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Managerial Objectives and Use Limits on Resource-Based Recreation

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MANAGERIAL OBJECTIVES AND USE LIMITS ON RESOURCE-BASED RECREATION

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ABSTRACT

This paper considers the restriction of visitor numbers to resource based recreational facilities. The motivation for restricting numbers using, for example, national parks is to limit the congestion and environmental degradation caused by recreation. Managers have adopted a management system known as Limits of Acceptable Change (LAC) to determine use levels. This paper presents a model of managerial decision designed to capture the impact of this policy. The efficient use level is compared to that under LAC. The adoption of LAC may see a significant reduction in use relative to the efficient level. Attention is also focussed on modelling the quality of user's recreational experience in a realistic way.

JEL Classification: Q26

The restriction of numbers using national parks and other resource based recreational facilities is controversial. Some see tight restrictions on visitors as the only way to protect the integrity of natural areas, while others see it as a right to have unhindered access to outstanding public lands. A recent judicial ruling has required the United States National Park Service to set maximum visitor numbers for the Merced Wild and Scenic River in Yosemite National Park (Haas, 2004). The US National Parks Service has resisted setting target numbers for this region, although it places limits on visitor numbers to Yosemite's backcountry. This paper reconsiders the issues of restriction of visitor numbers to resource based recreational facilities, particularly in the light of recent management schemes proposed by environmental researchers and adopted by the US National Park Service

The motivation for restricting numbers using national parks is to limit the congestion and environmental degradation caused by recreation. In wilderness areas environmental degradation is likely to be the more significant of these two effects.[1] Recreational use often significantly degrades the quality of a natural resource (Leung and Marion, 2000; Sun and Walsh 1988). For example, increased use of walking tracks through wilderness can cause erosion along the track and of nearby areas, while increased use of lakes for fishing can reduce fish stocks. As demand for the use of natural resources increases, it must be decided whether to control degradation by regulating access. Legislation usually requires managers of wilderness areas to both preserve the environment and allow recreational activities, thus avoiding the issue of what is the appropriate balance between the two. For example the US Wilderness Act requires lands to be managed "for the use and enjoyment of the American people" and "for the protection of these areas, the preservation of their wilderness character" (Brunson, 1998).

Economic reasoning would appear to be ideally suited to identifying the appropriate trade off between these incompatible goals. Instead, managers in the US and elsewhere have adopted a management system known as Limits of Acceptable Change (LAC) (Cole and Stankey, 1998). LAC requires managers to detail a list of goals for wilderness management. Amongst these goals is an 'ultimate constraining goal' or a 'hierarchy of constraining goals'. Constraining goals are usually environmental quality, and have a minimum acceptable

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[1] Cole (2001) states that there is "no empirical evidence that encountering more people than one prefers has a

standard associated with them. Under LAC these ‘ultimate constraining goals’ can be compromised ‘somewhat’ to achieve other goals (such as recreation), but must remain above the minimum standard. In the past it has been left to managers to determine what is an appropriate compromise of preservation goals, although more recently the public has become involved (Krumpe and McCool, 1998). A similar approach has been used to manage some Australian wilderness areas (Sawyer, 2000).

The explicit use of economic reasoning has been eschewed by the US National Park Service as well as those researchers who developed LAC and similar management schemes. The early literature on the “carrying capacity” of National Parks, especially Alldredge (1973) and Wagar (1974), contain intuitive economic reasoning that draws on the seminal economic analysis of Fisher and Krutilla (1972). However subsequent work by researchers did not utilise this theoretical framework. Rather, considerable effort was devoted to surveys of park visitors. As a consequence LAC and similar management schemes were developed to provide managers with an explicit account of the impact of decisions, and a guide to relative importance of competing goals.

As LAC is designed to be a practical guide for managers, it is largely a-theoretical. While emphasising a hierarchy of constraints, the objective of the manager is left unspecified. Of course, economic theory suggests that agents always act maximise some outcome. LAC does not address this, leaving the minimum standard of the constraining goal is left up to the judgement of managers. With its emphasis on environmental condition as the ultimate constraining goal, LAC inevitably leads to managers placing a higher weight on environmental considerations in their decision-making. As such, adoption of LAC reduces the relative importance placed on recreation in managerial objectives.

This paper presents an economic analysis to model managerial decisions regarding the use level of natural resource based recreation. To this end an economic model that captures the salient features of recreational use of a natural resource is developed. The model analysed in this paper is similar in approach to that developed by Fischer and Krutilla (1972). Central to the model is a measure of the recreational quality, which captures the user’s enjoyment of recreation per visit to the natural resource. Recreational quality is inversely related to environmental degradation and congestion, which are, in turn, related to the total level of recreational activity. This paper extends Fischer and Krutilla’s approach by

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substantial adverse effect on the quality of most visitors experience”.

incorporating managerial objectives in the analysis. The impact on efficiency of adopting LAC is investigated.

In this analysis, users treat recreational quality as exogenous, and do not take it into account in their choice of level of use. There is a role for management offsets the impact of the externality in order to achieve the efficient level of use. This would be a straightforward economic problem to analyse if the manager's objective function were concave, specifically if recreational quality were always concave. However, as noted by Starrett (1972) and Baumol and Oates (1988), problems involving externalities often exhibit non-concavities.

In their model Fischer and Krutilla (1972) derive the rules for efficient use, under the implicit assumption that recreational quality is a concave function of use. Consequently recreational benefit is concave. Following the finding of empirical studies, we consider cases in which recreational quality is not concave. Specifically recreational quality declines at a decreasing rate with use (i.e. is convex) beyond a threshold. At some 'high' level of use the marginal recreation benefit drops to zero. Once this happens, recreational saturation is said to occur. For example, recreational saturation may be said to have occurred along a popular walking track that has been hardened. The impact of an additional walker on either congestion or environmental degradation is negligible. It is demonstrated the social surplus may exhibit two local maxima at sufficiently high levels of demand: a 'low use' outcome in which price is used to restrict numbers so that recreational quality is just below its level, and a 'high use' outcome in which use is unrestricted and recreational quality falls to its minimum level. The low use outcome will be the globally efficient level when the gain from higher quality at that use level outweighs the gain from higher quality at the high use level.

Environmental degradation impacts on users through lowering recreational quality, but also lowers the manager's utility by compromising the preservation of the natural resource. The adoption of LAC is likely to result in the latter effect is given a greater weight. In this event, the manager will treat recreation as imposing a greater marginal cost, and may act to reduce use. The efficiency of these actions depends on the initial weighting given to the environment by managers. If this is low, insufficient attention will have been given to the environment in the past. The adoption of LAC may then improve efficiency, by lowing use toward it efficient level. If, on the other hand, environmental protection is initially assigned its correct weighting, the adoption of LAC under values recreation. This may leads to an inefficiently low use.

Section 1 models the demand for the recreation. This is used to develop the model of managerial decision regarding use. The manager's optimal use level is identified under the assumption that her objective function is concave. Section 2 further considers the specification of recreational quality as a function of use. The outcome of LAC is compared to the efficient use level when the recreational quality function exhibits recreational saturation. In section 3 considers an important special case of the analysis in section 2, one in which environmental degradation affects users, but does not compromise the ecological integrity of the natural resource. Section 4 concludes the paper.

1. PRICE DETERMINATION UNDER DECREASING MARGINAL RECREATIONAL QUALITY

1.1 Recreational Quality

Consider a natural resource, such as a region within a national park, which can be used for recreation. An individual's recreational use of the natural resource impacts on the environment and/or other users. As noted in the introduction the level of environmental degradation cause by recreation, d(N), increases with the number of uses per year. Hence $d'(N) \geq 0$. Similarly the recreational use increasing crowding, and possibly other negative social externalities. Denote the social impacts of recreation on users as g(N). An increase in use increases the social impact on users, hence $g'(N) \geq 0$.

