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MANAGING PROTECTED AREAS

A GLOBAL GUIDE

Edited by Michael Lockwood, Graeme L. Worboys and Ashish Kothari

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Natural Heritage Management

Jamie Kirkpatrick and Kevin Kiernan

The process of natural area management commences with a vision, progresses through planning and allocating resources, and culminates in a range of outcomes (Hockings et al, 2000). Management to conserve natural heritage involves assessing the significant qualities of an area, and ensuring the survival or restoration of these qualities, ideally in a self-sustaining condition rather than one that requires continual intervention. Achieving this end typically requires protection of functioning natural systems, rather than merely localized features and sites (ACIUCN, 2002).

The concept of 'natural' is a difficult one, given that *Homo sapiens* is one of millions of species that have evolved on planet Earth and depends upon the rest of the biosphere for survival. It is useful to distinguish between the human species and the rest of nature when discussing protected area management, although it may still be difficult to discriminate between the natural and the artificial, since people have often affected the nature of the atmosphere, the geosphere, the hydrosphere and the biosphere.

With organisms apart from *Homo sapiens*, the distinction is usually made between those organisms that we have helped to evolve and those that have evolved without our direct intentional intervention. The truly natural are those that have totally escaped our influence, such as species associated with submarine volcanic vents on mid-oceanic ridges. Such ecosystems are seldom the subject of protected area management, making it necessary to draw a line somewhere across the continuum between the natural and the anthropogenic. This line, for our purposes, approximates the edge of cultivated land, although we also recognize that some IUCN Category V and VI protected areas include cultivation.

The components of what we call 'nature' exist irrespective of human culture; but 'heritage' is a cultural construct – the 'things we want to keep'. Political processes determine what is accorded 'official' natural heritage status, a situation that inevitably disenfranchises some. It is the management of this 'official' heritage upon which we focus here, though it is appropriate that managers remain cognisant of other views and accommodate them, where possible, within the context of their consciences and formal duty statements. Formal instruments for protection exist at global to local scales. At the international level, there are World Heritage criteria (see Chapter 3), to which many nations subscribe. At other political divisions, such as the national level, there are differing interpretations of outstanding heritage.

In this chapter, we discuss general principles and approaches for managing natural heritage, and then address specific aspects of natural heritage management: water, geodiversity, fire, weeds, plant pathogens, animals, the impacts of people, and restoration and rehabilitation. In all cases, the specifics of protected area management for natural values will be highly contingent upon the nature of the protected area and the environment and society in which it is embedded. Thus, the chapter emphasizes ways of thinking about, and ways of conducting, natural heritage management.

Principles of, and approaches to, natural heritage management

The typical protected area has very few management staff. These managers often have a major role in the facilitation of tourism-related activities, and, consequently, relatively little time to maintain the natural values that attract at least some of the tourists and are usually the reason for the existence of the reserve. Some protected area managers also have to manage commercial or traditional use of resources within their parks. All of these human activities can affect the natural elements and processes in protected areas. In the context of these activities and other influences on natural ecosystems, any potential management intervention, or non-intervention, is likely to have benefits for some elements of nature, but may harm others. For example, the removal of domestic sheep from chalk grasslands in England favours trees and the native animals that use them, but is disastrous for many native herbs and the animals that feed off them.

Little time, conflicting goals, what to do? This section suggests some principles of, and approaches to, natural heritage management in the context of limited resources. The first step is to determine priorities for action. The next step is to be as efficient as possible in achieving these priorities.

Manage for those values most dependent upon particular protected areas

The manager needs to determine those natural elements and processes that their protected area is most important in protecting. The question that needs to be asked of your protected area is:

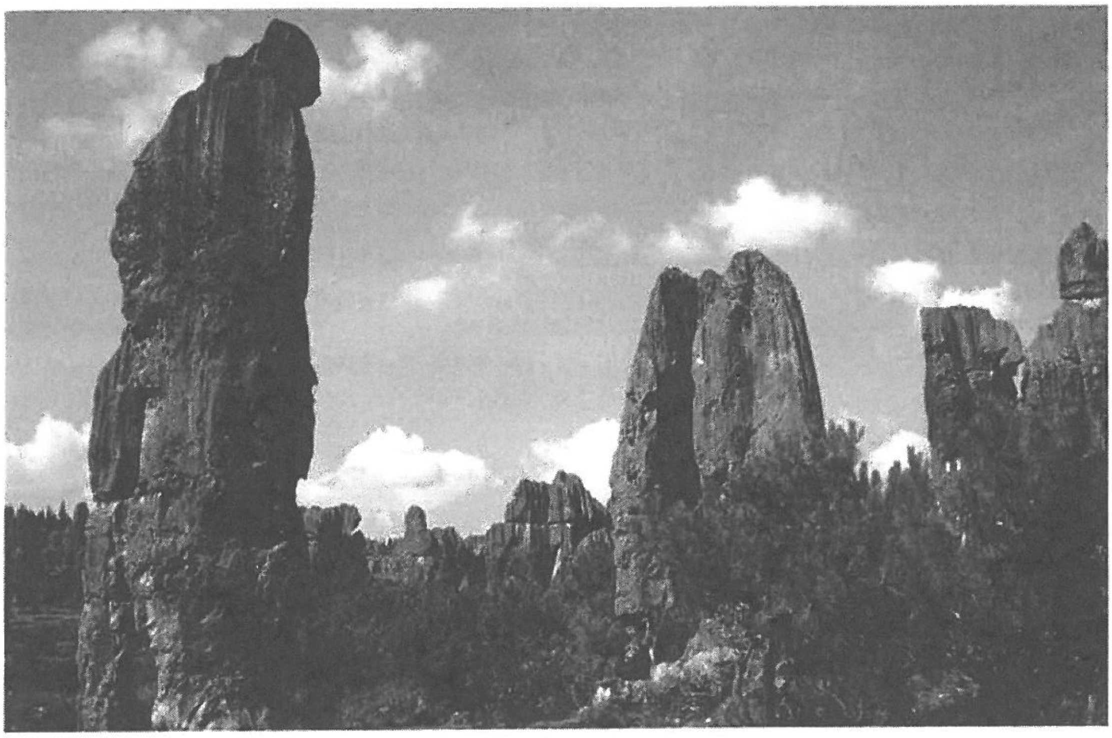
> *Are there any species, communities, landforms, geological features or processes that depend upon protected areas and are unrepresented, poorly represented or unprotected in other protected areas?*

If the manager has, for example, the only viable population of dwarf hippopotamus in the world in his or her reserve, but nothing else of any great significance, they should avoid constructing parking areas or visitor centres in areas that the species depends upon and should resolve any management conflicts in favour of the species. If their reserve also has the best example in the world of a particular type of rainforest, which is encroaching on hippopotamus habitat, the test of irreversibility needs to be applied. Holding back the best example of a common rainforest type is not going to destroy it – but losing a few more individuals of the dwarf hippopotamus might nudge them towards extinction, which is irreversible.

