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DETERMINATION OF OPTIMAL CAPACITY OF RESOURCE-BASED RECREATION FACILITIES†

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I

There are roughly three quarters of a billion acres of land in public ownership in the United States, a substantial part of which represents wild or undeveloped lands such as those found in the National Wilderness System, and also in the National Forest, Park, and Refuge Systems. Some of this land is reserved for uses incompatible with raw material exploitation by extractive industries. Examples are the Wilderness and Refuge System lands. Some is *de facto* wilderness; *i.e.*, land available for inclusion in the Wilderness System under terms of the Wilderness Act of 1964. Such tracts as yet unprotected by legal wilderness status are also subject to logging, mining, conversion to cropland and other extractive purposes pending determination of their status.

Demand for the services which wildlands have provided in their natural state has grown phenomenally over the first three quarters of this century. Table I shows the trends in the recreational use of National Park and National Forest lands. Perhaps most striking are the figures for use of the "other," largely unimproved areas of the National Forests. Rapid as the increase in use of all National Park and National Forest lands has been, it appears that the increase in use of just some of the more nearly natural areas has been several times more rapid. Also suggestive are figures for man-days of use of National Forest Wilderness Areas alone. Over a period of just 12 years, from 1947 to 1959, use increased by 356 percent.[1] Disaggregated figures for recent years show a continuation of these trends.[2]

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1. Outdoor Recreation Resources Review Commission, Wilderness and Recreation—A report on Resources, Values and Problems 226-29 (1962).

2. *See* monthly reports, U.S. Dep't of the Interior, National Park Service, Public Use of the National Parks (1967-69). *See also* U.S. Forest Service statistics on Recreational Use of National Forests, available from the Dep't of Agriculture, U.S. Forest Service.

Table I

Visits to National Parks and National Forests,
Selected Years 1904-1964
(in thousands of visits)

Year	National Parks	Areas Improved by Public Funds	
		National Forest Lands	Other Areas[1]
1904	121	–	–
1924	1,424	3,460	1,200
1946	8,991	8,763	9,478
1954	17,969	19,747	20,557
1964	34,048	35,629	81,062

1. Unimproved areas, *e.g.*, wilderness areas and a few public areas improved by non-federal means.

Source: M. Clawson, *The Federal Lands Since 1956* 60, 95 (Resources for the Future) (1967).

This rapid and sustained growth in demand for wildlands recreation, should it continue as there is reason to believe it will, poses some problems regarding the allocation of lands among the various uses. Most generally, the problem is one of determining the most efficient allocation of land, whether for purposes of producing extractive industry outputs on the one hand, or preserving the natural conditions for the recreational and other services they yield on the other. A related problem, perhaps a sub-problem, involves the allocation of land between low density and high density recreational uses. In either case we wish to compare the benefits from a given use with those from an incompatible alternative use to which the resources may be directed. The use of resources for one purpose simply precludes their uses for incompatible alternative purposes, and the benefits foregone are in effect the opportunity costs of the selected use, which must be added to any direct costs associated with that use.[3]

Typically, we would anticipate that the value of the services a tract of land would yield, and hence the value of the land and associated resources, would differ depending on the use to which it was put. The value of a site would then depend on its resource endowment and the elasticities of demand and supply for the respective services it might yield. From standpoint of economic efficiency the

3. Not all users are mutually exclusive, however. Logging in mature stands may improve light conditions for the production of understory brouse for ungulates thus improving recreational hunting, for example. Accordingly, there are some kinds of extractive and recreational activities which may be complementary to a point and the problem in its largest dimensions may be the specification of the optimal product mix where joint products are involved. While this represents an aspect of the total problem, we shall be abstracting from that aspect in the article.

objective would be to allocate wildlands and scenic resources in such a way as to maximize the value of the services they yield, *i.e.*, to allocate to their most highly valued uses over an appropriately long time horizon.

While highly developed markets tend to achieve an efficient allocation in this sense in some areas of the economy, allocation of wildland resources to the production of various goods and services has in large measure been handled by extra-market devices in the public sector.[4] Rather than appealing to observed market transactions' data, then, a variety of techniques for the estimation of data on benefits and costs have been developed as part of the apparatus of resource management.

Generally speaking, rather traditional benefit-cost analysis in conjunction with a wide array of inputs from the various resource management disciplines can provide reasonably good estimates of benefits and costs of various extractive activities. Even the art of estimating the demand for, and value of, resource-based, non-priced outdoor recreation services has developed in a promising way during the past decade or so.[5] Perhaps somewhat less well understood and correspondingly less developed is the methodology for evaluating the benefits from preserving unique natural phenomena, particularly those which will be reserved for or devoted to low-density recreational uses. One of the reasons in the latter case, of course, turns on the problem of optimal density for low-density recreational activities. Maximizing the value of a particular tract of wildland allocated, by whatever means, to the provision of low-density recreational services, will require than an optimal density be chosen.[6] This is only another way of saying that an optimal capacity needs to be defined. The development of operational concepts for defining optimal recreational capacity for low density recreational wildlands will be the objective of this paper. The significance of having operational concepts for determining recreational capacity will become obvious in the course of the analysis.

II

At the outset, it will be useful to distinguish and clarify two concepts of recreational capacity. The first we refer to as ecology's "carrying capacity." This is basically a biological or physical relation-

4. *See* J. Krutilla and J. Knetsch, *Outdoor Recreational Economics*, 389 Annals 63 (1970). J. Krutilla, *Conservation Reconsidered*, 57 Am. Econ. Rev. 777 (1967).

5. T. Burton and M. Fulcher, *Measurement of Recreation Benefits: A Survey*, J. of Econ. Studies (1967).

6. This assumes, of course, that growth in demand will continue posing problems of congestion and value reduction if some capacity constraints are not enforced.

ship between a given resource stock and its maximum sustained yield, *i.e.*, the maximum number of individuals of a species which can be supported by a given habitat under conditions of maximum stress.

The economist's conception of capacity is usually given in a physical measure but in terms of a product of constant quality. Accordingly, when we speak of a wilderness experience as the product or service sought, we recognize that solitude as well as primeval setting are dimensions of the quality of the service. With sufficient amount of wilderness area relative to the demand for the services, it is conceivable that a constant quality of the wilderness experience can be realized. However, at some point an increase in the number of wilderness recreationists will involve some trail and camp encounters impinging on the privacy and solitude sought. At this point one would anticipate an erosion of the quality of the recreation experience. Quality deterioration through what is referred to as the external effects of congestion may exceed the permissible level for optimal intensity of use, in an economist's sense, substantially before the carrying capacity in the ecologist's sense is reached. Conversely, for some areas supporting fragile ecosystems subject to some types of uses, the constraint may need to be set before significant congestion costs are experienced if the ecological integrity of the area is to be protected. It is important, then, to note the distinction between these concepts of capacity and to distinguish them in our treatment of the problem in what follows below.

Following Stankey,[7] albeit using an economic rationale, we shall consider a low-density (hereafter referred to as a wilderness experience) recreation use of a differentiated product catering to a relatively specialized clientele or sub-market. Stankey has employed a rationale based on an extra-market allocative device (political process) for selecting his "public," "clientele," or, in our terms, the relevant "customer" given the particular product market we are investigating. We can assume, as does Stankey, that the wildland tract in question has been designated as a *de jure* wilderness area, and our interest could center on determining what intensity of use would maximize the value of the service-flow. On the other hand, we can select for analysis a given tract in order to determine whether its value as a wilderness recreation resource would exceed its value as a high-density recreational resource, or alternatively even as a source of natural resource commodities exploited in a manner incompatible

7. G. Stankey, The Perception of Wilderness Recreation Carrying Capacity: A Geographic Study in Natural Resources Management (Ph.D. Thesis, Michigan State University, 1971).

with retaining its integrity as a natural area.[8] In the latter case, we would wish to establish the benefit of the tract when retained in its wild state by fixing the intensity of use at that level which would maximize the value of the preservation alternative for its comparison with the opportunity returns foregone by precluding the higher density development or the incompatible extractive alternatives.