It is assumed that the user's perspective of recreational quality, Q(N), is influenced by both the environmental degradation and the social impact. Write $Q(N) = \Theta(d(N),g(N))$, where $\Theta_1 \leq 0$ and $\Theta_2 \leq 0$. Note that marginal recreational quality is negative, that is $Q'(N) = \Theta_1 d'(N) + \Theta_2 g'(N) \leq 0$.

1.2 Individual Users

In this section the recreational demand by each of the users is considered. It is assumed that management of the natural resource sets a fee, P, per use. The number of users, L, is sufficiently large that each user contributes a negligible impact on recreational quality. Let N_i be the usage of the i^{th} user and $B_i(QN_i)$ be that user's benefit from N_i uses. The user's consumer surplus is:

$$V_i(N_i) = B_i(QN_i) - PN_i \qquad (1)$$

User i chooses the use level that maximise their consumer surplus. Thus, from (1):

$$B_i'(QN_i) = P/Q \qquad (2)$$

Define the recreation of user i as $n_i = QN_i$ and the price of recreation as $p = P/Q$. In this case:

$$B_i'(n_i) = p \qquad (3)$$

Equation (3) defines the user i's recreational demand, $n_i(p)$. User i's demand for use, $N_i(P,q)$, is thus given by:

$$N_i(P,q) = n_i(P/Q)/Q \qquad (4)$$

The elasticity of user i's recreational demand, ε_i^n, is given by:

$$\varepsilon_i^n \equiv -pn_i'(p)/n_i = -(P/N_i)(\partial N_i/\partial P) \equiv \varepsilon_i^N \qquad (5)$$

Thus elasticity of user i's recreational demand equals, ε_i^N, elasticity of user i's demand for use. The elasticity of user i's recreational demand with respect to quality, ε_i^Q, is:

$$\varepsilon_i^Q \equiv (Q/N_i)(\partial N_i/\partial Q) = \varepsilon_i^n - 1 \qquad (6)$$

An increase in recreational quality per use (Q) reduces the price of recreational quality (p), thus increasing demand (n_i). As recreational demand is the product of number of uses and recreational quality, the increase in recreational quality will reduce the number of uses if the elasticity of demand, ε_i^n, is less than one. On the other hand, if the elasticity of demand is greater than one, an increase in recreational quality increases the number of uses.

1.3 Demand for recreation

The total recreational demand, n(p), is given by:

$$n(p) = \sum_{i=1}^{L} n_i(p) \qquad (7)$$

and the total demand for uses is given by:

$$N = \sum_{i=1}^{L} N_i = \sum_{i=1}^{L} n_i/Q \qquad (8)$$

Equation (6) may be expressed as:

$$NQ(N) = n(P/Q(N)) \qquad (9)$$

which defines N(P), the market demand curve (for use). Let $\tilde{N}$=N(0). The following definition is useful in characterising demand for recreation.

Definition 1: Rapid deterioration is said to occur at use level N if $\varepsilon_Q(N) > 1$.

When rapid deterioration occurs an increase in use reduces NQ, and hence user benefit and consumer surplus.

The elasticity of users' demand, ε_n, is given by:

$$\varepsilon_n \equiv \sum_{i=1}^{L} \mu_i \varepsilon_i^n \qquad (10)$$

where $\mu_i \equiv n_i/n = N_i/N$. Taking the total derivate of (9) yields the following expression for the elasticity of market demand:

$$E_N \equiv -\frac{P}{N}\frac{dN}{dP} = -\frac{\varepsilon_n}{1-(1-\varepsilon_n)\varepsilon_Q} \qquad (11)$$

where $\varepsilon_Q \equiv NQ'(N)/Q(N)$. Note the market demand curve is downward sloping when users' demand is elastic. If users' demand is inelastic the market demand curve is downward sloping provided:

$$\varepsilon_n > \frac{\varepsilon_Q - 1}{\varepsilon_Q} \qquad (12)$$

This inequality is always satisfied when there is not rapid deterioration, ie use levels where $0 \leq \varepsilon_Q \leq 1$. Conversely the market demand curve is upward sloping if users' demand is ineleastic and the direction of the inequality in (12) is reversed. Note that it is necessary that

ε_Q>1, i.e. there is rapid deterioration, for this to occur. The demand curve is upward sloping because a reduction in quality per use increases a user's willing to pay when users' demand is inelastic. If ε_Q is sufficiently large, an increase in use will reduce quality per use sufficiently that the associated increase in demand will dominate the usual fall in willingness to pay with increased used.

The consumer surplus, v(p), is defined as:

$$v(p) = b(p) - pn(p) \tag{13}$$

where

$$b(p) = \sum_{i=1}^{L} B_i(n_i(p)) \tag{14}$$

Note that $v'(p)=-n$. Total consumer surplus may also be written as a function of recreational quality by substitution of the inverse total quality adjusted demand function:

$$V(n) \equiv v(p(n)) \tag{15}$$

Note that $V'(n) = v'(p).p'(n) = -p'(n)n = p/\varepsilon_n$, and $V''(n) = -(p'(n) + p''(n)n) = -p'(n)(1+\varepsilon_{p'})$, where $\varepsilon_{p'} = np''(n)/p'(n)$.

1.4 Management and pricing

The legislation or management plans that govern wilderness areas usually require managers to facilitate recreation and protect the environment. The managers of the wilderness areas are also inevitably constrained (or motivated) by the extent of subsidy (profit) they receive. Therefore it is assumed that management of the wilderness area has utility function $U(V,d,\pi)$, where the profit achieved from recreation, π, is given by:

$$\pi(N) = P(N).N - C(N) \tag{16}$$

where C(N) is the (pecuniary) cost of recreation. It is assumed that managers benefit from additional recreation, and wish to avoid environmental degradation. It is therefore assumed that $U_1 \geq 0$, $U_2 \leq 0$ and $U_3 \geq 0$.

Managers choose use levels to maximise their utility. Note that the managers' objective function may be non-concave for reasons well understood in economics. For example, if demand is inelastic for all use levels, profit is not concave. Similarly, non-concavities can be introduced through the first argument of the utility function (because V'' is likely to be positive for realistic specifications of consumer surplus) or through the specification of the manager's utility function itself. This paper abstracts from these complications, taking the view that they are unlikely to be relevant in practice. Rather the focus is on the concavities arising from the specification of environmental degradation and recreational quality. As discussed below, these will have a profound influence on the manner in which recreation is managed.

Environmental and recreational considerations do not create non-concavities in the manager's utility function when marginal use is increasingly damaging. In their seminal study, Fisher and Krutilla (1972) implicitly adopt the assumption of increasingly damaging marginal use. Marginal use is increasingly damaging if (i) marginal environmental degradation is increasing ($d''(N)>0$), (ii) marginal social impacts are increasing ($g''(N)>0$), (iii) the marginal recreational quality of environmental degradation is decreasing ($\Theta_{11}<0$), (iv) the marginal recreational quality of social impacts is decreasing ($\Theta_{22}<0$) and (v) the marginal recreational quality of environmental degradation is decreasing with an increase in social impacts ($\Theta_{12}<0$). Under these assumptions there is decreasing marginal recreational quality, i.e. $Q''(N)<0$. Under this assumption $\varepsilon_Q'(N)>0$ for all N. Hence rapid deterioration occurs for all $N>N^1$ where
$\varepsilon_Q(N^1) = 1$.

The first order condition of utility maximisation, dU/dN=0, yields the following result.

<u>Proposition 1:</u> Managers choose the use level to satisfy:

$$P(1-\varepsilon_Q) = \frac{\varepsilon_n(U_3C' - U_2d')}{(\varepsilon_n-1)U_3 + U_1} \qquad (17)$$

The RHS of (17) represents the manager's marginal benefit and LHS the marginal cost from use. By (17) price is discounted for the effect of the use on recreational quality. Although users treat this effect as an externality, managers internalises it. Equation (17) also indicates that the relative importance of marginal cost and marginal degradation depends on the manager's preferences, which will reflect the legislative environment. Note that (17) also implies that the use level is chosen at a level below that at which rapid deterioration starts. This result is to be expected, as consumer benefit will fall with increased use once the region of rapid deterioration is reached.