Understand your natural systems

In conjunction with heritage charters and management guidelines, a grounding in the biological sciences and geosciences is useful in helping protected area managers to understand what conservation management needs to be done in a reserve. However, reserves and their ecosystems are all different to the degree that a management recommendation developed in one place in one type of ecosystem might prove counterproductive in another place in the same or another ecosystem. Managers need to learn from their predecessors, scientists and locals, and then learn for themselves. The world is full of appalling conservation outcomes resulting from well-intentioned decisions by people unaware of the limitations of their expertise and the costs of this deficiency. Do not become one of them – seek advice even if you think you know it all or believe that the value closest to your heart, or in which you have trained, is inevitably the most important, or the only one, likely to be affected by an action.

Some managers consider scientific research in their areas to be detached from practical management issues. However, a cooperative scientist can provide invaluable insights into how ecosystems work and can be encouraged to collect data that you want for management purposes. Natural scientists tend to return regularly to their research sites, making them valuable repositories of all sorts of histories apart from the data they collect for their projects. Older people whose families have had a long history of exploiting, living in or recreating in your protected area can be invaluable



Lunnan stone forest, China

Source: IUCN Photo Library © Jim Thorsell

sources of information on how ecosystems work. Indigenous people with orally transmitted cultures can give particularly good insights to long-term processes, rare events and previous management regimes.

Before you have finished talking with all of these people, you may have been moved on to your next posting, leaving behind written briefings for your successors on what you have learned and done. All of this knowledge-seeking induces efficiency in conservation management because it helps to discriminate between things that *really* need to be done to protect important values, and actions that are either a waste of time or potentially destructive.

Do not obsess about naturalness

It is impossible to manage a protected area back to its 'pristine' landscape, and misguided attempts to duplicate older ways of management may, in fact, lead away from the 'purity' that is sought. For example, while attempted returns to indigenous-style fire regimes may serve the interests of biological diversity and may reverse trends towards ecosystem degradation (Marsden-Smedley and Kirkpatrick, 2000), the question inevitably remains: are the results 'natural'? Case Study 16.1 briefly examines some of the evidence for major vegetation transformation due to human activity, including the issue of fire-induced environmental change in Madagascar.

Think about processes

Conservation management should be based not just on localized phenomena, but on functioning natural systems. There are many reserves that present managers with insuperable obstacles because this reality has not been recognized – for example, cave reserves that protect the cave entrance but not the source of the water that forms the cave stream or seeps through its roof to form the speleothems, such as stalactites and stalagmites, which may have been the very reason that the cave was protected.

Case Study 16.1

Human impacts on fire and large-scale vegetation changes

Humans have used fire for over 1 million years, setting in motion a great wave of environmental transformation that continues today. In Africa, evergreen forests shrank and grasslands and savanna expanded. In North America, fire set by the first human settlers expanded the prairies and ate into woodlands and forests. In Australia, the vegetation of the continent was transformed first by Aboriginal firestick farming, and then by the burning practices of European settlers.

Most aspects of a fire regime can be modified to a greater or lesser degree by human intervention. Prescribed burns are nearly always constricted by the risk of damage to people and property, and can produce very different effects from the wildfires under which natural vegetation patterns evolved.

Large-scale human impacts on fire and vegetation have been claimed in many parts of the world; however, the evidence is circumstantial and controversial. The problem is that climate has changed over the long period of human settlement, and it is difficult to separate the respective effects of human occupation and climate.

Where human settlement has been relatively recent, vegetation change is less likely to be confounded by climate change. Madagascar, the world's fourth largest island, was first settled by humans only some 2000 years ago, and through a lethal combination of shifting agriculture and burning, vast areas were thought to have been transformed into grasslands and wooded grasslands. While there has been undeniable human modification of the island's vegetation, the importance of humans and fire in transforming Madagascar's great central plateau from forests to grassland is more controversial, with pollen and charcoal studies from a lake in central Madagascar indicating that open grassy vegetation and fire existed in the area for thousands of years prior to human settlement. Accordingly, it is difficult to attribute Madagascar's current vegetation to the human use of fire. Much the same problem occurs in other large-scale examples of supposed fire-driven vegetation change.

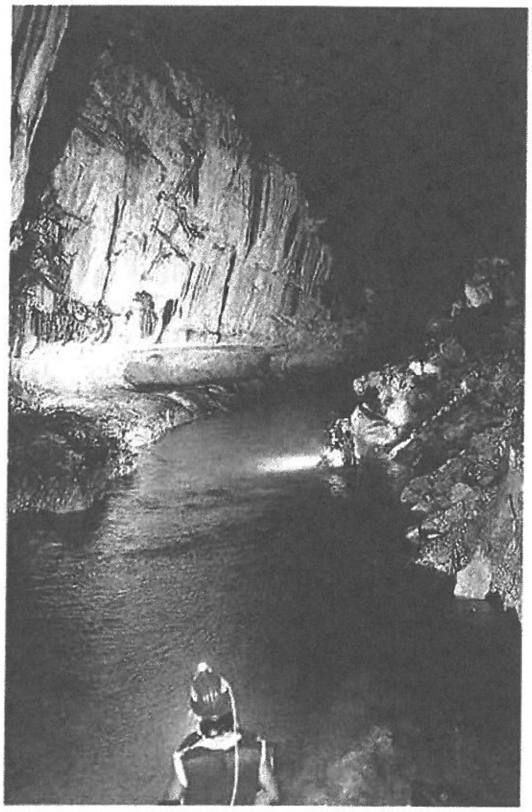
Source: adapted from Bond and van Wilgen (1996)

Deficiencies related to reserve boundary design may be beyond the control of the manager; but managers should never fail to identify the extent of the natural systems over which they have even partial jurisdiction and to ensure that they are managed in order to safeguard the values that depend upon them. For example, roadside drains and toilets should not be sited where seepage can enter underground karst drainage systems and their associated caves.

In a few cases, it may be possible to safeguard a feature with less consideration of the surrounding environment; for example, a geological exposure that exhibits an important fossil assemblage is likely to be essentially fossil itself, a relict of processes that no longer operate. The objectives of geo-conservation are not simply to safeguard geological features, landforms and soils, but also the natural processes by which these things come into being.

Floods, landslides, earthquakes, volcanic eruptions, wildfires, tornados and the like are perceived as disasters when the aspirations of humans place them in the path of these largely natural processes. However, the occurrence of such a major event in a natural area does not imply that it is an unprecedented disaster, however dramatic its short-term effects. Meteorological records or data on river discharge for remote protected areas are likely to be very short if they exist at all, and even a record over 200 years may not be sufficient to illustrate the magnitude of a flood with a recurrence interval of 100 years. Many high magnitude natural events have a still longer recurrence interval. It is important that managers incorporate sufficient time depth in their thinking – one of the many situations in which fostering good relations with scientists can be of immense benefit. It may not only change your attitude to 'disasters', but may better inform any attempts at environmental manipulation that you are considering.

The one exception to this long-term perspective on putative disasters arises when park managers are charged with protecting a critical natural heritage asset in a spatially constrained area that represents the last scraps of a former habitat



Karst, Gunung Mulu, Malaysia

Source: IUCN Photo Library © Jim Thorsell

and in which recovery of a species from localized damage is no longer possible. But in most cases, natural hazards in populated areas are, when they occur in protected areas, best regarded as part of the ongoing natural environmental systems.