Our analysis assumes a multi-modal distribution of tastes in recreation pursuits. That is, we are taking it for granted that those who elect to devote a significant portion of their leisure time to outdoor activities involving the remote back country as compared with those who devote vacation periods to more gregarious socially interacting situations, *tend* to cluster in mutually exclusive groups.[9] And as economists with a substantial respect for the efficacy of the market (where conditions for its efficient operation exist) in allocating resources to the gratification of the entire range of tastes, we address ourselves in this analysis to only those individuals "in the market" for the wilderness type experience.[10] From this point forward we shall be addressing that segment of the outdoor recreation market represented by the unambiguous wilderness experience seeker, for whom solitude is a desired objective, the satisfaction or utility gained from the wilderness experience tends to be inversely related to the number of encounters he experiences with others during a wilderness outing.[11]

III

In this section we shall review the analytics of determining an optimal recreation capacity for low-density recreational use facilities. Let us consider a relatively homogeneous group of recreationists who wish to enjoy a wilderness recreation experience. By homogeneous we intend the assumption that, as suggested in Section II, an increase

8. An example of the latter objective analysis involves the current controversy over whether to retain the remaining portion of Hells Canyon in its present condition as a wild and scenic recreational resource or develop the Snake River in this reach as a hydroelectric project.

9. That is, the backpacker in the wilderness, a solitude seeker, is unlikely to be found attending vacations at high-density vacation facilities. But preferences for solitude may be held ephemerally for "contrast" so that a lone backpacker during a vacation may be a socializing square dance buff as well.

10. This task of allocating resources to cater to the preferences of those seeking wilderness and related types of experience is one which the market would fail to perform efficiently, thereby justifying public intervention (*see supra* note 4). But if intervention is to be sufficient as well as necessary for an improvement in the efficiency with which resources are allocated, it must make provision for the entire range of tastes in proportion to the number of consumers involved and the elasticities, price and income, current and projected, of their demand. For purposes of our analysis, we address ourselves to that segment of the total market for recreational services which demands wilderness recreation services.

11. *See* Stankey, *supra* note 7.

in the probability of encountering others on a wilderness outing is attended by diminished utility obtained from the outing. For simplicity, we assume also a uniform distribution of recreationists temporally over the recreation season. A season in this context can be segmented into as many intervals as necessary to ensure a relatively homogeneous experience. We would distinguish between the summer backpacking season and the autumn hunting season, for example. There may be other finer divisions also.

With these assumptions we present in Figure 1 a rather special set of aggregate demand schedules. On the horizontal axis we have use intensity represented by the quantity of recreation days (or recreationists) per unit time. Thus q_1 represents a density half as great as q_2, a third as great as q_3, etc., and with an expected encounter rate peculiar to the use intensity in question. Along the vertical axis we have represented the price, or willingness to pay per recreation day. For convenience of diagrammatic exposition, let us assume momentarily that there are thresholds with any changes in intensity of use within ranges demarcated by such thresholds not resulting in any congestion costs, but intensity differences between one threshold and another, moving from the origin to the right, being attended by quantum jumps in utility-diminishing congestion effects. Accordingly, for any intensity of use within the range of 0 to q_1, we consider the quality of the wilderness experience constant. This experience, being free of adverse congestion effects, represents the range of highest unit value wilderness experience and is represented by the highest demand schedule $D_1 D_1'$ · The total value of the recreation service flow per unit time with capacity fixed at q_1 (and fully utilized) is represented by the area under the demand schedule $D_1 D_1'$, here $OP_1 D_1' q_1$.[12]

Admission of additional unambiguous wilderness experience seekers would be attended by the addition of utility enjoyed by them. But an increase in the density of recreationists would result in a deterioration of the quality of the experience as compared with the experience at the lower encounter level. The relevant demand schedule might then be drawn as $D_2 D_2'$ for a service with a quality now fixed by the use intensity represented by Oq_2. The demand curve for the changed quality of service being lower, represents the diminution of utility per unit previously enjoyed by those who experienced the wilderness with no adverse congestion effects. Accordingly, the gain in utility enjoyed by the additional numbers participating would be represented by the area $q_1 x_1 D_2' q_2$. The loss is represented by the

12. *See* J. Knetsch and R. Davis, *Comparison of Methods For Recreation Evaluation*, in Water Research (A. Kneese and S. Smith ed. 1966).

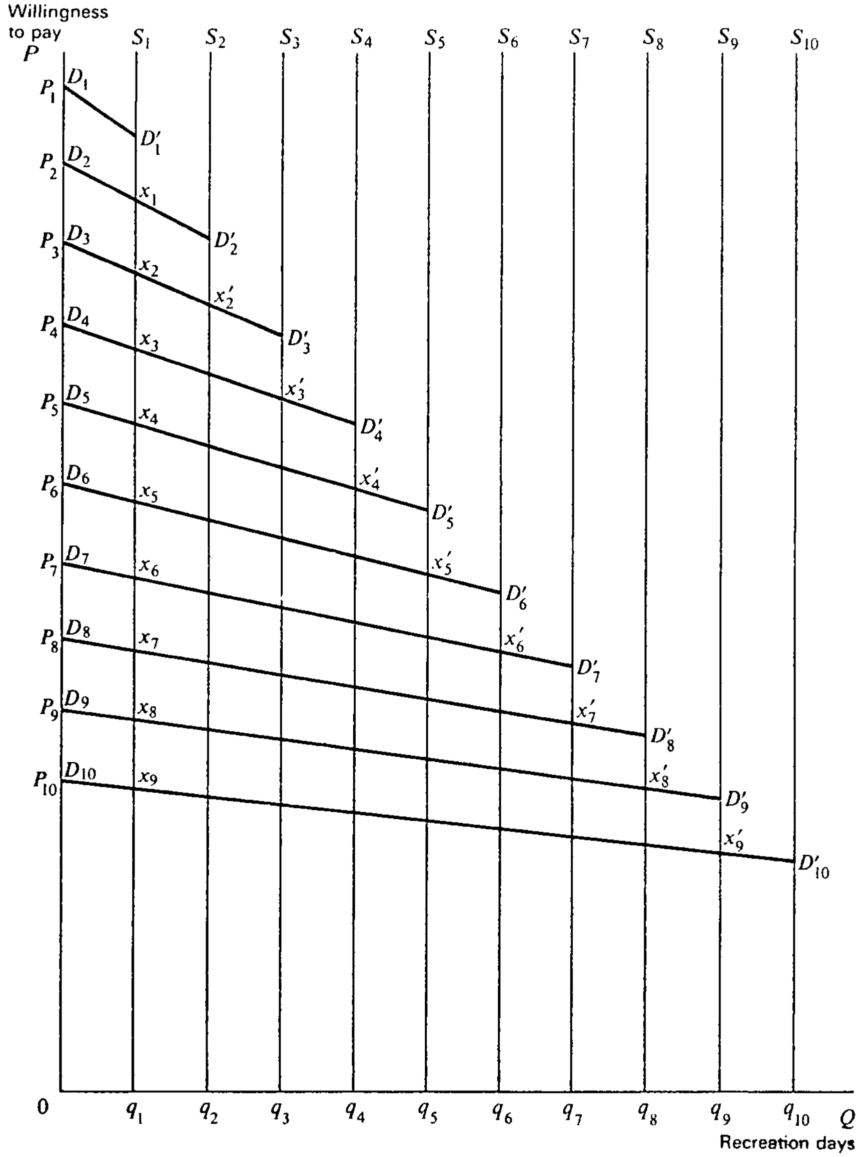

Figure 1.

area $P_2 P_1 D'_1 x_1$. As long as the gain from admitting additional numbers exceeds the loss due to congestion costs, aggregate net benefits will increase. Beyond a point the congestion costs exceed the gains experienced by the additional recreationists and total net benefits diminish. On the diagram, this occurs in the neighborhood of q_6.