Proposition 1 shows that the price, and consequently use levels, reflects the objectives of managers. Different types of manager can be modelled by adopting different specifications of utility. The manager who acts to maximise social welfare has a utility function of the form $U_1= -U_2= U_3=1$. The efficient price, P^E, is therefore given by:

$$P^E = \frac{C' + d'}{1-\varepsilon_Q} \tag{18}$$

The numerator of the RHS is the marginal social cost of use, while the denominator discounts price for the effect of addition use on recreational quality.

The manager who acts to maximise profit from recreation has a utility function such that $U_3=1$ and $U_1= U_2= 0$. The profit maximising manager sets price P^M, where:

$$P^M = \frac{\varepsilon_n C'}{(\varepsilon_n-1)(1-\varepsilon_Q)} \tag{19}$$

Note that the monopoly price is only influenced by environmental degradation through its effect on recreational quality.

The above formulation can be used to analyse the impact of the adoption of LAC. To simplify the analysis assume manager utility is linear, with $U_1=1$ and $U_2= -\beta$ and $U_3= \gamma$. The relative importance of environmental degradation in managers' decision making is modelled by varying the parameter β. The adoption of management systems, such as LAC, increases the importance of environmental preservation, hence increases β. The impact of a change in β is also dependent on the impact of profit on managers' decisions. Two cases are worthy of attention. Both are consistent the goals of the US Wilderness Act discussed in the introduction. One in which the manager weighs the net recreational benefit (consumer surplus plus profit) against environmental degradation, in which case $\gamma=1$. In this event, the manager sets price, $P^L(\beta)$, where:

$$P^L(\beta) = \frac{C' + \beta d'}{(1-\varepsilon_Q)} \qquad (20)$$

The impact of adopting LAC depends on the current value of β. If traditionally managers treated β as less than 1, then adoption of LAC will move use toward its efficient level. On the other hand, if β =1, the adoption of LAC causes an inefficiently low use to occur.

In the second case the manager is concerned only with user satisfaction (consumer surplus) and the state of the natural resource. She is unconcerned with profit (subsidy) levels per se, hence $\gamma=0$. The manager sets price $P^l(\beta)$, where:

$$P^l(\beta) = \frac{\beta\varepsilon_n d'}{1-\varepsilon_Q} \qquad (21)$$

The price chosen by the manager increases with elasticity of demand. The higher the elasticity of demand, the smaller is the consumer surplus lost when price is raised. Thus the opportunity cost of environmental protection is lower with a higher elasticity of demand. The price is also higher the greater is β, the weight attached to environmental degradation. Increasing the importance of the environmental state causes the manager to restrict use, and thus environmental degradation. From (21), the effect of adopting LAC on social welfare is ambiguous. Where demand is inelastic an increase in β will drive price toward its efficient level. However where demand is elastic an adoption of LAC may drive price above its efficient level.

There is no clear hierarchy among the prices P^E, P^M, $P^L(\beta)$, and $P^l(\beta)$. By inspection of equations (18), (19) and (21) it is clear that the relative magnitude of the prices (and consequently use levels) depends on the relative size of C', d' and ε_n in addition to β. Thus, under the above conditions, it is not possible to unambiguously claim the adopting LAC results in decreased efficiency. Indeed, in practice, it is difficult to obtain precise estimates of marginal deterioration, marginal cost, the elasticity of recreational quality and the elasticity of demand. It is therefore difficult to obtain precise estimates of the efficient price compared to that under LAC. In practical terms, therefore LAC may not result in material difference from efficient use. However this conclusion relies on the assumption that (18) and (21) represent unique use levels. This in turn relies on the assumption that marginal recreational quality is decreasing. The next section considers the impact of adopting LAC when this assumption does not hold.

2. Efficient vs. LAC Pricing When Recreational Saturation Occurs

The assumption that marginal use is increasingly damaging is not always warranted. In some instances both environmental quality and social impacts plateau for ‘high’ use level. This section compares the efficient and LAC use levels under this assumption. For simplicity, it is assumed in this section that recreational quality is simply a function of environmental quality. Write $Q(N) = q(d(N))$, where $q' \leq 0$. This assumption may not be unwarranted. Cole (2001) argues that empirical studies of wilderness users indicate that, although use density changes the nature of a recreational activity, “use density has little effect on the quality of recreational experiences”. It is also assumed that marginal cost, C', is zero. This assumption may also be realistic. The existence of a wilderness area may require the presence of management facilities and a certain number staff irrespective of the number of visitors. In this event all costs would thus be fixed. Circumstances in which these two simplifications are not appropriate could also be analysed using the approach of this section, albeit at the cost of increased analytic complexity.

2.1 Deterioration and recreational quality

The assumed nature of the relationship between environmental damage and recreational use of wilderness areas is summarised in the north-east quadrant of figure 1(a). This relationship is suggested by a considerable number of scientific studies, which are surveyed by Leung and Marion (2000). They note that most studies “found a non-linear asymptotic relationship between amount of use and amount of impact” (p.36). That is, $d''(N)<0$. However some soil and vegetation types are robust until a threshold level of use occurs (see for example Whinam and Chilcott, 1999).

These findings are used to define the theoretical deterioration function used in this paper as follows. Assume that the pristine state of the natural resource is assigned a value of $\underline{d}$, i.e. $d(0) = \underline{d}$. The natural resource is assumed robust at low levels of use, so increased use does not cause deterioration. However beyond the threshold use level, $\underline{N} \geq 0$, environmental degradation increases with use, and plateaus at a maximum degraded level, $\bar{d}$, once usage reaches $\bar{N}$. Hence $d'(N) = 0$ for $0 \leq N \leq \underline{N}$, $d'(N)>0$ for $\underline{N}<N<\bar{N}$ and $d'(N)=0$ for $N>\bar{N}$.

The above scientific studies suggest that environmental degradation increases at a decreasing rate for a significant subset of $[\underline{N}, \bar{N}]$. Let $d''(N)<0$ for $\hat{N}<N<\bar{N}$. If $d'(N)$ is continuous (or $d(N)$ differentiable) then $d''(N)>0$ for $\underline{N}<N<\hat{N}$. Further $d''(N) = 0$ for $0 \leq N < \underline{N}$, $N=\hat{N}$ and $N>\bar{N}$. Environmental degradation and its rate of change with use are thus as depicted in figures 1(a) and 1(b) respectively. This specification has a number of important special cases. For example, if deterioration increases at a decreasing rate for all use levels then $\underline{N}=\hat{N}=0$ and $\bar{N}=\infty$.

Figure 1(a) also indicates how recreational quality is derived graphically from environmental degradation. Note that recreation quality declines over the use levels $[\underline{N}, \bar{N}]$, but is constant elsewhere. This observation suggests:

<u>Definition 2</u>: Recreational saturation is said to occur when $N>\bar{N}$, and hence recreational quality is given by $\underline{Q} = q(\bar{d})$.

When recreational saturation occurs use is so large that environmental quality has degraded to its minimum level.

Figure 1(c) shows the marginal and average recreational quality. The elasticity of recreational quality, $\varepsilon_Q(N)$, is equal 1 at the use levels these curves cross (as $Q/N= -Q'$). Let N^1 be the minimum value of N such that $\varepsilon_Q(N)=1$.There is rapid deterioration for those use levels for which average recreational quality is below marginal recreational quality (i.e. $Q/N< -Q'$). If rapid deterioration does occur, NQ, and hence consumer benefit, is declining over a subset of use levels in $[N^1, \bar{N}]$ with increased use. However under the above assumptions rapid deterioration may not occur. Specifically, it is possible that $Q/N> -Q'$ (or $\varepsilon_Q(N)<1$) for all $N\in[\underline{N}, \hat{N}]$.