Thinking about processes is efficient because one process intervention may be more effective than a thousand restoration or protection activities related to individual elements of natural diversity. In a similar vein, until you have learned as much as is available on the ecosystems of your protected area, hasten slowly.

Be cautious in changing management regimes

Many protected areas have been managed in the same way for decades, up to millennia. You know that the species, features and ecosystems of the reserve have survived this treatment. You do not usually know the potential impacts of altered management regimes. If you suspect that the current management regimes are leading to a progressive loss of the more important values of your protected area, experiment with limited change in a process of adaptive management, rather than imposing change on the whole system – otherwise you might end up with an unnatural disaster, like those intense and extensive wildfires induced by the fire suppression policies associated with Smoky the Bear in the US. Of course, there may be desperately needed management changes in natural areas that require no more than a few seconds' thought before implementation, such as preventing the dumping of rubbish in sink holes.

Observe the 'canaries'

Caves are the major features of many protected areas. In northern Thailand and many other places, colonies of bats sleep out the day clinging to their roofs. Their profuse droppings react with the floor of the caves, drawing oxygen from the air. Candles, rather than the canaries of miners, are used by guides to indicate this danger to the lives of tourists. Looking for such 'canaries' is efficient because no manager can afford to monitor everything, and early diagnosis gives the best prospect of a cheap cure. The protected area manager is well advised to seek canary or candle surrogates that can be used to indicate imminent danger to the important values of their protected area.

Caves again provide a good example. These typically contain a wide variety of resources that may include important palaeoenvironmental archives in the form of sediments, accumulations of fossil bones, archaeological relicts, attractive speleothems, rare minerals, unusual hydrological and microclimatic characteristics, and ecosystems comprising biota adapted to existence in a stable low-energy environment of permanent darkness. In some cases, access to caves has been limited in recognition of the particular sensitivity of natural cave microbiota (a phenomenon that has generally been annihilated by the inevitable contamination caused as soon as humans enter). Moreover, safeguarding this most-at-risk value simultaneously allows the other values for which the site is important to also be protected.

Undertake efficient inventories and monitoring

A knowledge of the distributions of the key environmental assets of any protected area is a fundamental requirement for effective management. It is axiomatic that such inventories should be as objective as possible, unsullied by policy considerations – inventories should not be distorted by second guessing political intentions. The development of policy and practical measures to further the protection, or destruction, of the inventoried assets should be a distinct and separate process. Regionalization (based on the idea that an assemblage of different areas can be sufficiently unified by enough common characteristics as to outweigh the factors that allow distinction between them) can be useful where the area is large, poorly known and there are insufficient resources for a detailed inventory. More detailed inventories can be developed using genetic classifications or measures of objective physical and biological characteristics. Generalized surveys of broad areas can be employed to identify important phenomena, although they may be unintentionally skewed by the inventory compiler if that person's expertise is limited to only one or a few attributes.

Maps, in whatever form, are valuable tools for recording the locations of natural assets, including vegetation types, rare or threatened species and geomorphologic and geologic features; artefacts, such as roads, tracks, huts and visitor centres; management activities, such as weeding, planned burning and restoration; monitoring sites; unplanned disturbance events, such as wildfire and land slips; and permitted activities, such as zones in which hunting is an allowable activity. These layers of information can be used as a planning tool. For example, the location of a new walking track can be planned to avoid rare or threatened species habitat and boggy ground, as indicated by particular vegetation types (Kirkpatrick, 1990).

Aerial photographs and similar imagery, coupled with sophisticated computer software, are valuable aids in mapping and monitoring natural phenomena. Monitoring can be difficult to implement effectively, although it is essential if decline in the condition of park assets is to be identified sufficiently early for appropriate remedial action to be taken. Many management plans include a provision for monitoring; but frequently neither an appropriate monitoring strategy has been formulated, nor resources committed to this end.

More detailed (and time-consuming) monitoring should be restricted to what is necessary to determine changes in population or those elements of biodiversity and geodiversity for which the protected area is most important and which are thought to be subject to some threat. For such monitoring, adopt the cheapest and quickest option that gets the outcome you need. In the cases of plant species and vegetation, permanent photo points can be extremely efficient and effective. Photo-monitoring in caves is feasible, but is more difficult than it sounds due to the vagaries of consistently reproducing comparable artificial lighting conditions. It is a waste of time, and unnecessarily distressing to the animals, if you have an expensive trapping programme for a rare vertebrate when you can design a way to get an approximate idea of the trend in their numbers by counting scats, diggings or scratchings in permanent plots or transects (see Table 16.1).

Nevertheless, sound design is necessary for monitoring, so consult your scientific contacts. This may be particularly important in terms of fitting the sampling protocol to the phenomenon – sampling undertaken at a consistent time or date each week may miss the key events you most need to identify, such as pulses of water contamination related to rainfall and runoff events.

It is particularly important to monitor the impact of your own intervention in natural systems, such as those related to infrastructure development. There must be commitment to responding appropriately and rapidly if there is evident harm outside the parameters set in management plans.

Managing water

Water is a fundamental resource for sustaining natural environmental processes, scenery, ecosystems and people in protected areas. Management needs to be based on an understanding of natural drainage systems, including groundwater, streams, rivers and lakes. The fundamental principle of

Table 16.1 Fauna inventory: Some field survey techniques used

Fauna field survey technique	Notes
Direct identification – observation and listening	Skilled observers are invaluable for enhancing information about wildlife. Bird, frog and some mammal species have distinguishing calls or sounds from which they can be identified. Standard fauna inventory forms have been produced by many organizations to facilitate the recording of observations.
Observation – fauna tracks and diggings	While often difficult to discern, signs of fauna, such as footprints and scratchings, are an invaluable aid to fauna observers and researchers.
Collection and analysis of fauna scats	Predator scats can be valuable for rapid inventory of native fauna populations. Researchers have found that the scats from such animals are deposited close to the food source. After *carefully* collecting the scat (given the chance of contracting a disease such as hydatids), it can be dried and analysed for hair and bone content. Scats from native animals themselves are important inventory diagnostics.
Collection and analysis of bird pellets	Some birds regurgitate bone, feather, fur and other fragments of their meals that they are not able to digest. Owl pellets, for example, contain a wealth of small mammal bones in stratified deposits at some cave sites. They have provided valuable contemporary and historical records of small mammal populations used as prey by the birds.
Fauna signs in their habitat	Animal runways in heath and native grasslands, burrows, nesting hollows, incisions in trees that mark nesting sites, claw marks on trees, and litter and damage to trees and shrubs from animal feeding are all signs that indicate the presence of fauna.
Trapping and collection of insects	Water traps, flight interception traps, light traps and bait traps are methods used for collecting insects.
Spotlighting	Many species are only active during the night. The use of a portable light will reflect the retina colour of animals' eyes. The colour, shape and size will help in identifying species.
Call playback	Many animals have distinctive calls, and when these are recorded and played back through a loud speaker, species can be prompted to respond.
Use of pit-traps	This is a technique used by zoologists to capture small mammals, reptiles and invertebrates. Use is made of a barrier and a small container that is sunk into the ground. Animals are directed to the container by the barrier and are captured in the pit as they try to pass through the 'opening' in the barrier.
Reptile searches	This technique is usually undertaken for a small area and during the middle of the day. Favoured habitats for these species (under logs and rocks, in leaf litter, in hollows and so on) are searched.
Use of hair tubes	A hair tube is a length of plastic pipe (about 90mm in diameter for small species) that has a bait sealed at one end and double-sided sticky tape on the side of the pipe. When feeding, the small mammal leaves some hair on the tape, which is subsequently analysed to determine the species.
Use of small mammal traps	Collapsible aluminium traps (Elliot traps), which capture their specimens live using a bait, pressure pad and spring rear-door trap, are a common tool of scientists undertaking fauna inventories. Typically, specimens are captured, identified, weighed, measured and released on site. Larger live traps (cage traps) are used for the capture of larger specimens.
Use of nets, including harp nets and 'fish' nets	Harp nets (vertical filaments of nylon organized to form a barrier to bats) are generally placed on bat flight paths. They are designed to minimize their detection from bat sonar signals and to minimize any impact on the bats. Nets are commonly used for the capture of birds.