Now if there are no costs other than the so-called "externalities" or adverse effects of congestion, the maximum net total benefit level of use would also define the optimal recreation capacity for such a low-density recreation facility or natural area. But there may, and normally will, be other costs as well. For example, the cost of potential environmental degradation of the sort Brandborg has alluded to, where recreational pressure may exert an adverse effect on the ecological environment.[13] Moreover, as Wagar and others[14] have noted, costs in the form of operating expenditures may be incurred to reduce, modify or eliminate the adverse effects of congestion. Further, costs in the form of investment outlays to further expand the intensive margins (e.g., laying out a duplicating but non-intersecting trail system to reduce or eliminate the probability of increased encounters with increased recreational density), may, and in the normal situation would, qualify for consideration in a well-managed wilderness area or system. Accordingly, the maximum total benefit as defined above is not likely to indicate the optimal recreation capacity for the wilderness tract in question. The reasons will be: a) ecological degradation costs will not have been taken into account, and b) the possibility of incurring capacity augmenting expenditures must be considered at any time—and over time—in determining optimal recreation capacity for a given tract of land.

To take account of these factors in our diagrammatic analytics, we need to return to Figure 1, and from the basic notions contained therein, derive an additional set of geometric relationships.

If we now change our assumption that we experience constant quality recreation services within appreciable ranges limited by discrete threshold values to an alternative assumption that these ranges can be made appropriately small, we can postulate a total net benefit function as shown in Figure 2. Here we have the benefit measured along the vertical axis with the quantity of recreational services (user days) measured along the horizontal axis. All points on the total benefit function measured by the vertical distance, divided by the corresponding quantity (given by the perpendicular dropped from a given point to the horizontal axis) will yield the average benefit, represented by the slopes of the chords shown in Figure 2.

13. S. Brandborg, *On the Carrying Capacity of Wilderness*, 82 Living Wilderness 28 (1963). *See also* R. Held, S. Brickler and A. Wilcox, A Study to Develop Practical Techniques for Determining the Carrying Capacity of Natural Areas in the National Park System (1969), for a more extended discussion of the inevitable adverse ecological effects from, for all practical purposes, the negligible with the first footstep, to the severe as for example the overgrazing and trampling of fragile alpine meadows by pack stock.

14. J. Wagar, The Carrying Capacity of Wildlands for Recreation, Forest Service Monograph 7 (1964). *See also* M. Clawson, *Philmont Scout Ranch, An Intensively-Managed Wilderness*, American Forests (May 1968).

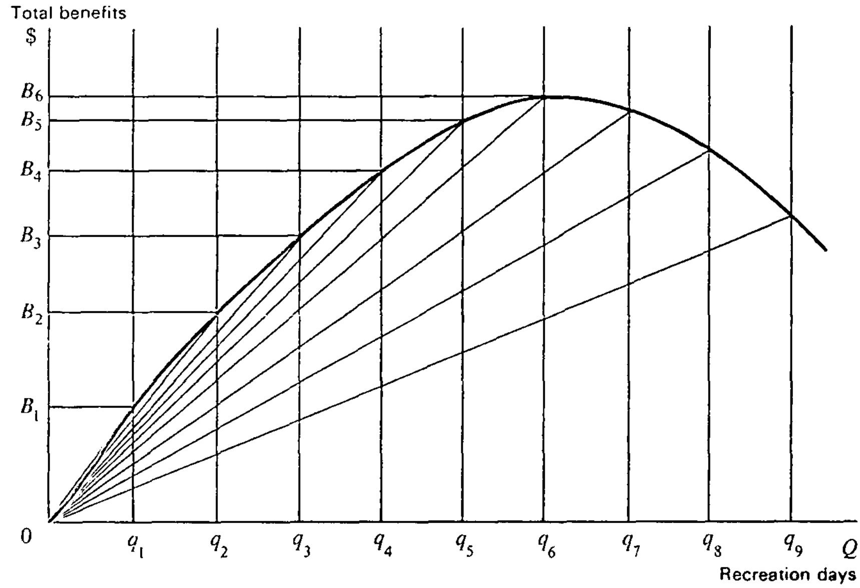

Figure 2.

These average benefit computations can be represented in an average benefit curve such as the one B/q of Figure 3, and the relation of the incremental (or marginal) benefit to the average and total, is represented in standard textbook form as the dashed line in Figure 3. We note in passing that the point of maximum net benefit (use intensity represented by q_6) is the point at which the cost of incremental congestion disutilities just equals the benefit of incremental gains to utility and hence the net marginal or incremental benefit function at that point equals zero.

If there were to be no costs other than those associated with congestion, the optimal capacity would be at the point at which the total benefit was a maximum and the incremental or marginal benefit was zero. With the introduction of ecological degradation costs, adjustment to the use intensity for purposes of defining the optimal capacity may be required. Conceivably one could argue that the adverse impact on the area's environment would be reflected in diminished utility to the wilderness user, and thus should be incorporated, as were congestion disutilities, in the net marginal benefit function. On the other hand if such damage is extensive, permanently endangering the existence of a particular species, it will have a significant adverse, irreversible effect on the ecology having a disutility for individuals extending beyond those who may ultimately

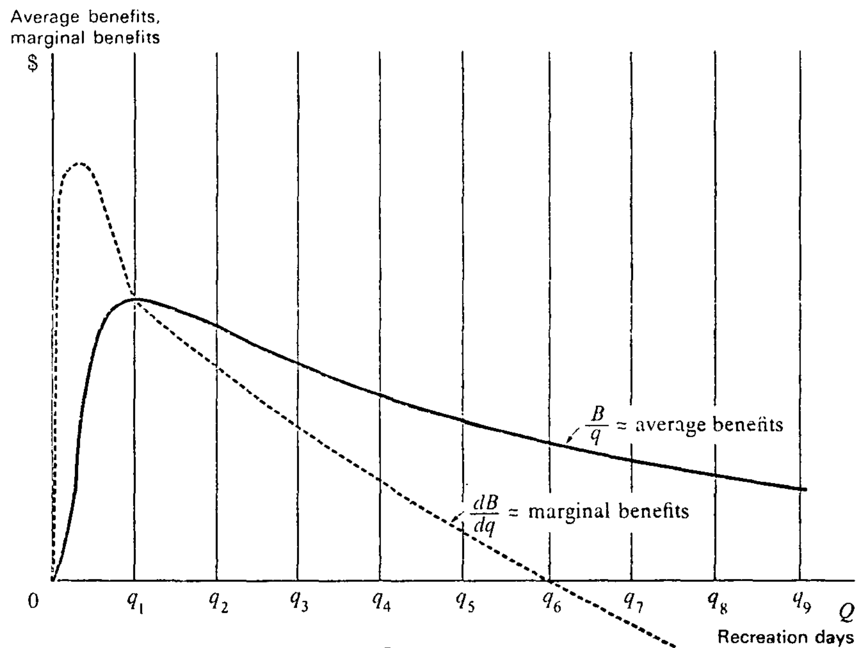

Figure 3.

appear *in situ* to observe these effects directly.[15] Accordingly, it is desirable to show these costs in some way separate from the more conventional disutilities associated with congestion. We do so in Figure 4 by means of a separate marginal cost of ecological damage function (MC_d) arising out of the adverse impact of wilderness users on the ecology of the wilderness areas as the intensity of use increases. Now if such ecological damage were to take effect before the maximum total net benefit (excluding this latter consideration) was reached, we would show such marginal costs intersecting the net benefit schedule short of the q_6 intensity of use level. Thus ecological damage as the effective constraint or "limiting factor" would determine use optimally at a quantity represented by the intersection of a perpendicular dropped from the intersection of the MC_d and MB

15. The disutility here will include loss of an option to view an example of the remaining and diminishing untrammeled natural environment, whether or not the option will in fact ever be exercised. This option value will be of utility to an individual either for his own potential exercise of the option, or for its potential exercise by his heirs. For a discussion of this phenomenon, *see* Weisbrod, *Collective Consumption Aspects of Individual Consumption Goods,* Quarterly Journal of Economics, (1964) and Cicchetti and Freeman *Consumer Surplus and Option Value in the Estimation of Benefits,* Quarterly Journal of Economics (1971).