The recreational quality function has been derived in the context of the environmental impact of wilderness use. The type of use of the country is not assumed to change. However the recreational quality function depicted in figure 1(a) may be applicable in a wider context.

For example, consider the possible development of an area of backcountry. At low use levels the country is in pristine condition, possibly with unmarked trails used by visitors. As use increases, marked trails may be introduced. This lowers wilderness values slightly, and moves the region into the range $[\underline{N}, \hat{N}]$, with increased trail development lowing recreational quality. Further development might see a rough road introduced, then a sealed road, and finally a visitor's centre. As this development occurs, the loss of wilderness, and hence recreational quality, accelerates. The last few steps of development would see a decline in recreational quality as the region's environmental worth falls through the use levels in $[\hat{N}, \bar{N}]$. Once the sealed road and visitors centre are in place, recreational saturation would have occurred, with the marginal visitor having a negligible effect on recreational quality.

The relationship between recreational quality and use depicted in figure 1(a) may also apply when the main influence on recreational quality is congestion. For instance, Manning and Lawson (2002, p.159) propose a similar relationship between user acceptability and number of groups encountered during recreation. The most important criticism of the relationships depicted in figure 1(a) is that they are too restrictive. For example there may be two ranges of use in which Q'' is negative, one associated with the onset of environmental degradation and the other with congestion. This possibility is considered in the analysis in section 3. However for brevity and ease of analysis such an extension is not considered in this section. Nonetheless, even if the specification of $Q(N)$ is extended in this way, it will exhibit (i) recreational saturation, and (ii) decreasing marginal recreational quality at some low use level. Thus, the key findings of this paper's analysis would still hold.

2.2 Efficient use

If environmental degradation takes the form illustrated in figure 1(a), the surplus may be non-concave. In this event the following definition is useful.

> Definition 3. The use level in $[0,\tilde{N}]$ which maximises the surplus is termed the globally efficient use level (GEUL). If the surplus attains a local maximum at a given use level in $[0,\tilde{N}]$, that use level is termed a locally efficient use level (LEUL).

There are two sources of non-concavity in the surplus. One source is the convexity of the environmental degradation $d''<0$, over the region $[\hat{N},\bar{N}]$. The other source will only occur if marginal recreational quality is increasing environmental degradation, i.e. if.$q''>0$. Intuitively, assuming $q''>0$ implies that users are less concerned with increased degradation the higher is degradation. To identify the conditions under which this prospective non-concavity is not critical, let $\varepsilon_{q'}(d) \equiv d.q''(d)/q'(d)$.

Proposition 2: Supposes that:

$$\varepsilon_{q'}(d) < \frac{(1-\varepsilon_q\varepsilon_d)^2}{\varepsilon_n\varepsilon_q\varepsilon_d^{\;2}} + \frac{2}{\varepsilon_d} + \frac{\varepsilon_{d'}}{\varepsilon_q\varepsilon_d^{\;2}} > 0 \tag{22}$$

for all $N\in[\underline{N}, \hat{N}]$. Then a use level in $[\underline{N}, \hat{N}]$ satisfying (18) will be a LEUL. Furthermore suppose there is rapid deterioration. Then there exists a LEUL in $[\underline{N}, N^1]$.

The proof of Proposition 2, and the proofs of the propositions below, is given in the appendix. Note that Proposition 2 indicates that the surplus is concave over $[\underline{N}, \hat{N}]$ unless q'' is sufficiently positive. Thus (22) holds in many conditions. In particular (22) holds if q(d) is linear or iso-elastic, or more generally, if $\varepsilon_Q'(N)>0$ in $[\underline{N}, \hat{N}]$. Proposition 2 indicates that a LEUL will occur prior to rapid deterioration setting in. This result is analogous to that in Proposition 1.

A LEUL is a use level where the marginal benefit of use is offset by the marginal deterioration in environmental quality. The number of LEULs is shown below to depend on the level of demand. The following definition is required to demonstrate this:

Definition 4: There is said to be (i) very low demand if $0< \tilde{N} < \underline{N}$, (ii) low demand if $\underline{N} < \tilde{N}< \hat{N}$, (iii) medium demand if $\hat{N}< \tilde{N}< \bar{N}$ and (iv) high demand if $\tilde{N}>\bar{N}$.

The efficient use levels under each level of demand are considered below.

Proposition 3. (a) If there is very low demand for the natural resource then $\tilde{N}$ is the unique LEUL. (b) If there is positive demand for the level of use $\underline{N}$, i.e. $P(\underline{N})>0$, the GEUL is strictly greater than $\underline{N}$. (c) If there is low demand for the natural resource and (22) holds, the unique LEUL lies in $(\underline{N},\tilde{N})$. (d) Given medium or high demand, LEULs need not be unique even if (22) holds.

Proposition 3 can be understood using figure 2 by noting that the social surplus is increasing with use when the MB curve lies above the d′ curve. Under very low demand the MB curve, MB_{VL}, lies above the d′ curve (which is zero) for all $N<\tilde{N}_{VL}$ and hence the efficient use level occurs when $N=\tilde{N}_{VL}$. If demand is positive at $N=\underline{N}$, then the MB curve is also positive and thus the surplus increases with increased use. Hence Proposition 3(b) implies that the efficient use entails some deterioration in quality from the pristine level. Under low demand, the efficient level of use, N_L^*, occurs where the MB curve, MB_L, cuts the d′ curve.

The MB curve, MB_M, in figure 2 indicates how there need not be a unique LEUL under medium demand. Specifically, multiple LEUL will occur if the MB curve 'follows' the d′ curve over some part of $[\hat{N},\bar{N}]$. However, it requires special circumstances to align one curve with the other in practice. For example, an increase or decrease in demand would shift the MB_M curve in figure 2, and would remove the LEULs in $[\hat{N},\bar{N}]$. Consideration of the conditions required to ensure no LEULs exist in $[\hat{N},\bar{N}]$ is a rather technical exercise, and is thus beyond the scope of this paper. Instead we restrict consideration to LEULs that lie outside this region, as they are likely to be more important in practice.[2] Similar reasoning applies to LEULs in $[\hat{N},\bar{N}]$ when there is high demand. However:

Proposition 4. Assume there is high demand for the use of the natural resource. Then $\tilde{N}$ is a LEUL.

Under high demand, the MB curve cuts the N axis above $\bar{N}$. As use increases toward the intersection of the MB curve and the N axis at $\tilde{N}$, the social surplus increases (as MB is positive and d′ is zero). Hence $\tilde{N}$ is a LEUL.

If there is both rapid deterioration and high demand then there will be at least two LEULs. This is depicted in figure 3 by the MB curve MB_R. Intuitively the presence of the two LEULs can be explained as follows. The rapid loss of quality that occurs after the threshold level of use is passed causes the social surplus to peak at the 'low use' level, the loss of quality outweighing the gain in user benefit. However, as quality moves to its minimum level with increased use its value stabilises, and the social surplus grows again because of the benefit of increased use.

---

[2] In adopting this approach, we are following the lead of Burrows (1986), who argues that the non-convexities caused by the presence of externalities are unlikely to be of practical importance.

