SOME USER IMPACTS ON CAVE ENVIRONMENTS AND THE CONCEPT OF A CAVE CARRYING CAPACITY AS A CENTRAL MANAGEMENT PRINCIPLE

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Abstract

Impact of human use of cave environments is considered in terms of flora and fauna, cave atmosphere and the physical and chemical conditions. Management principles are discussed and include the concept of a cave carrying capacity.

Introduction

I propose to do two things. Firstly, to make a quick review of the broad parameters of the human use impact on cave environments mostly in relation to cave tourism; and secondly, to speak about the concept of a cave carrying capacity as a central cave management principle.

1. Human Use Impact on Cave Environments

A review of the rather limited material available on user impact in the cave tourism situation suggests three broad areas where visitors may significantly disturb the natural parameters of the caves concerned. These are:

- disturbance of cave fauna,
- disturbance to the cave atmosphere including contamination by algae, and
- impact on physical and chemical conditions of caves.

Although each is considered separately it is important to remember that they are really interconnected. This should become evident as these are discussed.

Disturbance to Cave Fauna

Few studies have been carried out with respect to the whole range of cavernicoles (cave animals) and the impact that human visitation has on them. Those that have been made normally relate to the more obvious animals such as the bat.

Cave fauna have a precarious existence under natural conditions because they are completely dependent upon the surface for all food and because of the extremely low reproductive potential that adaptation to the cave environment entails. This means that cave animal life is extremely fragile and if disturbed cannot quickly recover. However, with the exception of bats, little is known of the actual impact of visitation, mainly because the need for monitoring this impact is only a recent phenomenon. As a result the principles upon which management of cavernicoles in general should be based have not yet been developed.

Bats are one of the most important means by which cave life is provided with food. At Blanchard Springs Caves in north central Arkansas, noticeable declines in the bat populations are expected as a result of recent development of this cave for visitation. This may have repercussions on the cave life that is dependent upon bats for food.

In the United States and Australia and also in Eastern Europe, bat populations have been given some protection through Federal and State government legislation. However, their supervision poses major administrative problems particularly when connected with caves in private ownership.

Studies of the bat's seasonal and daily behaviour suggests that visitation should be well away from them. Even the quiet tread of visitors over rocky cave surfaces has a highly disturbing effect on their hibernating. A more generally recognised effect of even slight disturbance – sound, lights

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and especially heat from lights – is to onset arousal, which inevitably continues to complete arousal and flight. Significant losses in body weight have been reported by studies in the U.S.A. and Canada due to disturbance of this nature. These disturbances can lead to a decline in the bat population of the cave affected if not their total departure from it.

Disturbance to Cave Atmosphere and Contamination by Algae

This form of visitor impact on the cave environment has received some study though mainly in connection with the growth of unsightly algae which has been reported from show cave locations all over the world.

Fodor (1965) recently argued that visitors to Dobsina Cave in Hungary have destroyed the natural equilibrium of its microclimate. He goes on to claim that this effect was increasingly apparent in many caves in Eastern Europe and should serve as a warning that careful monitoring of the changes induced by visitation on the microclimate of caves must be carried out since this was likely to help off-set the consequent diminished growth of decorations and unsightly algae.

The importance of cave atmosphere disturbance by visitation may also be closely connected with the growth of algae in show caves. This has been demonstrated by Lefevre and Laporte (1969) in their studies at Lascaux Cavern in France, famous for its paleolithic art. More recent examples of this have come from Spain.

The Lascaux Cavern, discovered in 1940, had by the late 1950's received more than 175,000 visitors per year. At certain periods, conditions became extremely uncomfortable in the cave. Subsequent analysis revealed increases in carbon dioxide, relative humidity and temperature. These together with the cave lighting provided suitable conditions for the development of algae mats on the cave walls, some of which had begun to creep over the cave paintings. The result of the studies indicated that algae were carried into the cave via visitors' footwear and that development for visitation had significantly altered the air circulation in the cave. This was the means by which the algae reached the cave walls from the visitors' shoes. The alteration of cave atmosphere parameters provided the right conditions for growth. As a result, the cave was closed to visitation, airlocks were installed together with elaborate air conditioning designed to maintain specified atmospheric conditions. Monitoring of temperature, relative humidity and carbon dioxide levels is continuous and visitation is strictly controlled and limited by a permit system.