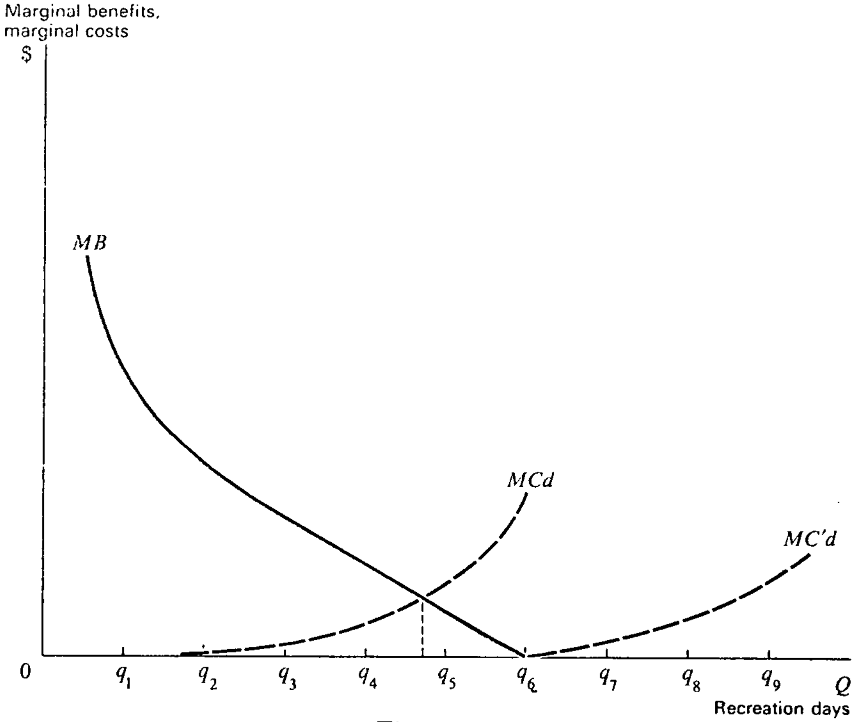

Figure 4.

functions, to the horizontal, i.e., in the neighborhood (just short of) q_5 in Figure 4. On the other hand, were the maximum benefit capacity reached (where $\Delta B = \Delta C$) before the intensity of use resulted in non-negligible ecological damage, the ecologist's concept of carrying capacity would not serve as the effective constraint. This is represented by the curve MC'_d.

We need to attend to another practical consideration before proceeding to a consideration of capacity augmenting public land management agency expenditures. Up to now we have assumed implicitly that costs of restricting entry to the wilderness tract in question were negligible. In a practical sense this is not likely to be true. Some consideration of administrative costs are required for defining optimal capacity, other things remaining equal. In Figure 5, assuming now that the ecological damage cost is negligible within the relevant range (between 0 and q_6) the net benefit will not be maximized at q_6 as when administrative costs were taken to be zero, but at some point short of q_6 given by the intersection of the marginal benefit function, net of congestion costs, and the marginal cost of ad-

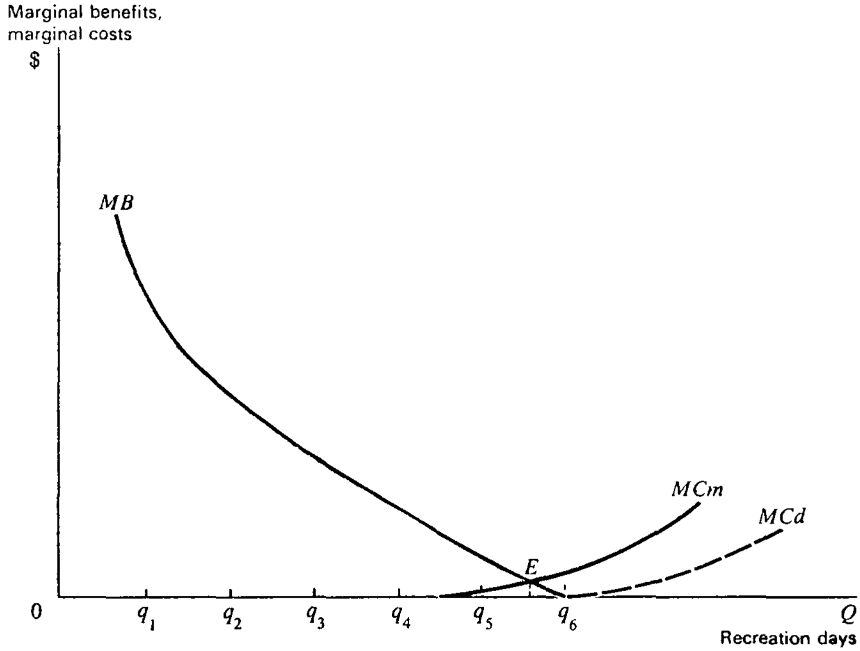

Figure 5.

minstering the intensity of use (MC_m) indicated by the new efficiency point E, i.e., at a use intensity somewhat short of q_6.[16] The administrative cost here reflects simply an attempt to ration use, without affecting the spatial or temporal distribution of users.

If we consider the possibility of affecting the distribution of use, for example by redistributing the use more uniformly over the wilderness tract in terms of the spatial dimension,[17] we can consider more labor intensive management to increase the capacity of a given facility without a degradation of the quality of experience. We show this in Figure 6. Here the MC_m' curve represents the increase in management expenditures devoted to the more intensive management of the *recreationists* in order to provide a more congestion-free

16. Since the services are provided independently of costs incurred for rationing, the equating of MB and MC_m is only a partial criterion. It is necessary also that the direct and opportunity costs of rationing do not exceed the reduction in congestion costs which they are intended to achieve. If the congestion cost reduction through rationing does not exceed the rationing costs, of course, no rationing is justified. We will have more to say about this in section III below.

17. *See* M. Clawson, *supra* note 14, for an interesting discussion of the use of advance reservations, period of orientation, and dissemination of information to Boy Scout backpack groups at the Philmont Ranch, used to increase the aggregate number of recreation days without proportional deterioration of the wilderness experience.

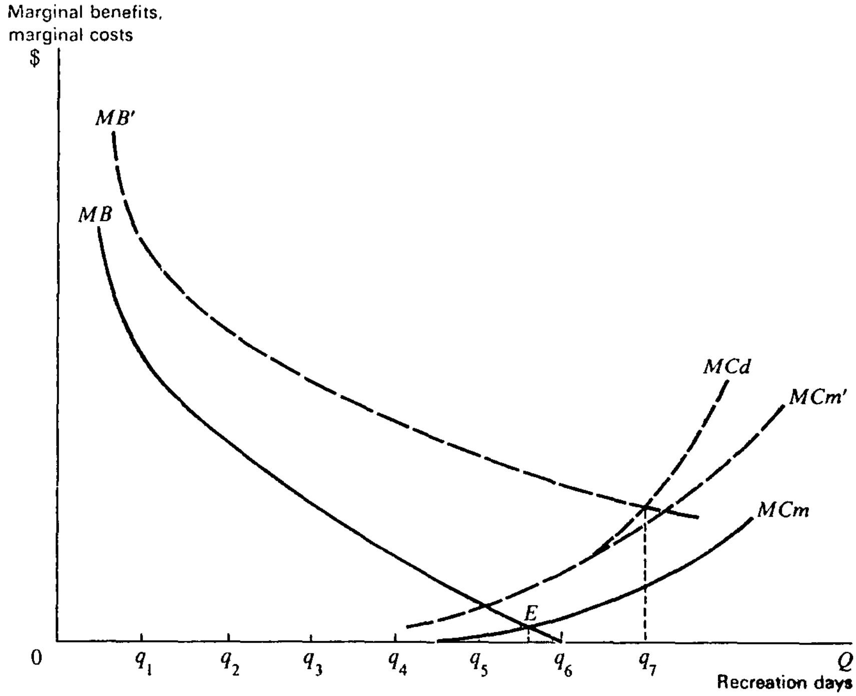

Figure 6.

wilderness experience. The incremental cost shift from MC_m to MC_m' has the effect, as well, of shifting the marginal (net of congestion disutility) benefit schedule from MB to MB', providing for all wilderness users a higher valued wilderness experience. This follows from the manner in which the MC_m' expenditures have shifted the (net of congestion disutility) marginal benefit function MB'. This was achieved, by assumption, at an increase in both ecological damage costs (MC_d) for the increased level of use and of direct public agency management expenditures (MC_m'). We now have the optimal level shifting from a use intensity something short of q_6 to one in the neighborhood of q_7, i.e., below the intersection of the MB' and the vertical sum of the MC_m' and MC_d curves.