Proposition 5: Suppose $\tilde{N} > \bar{N}$ and $N^* \in [\underline{N}, \hat{N}]$ are both LEULs. Then $\tilde{N}$ is the GEUL if:

$$B(\tilde{N}Q(\tilde{N})) - B(N^*Q(N^*) \; > d(\tilde{N}) - d(N^*) \tag{23}$$

That is, use level $\tilde{N}$ is more efficient than use level N* if the increase in user benefit outweighs the loss in environmental quality. In this event it is not necessary to impose a fee to achieve the globally efficient level of use. If the inequality sign in (23) is reversed the use level N* is more efficient than use level $\tilde{N}$. From (8), this level of use can be achieved by setting price $p^* = d'(N^*)/(1-\varepsilon_Q(N^*))$

2.3 LAC use

In modelling the impact of LAC, it is assumed the manager acts with U_1=1 and U_2= -β and U_3= 1. The manger's optimal price and use level thus satisfies (20). As C′=0, this assumption is equivalent to assuming the manager trades off consumer benefit against environmental degradation, The manager's marginal rate of substitution between these outcomes is β. Under this interpretation, the above analysis of efficient use is readily modified to analyse the impact of managers adopting LAC. The following definition is an analogue of Definition 3.

Definition 5. The use level in $[0,\tilde{N}]$ which maximises the outcome-focussed manager's utility is termed the global utility maximising use level (GUMUL). If the utility attains a local maximum at a given use level in $[0,\tilde{N}]$, that use level is termed a local utility maximising use level (LUMUL).

Hence:

> Proposition 6: (i) If there is very low demand $\tilde{N}$ is a GUMUL. (ii) If $N^L(\beta) \in [\underline{N}, \hat{N}]$ is a LUMUL, an increase in β reduces $N^L(\beta)$. (iii) Suppose $\tilde{N} > \underline{N}$. There exists a LUMUL $N^L(\beta) \in [\underline{N}, \hat{N}]$ for sufficiently high β, where $N^L(\beta)$ satisfies (21).

Environmental degradation does not occur at very low use levels, so $\tilde{N}$ is both the GUMUL and GEUL. An increase in β increases the manager's perception of marginal environmental damage. Hence an increase in β will reduce a LUMUL that occurs within those use level where environmental degradation occurs. As noted above, when there is high demand a LEUL need not occur at 'low' use levels. A sufficiently high β raises manager's perceptions of environmental degradation sufficiently to ensure that a low use level is a LUMUL. The following proposition is an analogue of Proposition 5.

> Proposition 7: Suppose there is high demand, so that $\tilde{N} > \bar{N}$ and $N^L(\beta) \in [\underline{N}, \hat{N}]$ are LUMULs. Then, if these are the only LUMULs, $\tilde{N}$ is the GUMUL if:
>
> $$B(\tilde{N}Q(\tilde{N})) - B(N^L Q(N^L)) > \beta(d(\tilde{N}) - d(N^L)) \qquad (24)$$
>
> An increase in β increases the manager's utility at use level $N^L(\beta)$ relative to that at $\tilde{N}$.

Proposition 7 suggests that the effect of adopting LAC may be dramatic. By sufficiently increasing the importance of environmental quality in decision-making, LAC shifts the use level from a high to a low level. In particular LAC prevents use moving into the regions of rapid deterioration and thus prevents recreational saturation occurring. Should the GEUL be $\tilde{N}$, then adoption of LAC results in a striking divergence between the actual use level and the efficient use level.

3. DEGRADATION AFFECTS ONLY RECREATIONAL QUALITY

In some instances, recreational use of wilderness areas impacts on a minuscule fraction of the area of the wilderness (see Leung and Marion p.25). For example, hiking may cause degradation along a trail and at campsites, but these areas represent a tiny fraction of a national park. Degradation in the small areas used for recreation thus has a tiny impact wilderness values. Nonetheless the localised degradation does directly impact on users, and thus influences recreational quality.

These circumstances can be analysed by adapting the model presented in section 1. Managers treat marginal degradation from recreation as zero. Specifically the second argument in the manager's utility function is treated as constant. However both congestion and degradation around recreation areas affects recreational quality. Maintain the assumption that C'=0. From (17) managers choose use according to:

$$P(1-\varepsilon_Q) = 0 \qquad (25)$$

That is, as the total marginal cost of recreation is zero, the manager chooses use according to marginal benefit equals zero. Note that (25) is satisfied by either P=0 or ε_Q=1. If rapid deterioration never occurs (ε_Q<1 for all $N \leq \tilde{N}$) for all N, then the manager chooses P=0, and thus there is unrestricted access.

On the other hand there may be multiple regions of use levels for which rapid deterioration occurs. Figure 4 considers the manager's choice under these conditions. The use levels for which rapid deterioration occurs are those for which the marginal benefit curve, MB, is negative. In figure 4, two ranges of use occur for which rapid deterioration occur. In this case, N^1, N^2 and $\tilde{N}$ satisfy (25). The manager prefers N^1 to N^2 is the area A+B<0. Similarly N^1 is preferred to $\tilde{N}$ if the area A+B+C+D<0.

In general, it can be seen that the number of local maxima the manager has to choose between depends on the number of ranges of use levels for which there is rapid deterioration. The number of local maxima to choose between is one more than the number of number of ranges for which there is rapid deterioration.

The above two sections it was assumed LAC affected manager's weighting of environmental degradation. Such a possibility does not arise when managers treat environmental degradation from recreation as negligible. However, as noted in the introduction, LAC has a hierarchy of goals. Recreation is usually the second of these goals. In this event, adoption of LAC causes managers to protect recreational quality. One straightforward way to model this change is to assume that LAC heightens manager's perception of the effect of use on recreational quality. Manager's perceptions of the marginal benefit of recreation would reduce. In the example of figure 4, the MB curve would shift downward and the use levels N^1 and N^2 would shift leftward. The areas A and C would increase, while the areas B and D would decrease. The incentive for managers to choose use level N^2 rather than $\tilde{N}$, and N^1 rather than N^2, will have increased.

4. DISCUSSION

Natural resources based recreation is currently being managed by LAC and similar management schemes. To determine the impact of such policies, this paper develops a model of managerial decision regarding use levels. The efficient outcome and outcome from adoption of LAC are special cases of the model. Attention is focussed on the case in which recreational quality exhibits recreational saturation.

The nature of the efficient use level depends on the level of demand. Under very low demand, use does not impact on recreational quality, thus it is optimal for managers to allow unrestricted access. Under low and medium demand the marginal user degrades the environment and reduces recreational quality. It is efficient to restrict access to the point at which the marginal benefit of use equals the marginal cost.

Under high demand, unrestricted access is locally efficient. At this level of use recreational saturation occurs, and thus recreational quality is at its minimum level. If the rate of environmental degradation from use is sufficiently great, a ‘low’ use level may also be locally efficient. Which of these two locally efficient use levels is globally efficient depends on the benefit of additional recreation compared to the cost of environmental degradation.

LAC is a management strategy that aims to focus manager’s attention on a hierarchy of goals. The most important of these is environmental preservation. The principal impact of adopting LAC is to raise the relative importance of environmental integrity in managerial goals. Under low demand, the impact of adopting LAC would be to lower the use level somewhat. Under high demand the impact could be more dramatic. The manager may choose to restrict use to a low level rather than allowing unrestricted access.

The model’s prediction is that parks with very low demand will have unrestricted access. Under low and medium demand the managers restrict use. Under high demand mangers may restrict use when they are worried about environment degradation or a significant drop in recreational quality. But managers may also allow unrestricted access under high demand. This appears consistent with the manner in which parks are managed. Consider overnight access to national parks. The Gates of the Artic National park, which is very remote and thus has low demand, does not have limits placed on use. However both Denali and Yosemite National Parks have limits on numbers using as areas of their backcountry each day. In both these parks managers are concerned about the impact on the quality recreation from uncontrolled access. However the very popular Appalachian Trail does not place numbers on use.

Similarly, the US Parks Service resisted identifying maximum use levels on for the Merced Wild and Scenic River in Yosemite National Park. Rather, prior to complying with a judicial ruling to set use limits, its approach was to allow unrestricted access, and monitor the consequences. (In doing this, the US Parks Service was following a management scheme similar to LAC.) These actions are consistent with the Parks Service acting according to the belief that recreational saturation had occurred in this region of Yosemite, but maintained monitoring to assess this belief.