Table 16.1 Continued

Fauna field survey technique	Notes
Use of specialized traps	Large traps are often used for the capture of bigger animals, such as salt-water crocodile (*Crocodylus porosus*) of northern Australia. This technique is used when a 'problem' animal needs to be relocated.
Aerial monitoring	Aerial methods of monitoring fauna and their environment offer distinct advantages when dealing with remote areas or areas that are otherwise inaccessible, such as major waterways or other water bodies to count waterfowl and eagles. Even relatively small fauna may be indirectly monitored in this way – for example, beaver dams. Analysis of aerial surveys may be facilitated using computer programmes.
Global positioning systems (GPS) and geographic information systems (GIS)	GPS and GIS permit efficient and accurate collection of spatial data, while combining and comparing time-sequential maps and satellite imagery for estimating, for example, global change and environmental degradation. GIS are also ideal for comparing flora or fauna species diversity with variables in their habitats in order to help manage conservation areas. Conversely, habitats can be identified with overlay analysis, producing maps of where field teams might locate rare or endangered species of plants and animals (see Case Study 16.2).

Source: adapted from Worboys et al (2005)

Monitoring bats using a harp net, Central Eastern Rainforest Reserve, Australia

Source: IUCN Photo Library © Jim Thorsell

water management is that strategies need to be catchment based, rather than attempting to manage on the basis of individual parts of the system in isolation.

Managers should also recognize the possibility that components of drainage systems that appear to be inactive (such as normally dry channels in arroyos, alluvial fans or in karst) are there for a reason – that discharge is likely to occur through them during low-frequency high-magnitude events, and that failing to manage them appropriately may ultimately incur harmful erosion, ecological damage, damage to infrastructure or risk to human life. Managers must try to maintain the magnitude, timing and rate of natural processes in as near to natural condition as possible; this is of particular significance in water management, where the critical issues are the maintenance of discharge, flow regimes and water quality. Where any of these elements is compromised in a manner that is beyond the control of the manager, she or he is faced with the challenge of trying to cope or adapt.

Dams can change the flow regime, sediment load, temperature and oxygen status of stream systems. Construction of a dam may flood natural or cultural assets, as in the case of the Hetch

Case Study 16.2

Determining panda populations using global positioning systems (GPS) and geographic information systems (GIS), China

The State Forestry Administration in China has revealed that increased national efforts at protecting wildlife such as the giant panda (*Ailuropoda melanoleuca*) have seen dramatic increases in the population of this endangered species, including more than 500 new pandas born within the past 16 years.

The inventory began in 1999 and was carried out in the endangered bear's major habitats, including the western provinces of Sichuan, Shaanxi and Gansu. It was the third ever conducted in China, with earlier counts carried out during the 1970s and 1980s. The latest inventory found that the number of giant panda in the wild has increased from 1100 in 1988 to more than 1590 in 2003.

Global positioning systems (GPS) and geographic information systems (GIS), along with specially designed computer software, were used to annotate the exact spots where wild pandas or their footprints, droppings and bamboo stem fragments or other traces were found, thereby improving the accuracy of the inventory. The increase of the panda population is attributed to the improvement of their habitat and successful research in artificial insemination and conception. The inventory of the giant panda has been complemented by a national survey of major wild fauna and flora and wetland resources from the mid 1990s.

Source: adapted from Zhuo Rongsheng (2004)

Hetchy dam in Yosemite National Park, which inundated a valley as significant as the more famous Yosemite Valley. Wave action may erode slopes that are not naturally adjusted to that form of disturbance, and soil moisture changes related to periodic draw-down of the reservoir may cause landslides. Dams act as settling ponds that may limit the through-flow of natural sediments and nutrients, as has occurred below the Glen Canyon dam on the Colorado River, with harmful consequences for the Grand Canyon, such as sandy shorelines being washed away and native fish species disappearing. Channels downstream of dams can progressively become filled with sediment once regular flushing by high flows is halted; as a result, during a major flood event there may be insufficient channel capacity to accommodate the water that spills onto the surrounding landscape, causing flooding. Change in downstream water quality, including oxygen status and temperature, can have ecological repercussions.

Protection of water quality is essential. The fact that many natural waters have suffered contamination highlights the importance of those pristine waters that remain; but many managers are faced with the need either to repair previous degradation or prevent matters from becoming worse. An important principle is to focus initial efforts to improve water management on more upstream sites and *then* extend them downstream, reducing the potential for efforts to be sabotaged by continued 'bleeding' from higher in the watershed.

Groundwater is particularly important in some protected areas. In some arid and semi-arid environments, the groundwater has accumulated during times when climatic conditions were very different than now. In coastal and island settings, a freshwater lens may be perched on denser, more saline groundwater, and overexploitation of the freshwater may lead to unexpected salinization of bores. Water-bearing rocks (aquifers) may be generally porous and permeable, permitting only slow flow, or they may be fractured and fissured, permitting faster flow. The most rapid flow occurs in conduit aquifers, such as those formed in karst areas or volcanic landscapes in which subsurface lava tubes are present. There is often a dangerous assumption that groundwater is inherently pure; but groundwater in conduit aquifers has limited exposure to any of the natural self-purification processes (sunlight, biological processes and ionic exchange with surrounding materials), posing severe dangers for humans and for groundwater-dependent ecosystems.

Difficulties arise in karst terrain because directions of groundwater drainage are typically governed by geological structures, rather than by surface topography, meaning that topographic maps will provide little guidance. Streams often flow underground from one valley into another. Because karst landscapes can be like a giant underground sponge in which there are many interconnected spaces, water may flow in one direction when conditions are relatively dry, but spill in various other directions as conditions become wetter and there is more water in the 'sponge'. Hence, contaminant transmission by groundwater or unexpected floods bursting from the ground in apparently unlikely places can pose hazards for ecosystems and humans alike. There is no 'quick fix' available – responsible management of karst areas requires careful water tracing experiments to enable an adequate understanding of the groundwater systems.