An alternative would be to reduce congestion disutilities by investment, e.g., additions to the trail system, thus increasing capacity without a proportional increase in encounters. This would involve a trade-off between more labor intensive (current) expenditures and capital improvements. It might also avoid some disutility for a given amount of congestion by eliminating the element of "regimentation"

which regulating the time and place of wilderness use would undoubtedly have for some. To show the effect of capital improvements, however, it might be best to return to the form of the total benefit curve (as in Figure 2). We reproduce it in Figure 7 as the TB curve (compressed along the horizontal dimension). From any given investment cost level OM (i.e., the present value of the opportunity returns foregone by precluding an alternative use of the tract), a total cost curve TC will trace both the fixed and variable costs, and the

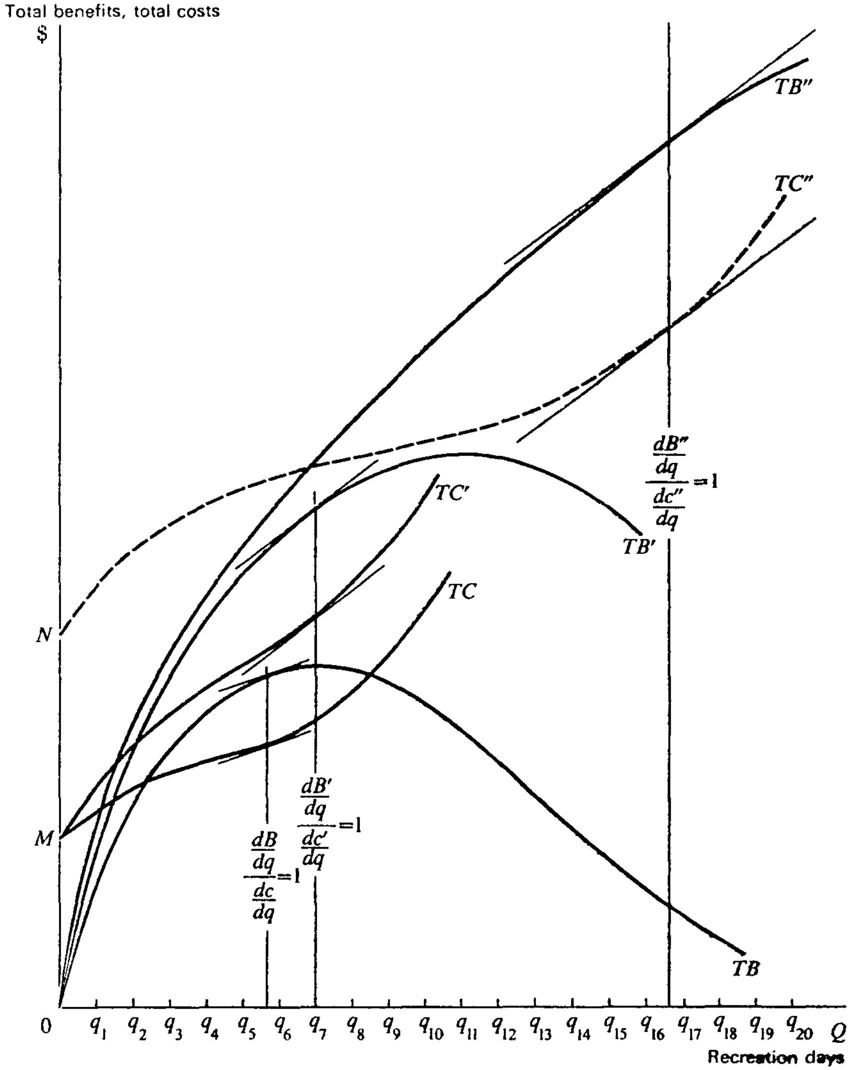

Figure 7.

slope of the TC curve will give the marginal cost. The optimal capacity (at E, Figure 5) would be shown on Figure 7 where the slopes of the TB and TC curves were equal—where marginal benefits equal marginal costs—just short of q_6. The optimal capacity (at q_7) resulting from the shift in the total benefit curve TB to TB′ due to additional expenditure on more intensive management (represented by the shift of TC to TC′) is shown similarly, paralleling the exposition in Figures 5 and 6. But, Figure 7 can illustrate in addition the effects of an investment as an alternative to more labor intensive expenditures to increase the capacity in question.

Consider then an increase in the investment of an amount corresponding to MN. Assume first that this is associated with an expanded but non-intersecting trail system which could accommodate larger numbers of individuals without increasing the probability of encounters. The increased capacity[18] is reflected by the change in the position of the total benefit curve from TB to TB″. The difference between the two total benefit curves (TB and TB″) at any q represents the diminution of congestion disutilities due to the increased capacity of the trail system. To obtain the optimal intensity of use for the enlarged facility, we would trace the total cost curve TC″ beginning at q_O from ON, and find the point at which the first derivative of the total cost curve TC″ equaled the first derivative of the total benefit curve, TB″, namely where the marginal benefits and costs were equal. In the illustration using Figure 7, this would be in the neighborhood of q_{17}.

Of course, to consider any level of investment as optimal, the level of investment must be chosen so that the difference between the total benefit and total cost curves at the points at which their first derivatives are equal, is at a maximum, *i.e.*, at the optimal mix of current and capital expenditures. Moreover, if we are going to optimize, we will need to consider not only the relative gains as between current and capital expenditures (operating maintenance expenditures versus capital improvements), but also the relative gains to capital outlays for augmenting capacity by investment within a given wilderness tract as compared with investment in additional wildlands. (This could be either for additional land for the wilderness tract in question or for land elsewhere in the wilderness system.)

There is, however, an additional complication involving potential irreversible consequences when facing a choice to invest in the internal capacity-augmenting option as an alternative to adding existing

18. Defined as an increase in number of recreation days which can be accommodated for any given probability of encounter—or, alternatively, as a gain (reduction) in utility (disutility) for any given number of recreation days.

de facto wilderness land to the system. If *de facto* wilderness, unprotected by wilderness status is subject to depletion by other incompatible uses, the value of the present option will be lost, whereas the option to invest in internal improvements remains open. In fact, this option would remain as an alternative in the event the opportunity costs of holding wilderness tracts would rise sufficiently to counsel disinvesting in extensive tracts. As these considerations are substantial, meriting separate investigation, we note them here only in passing.[19] This article, as an initial effort, will abstract from the problem of defining criteria for choice, involving irreversibilities and uncertainty.

We may then summarize the optimality conditions (given the above qualifications) analytically by the following expressions:

$$(1) \qquad \pi = B - (C_d + C_m + C_k)$$

Where:
- π = net benefits
- B = benefits (net of congestion disutilities)
- C_d = cost of damage to ecological environment
- C_m = current expenditures
- C_k = Capital expenditures, i.e., the relevant interest and amortization charges (or depreciation charges), the latter fixed by the relevant time horizon (or physical life of capital improvements).

Our criterion for optimal use of the area, maximination of π, is achieved by differentiating with respect to q, and setting equal to zero. Thus:

$$(2) \qquad \frac{d\pi}{dq} = \frac{dB}{dq} - \frac{dC_d}{dq} + \frac{dC_m}{dq} + \frac{dC_k}{dq} = 0, \quad \text{and} \quad \pi > 0$$

Or letting $MB = \frac{dB}{dq}$, etc.

$$MB = MC_d + MC_m + MC_k \quad ,$$

i.e., the marginal benefits from an increase in recreational services (MB) whether quantity, quality or the combination, must equal the sum of the marginal costs, whether increased management expenditures (current costs), damage to the ecological environment, or investment in improvements (capital costs). These are generally all well understood considerations in the area of benefit-cost analysis.

