatoms are similar to those found in *Archaias angulatus*, it is expected that calcium carbonate production in these symbioses will be nearly directly proportional to the photosynthetic rate of the diatom endosymbiont.

Symbiosis with diatoms and other unicellular algae has allowed a variety of larger foraminifera to successfully exploit shallow, nutrient-poor marine environments. They achieve high population densities and substantial rates of calcium carbonate production. As a result, they are frequently the dominant component of marine sediments in these areas, and are thus of considerable geological significance.

For background information *see* DIATOM; ECOLOGICAL INTERACTIONS; FORAMINIFERIDA in the McGraw-Hill Encyclopedia of Science and Technology. [DENNIS L. TAYLOR; LINDA E. DUGUAY]

Bibliography: L. E. Duguay and D. L. Taylor, *J. Protozool.*, 25:356–361, 1978; J. J. Lee, Towards Understanding the Niche of Foraminifera, in R. N. Hedley and C. Adams (eds.), *Foraminifera*, vol. 1, 1974; J. J. Lee et al., Symbiosis and the evolution of larger foraminifera, *Micropaleontology*, 25:118–140; J. J. Lee and W. D. Bock, *Bull. Mar. Sci.*, 26(4):530–537, 1976; S. Leutenegger, *Cahiers Micropaleontol.*, 3:5–53, 1977; R. Röttger, *Verh. Deutsch. Zool. Ges.*, 65:42–47, 1972; R. Röttger and W. H. Berger, *Mar. Biol.*, 15:89–94, 1972.

Forest and forestry

In 1964 Congress passed the Wilderness Act, establishing a legislatively protected National Wilderness Preservation System (NWPS). This legislation replaced administrative procedures for wilderness preservation first implemented in 1924. The principal objectives of the Wilderness Act were (1) to protect selected areas so that ecological processes would be, to the maximum extent possible, uninterrupted by human influence, and (2) to provide outstanding opportunities for solitude or a primitive kind of recreation. But rapid growth in the recreational use of wilderness poses serious threats to these objectives. To assure adequate protection, use is being managed to some degree on nearly all wildernesses, and this management will probably become more widespread and stringent in the future.

Wilderness management. The term wilderness management seems contradictory. Wilderness is generally conceived as beyond human control. Certainly, at one time, use levels were so low that there was little reason for concern about management. But recent growth in wilderness use no longer permits this unconcern. For example, in California, wilderness use grew an average 16% annually between 1970 and 1975. With such growth, the problems—damage to vegetation and soil, water pollution, wildlife disturbance, and crowding—that arise threaten the values that prompted the establishment of wildernesses in the first place. Thus, the real question is not whether to manage or not to manage, but rather how to manage.

There are two principal means for controlling impacts. First, managers could "harden" wilderness sites. That is, engineering-type solutions could be employed to offset or prevent undesired impacts. Trails could be paved, campsites provided with facilities, and visitor activity channeled through the use of barriers, signs, and facilities.

But the kind of opportunity wilderness is intended to provide, with emphasis on naturalness and the lack of human influence, makes such a solution inappropriate. Both legal constraints and the historical spirit of wilderness decry engineering solutions. The alternative is to manage use to control impacts through regulation of visitor behavior.

G. Gilbert and colleagues outlined a continuum of management actions (see table). Direct management imposes regulation over individual behavior, with managers holding a high degree of control; an example is the imposition of use rationing. At the opposite end of this continuum, indirect management features efforts to subtly influence or modify behavior, with individual freedom of choice largely retained; providing visitors with information is an example of this approach.

Research by G. Stankey and others indicates a preference among visitors for indirect management techniques. Such an approach is also more consistent with the motives commonly associated with wilderness users. However, both types of visitor management are appropriate in certain circumstances.

Visitor management. Three specific examples of visitor management are regulations, use redistribution, and rationing.

Regulations on use. Regulations on use are intended to reduce the per capita impact of use. That is, if the impacts of an individual's use can be ameliorated or prevented by regulation, more users can be accommodated in the area without adverse impact. An example of such a regulation would be limitations on visitor party size. Research by Stankey suggests that large groups have a disproportionate impact upon the experience of other groups. There is also concern that large groups have excessive impacts upon vegetation and soils. In the 1970s permissible party size in most areas dropped from about 30 people to about 15.

Such regulations can be extremely useful in reducing or eliminating visitor impacts without imposing more drastic controls on behavior. However, effectiveness depends upon visitors' knowing and complying with regulations. Studies have revealed that the levels of visitor knowledge and compliance are low. For example, current Forest

Service policy calls for visitors to carry out all noncombustible trash. One investigation revealed that only about one-quarter of surveyed visitors knew that this was the required method of disposal. Most visitors burned and buried such materials, a technique no longer considered appropriate since buried materials can be dug up by animals or unearthed by frost heaving.