The efficiency of adopting LAC depends on the initial weighting given environmental preservation. It could be argued that park managers are under constant political pressure from user groups and government to increase recreational opportunities and reduce subsidies respectively. In this case insufficient weight would be given to environmental preservation. LAC would be a tool to ensure a more appropriate weight is on placed environmental preservation. On the other hand, it might be argued that managers and academics engaged in ecological research have a greater interest in environmental preservation than the average citizen. In addition managers may be sensitive to public criticism of environmental change in protected areas. Under these circumstances LAC may provide a mechanism to place an excessive weighting on environmental degradation.

The model suggests that under very low demand LAC yields the efficient use level. Thus unrestricted access to the Gates of the Artic is currently efficient. Under low to medium demand it is efficient to restrict recreation. At a theoretical level LAC will not yield the efficient use level (unless $\beta=1$). However, given the uncertainties surrounding measurement of marginal environmental damage, recreation quality, etc, there is unlikely to be a material difference between the use level under LAC and the efficient one. However under high demand there may be significant difference between the outcome under LAC and the efficient one. The model begs the question of whether it is efficient (for example) to restrict access to backcountry regions of Yosemite and Denali or allow unrestricted access the on the Appalachian Trail? Such an assessment would need to be carried out on a case-by-case basis. However the model suggests a straightforward methodology: does the gain in environmental preservation from restriction use outweigh the loss of recreational benefit? Variations in use of the Appalachian Trail are unlikely to significantly affect the environment, suggesting the answer to this question is no in that case. However, in the case of Yosemite and Denali there is still insufficient scientific information on the relationship between environmental impacts and limits on use to make this assessment (van Wagtendonk, and Parsons, 1996; Cole, 2001; and Cole, Manning and Lime, 2005).

There are two additional issues that are not dealt with by the model, yet are important in practice. When numbers are restricted, such as in the backcountry of popular national parks, pricing is not used ration the scare places. Rather, in spite of the enactment of the 'fee demonstration program' in the US, parks such as Denali and Yosemite allocate permits to use the backcountry on the basis of some form of queuing. (See Wilman, 1988, and Turner, 2000, for a discussion of efficient pricing for outdoor recreation.) This introduces an inefficiency associated with restricting use not captured by the model presented in this paper.

A second issue not dealt with by the model is the availability of substitute sites for outdoor recreation. The implications of Fisher and Krutilla original analysis is that as demand grows it is efficient to spread users across sites so marginal surplus from each site is equal. In practice that would mean that as demand grows use at each site would grow. The concern expressed by Wagar (1974) is that this approach leads to a "lowest common denominator" recreational experience. Managers and non-economist academics rejected this approach to management at an intuitive level arguing that it lead to unrealistic conclusions (see Cole, 2001
p. 12).

The adoption of the recreational quality function that exhibits recreational saturation does not necessarily lead to these conclusions. Consider two identical sites: assume that users treat these sites as perfect substitutes and the recreation quality function of each are identical. Suppose there is sufficient demand for recreation that if users were spread evenly across sites recreational saturation would occur. In this case spreading users evenly across sites is inefficient. The social surplus can be increased by allowing only N users (or better still N^1 users) at one site and the remaining users at the other site. This appears to be the approach to managing increased demand advocated by Wagar (1974).

While intuitively appealing, this reasoning is not robust. If there is a sufficient diversity of preference it is not possible to efficiently shift users from one site to another. As an extreme example suppose the users are evenly divided in their preference for one park, and care nothing for the other. Shifting users away from an even distribution would necessarily lower welfare. Clearly, therefore, an understanding of the extent of substitutability between various regions is critical in determining an efficient allocation of use. This type of issue is ideally suited to economic analysis, and would be a fruitful subject of future work. Management regimes like LAC, with their emphasis on the cost of recreation, are not well suited to assessing the benefits of recreation. They are therefore not capable of weighing the costs and benefits of recreation, and thus provide an incomplete guide to the managers of natural resources used for recreation.

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Mathematical Appendix to:

MANAGERIAL OBJECTIVES AND USE LIMITS ON RESOURCE-BASED RECREATION

Proof of Proposition 2

Then a use level in $[\underline{N}, \hat{N}]$ satisfying (18) will be a LEUL if $U''(N) < 0$in $[\underline{N}, \hat{N}]$. The surplus is:

$$U(N) = B(Q(N)N) – d(N)$$

where $Q(N) = q(d(N))$. Hence:

$$U'(N) = B'(N)(Q+NQ') - d'(N)$$

where $B'(N)=P/Q$, and:

$$U''(N) = B''(N)(Q+NQ')^2 + B'(N)(2Q'+NQ'')- d''(N)$$

Note:

$$Q' = q'd'$$

$$Q'' = q''d'^2 + q'd''$$

$$\varepsilon_n = QNB'/B''$$

Hence:

$$U''(N) = \frac{-d'}{N}\left(\frac{1-\varepsilon_q\varepsilon_d}{\varepsilon_n} - \frac{\varepsilon_q\varepsilon_d(2-\varepsilon_q\varepsilon_{d'}+\varepsilon_{d'})}{1-\varepsilon_q\varepsilon_d} - \varepsilon_{d'}\right)$$

$U''(N) < 0$ when

$$\varepsilon_{q'}(d) < \frac{(1-\varepsilon_q\varepsilon_d)^2}{\varepsilon_n\varepsilon_q\varepsilon_d^2} + \frac{2}{\varepsilon_d} + \frac{\varepsilon_{d'}}{\varepsilon_q\varepsilon_d^2} \qquad (22) \qquad ||$$

Proof of Proposition 3

(a) For all use levels $N \in [0, \tilde{N}]$ the surplus is increasing with N as:

$$U'(N) = q(\underline{d})B'(Nq(\underline{d})) > 0.$$

Hence $\tilde{N}$ is the GEUL. ||

(b) If $P(\underline{N})>0$ then $P(N)>0$ for all $N \in [0,\underline{N}]$. Hence $U'(\underline{N}) = q(\underline{d})B'(Nq(\underline{d}))>0$ for all $N \in [0,\underline{N})$ and $U'(\underline{N}) = q(\underline{d})B'(\underline{N}q(\underline{d}))> 0$.

(c) Over the range $N \in [\underline{N}, \tilde{N})$ $U'(N)$ has an indeterminate sign, but $U'(\underline{N}) = q(\underline{d})B'(\underline{N}q(\underline{d})) > 0$ and $U'(\tilde{N}) = -d'(\tilde{N}) < 0$. When (22) holds $U''(N) < 0$ in $[\underline{N}, \hat{N}]$. Thus $U(N)$ must reach a maximum for a use level in $(\underline{N}, \tilde{N})$. By proposition 2 it must be unique.

(d) Note:

$$U''(N) = B''(N)(Q+NQ')^2 + B'(N)(2Q'+NQ'') - d''(N)$$

For $N > \hat{N}$ $d''(N) \leq 0$ and (22) is not assumed to hold. In this case there is no guarantee that $U''(N) < 0$. ||

Proof of Proposition 4

For high demand $\tilde{N} > \bar{N}$, hence:

$$U'(\tilde{N}) = 0$$

and:

$$U''(\tilde{N}) = \bar{Q}B''(\tilde{N}) < 0$$

Thus $\tilde{N}$ is a LEUL. ||

Proof of Proposition 5

The surplus at use level N* is:

$$U(N^*) = B(N^*Q(N^*)) - d(N^*)$$

while the surplus at use level $\tilde{N}$ is;

$$U(\tilde{N}) = B(\tilde{N}Q(\tilde{N})) - d(\tilde{N})$$

$\tilde{N}$ is the GEUL if $U(\tilde{N}) - U(N^*) > 0$, which yields (23) ||

Proof of Proposition 6

(i) The Manager's utility function is given by:

$$U^L(N) = B(NQ(N)) - \beta d(N)$$

For all use levels $N \in [0, \tilde{N}]$ the manager's utility is increasing with N as:

$$U'(N) = q(\underline{d})B'(Nq(\underline{d})) > 0.$$

Hence $\tilde{N}$ is the GUMUL.