Today the few visitors who are allowed must stand in a tray of disinfectant before entering the cave.

Studies on algae growth in show caves have been carried out in Eastern Europe, Britain and the United States.

These studies have indicated a relationship between the intensity of light, constant temperature and high relative humidity and the growth of algae mats. Two broad methods have been used to deal with the algae problem:

1. Preventive measures such as reducing the light intensity; chemical application of disinfectant to kill the algae on visitors' footwear before they enter the cave; minimising the operational periods of lighting; and providing only that light necessary to do the job.
2. Eliminating the existing mats by chemical means. Many methods have been adopted here, including steam cleaning and plain scrubbing with brush and water; however these methods are either ineffective or too expensive. The reduction of light intensity by shading and the use of U.V. – clear bulbs appear to provide successful control over algae and moss growths.

A final note on cave atmosphere concerns bats which require special microclimates for nursery colonies and for hibernation. Any human activity at either time may alter special wind, moisture and temperature conditions necessary for their activity and may either cause death in the colony or cause it to leave the cave. This highlights the important interaction between different biological and physical subsystems of a cave environment.

Impact on Physical and Chemical Conditions in Caves

Only a few references have been made about the impact of visitors on the physical and chemical aspects of limestone show caves. Problems concerning this have been raised in Britain, the United States and Europe. Most of the references are confined to the physical aspects of visitor impact. Physical damage has generally been defined in terms of litter, graffitti and the breaking, damage or removal of cave mineral decorations.

In a survey of damage to caves in Britain carried out by the National Caving Association (NCA), it was found that some 20% of all cave resources were either damaged, lost or vulnerable to this and in particular that show caves were probably less susceptible to certain forms of damage caused by graffitti, littering etc. However, at the same time, it considered that for the whole of Britain, over 40% of show caves were already severely damaged and that a further 15% were vulnerable to further damage.

Studies by Hill (1975), in the United States claimed that an unintentional form of physical and chemical damage resulted from the addition of lights, heat and visitors to the cave. The consequences included drying up or dessication of cave mineral decorations, development of algae mats and greying of surfaces through dust and lint particles brought in by visitors. These affect the mineral surfaces and destroy the natural crystalline exterior of mineral decorations. Confirmation of these general comments is provided by the cave management experiences of the United States National Park Service. Here developments in both the Carlsbad and Mammoth Show Caverns have brought about irrevocable changes to their physical and chemical character.

In Europe, and particularly Eastern Europe, Lavaur (1973) has argued that many tourist caves exhibit extreme degradation of their physical and chemical character. He claimed that, despite considerable management efforts, the general problems of visitor impact remained because management methods did not appear to be translatable from cave to cave and because all the theoretical elements of the processes operating in limestone caves and the impact of visitor developments on them were not understood.

Where damage to cave decorations and formations has been particularly acute, legislation has been resorted to, for example, the *Cave Protection Act* of West Virginia lays down heavy penalties for acts of vandalism, littering and the sale of cave mineral decorations. However, it is freely admitted that enforcement is difficult, particularly at caves in private ownership. In Austria, there is also protection against damage under the 'National Cave Law', which places all limestone caves, public or private, under strict control as National Monuments. In Britain some of its show caves have been classified as Sites of Special Scientific Interest (SSSI) by the Nature Conservancy.

But as the NCA report *Caves and Conservation* points out, the law is almost totally inadequate in so far as much of the damage is concerned.

Specific studies of some of the key variables thought to be responsible for damage to caves in general are scarce. In Britain, the NCA attempted to do this with respect to three key variables:

i. accessibility,
ii. degree of usage, and
iii. length of time over which the cave had been utilised.