The usefulness of these regulations also depends upon knowing that they are, in fact, effective at controlling the impact. For instance, many wildernesses have imposed regulations that prohibit camping within some minimum distance of lakes and streams. These regulations are intended to reduce water pollution, to protect shoreline vegetation, and to prevent bank erosion. Studies by L. C. Merriam and associates, however, reveal little water pollution danger from camps located in proximity to water. Moreover, such setbacks may greatly reduce the area available for overnight camping. In the Spanish Peaks Primitive Area in Montana, a 200-ft (60-m) no-camping restriction around lakes would result in a loss of 95% of all existing overnight sites.

Regulations can easily proliferate to the point at which they seriously conflict with the kind of recreational experience visitors seek. Excessive numbers of regulations become counterproductive, with visitors overwhelmed by their sheer volume. At some point, it is more satisfactory to impose some other form of use control (for example, rationing), leaving those who are admitted with a minimum of control. Proliferation of regulations also leads to an increased need for enforcement, a task that is often not welcome.

Use redistribution. The distribution of visitors both between and within wildernesses is typically very uneven. On a visitor-day-per-acre basis, the Galiuro Wilderness in Arizona received only 0.02 visitor-day per hectare in 1975; at the other end of

Direct and indirect techniques for managing the character and intensity of wilderness use*

Type of management	Method	Specific techniques
Indirect (Emphasis on influencing or modifying behavior. Individual retains freedom to choose. Control less complete, more variation in use possible.)	Physical alterations	Improve, maintain, or neglect access roads. Improve, maintain, or neglect campsites. Make trails more or less difficult. Build trails or leave areas trailless. Improve fish or wildlife populations or take no action (stock, or allow depletion or elimination).
	Information dispersal	Advertise specific attributes of the wilderness. Identify range of recreation opportunities in surrounding area. Educate users to basic concepts of ecology and care of ecosystems. Advertise underused areas and general patterns of use.
	Eligibility requirements	Charge constant entrance fee. Charge differential fees by trail zones, season, and so on. Require proof of camping and ecological knowledge or skills.
Direct (Emphasis on regulation of behavior. Individual choice restricted. High degree of control.)	Increased enforcement	Impose fines. Increase surveillance of area.
	Zoning	Separate incompatible uses (hiker-only zones in areas with horse use). Prohibit uses at times of high damage potential (no horse use in high meadows until soil moisture declines, say, July 1). Limit camping in some campsites to one night, or some other limit.
	Rationing use intensity	Rotate use (open or close access points, trails, campsites). Require reservations. Assign campsites or travel routes to each camper group. Limit usage via access point. Limit size of groups, number of horses. Limit camping to designated campsites only. Limit length of stay in area (max/min).
	Restrictions on activities	Restrict building campfires. Restrict horse use, hunting, or fishing.

*Modified from C. G. Gilbert, G. L. Peterson, and D. W. Lime, Toward a model of travel behavior in the Boundary Waters Canoe Area, *Environ. Behav.*, 4(2):131–157, 1972; used in J. C. Hendee, G. H. Stankey, and R. C. Lucas, *Wilderness Management*, USDA Forest Serv. Handb. no. 1365, 1978.