Managing geodiversity

Physical features, such as the landforms that surround us, sustain and enrich our lives in much the same way as do the plants and animals with which we share the planet. They are equally deserving of careful stewardship as valid parts of the cosmos significant in their own right, for their underpinning of functioning natural environmental systems, including ecosystems, and for the instrumental opportunities they offer humans. Gray (2004, p8) defines geodiversity as:

> *... the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (land form, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems.*

The management of geodiversity involves safeguarding important geological sites, landforms and soils, as well as sites of natural geo-processes. There is a common perception that the prefix 'geo' implies phenomena made of rock that are therefore likely to be inherently robust and require little consideration. However, this misconception is soon obvious to the manager who has to confront:

- theft of important fossils;

Ha Long Bay, Viet Nam

Source: IUCN Photo Library © Jim Thorsell

- destabilization of sand dunes;
- vandalism or accidental damage to fragile speleothems in a karst cave; or
- serious soil erosion problems.

Many landforms are relicts of environmental conditions over millennia. Breeding geological sites or landforms in zoos or botanical gardens is not an option when geodiversity is lost.

Just as there are different species of plants and animals, so too are there many different types of waterfall, sand dune and other landform categories. There are also different types of landform assemblages, much as there are communities of plants and animals, and there are composite landform communities, such as those that occur where glacial processes are superimposed on limestone. Like biotic species, some landform types are common and some are rare, some are robust and some are fragile – hence, a variety of management actions may be required.

Some sites of geo-conservation significance are very fragile, while many others are relatively robust, and still others are seemingly indestructible. Accordingly, it is unnecessary that all significant geo-conservation sites be protected; however, it is useful to have an indication of just how robust or fragile a specific site is. This may be built into a landform classification system such as the one outlined in Box 16.1, which distinguishes between sites on the grounds of their vulnerability, based on the intensities and patterns of disturbances entailed in particular land-use practices. Disturbing a site may not *necessarily* degrade its geo-conservation values – it is the vulnerability of those values that is important.

Box 16.1 Vulnerability of geo-conservation values

1 Values are vulnerable to inadvertent damage simply as a result of diffuse, free-ranging human pedestrian passage, even with care. Examples include fragile surfaces that may be crushed underfoot, such as calcified plant remains, or gypsum hairs in some karst caves that can be broken by human breath.

2 Values are vulnerable to the effects of more focused human pedestrian access, even without deliberate disturbance. Examples include risk of damage by entrenchment through the advent of pedestrian tracks; coastal dune disturbance; drainage changes associated with tracks leading to erosion by runoff; risk of damage as a result of changes caused by changes to fire regime; and defacement of speleothems simply by touching their surface.

3 Values are vulnerable to damage by scientific hobby collecting or sampling, or by deliberate vandalism or theft. Examples include exploitation of some fossil and mineral sites and karst caves.

4 Values are vulnerable to damage by remote processes. Examples include hydrological or water-quality changes associated with the clearing or disturbance of watersheds; fracture/vibration due to blasting in adjacent areas (potentially causing such damage as breakage of stalactites in caves); and sites susceptible to damage if subsurface seepage water routes change due to the creation of new fractures.

5 Values are vulnerable to damage by higher intensity, shallow linear impacts, depending upon their precise position. Examples include vehicular tracks, minor road construction and the excavation of ditches or trenches.

6 Values are vulnerable to higher intensity but shallow generalized disturbance on site. Examples include clear-felling of forests and replanting, but without stump removal or major earthworks and associated drainage changes.

7 Values are vulnerable to deliberate linear or generalized shallow excavation. Examples include minor building projects, simple road construction or shallow borrow pits.

8 Values are vulnerable to major removal of geo-materials, or large-scale excavation or construction. Examples include quarries and sites of large dam construction.

9 Values are vulnerable only to very large-scale contour change. Examples include mega-quarries.

10 Special cases include erosion caused by sea-level rise resulting from humanly induced greenhouse warming, and sites where the value is rendered inaccessible through inundation beneath an artificial reservoir, although the physical characteristics of the site may remain intact.

Source: Kiernan (1997)

Landforms are the product of interactions between geological substrates, geomorphological processes and time. Diversity is not everything – many of the most cherished landforms are, in fact, examples of relatively common phenomena. The World Heritage-listed Skojcan Caves in Slovenia are viewed as outstanding, even though they are but one example of a phenomenon – limestone caves – of which there are hundreds of thousands around the world. While Earth's geo-environments encompass a diverse range *at a global scale*, at a local scale there may be monotonous repetition, as within the outstanding dune fields of some large deserts. The lack of diversity at a local scale does not diminish the conservation value of such a place on a broader canvas. The fact that there are many waterfalls in the world, furthermore, does not diminish the beauty and local significance of a local cascade that is dear to the heart of a small community.

Managing geo-heritage

Geo-heritage management, whatever the spatial scale of significance and whatever the extent of the area, requires respecting the phenomena involved; minimizing intervention in the functioning of the healthy natural systems that sustain it; the application of knowledge and experience derived from a wide range of specialists, including, but by no means limited to, scientists; and that cognisance be taken of all aspects of the natural significance of a place, including its possible cultural heritage significance. Geo-heritage may be regarded as being worth conserving for three main reasons:

1. From the perspective of intrinsic values (see Chapter 4), physical features do not require human approval or certification to be a valid part of the cosmos, but simply deserve respect in their own right.
2. Protection of geo-heritage is important in order to safeguard natural process values, recognizing the interdependence of all things and the impossibility of achieving other conservation outcomes unless hydrological, geomorphic and life-support systems are respected.
3. Physical features such as landforms have myriad instrumental uses to humankind as objects of spiritual, aesthetic, recreational, scientific, educational, economic or other significance to humankind, including the provision of environmental system services such as clean air and water.

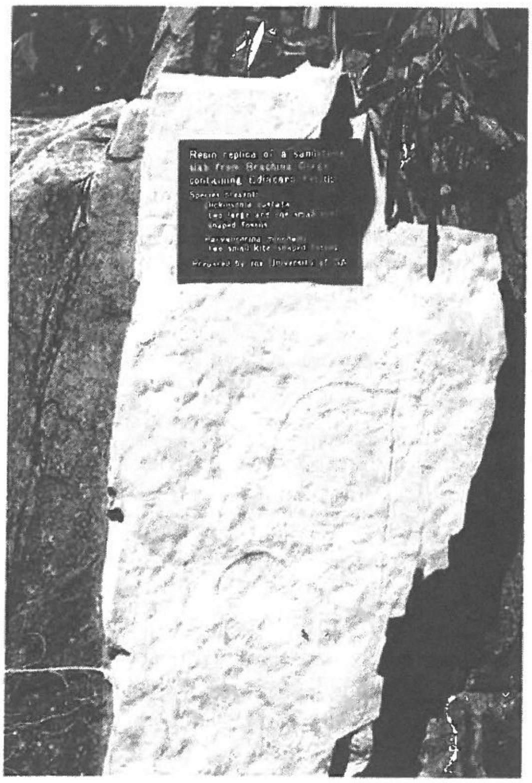
In assessing geo-heritage significance, there is a need to recognize:

- why the site is significant;
- to whom it is significant;
- the scale of its significance;
- whether that significance is likely to be temporary or permanent; and
- the adequacy of the information base or expertise upon which the evaluation is founded.