(ii) An increase in β reduces N^L. This follows from (20). An increase in β increases price thus reduces use.

(iii) The Manager's utility function is given by:

$$U^L(N) = B(NQ(N)) - \beta d(N)$$

Hence:

$$U^{L\prime}(N) = B'(NQ(N))(Q+NQ') - \beta d'(N)$$

Now:

$$U^{L\prime}(\underline{N}) = B'(\underline{N}Q(\underline{N}))Q(\underline{N}) > 0$$

and:

$$U^{L\prime}(\hat{N}) = B'(\hat{N}Q(\hat{N}))(Q(\hat{N})+\hat{N}Q'(\hat{N}))- \beta d'(\hat{N})$$

Note that $U^{L\prime}(\hat{N})<0$ as $\beta\rightarrow\infty$. Hence, assuming $U^{L\prime}$ is continuous, there must be an $N^L(\beta)\in[\underline{N}, \hat{N}]$ which satisfies $U^{L\prime}(N^L(\beta)) =0$. ||

Proof of Proposition 7

The surplus at use level N^L is:

$$U^L(N^L) = B(N^L Q(N^L)) - \beta d(N^L)$$

while the surplus at use level $\tilde{N}$ is;

$$U^L(\tilde{N}) = B(\tilde{N} Q(\tilde{N})) - \beta d(\tilde{N})$$

$\tilde{N}$ is the GEUL if $U^L(\tilde{N}) - U^L(N^L) > 0$, which yields (24).

An increase in β increases $U^L(N^L)$ relative to $U^L(\tilde{N})$. From the envelope theorem:

$$\partial U^L/\partial\beta = -d(N).$$

Hence an increase in β lowers utility more at the high use levels. ||

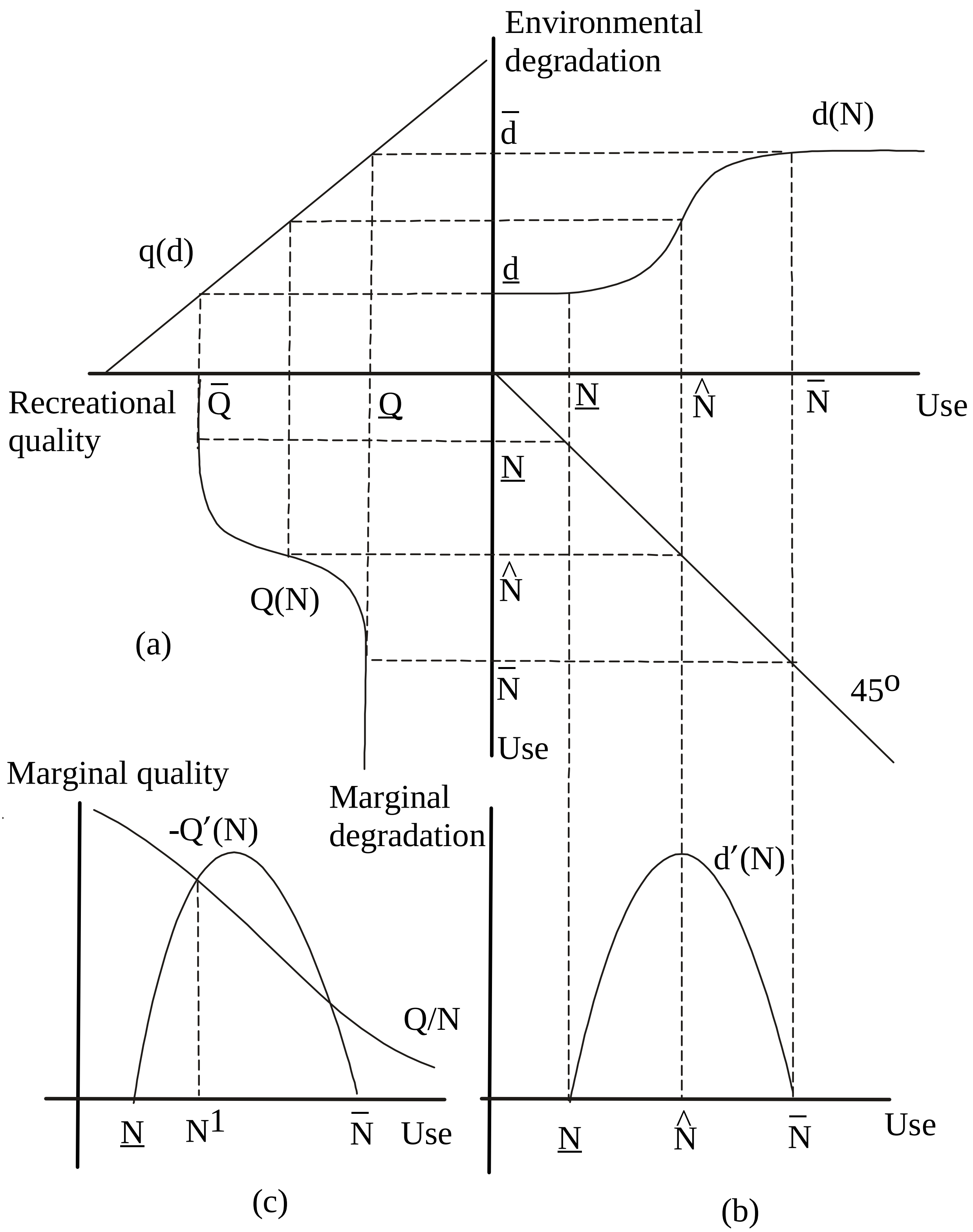

Figure 1. Environmental degradation and recreational quality.

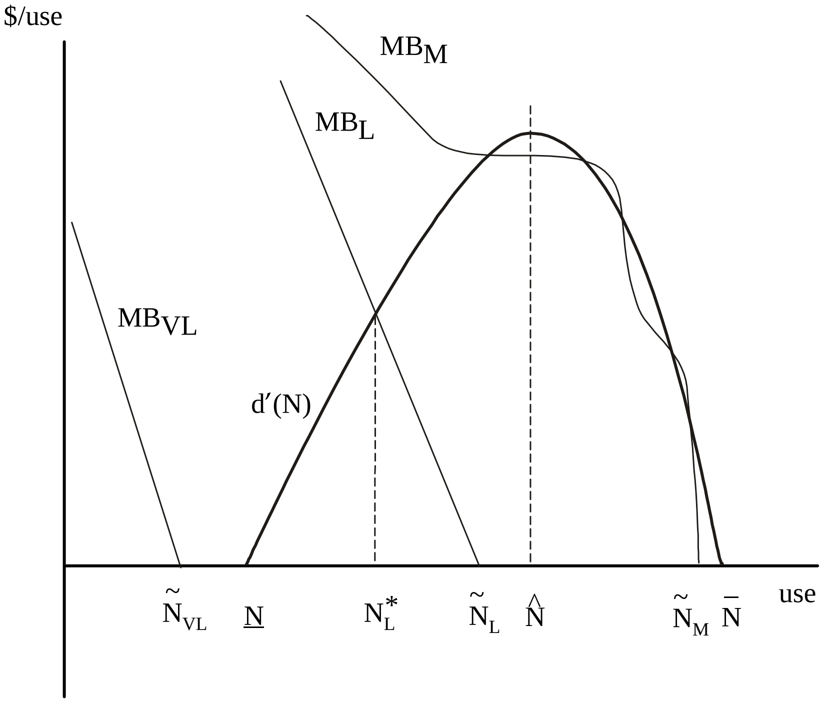

Figure 2. LEULs under very low, low and medium demands.