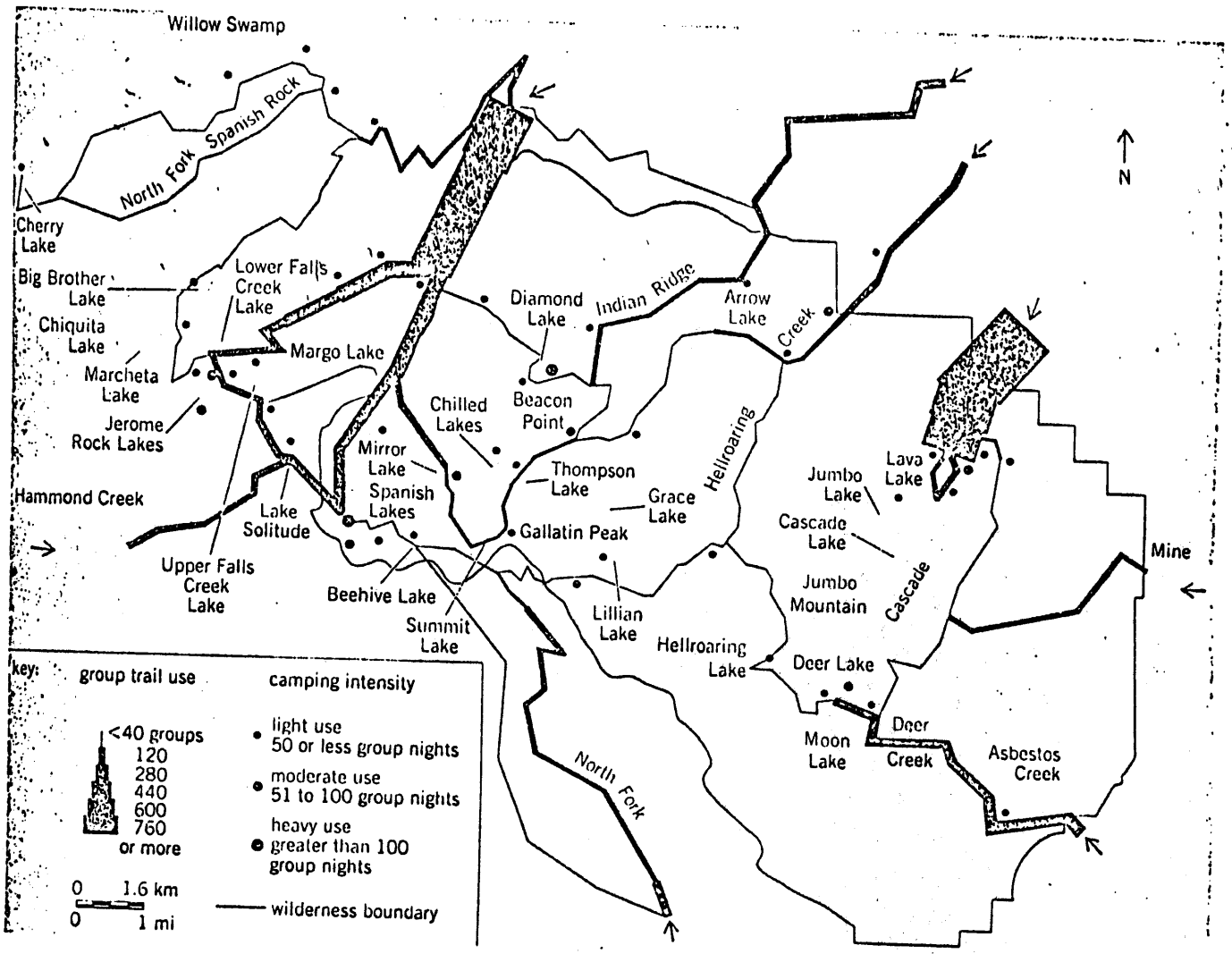

Fig. 1. Recreational use of the Spanish Peaks Primitive Area from June 14 to November 13, 1970.

the scale, the San Gorgonio Wilderness in California received over 12. Reasons for this variable drawing power are poorly understood. Proximity to population is one major factor, and the presence of attractions is another. But the visitor-day-per-hectare index is a crude measure. For example, it does not account for length of season that ranges nationally from 2 months in the northern Rocky Mountains to year-round in other areas. Nor does it reflect variations in the proportion of land actually available for use. In steep, rough country, use is concentrated in a few lake basins and stream bottoms, whereas in areas of more gentle topography, almost the entire area may be available for visitors.

Two measures that more realistically describe distribution potential are the number of entry points per 100 hectares and trail distance per 1000 hectares. The number of entry points per 1000 hectares provides an index of the potential for distribution around the boundary of the area. For the nation as a whole, there is an 80-fold difference among areas ranked on this variable. Trail distance per 1000 hectares provides an index of the potential for distribution within the area. Again, there is a great range: the area with the densest trail network has nearly 20 times the potential for distribution of the lowest-ranked area.

Use distributions are similarly skewed. For example, in the Boundary Waters Canoe Area in Minnesota, nearly 70% of the user groups entered on 10% of the available entry points. In the Mission Mountains Primitive Area in Montana, however, the respective figures were 90% of the use on 10% of the entry points.

Wilderness travel is typically concentrated along a few trails. Figure 1 is a use distribution map of the Spanish Peaks Primitive Area. Most use is located along certain rather short segments of the trail system. This concentration can be illustrated by graphing cumulative visitor travel (total distance traveled by all visitors) against cumulative trail distance. Figure 2 shows this concentration index (CI) for the map in Fig. 1. For example, only 10% of the total trail distance accounted for 50% of the total visitor distance traveled. This typical pattern of spatial concentration is matched by a temporal concentration, with intense use on weekends. These factors combine to create serious crowding in nearly all areas.