When these variables were compared to the damage index based on a rating scale incorporating physical damage to decorations, littering and graffitti, a significant correlation was found between the degree of usage and the degree of damage. No significant associations could be demonstrated between accessibility and the length of time over which the cave had been open for use though it was suggested that there were some problems with measuring the length of time variable which may have affected the result. The inference to be drawn from this, however, is that if usage or visitation increases, then there will be continued damage to the caves concerned. This therefore raises the question of the methods by which damage can be controlled.

2. Cave Carrying Capacity

This concept has occupied the minds of some public recreation managers for a considerable time. If, however, it is accepted that the future of a limestone cave rests on balancing the use of visitation with that of conservation then the concept of a carrying capacity would seem to be equally relevant. The concept should therefore be a fundamental consideration in managing the flow and distribution of visitors to limestone caves.

Brotherton (1973) in some work connected with the Countryside Commission in England considered the concept of a carrying capacity to have four major dimensions. The first is the ecological capacity which he defines as the maximum level of use that a particular ecosystem can support without unacceptable change. This change is determined by visitor or management perception of the state of the site which itself is a function of the processes operating there, its management history and the cumulative effects of previous visitation.

Perceptual capacity is the next dimension considered by Brotherton and he defined this as a function of the degree of crowding at the site that an individual would accept. Brotherton suggested that different sites such as wilderness areas and urban fun-fairs have different tolerances for the same individuals. For example it could be argued that the crowding tolerance as measured by the level of use and the degree of satisfaction derived by users would be much lower at show caves than at urban fun-fairs. This is particularly relevant to show caves where the self-regulating character of perceptual capacity cannot operate as it does for beach, picnic and camping sites, where visitors can adjust their spatial position to what is comfortable for them.

The next dimension that Brotherton discusses is the economic one. This relates to situations of multi-purpose use such as cave inspections, kiosks, cafe, restaurant and accommodation provisions. The object is to obtain the maximum aggregate benefits from the combinations of these at the site. Finally, Brotherton considers a physical carrying capacity which is the relationship between usage and the facilities required to accommodate it. The predicted rate of demand and average turnover time per user are the main variables used in determining the physical capacity of a facility. From the points of view of management, Brotherton claims that the recreational carrying capacity of a site can be taken as either its ecological or perceptual capacity, whichever is the lower.

Material on 'cave carrying capacity' is extremely scarce. there is little evidence that the concept even in its physical sense as defined by Brotherton is utilised in private or public cave management. The cave carrying capacity is defined as the maximum number of people who in a given time frame can beneficially utilise the cave resources without causing any harm to them.

This concept is akin to Brotherton's ecological carrying capacity although researchers in the USA tended to emphasise more the physical characteristics of the resources such as cave decorations and formations. It has been suggested that the cave carrying capacity can be altered by changing to different management methods. For example the physical carrying capacity of Carlsbad Show Cavern operating under guided tours had been exceeded by 1952 when an average of nearly 3,000 persons per day were visiting the cave. With the introduction of self guided system coupled with adequate manpower to protect cave resources the carrying capacity of the cave has been increased considerably without apparently further increases in manpower and further reductions in quality. Capacities were determined and elevators were installed to operate so that now more than 1,100 persons per hour could be carried into the cave. How's that for solving your environmental problems. Details concerning the nature of the capacity so determined in the case of Carlsbad are not available and it is strongly suspected that it is really a physical capacity in the cave based on the number of interpretive units and the supervisory manpower to which the elevator capacity has been matched.

There is some question about the use of the concept of carrying capacity in cave management. The concept of a carrying capacity as applied to caves differs in two important ways from its normal conception. Firstly the concept was initially developed for paddock management, such as the number of sheep to the acre where the resource 'grass' was renewable. Here, if sheep began to eat the roots (or the non-renewable part of the grass resource) then the carrying capacity of that land would decline. In the case of caves, however, if not all of the resources are essentially non-renewable and, therefore, damage to these resources will continue even if the carrying capacity determined by whatever means, is not exceeded. Secondly, it can be argued that while in the paddock example where damage to the non-renewable resources decreases the carrying capacity, in the case of caves exactly the reverse happens. For example, the presence of rare cave mineral decorations would imply a low carrying capacity; if, however, these were to be destroyed by vandals, then the capacity of the cave would in fact be increased if the capacity is dependent upon the visitor perception of quality as Brotherton has suggested.