19. For a rigorous treatment of this problem, *see* Fisher, Krutilla and Cicchetti, *The Economics of Environmental Preservation*, 62 Am. Econ. Rev. 605 (1972).

The problem, as in the case of all things which are rather well understood in principle, is application in practice. We make our initial efforts in exploring application in the next section.

IV

Let us now consider the question of how to make operational the benefit and cost constructs specified in equations (1) and (2). As noted in the preceding section, (total) benefits from a non-priced service, such as most resource-based recreation, are conventionally measured as the area under an imputed demand curve for the service, represented in Figure 8 below. This demand is just the marginal benefit introduced in the preceding section. The area under the curve is also known as the consumers' surplus, the sum of the amounts each consumer of the resource would be willing to pay in order to continue consuming.[20]

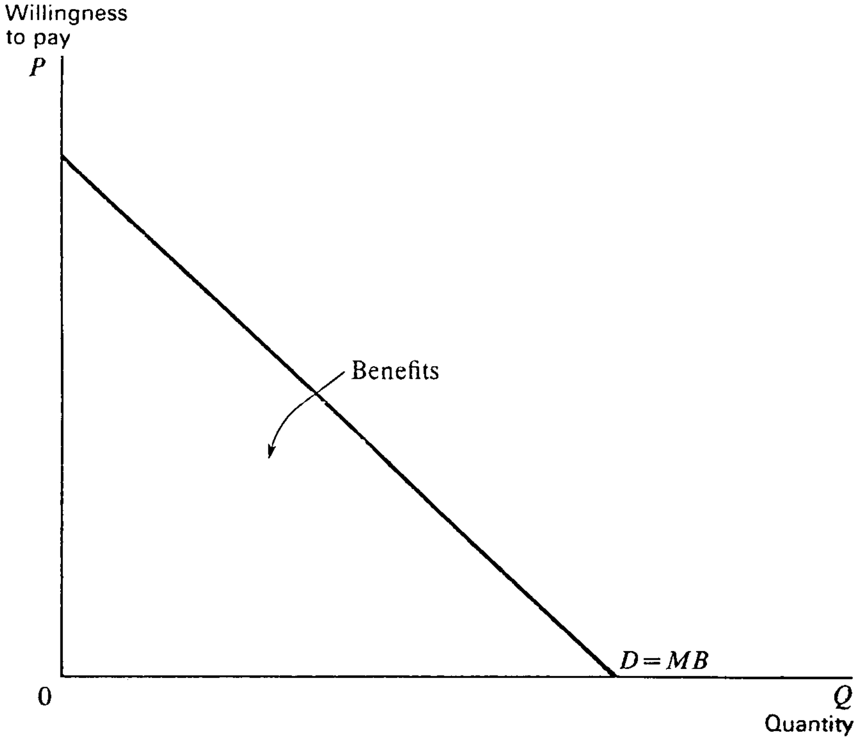

Figure 8.

20. For a detailed discussion of the concept of consumer surplus, including mention of an alternative definition, *see* Fisher, *supra* note 15.

Our problem, then, is in part the familiar one of finding a way to observe and aggregate consumer willingness to pay for recreation, but only in part, as we are concerned also to capture the effects of varying levels of congestion on this willingness to pay. Thus the marginal benefit curve of Figure 8, like those of Figures 4, 5 and 6, represents benefits excluding congestion costs. Most of the remainder of this article details our proposals for estimating this curve for a particular recreation season at a particular site.[21] In our judgment, supported further on by some brief discussion of costs, this estimation constitutes the heart of the optimal capacity problem.

Before proceeding, let us try to indicate why a monetary measure, such as willingness to pay, is to be preferred to some non-monetary alternative measure of benefits. Suppose, first, that benefits could be measured, and then aggregated, in some agreed upon non-monetary, arbitrary utility units (AU's). Suppose, further, that ecological damage costs are not significant. Recalling the discussion of the preceding section as summarized in eq. (2), it can be seen that efficient utilization of the environmental resources for recreation requires a balancing of marginal AU's against the marginal dollar expenditures of the management agency. Now if marginal benefits were observed to be negative in the absence of any restriction on use, there would be a presumption that some restriction might be desirable. But, there would be no way of knowing how much, as there would be no way of comparing incremental changes in benefits measured in AU's with incremental changes in the costs incurred in restricting use measured in dollars.

Moreover, it is generally understood that there is not in fact any legitimate way to aggregate intensities of preferences (the AU's) across individuals, as would be required for the above procedure.[22] Even assuming some cardinal measure of utility to be associated with a particular wilderness outing for each individual, it seems that aggregation would require further assumptions of a dubious nature. To see this let us assume that there exists for each individual a function relating the "percent of complete satisfaction" from a wilderness outing to its degree of congestion. Now in order to aggregate, say, 90 percent satisfaction (90 AU's) for one individual with 90 percent

21. Our definition of "recreation season" is a fairly loose one. Essentially, it is designed to avoid lumping in various activities with dissimilar congestion effects, such as summer backpacking, fall hunting, and winter skiing, that might be undertaken over the course of a single year in an area. We owe this point to Gunter Schramm's discussion of an earlier draft of the article.

22. This is a very old problem in welfare economics. Some notion of the difficulties can be obtained by consulting K. Arrow and T. Scitovsky, A.E.A. Readings in Welfare Economics (1969).

satisfaction (90 AU's) for another to get a total of 180 AU's for a given outing, we would need to make interpersonal comparisons. This would involve assuming that both individuals have an equal capacity for enjoying the outing and, moreover, that both have an equal proportion of their welfare associated with it. To appreciate that this would not, in general, be true we can imagine two individuals, one having a keen interest in the outing with high expectations associated with it, and the second only mildly enthusiastic. Both may have their expectations realized to the same degree, and would indicate the same percentage of complete satisfaction, yet the amount of utility each would derive from the experience would differ. This difference should be reflected in any measure of aggregate benefits.

On the other hand, if it could be learned from each individual what he would be willing to pay for a day of wilderness recreation characterized by a given degree of congestion, intensities of preferences would be reflected in an easily aggregated measure. Of course, even this measure is not free from interpersonal considerations, as it is dependent on the existing distribution of income. There are however several possible answers to objections on distributional grounds to a monetary measure of recreation benefits. First, we might assume an exogenous, socially sanctioned distribution of income, affected perhaps by explicit policies for redistribution such as a negative income tax. This is the tack generally taken by economists focusing on the efficiency of a particular allocative scheme. Second, we might note the positive relation between participation in wilderness recreation and income (and education), and that such recreation can be classed as a "luxury" good, i.e., one for which demand rises more than proportionally with income.[23] Finally, we have to this point considered the monetary measure merely as a conceptual device for benefit evaluation. Nothing has been said about actual institution of user charges.

Use of a monetary measure makes possible the solution of another aggregation problem as well. Individual demand may encompass willingness to pay for not just a single day in the wilderness, but for several days. Thus if we know that an individual is willing to pay, say, $10 for one day, and $15 for two days, then the marginal value of the first day is obviously $10, and of the second, $5. The total value of an area for a recreation season is the sum of all such marginal day values over all participating individuals.

23. *E.g.*, Cicchetti, Seneca and Davidson, The Demand and Supply of Outdoor Recreation (1969).