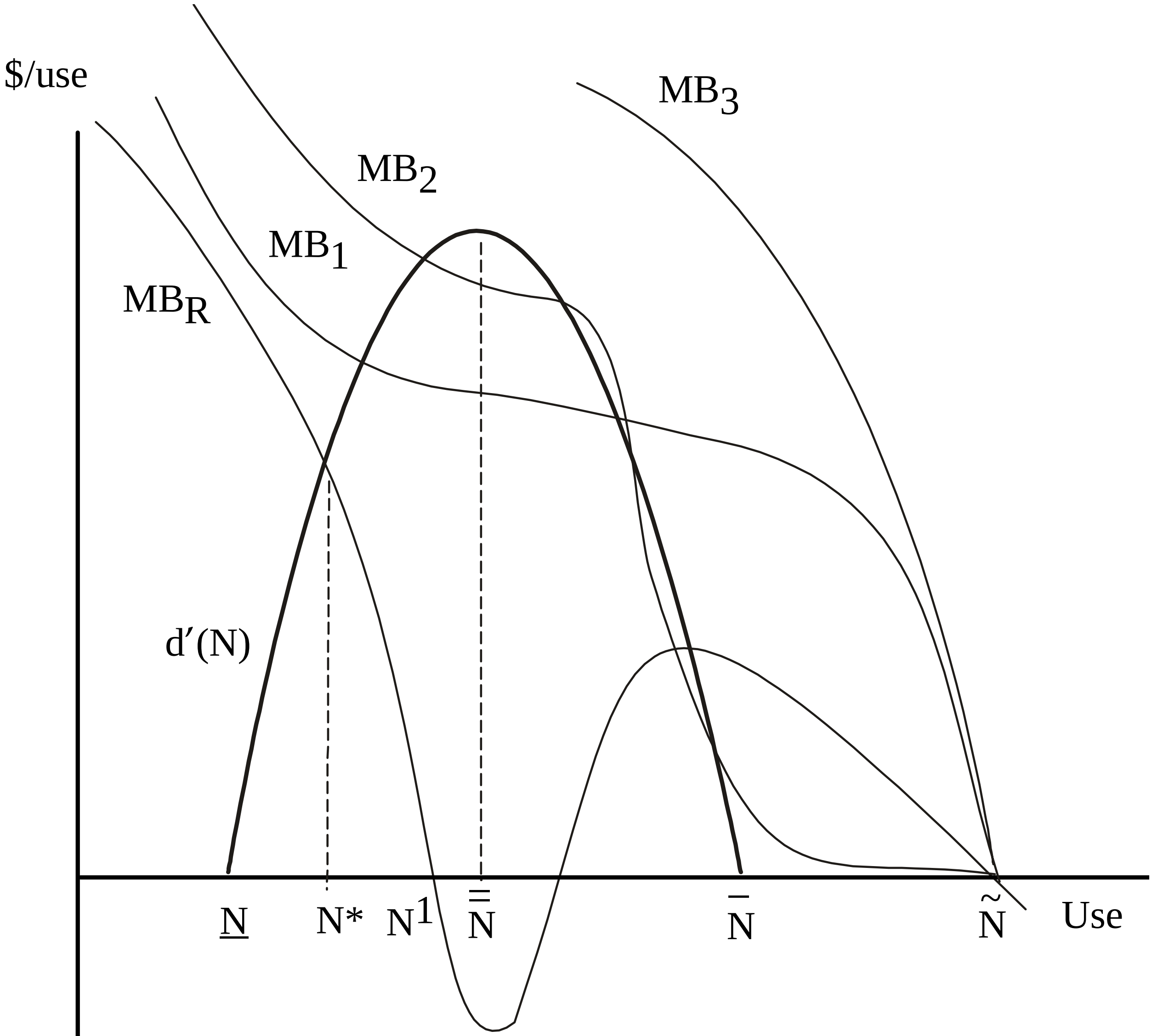

Figure 3. High Demand

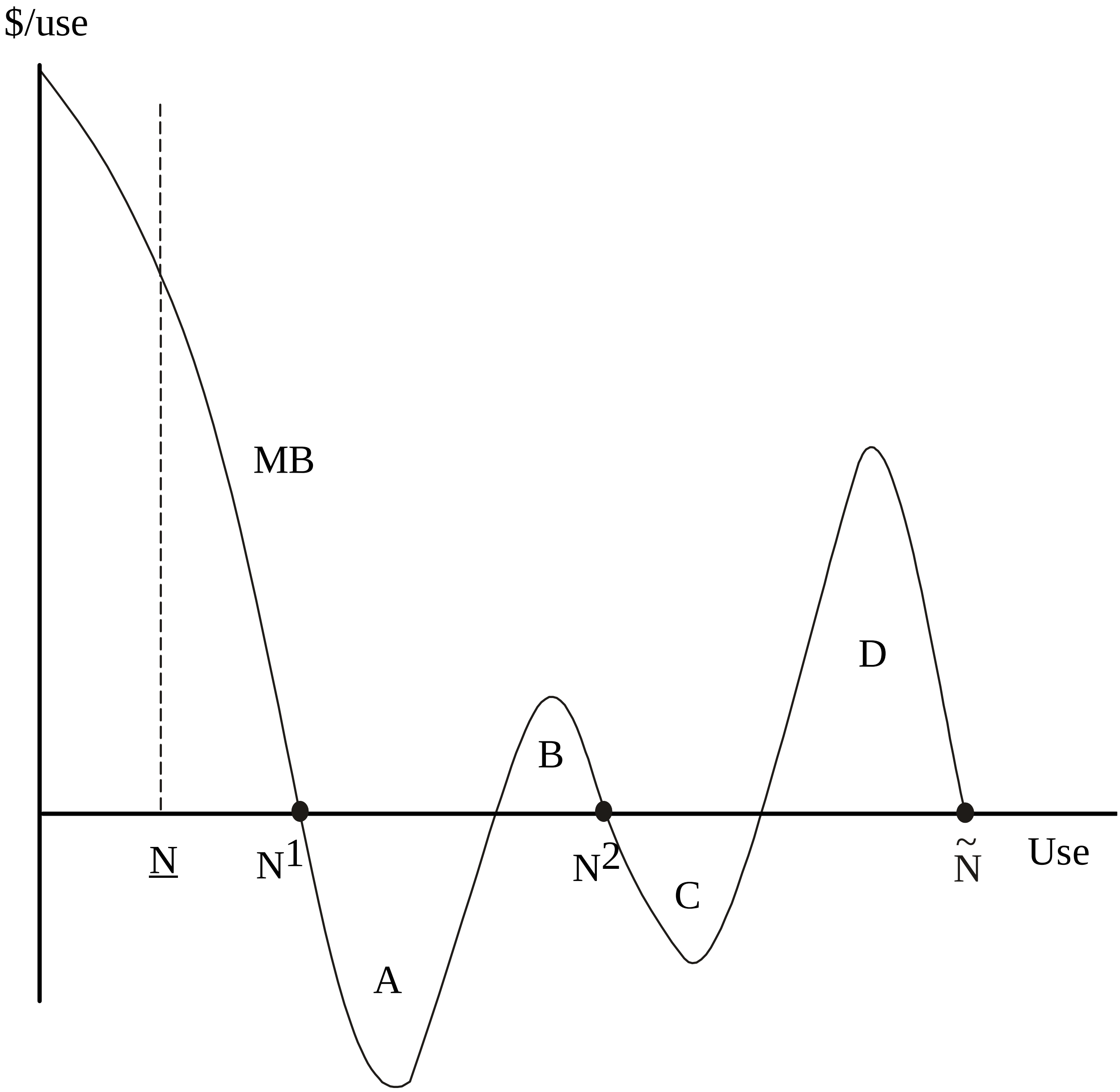

Figure 4. Multiple regions of rapid deterioration

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