The rate and volume of visitation should be determined both by the physical, chemical and biological features of the cave and by the character of the user groups. This conception should incorporate the ecological and perceptual dimensions of the concept developed by Brotherton. One useful approach for management suggested in the available literature that also seemed more practical, was to determine which features of a cave were most sensitive to visitor use. The capacity of the cave could then be matched by this, thus avoiding some of the complicated procedures that have been suggested by others in determining capacity. This places great emphasis on the concept of a limiting factor in caves, an analogy which has been drawn from the silvicultural principles taught in forestry schools. This is that there are many factors which can affect tree growth but in any given situation there are seldom more than one or two factors which limit growth.

An attempt has been made by Brucker (1975) to provide a cave carrying capacity decision making model based on work carried out by Bross (1956). This model has four major components:

1. An alternative probability system which contains a list of factors pertaining to visitor de-

mand, staffing resources, budgets, cave resources as well as other limiting factors and alternatives to which probabilities may be assigned.

2. A value system which contains a list of values in order of importance for the situation, such as degree of visitor solitude, visual remoteness, minimal physical damage, minimal algae growth and contamination, safety, education and entertainment.
3. A decision criterion system which determines the choice of the best alternative based on the purpose of management e.g. conservation, visitor use, etc. All purposes must be listed.
4. Recommendations, which flow out from components 1 to 3.

Fig. 1 illustrates this model conceptually.

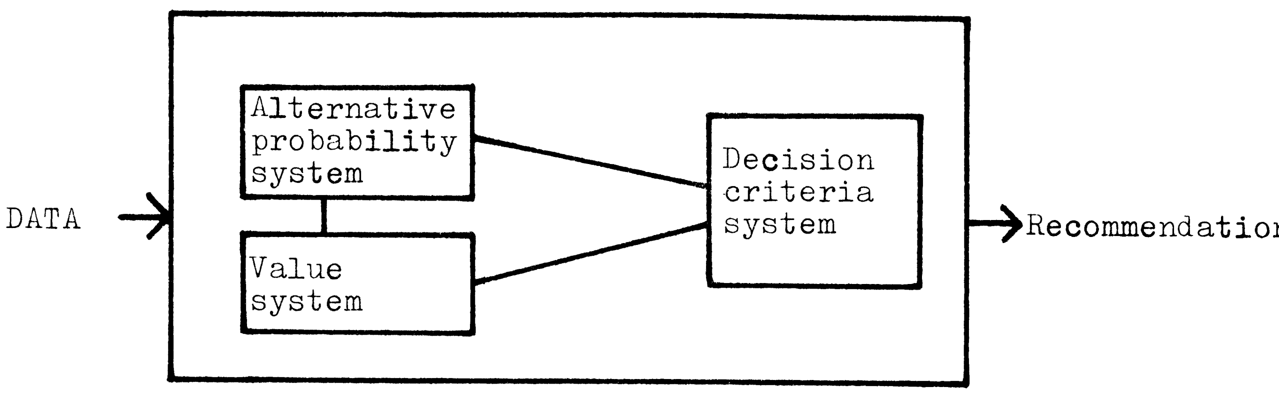

Fig. 1. Carrying capacity decision maker model. Source – Bross (1965).

The major problems with such models is that the necessary data pertaining to ecological and perceptual carrying capacity determination are not available. In addition to this the model requires clearly set objectives and awareness of values.

It would seem that if the idea that the cave resources needs to be protected from the impact of visitors is conceded, then since cave attractions concentrate visitor use, particularly where there are only one or two entrances, then the number of visitors that can be accommodated may not simply be a function of limited manpower, vehicle and cave space, but rather of a cave carrying capacity based on ecological and human perception principles.

If we are to realistically determine carrying capacities, we need a good understanding of cave features, and of the impacts of use upon these. Existing management agencies seldom have this type of knowledge or expertise, while those who have cave expertise typically lack experience in management. There is therefore a great need for the two groups to come together.

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