The problem of conformable units is also encountered in assessing the costs of ecological damage. Although uncertainty about benefits from future recreation activity in an area, as well as possible unforeseen applications of gene pool conservation and scientific research, are likely to make precise evaluation impossible, significant costs might be associated with such irreversible losses as destruction of the scenic or wildlife resources on which the recreation activity is based. For our purpose we would want to identify a region of discontinuity or rapid rise in the MC_d curve, within which optimal capacity would then fall—so long as congestion costs were not yet significant.[24]

Let us turn now to our suggestions for measuring consumer surplus benefits net of congestion costs. A prerequisite for any discussion of this problem is the definition of an operational measure of congestion. As hinted in our earlier discussion, we propose for this purpose the number of encounters E of recreationists with each other over a fixed period, say a day. Clearly, different types of encounters, in different circumstances, are conceivable—with correspondingly different effects on recreationists' utility. An encounter at a trailhead, for example, is less distasteful to the wilderness solitude seeker than one at his backcountry campsite. The possibility of even greater variation in the costs of encounter is raised by a definition that would include, in addition to direct contacts with others, "encounters" with evidence of their presence, such as litter, trampled vegetation, and so on.[25]

Ideally, then, we are interested in information of the following sort: what are the amounts each individual would be willing to pay for a single recreation day characterized by a given set of encounters; similarly for two such days, and so on. In symbols, individual i's willingness to pay can be represented (for any given number of days) as

$$(3) \quad P_i = f(E, \overline{O}, \overline{T}_i)$$

where E is a vector $\begin{bmatrix} E_1 \\ E_2 \\ \cdot \\ \cdot \\ \cdot \end{bmatrix}$ of different types of encounters, E_1, E_2, . . .,

24. Professor Robert Ream, a plant ecologist with extensive backcountry experience, however, has suggested that typically extensive ecological damage from wilderness use will not occur until after the congestion constraints become effective. There may be an exception to this observation, we would imagine, if pack stock is used as a mode of travel in wilderness areas.

25. This broad view of the encounter phenomenon we owe to Blair Bower's discussion of an earlier draft of this article.

and $\overline{O}$ and $\overline{T}_i$ are respectively other characteristics of the recreation experience, and the individual's tastes, taken as exogenously determined.

Assuming we can get this information, how is it related to level of use? That is, how is the vector of encounters determined? To answer this question, we propose a model to simulate the travel behavior of recreationists through the wilderness tract, coupled with an assumption about the time pattern of use over the recreation season. For the purpose at hand we assume for simplicity, with no loss in generality, a uniform distribution of recreation days over the season. This gives the number of individuals present on any one day as $\frac{R}{n}$, where R is the total number of recreation days over the season and n is the length of the season (in days). Now using the simulation model, we can relate this number $\frac{R}{n}$ to the numbers of (different types of) encounters expected. Of course, the number of different types of encounters that can be handled in this fashion will depend upon the complexity built into the simulator. In principle, an indefinitely large number could be considered, though in a first application perhaps only four–say trail and campsite and mode of travel, *i.e.*, foot and horseback–may be attempted.[26] For the remainder of this discussion we abstract from this problem and speak simply of encounters, recognizing that this may refer to anything from undifferentiated encounters to a vector of different types of encounters. The information obtained would appear as shown in Table II.

Let us return now to the question of how the required information on willingness to pay is to be obtained. In the absence of the ordinary market price data, there are essentially two possibilities: (1) an explicit set of questions put to individuals requesting them to state the value of the experience; or (2) indirect inference of the value from some aspect of their observed behavior. For reasons we will indicate shortly, economists have traditionally favored the latter approach, at least in principle. Clawson and Knetsch have shown how an aggregate demand schedule can be inferred from recreationists' observed travel costs, and then used to calculate their consumers' surplus benefits.[27] Unfortunately, there is no obvious way to extend the technique to treat the congestion externalities which are our main concern.

Since we are constrained to adopt the approach which seeks to learn directly from individuals what they are willing to pay for a

26. Work on a somewhat more complex model is currently going forward in the National Environments Program at Resources for the Future.

27. M. Clawson and J. Knetsch, Economics of Outdoor Recreation (1966).

recreation experience characterized by a given degree of congestion, we should note the possible pitfalls. Two reasons have been suggested why a response to a hypothetical question of this sort may be un-

TABLE II
Expected Encounters as a Function of Intensity of Use

Use-Recreation Days	Probabilities	Expected Encounter	Encounters
	0	.75	
	1	.15	
10,000	2	.05	0.4
	3	.03	
	4	.02	
	0	.50	
	1	.31	
19,500	2	.10	0.8
	3	.06	
	4	.03	
	0	.20	
	1	.40	
28,500	2	.25	1.4
	3	.10	
	4	.05	
	0	.10	
	1	.25	
37,000	2	.35	2.0
	3	.20	
	4	.10	
	1	.10	
	2	.25	
45,000	3	.35	3.0
	4	.20	
	5	.10	
	2	.10	
	3	.25	
52,500	4	.35	3.9
	5	.20	
	6	.10	
	3	.10	
	4	.25	
59,500	5	.35	5.0
	6	.20	
	7	.10	
	4	.10	
	5	.25	
66,000	6	.35	6.0
	7	.20	
	8	.10	

reliable. First, as Samuelson has pointed out, the individual has an incentive to understate his willingness to pay for a publicly provided good, as he may reckon he can continue to enjoy it without being assessed his full consumer surplus.[28] To eliminate this general bias, an interview procedure formulated by Davis specifically for outdoor recreation studies is very useful.[29] The idea is to have the individual react to the possibility that he *can* be excluded–plausible in this, if not in the typical public good, case–for failure to pay a sufficient price. Also relevant, perhaps, is that in a recent controlled experimental study of the consistency of consumer responses to questions concerning their willingness to pay for entertainment services, the expected bias did not appear.[30]

The second objection to the interview procedure is that, even where there is no dissimulation in responses, it is not clear that a respondent's speculation as to how much he would be willing to pay when confronted with a hypothetical situation would reflect his behavior in a similar real situation. Response to a hypothetical situation cannot be assumed to correspond exactly to behavior in a real situation since in the former an individual might answer without being influenced by his income constraint, whereas in the latter the constraint would be effective. Accordingly, there might be a tendency to overstate willingness to pay in the hypothetical situation. Indeed, one explanation of the experimental results reported above may be found in the relatively small amount of money involved.[31] However, if the purpose of a willingness to pay question is to estimate benefits from recreation for comparison with benefits from alternative uses of a tract of wildland, then an income-constrained estimate may itself have a downward bias. This is because it corresponds to the Hicksian "price-compensating" measure of consumer surplus, whereas the "price-equivalent" measure may be the more relevant when a change from *de facto* wilderness to an incompatible use is contemplated.[32] Since the difference between the two measures is related to the presence or absence of the income constraint, what appears to be an upward bias in response to a question regarding willingness to pay in

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28. Samuelson, *The Pure Theory of Public Expenditures,* Review of Economics and Statistics (1954).

29. R. Davis, The Value of Outdoor Recreation: An Economic Study of the Maine Woods (Ph.D. Thesis, Harvard University 1963).

30. Bohm, *Estimating Demand for Public Goods: An Experiment,* forthcoming in The Swedish Journal of Economics.

31. *Id.*

32. *See* J. Krutilla, C. Cicchetti, A. Freeman III, and C. Russell, *Observations on the Economics of Irreplaceable Assets* in Environmental Quality Analysis: Research Studies in the Social Sciences, A. Kneese and B. Bower (1972).

a hypothetical situation may simply be a reflection of a more appropriate measure of benefit.

V

Now let us assume that we can agree both on what we mean by "encounter," and on a method for measuring individual willingness to pay for recreation days characterized by varying expected numbers of encounters. Recall that, using the travel behavior simulator, we can generate an expected number of encounters per day as a function of any given total number of recreation days in a season. Given this relation, a sample from some known number of recreation visits can be questioned as to willingness to pay for one day with the expected number of encounters, two days, and so on.

For purposes of illustration, suppose the use of an area is 37,000 recreation days uniformly distributed over the season so that just two encounters could be expected on any day (see Table II). Suppose further that each user could be placed in one of five different categories, corresponding to his monetary evaluation of the two-encounter day. This information might be presented as in Table III below.