It is essential that a clear distinction is maintained between the values for which a geo-heritage site is considered important and the instrumental uses to which it may be put. Tourism may be a potential use of a particularly scenic site or one that contains an endearing animal species; but as noted above, the site also has value in its own right. Failure to recognize and act upon this distinction can erode the fundamental asset. Beware of the content-free manager, politician or developer who tries to tell you that a resort deep inside a park is appropriate because the tourism potential of the area is one of its conservation values. A limestone cave and its contents represent a conservation value for which protective management is required; development of that cave for commercial tourism represents a use value.

Geological sites

Significant geological sites may include outcrops of particular rock types, sites where fossils occur, exposures that reveal the nature of subsurface structures and a variety of other phenomena. 'Type sites' that provide the earliest or best example of particular phenomena provide important reference sites against which evidence found elsewhere can be compared in order to advance geological knowledge of broader regions. Such sites can be lost during some construction activities, such as bulldozing embankments to establish



Artificial cast of fossils at Ediacara, South Australia

Source: Kevin Kiernan

roads. An adequate inventory of geological assets and prior examination of proposed development sites by appropriate specialists is desirable. Theft of gemstones or fossils may be a problem. Geological sites are vulnerable to unscrupulous people harvesting fossils for a thriving collectors' market. Such issues can be particularly acute where no manager is present on site to provide advice or protection, or where the establishment of protective structures is impossible for practical or other environmental reasons. There may be nothing to prevent the clients of an 'eco' tourism enterprise later returning independently to an unsecured sensitive site with a group of their equally inexperienced friends. For example, at Ediacara, South Australia, all that remains is an artificial cast of the fossils that once made the site important.

Landforms

For many traditional societies, respect for the natural environment stems from a spiritual connection to particular physical features. Some of the earliest formal reserves were created to safeguard physical scenery imparted by the juxtaposition of landforms, largely irrespective of the biological values that have tended to dominate the language of conservation management over recent decades. Hence, the first reservation of land in what is now Banff National Park in Canada was in order to protect a small limestone cave that contained a warm spring.

Geomorphology is defined by the contours of the land; any artificial change to those contours, at whatever scale, by definition represents damage to the natural geomorphology. The question that arises is whether the landform is significant and the extent of the damage. A feature made of solid rock is more robust than one formed of unconsolidated fine sediment, such as a sand dune, that may blow away if de-vegetated. Fire-induced spalling (flaking) may remove weathering features such as surface solution sculpture (karren) on limestone, and smoke can discolour speleothems in karst caves due to airflow underground as the cave atmosphere continually equilibrates with changes in air pressure or temperature in the outside environment.

Cave management

In addition to the importance of karst caves as landforms in their own right, they often also contain other natural values related to geology, mineralogy, hydrology or climatology. They may be warehouses of palaeoenvironmental information, housing ecosystems in which organisms are physiologically adapted to a life of constant darkness and limited nutrient input, existing in such low numbers that the loss of even a few individuals may be sufficient to cause genetic drift or even extinction. Caves may contain bones of extinct animals, fossil pollen or chemical isotopes, and cultural legacies such as archaeological sites.

Karst caves illustrate many broader natural area management issues in microcosm, but on a particularly sensitive palate. Cave management needs to be founded on an understanding of the stream and seepage water catchments that sustain both speleothems and ecosystems, and maintaining the exchange of water and air between surface and subsurface environments in as natural a condition as possible. Particular care needs to be taken in utilizing any chemicals, control of feral animals and development of infrastructure both above and below ground. The closure of natural infiltration routes through the construction of sealed roads and car parks in close proximity to caves is to be avoided, although in the wider catchment sealing traffic areas may sometimes be preferable to allowing an unsealed surface to contribute sediment into the karst system. Composting toilets or removal of wastes is preferable to septic systems sited where seepage can enter karst systems to the detriment of physical features and sensitive cave ecosystems.

Concepts such as carrying capacity may be of little use because features such as broken stalactites do not grow back relatively rapidly like vegetation, but instead form over geological rather than human time scales. Below ground, there may be a need for rationing of use and well-trained guides to minimize potential damage by inexperienced visitors. Routes may need to be delineated through sensitive areas and promoted as a means of centralizing damage. Even if visitors do not break stalactites, permanent disfiguration may result from people merely touching speleothems because dirt and body oils can become sealed beneath the next layer of clear calcite that forms. Infrastructure facilitating visitor access or asset protection underground should be constructed to allow easy removal with minimum impact, using a material that will not cause problems, such as corrosive or toxic runoff from some metal fixtures, or the unnatural food resource provided by rotting wooden structures. Visitor safety is a particular concern given the massive damage that can be inflicted trying to rescue an injured visitor from a cave – vegetation cut away to allow movement of a patient on a stretcher may grow back relatively quickly, but stalactites broken during a similar process may take millennia to reform. Inappropriate lighting may cause the build-up of damaging algae, dirt carried underground on clothing and footwear will accumulate and its removal will pose challenges, and the cave climate may be modified. Carbon dioxide levels may sometimes pose dangers for visitors, and accumulated exposure of staff to radioactive radon gas in caves may be an issue.

The management response must include managing recreational cavers, tourists, scientists *and* the managers themselves. Thousands of years of history have commonly lain protected in caves through the coming and going of ice ages and the rise and fall of different human cultures. Its potential removal to nourish a few pages of a 21st-century scientific journal that may be ashes or compost within a few decades warrants utterly scrupulous evaluation. Managers changing light globes in off-track sections of tourist caves or repeatedly visiting sensitive sites to monitor impacts will generate their own impacts.

Soils

It is appropriate that. examples of different soil types and catenas (soil groupings that are typically found in certain topographical conditions) are given protective management as important elements of geodiversity. But soils are also essential to the functioning of most natural systems in protected areas, from plant communities to the herbivores that graze upon them and the karst cave systems that may be dissolved from the rock beneath them by water that has become acidified while percolating through soil.

Soils may be damaged by direct impacts, such as quarrying or infrastructure development. They may become subject to unnatural erosion resulting from disturbance to vegetation that allows running water or wind to remove soil particles. Soils may be compacted or their profiles inverted due to the passage of inappropriate vehicles, with long-lasting damage particularly evident in permafrost environments when traffic is allowed on the seasonally thawed uppermost horizons during summer. Soils may be polluted or contaminated due to direct application of chemicals or atmospheric fallout of industrial pollutants or vehicle emissions. Soil nutrients are volatilized during fires and can be removed with the highly erodible ash fraction that remains. Hence, management of these pressures is fundamental and may require regulation of activities, strategies to maintain ground cover and construction to

Table 16.2 Examples of soil management actions

Management goal	Possible management actions
To control soil erosion	Regulate activities that can cause soil erosion, including overuse of visitor destinations, illegal four-wheel-drive activities and excessive use of horses.
	Manage for a minimum suitable natural ground cover.
	Take steps to control soil erosion, where necessary, including re-vegetation of disturbed areas and 'roll-over' drains for management access tracks.
To minimize the impacts of introduced soil pathogens	Clean earth-moving plant and equipment prior to entry into protected areas.
	Use, if necessary, pathogen treatment solutions for plant and equipment prior to their use in protected areas.
	Provide boot-cleaning stations for hikers at trailheads to reduce the artificial spread of soil pathogens such as cinnamon fungus – this method is used in protected areas in South-Western Australia (Barrett and Gillen, 1997).
To minimize the impacts of soil compaction	Confine plant and equipment to defined routes.
	Use alternative transport techniques, such as helicopters, to eliminate the use of vehicles in areas prone to soil disturbance.
	Use elevated walkways for areas of intensive visitor use to prevent soil disturbance.
To minimize the impacts of trace elements	Many trace elements such as zinc are highly toxic to plants and animals when leached into soils – galvanized and similar products must be used with care and knowledge.
To minimize the impacts of introduced seeds	Use clean earth-moving equipment in natural areas.
	Use only clean (weed-seed free) soil, gravel or hay mulch.