Achieving more even use would bring important benefits. Much of the crowding would be relieved by better distribution of visitors in space or time,

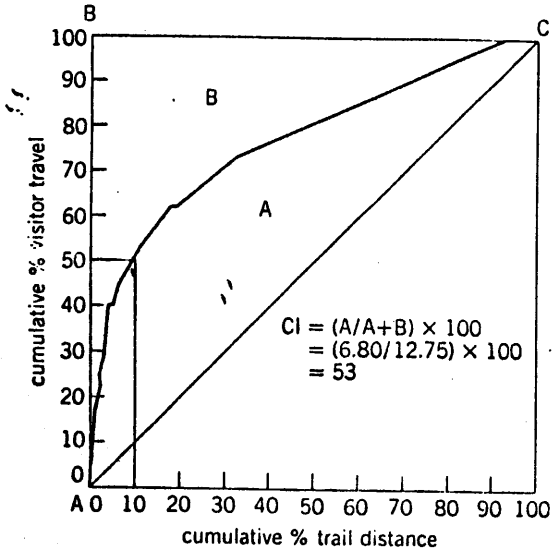

Fig. 2. Spanish Peaks use concentration index (CI) for all trail use during 1970.

or both. Some of the crowding has been reduced without directly assigning routes or visiting dates. Instead, visitors have been provided with information about use levels, attractions, alternative locations, and so forth. With such information, visitors themselves decide when or where to go. For example, about 75% of the visitors sampled in the Boundary Waters Canoe Area reported that they used information contained in a simple brochure, especially to find out when and where crowding occurred. The effect of these programs may take time to be fully realized, but it is now known that use can be shifted without direct control.

Shifting use is a two-edged sword, however. Raising use levels in areas once lightly used can mean the loss of "outstanding opportunities for solitude," as prescribed by the Wilderness Act. It can also result in use pressures on wildlife that may have relied upon these lightly used areas for sanctuary. Nevertheless, redistribution of visitors remains a useful management tool.

Use rationing. Rationing was first instituted in 1972 in the backcountry portions of several national parks and is found today in a number of other areas as well. Rationing involves the direct regulation of the number of persons permitted in an area at any one time. The specific number permitted is based upon a calculation of the area's capacity to withstand use without losing its wilderness qualities.

Stankey and J. Baden described five general rationing systems: reservations, lottery, queuing, pricing, and merit. Each technique has advantages and disadvantages for visitors and administrators alike. Currently, most areas with a rationing program use reservations or a queue (first-come, first-served). Studies of visitors to areas currently rationed indicate that an overwhelming percentage of visitors, including those not selected, support such controls. J. Fazio and D. Gilbert report that 80% of the unsuccessful applicants for backcountry use permits in Rocky Mountain National Park felt that rationing was necessary, a percentage similar to that reported by Stankey for two southern California wildernesses.

One critical problem with rationing through reservation is the "no-show" with which airlines must also contend. Some areas report that more than 50% of reservations made are not picked up. Failure to allocate these unused openings would result in an underutilization of an area's capacity. By combining types of rationing schemes, as has been done in some areas, particularly with a queuing system, unused reservations can be taken by the next in line, so that optimal use of the area is achieved.

However, rationing is clearly an extreme step. It should be used only after other, less authoritarian and less direct measures have proved to be ineffective, or when existing conditions of resource impact or crowding are so severe that extreme action is warranted. That is, by using only that level of management action needed to achieve a management objective, the potential value of rationing will not be lost through premature use, nor will visitors' experiences be unnecessarily interfered with by unneeded controls. This principle of minimum regimentation will help ensure that excessively restrictive measures are not inappropriately applied. Judicious use of regulation, use redistribution, and rationing will help ensure the long-term preservation of an "enduring resource of wilderness."

For background information *see* FOREST AND FORESTRY; WILDLIFE CONSERVATION in the McGraw-Hill Encyclopedia of Science and Technology. [GEORGE H. STANKEY]

Bibliography: J. C. Hendee, G. H. Stankey, and R. C. Lucas, *Wilderness Management*, USDA Forest Serv. Handb. no 1365, 1978.

Forest soil

Detailed qualitative studies on fungi in forest soils have been published regularly since the early 1950s and, through these, ideas on successional patterns of fungi on forest litter (particularly leaf litter) have been developed. A. Hayes has reviewed these data and reemphasized the concept of a three-stage successional pattern on plant litter. He stated that despite the qualitative data which have been obtained, there is considerable ignorance of the ecological functions of the fungi which have been isolated. This ignorance is likely to continue until the decomposer processes are studied by biochemists and enzymologists.

Recent interest has centered on quantitative determinations of fungal standing crop and fungal biomass in the organic and mineral horizons of forest soils. This interest developed initially from the realization that fungi produce considerable biomass in both organic and mineral soil horizons (that is, tying up considerable amounts of nutrients) and that they are probably the predominant microorganisms in the early stages of decay of plant debris, thus playing a vital role in nutrient cycling. The possibility of competition between actively growing fungal hyphae and higher-plant roots for nutrients present in soil in limiting concentrations has been suggested. Additional attention has been directed to the importance of fungal-faunal interactions in the processes of organic