TABLE III
Willingness to Pay for Two-Encounter Recreation Days
For Five Different Categories of Individuals

Number of Days	Category A	B	C	D	E
1	10	12	9	7	5
2	18	19	17	12	9
3	25	25	23	16	12
4	31	30	28	19	14
5	36	34	32	21	15
6	40	37	36	22	--
7	43	39	39	--	--
8	45	41	41	--	--
9	46	42	42	--	--
10	47	43	--	--	--

Next suppose that the distribution of users among the five categories is: 33.33 percent equally divided among A and E, 41.67 percent equally divided among B and D, and 25 percent in C; and that the clientele for the area and season numbers 6,000 in total, so that there would be 1,000 individuals in A and E, 1,250 in B and D, and 1,500 in C. Then, in order to compute the total benefits of the 37,000 recreation days, (in descending order), we simply add in the amounts each of the recreationists is willing to pay for another day

of recreation. Total and marginal benefits would be as follows. The highest amount, $12 per day, will be paid by individuals of group B, of which there are 1,250, giving an aggregate marginal and total benefit of $15,000 (1,250 multiplied by $12/day). Proceeding to the next highest "bid" we find this to be $10 from individuals in group A, which in turn produces a marginal benefit of $10,000 (1,000 individuals multiplied by $10/day). The third (block of) day(s) would be claimed by individuals of group C, of which there are 1,500 with a $9/day willingness to pay or $13,500 for a cumulative benefit of $38,500. These computations are illustrated in Table IV. A user fee might be set such that only 37,000 recreation days in total are claimed so that the encounter level would remain at the expected number of two per day. From Table IV, Column 4 it is apparent that the user fee should be something a bit over $2.00 per day, for at $2.00 something over 40,000 recreation days would be taken. Hopefully this example is sufficient to illustrate the mechanism by which the expected encounters could be manipulated, and hypothetical discriminating monopoly receipts serve as an aggregate measure of benefit.

A similar exercise could be performed involving responses to questions of an identical sort when the "product" offered is an outing with an expected three encounters per day, four encounters per day, and so forth. For each set of responses to questions regarding willing-

TABLE IV
Computation of Benefits Based on a Two-Encounter per Day Recreation Experience

User fee for given day 1	Number in Relevant Group 2	Number of Days by Group and Price 3	Cumulative Number of Days 4	Marginal Benefits 5	Total (Cumulative) Benefits 6	Source of Marginal Benefit 7
$12	1,250	1,250	1,250	$15,000	$ 15,000	B
10	1,000	1,000	2,250	10,000	25,000	A
9	1,500	1,500	3,750	13,500	38,500	C
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
2	1,250	1,250	36,500	2,500	190,000	B
2	1,000	1,000	37,500	2,000	192,000	A
—						—
2	1,250	1,250	38,750	2,500	194,500	B
2	1,500	1,500	40,250	3,000	197,000	C
1	1,000	1,000	44,250	1,000	198,000	E

ness to pay for an outing with a different expected number of encounters, a computation corresponding to the Total Cumulative Benefit (col. 6, Table IV) would result, giving benefits measured in monetary units for each intensity of use. From the illustrative figures we would find the maximum (net of congestion disutilities) benefit in the neighborhood of 45,000 recreation days (Table V).

TABLE V
Relationship of Aggregate Benefit to Number of Recreation Days

Recreation Days 1	Expected Number of Encounters 2	Aggregate Willingness to Pay, i.e., Benefits 3	Marginal Benefits 4
10,000	0.4	–	–
19,500	0.8	–	–
28,500	1.4	–	–
37,000	2.0	$197,000	–
45,000	3.0	239,560	$42,560
52,500	3.9	233,811	5,749
59,500	5.0	201,795	32,016
66,000	6.0	–	–
72,000	7.0	–	–

Returning to the aggregation problem cited earlier, it is easily seen that this procedure aggregates all of the highest valued uses of the area, even if this means adding in two or three days for some individuals before the first days for others.

Note that none of the above *requires* that use be rationed by money prices. Thus far we have considered monetary units only as a measure of benefits. However, there would seem to be an important advantage in employing user fees as the rationing device as well. If management set a fee equal to the willingness to pay of the last or marginal users, then each of the days included would bear a higher value than each of the days excluded. Alternatively, admitting the daily ration of the first 45,000 recreation days per season on a first-come-first-served basis, at a zero user fee, this would not ensure that individuals who valued the wilderness tract most highly would be admitted. That would, of course, affect the value of the wilderness tract, as it would not be allocated to its highest valued use.[33] Again, this assumes the income distribution (which affects individuals' willingness to pay) is a socially sanctioned distribution. If non-efficiency benefits from the use of wilderness would accrue to society by an alternative admissions' policy, we would be able to weigh these alleged benefits against the losses resulting from the exclusion of

33. *See* J. Seneca, *The Welfare Effects of Zero Pricing of Public Goods*, Publc Choice at 101-110 (Spring, 1970).

some willingness to pay, in order to better evaluate the merits of the alternative admissions' policy.[34]

Another advantage of price rationing is that any initial miscalculation could readily be corrected through subsequent price adjustment. For example, suppose management, on the basis of prior information concerning user willingness to pay, set a user fee expected to optimally restrict use to the 45,000 days in our illustration. If, following the institution of this fee, only 35,000 days are taken, then clearly the consumers' surplus measure of benefits has been overestimated, and the fee might be lowered. This sort of iterative procedure then can provide additional information about consumer tastes that should be of value to managers.

VI

In the preceding section we have worked through a simplified example designed to illustrate how a wilderness tract might be managed in accordance with economic principles to provide maximum recreation benefits. In doing so we made reference to the need for a user travel-behavior simulator and a survey research effort. These would be for the purpose of obtaining respectively estimates of wilderness users' responses to different circumstances as a result of the differences in intensity of use. The latter responses would be registered as differences in the amounts such users would be willing to pay for differences in the quality of the experience defined in terms of the freedom from congestion. To carry out such investigations represents a substantial study in itself which goes considerably beyond the scope of this effort. While these studies have not yet been carried out, something might be said about their character.

The Spanish Peaks Primitive Area of Montana has been selected as a prototype from which data can be obtained to endow the simulator with considerable realism. Data are available on the characteristics of the area, trails, campsites and terrain, and on the distribution of wilderness users by trailhead, routes, lengths of stay and mode of travel for the present level of use intensity.[35] A simulator is being

34. *See* D. Nichols, E. Smolensky, and T. Tideman, *Discrimination by Waiting Time in Merit Goods,* Am. Econ. Rev. (1971), for an argument that discrimination by waiting time is to be preferred to discrimination by money prices in certain "merit good" cases. For reasons indicated in J. Krutilla and J. Knetsch, *Outdoor Recreation Economics,* 389 Annals 63 (1970), this argument is applicable to population-oriented "inner city" recreation, but not to the resource-oriented wilderness recreation that is the concern of this article. Additional analysis of the mechanism for provision of public goods is found in C. Cicchetti and R. Haveman, Optimality in Producing and Distributing Public Outputs (unpublished manuscript).

35. These data represent the contribution of the Wilderness Research Project undertaken by Robert Lucas and George Stankey.

developed, using these data, which will mimic the behavior of existing users, registering the number of encounters by location (whether at periphery or interior of area) type of encounter (while traveling on trail or during campsite occupancy) and mode of travel (whether by foot or pack stock and horseback). Given a functioning simulator, if run for an appropriate number of times for each intensity of use postulated, estimates of the expected encounters by location, type, and mode can be developed and functionally linked to the number of recreation days of specified composition.

Concurrently a survey is being prepared to elicit information on the nature of individual user's willingness to pay functions under preassigned conditions which reflect the intensity of use. Now it is clearly impossible to account for every relevant dimension of the quality of a given experience. Such an accounting would require that users can be asked an excessive number of questions. The strategy to be employed will be to select a limited number of questions to address to each potential respondent, raising as many of the questions relevant to determining the schedule of willingness to pay as possible within our sampling constraints. This is intended to produce a scatter of observations which will permit obtaining an estimate of the functional relationship between willingness to pay and encounters of various sorts for various lengths of stay, by applying conventional econometric techniques.

It should be acknowledged that to the best of our knowledge neither the simulation study nor the survey research proposed here has been attempted in precisely such circumstances by others. On the other hand, the strategy outlined above at this point appears sufficiently promising to warrant the effort. The information resulting from such a study would aid in solving increasingly vexing problems for public land managers.