Source: adapted from Worboys et al (2005)

address problems in areas subject to damage. The latter can involve improvements to drainage or construction of elevated walkways. Materials used for construction may need to be chosen with care to reduce the risks of toxic effects, such as those associated with some products that contain zinc. Treatment of equipment to reduce the risks of transferring soil pathogens is an important consideration. Some of the major soil management actions are summarized in Table 16.2.

Managing fire

Determining what is appropriately regarded as a natural fire regime can be difficult (see Case Study 16.1). In 'natural' landscapes, fires tend towards particular regimes (patterns of frequency, intensity and seasonality), controlled largely by rates of fuel accumulation since the last fire, and temporal patterns in both fuel moistness and natural ignition incidences. These regimes vary from the almost total absence of fire, as in most areas covered with evergreen rainforest, to annual burning, as in many grasslands. The most worrying fire regimes for managers are ones of intermediate frequency. If fires occur annually or biannually, as they do in savannas in the wet/dry tropics, they are regarded as much a part of the normal environment as the wet and lightning seasons. If there is little evidence of fire anywhere, as in the rainforests of the Peruvian Yungas, managers do not perceive fire as a major concern. However, if fires tend to occur at intervals of decades, they are perceived as highly destructive events, often invoking in managers a desire to reduce the hazard.

The controls on the incidence and severity of fire in natural ecosystems are well understood.

Fire requires fuel. This is potentially any dead organic material smaller in diameter than the little finger of a medium-sized human being. Once the dead material ignites, green material of the same size range may also burn. However, vegetation that is all green is unlikely to burn because of its high moisture content. Similarly, dead organic material needs to be relatively dry before it will support flames. Thus, past and present weather conditions are critical in determining whether a fire will ignite and carry at any one time. If the soil is moist at its surface, dead fuel on the ground is also likely to be moist.

Given that the weather is uncontrollable, fuel moistness is also uncontrollable. However, managers can control fuel levels by planned burning. Alternatively, managers may decide that the best way to prevent extensive and severe unplanned fires is to prevent those ignitions that can be prevented, and to suppress the ones that cannot be prevented as soon as possible after ignition. Neither of these approaches has been widely successful in preventing the severe and extensive unplanned fires that can occur in extreme weather conditions.

When applied in close proximity, fuel reduction has proven to be successful in protecting fire-susceptible assets in extreme fire weather conditions, but only if the assets themselves are not in a highly flammable state. Broad acre hazard-reduction burning may create relatively safe places from which to back-burn, and may prevent crown fires; but, except for a very short time after the planned burn, it cannot prevent the spread of fire in extreme weather conditions. Some recent modelling studies indicate that huge areas would have to be hazard-reduction burned each year even to have any effect on the average size of all unplanned fires.

On top of its ineffectuality in preventing the spread of the severest of fires, broad acre hazard-reduction burning may also prevent a transition from highly flammable vegetation to less flammable vegetation. For example, in New Zealand, introduced gorse (*Ulex europaeus*) forms highly flammable thickets that act as a nurse crop for some native rainforest trees. If the fire hazard presented by gorse is kept temporarily low by burning, the gorse survives, but the rainforest species do not. If the vegetation is left unburned, the rainforest trees eventually shade out the gorse, and the understorey becomes largely bare, with rapidly decaying litter that is usually too moist to support fire.

Fire suppression is a difficult option. In many parts of the world there is a culture of fire lighting that may take a generation to change. It is impossible to rapidly change the culture of pathological fire lighters, who tend to light fires in the severest of conditions. Lightning storms tend to light many fires at once, stretching suppression resources. In severe weather conditions, fires must be accessed extremely quickly, as they rapidly become unstoppable by all but weather change. In less severe weather conditions, successful suppression means that vegetation remains unburned that could have been burned, thereby increasing fuel loads and, thus, the potential severity of a future fire. The general outcome of suppression strategies has been a reduction in the frequency of fire, but an increase in fire severity and fire size, creating the very problem that they were designed to avoid. A second negative outcome, wherever managers have access to heavy machinery when fighting fires, has been the creation of mazes of bulldozer-cut tracks. These are destructive of nature in themselves, a major cause of sedimentation of streams and caves, and they improve access for exotic plants, animals and pathogens to previously undisturbed ecosystems.

Given the above, we conclude that, except directly around specific assets, both fuel-reduction burning and fire suppression are likely to be counterproductive strategies in protected area management. However, there are a large number of examples of inappropriate fire regimes within protected areas leading to the gradual decline to extinction of vegetation types and species of conservation significance, and fire is one of the tools available to repel the invasion of some exotic organisms.

Why, if fire regimes are as natural as rain, do we require burning of parts of protected areas for conservation purposes? Most of the terrestrial natural vegetation of the Earth has not only been ignited by natural causes, such as lightning, but also by people, who have thereby influenced biotic patterns over most of the 10,000 years of present climatic conditions. A lack of traditional burning would not be so much of a problem for nature conservation if natural vegetation still covered most of the planet. After all, almost all of the species on the planet are likely to have been present before human beings evolved. However, protected areas increasingly tend to be islands of natural vegetation in seas of cultural vegetation. Your reserve may be smaller than the pre-agricultural size of individual fires, and less likely to burn at this size than as a part of an unbroken expanse of natural vegetation; yet, fire is still needed for ecosystem survival and functioning, and unburned areas within your reserve are necessary as sources of disseminules (reproductive plant parts, such as seeds or spores, that facilitate dispersal) of the species that recolonize burns through wind dispersal.

There are few protected areas in the world that have not been changed by the biotic diaspora associated with the European invasions and the development of modern trade networks. Exotic organisms have both caused the extinction of native organisms and become components of the naturalized biota. The presence of exotic organisms in a protected area and the absence of native organisms previously present can both require variations from the natural, or pre-industrial, fire regimes. For example, the sweet pittosporum (*Pittosporum undulatum*) is an Australian rainforest tree that has invaded many other parts of the temperate and tropical world. As an individual, it is easily killed by fire; but if left unburned, it will form a closed community resistant to the ingress of flames.

All forms of planning for nature conservation management require clear objectives. In fire management these should relate to asset protection and the maintenance of conservation-significant environmental diversity.

Assets can be elements of geodiversity, biodiversity or cultural heritage of conservation significance that could be severely damaged, or destroyed, by a single fire, or too frequent fire, or they may be artefacts such as park infrastructure. It should not be assumed that protective action is needed for all natural phenomena. In most cases, the fire-susceptible natural phenomena survive in protected areas because they are protected by their locations (such as in deep rocky gorges) or by their inherent qualities (such as non-flammable foliage and very low ground-fuel levels).

The situations in which protective action is needed to maintain natural phenomena are generally those in which the probabilities of ignition and spread have been increased by improved vehicle access, or an increased use of fire for land management upwind of the reserve, or a decreased use of fire in upwind vegetation, leading to high fuel accumulations. In some cases, disturbances by introduced animals, such as cattle, may make forest edges more flammable than they otherwise would have been. In other cases, invasive introduced plants may be more flammable and have greater biomass than the native species.

Protective actions for assets do not necessarily have to be the establishment of a low fuel zone around its margin. In the examples given above, restrictions on land use upwind of the reserve, the removal of cattle, and herbicide application to the exotic plant could provide protection. Of course, each of these alternatives has their own hazards, which need to be assessed. If low fuel zones are to be established, they do not need to be wide. They also do not need to be bare or involve the removal of all trees. Mowing beneath trees, or in open vegetation, is an effective option to create a low fuel zone in many areas. Wet season burning can eliminate highly flammable annual grasses from the ground layer in monsoon forests and woodlands, providing adequate protection for built assets.

Planned burning for the purpose of maintaining elements of nature requires an understanding of the fire responses of these elements. In planning ecological burns, it should be understood that planned burns are unlikely to eliminate unplanned burns, so a planned fire regime needs to be a response to an inadequate number or type of unplanned fires. It is very difficult for planned burns to simulate some fire regimes, such as the fires that regenerate Californian redwood (*Sequoia sempervirens*) forests, because the intensity of the planned fire would have to be such that escape and damage would almost be guaranteed. We have to leave regeneration burns in such situations to chance. Planned fires in less demanding vegetation tend to be low intensity and patchy, although the patterning of ignition can be used to create local hotspots, if needed. Managers also tend to demand relatively secure boundaries. Ideally, these should be recently burned areas of the same vegetation type, streams and other water bodies, or the boundary of the burned vegetation type with other less flammable vegetation types.

If a particular vegetation type needs to be 'planned burned' in order to maintain a favoured species or community, it is important that not all the vegetation type in any particular protected area is burned at once as the nature of post-fire vegetation succession is known to be affected by the particular climatic conditions that prevail after any fire, as well as the distance of the burned area from sources of wind-dispersed obligate-seeder species. Many plants, fungi, invertebrates and vertebrates are dependent upon particular successional stages after fire. Unless all stages are present in a reserve, there is a danger of losing some of these species.

There are general rules for safe and effective planned burning. Burning should only occur when fuel dryness and wind conditions are (and are likely to continue to be) in the appropriate window for the vegetation type at its present fuel load, and only after a test fire. Burning is ideally conducted in late afternoon so that increased relative humidity at night can help to prevent escapes. The fire needs to be ignited into the wind and/or downhill to mitigate the chances of it leaping the leeward boundary. However, the specifics of prescriptions for safe fire lighting vary enormously between vegetation types and environments. Laws related to fire vary enormously between jurisdictions. Managers need to obtain or develop the appropriate specific prescriptions for their land and follow their local laws and regulations.

Managing weeds and introduced pathogens

Weeds are plants that we do not want, commonly because they are perceived to be a threat to native species. They may also impinge on the character of landforms, as in the case of marram grass (*Ammophila arenaria*), which usually fosters a dune morphology quite different from that which results from sand trapping by native grasses in places where it has been introduced. In protected areas, most weeds are species that have recently invaded from other continents, or other regions on the home continent, usually through the agency of our species. In some protected areas, such as many of those in continental alpine areas, there are few or no weeds, and weed management is not a major issue. In others, such as those on remote oceanic islands, weeds can be a major management issue.

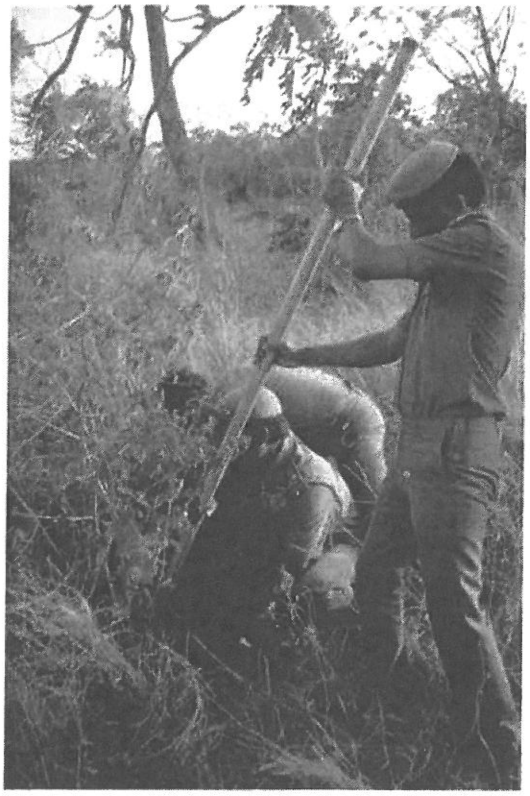
Most weeds are ruderals (short-lived plants that colonize disturbed areas). However, a subset of weed species can establish in undisturbed native vegetation. Another subset can establish in response to natural disturbances and be far from short lived. The weeds that most threaten nature conservation values are those that have adaptations for long-distance dispersal, usually by wind, birds or water, and also fall in one of the latter two subsets.

Newly introduced weeds have a period of grace within which they are relatively free of damage from herbivores and diseases. In most cases, local animals and diseases, or other introductions, eventually make use of them. By this time the weed may be widespread and abundant. In some cases, the weed may even have become an important resource for some native animals. This needs to be taken into account in any weed management planning.

Prevention is better than cure

Quarantine measures are never going to be effective at a national level while trade and tourism are regarded as more important than nature conservation and primary industry. Accidental introductions are unavoidable in this situation. Quarantine should be able to prevent most deliberate introductions. However, plants present particular difficulties in import screening of ornamentals and crops – it has proven impossible to reliably predict which species might be dangerous invaders. The best tactic seems to be extreme caution.

Within any particular protected area, quarantine can be effective for many weed species. The disseminules of a large proportion of weed species



Removing weeds, Gir National Park, India

Source: IUCN Photo Library © Jim Thorsell

can be spread in building and road materials, and in mud and dirt adhering to machinery and vehicles. This is a strong argument for minimizing road and building construction within protected areas, cleaning vehicles and machinery before entry, and sterilizing construction and road materials. It is dangerous to bring in pot plants, even if grown from local seed or cuttings, in case this becomes the source of an infestation. Protected area managers need to consider if concessionaires and leaseholders should be allowed to plant ornamentals in their ski villages and around their 'ecotourism' resorts.

Determining priorities for weed control

Once introduced to a new region, a plant that is going to become invasive necessarily takes some time to attain this state, if only through the shape of its exponential population growth curve. A new weed in your protected area should therefore be subject to precautionary extirpation as the highest priority in your weed management programme.

Weeds that should *not* be removed are those that are important for maintaining populations of some of the most significant species and that present little danger to other significant park assets. These are generally introduced species that have become well integrated within the ecosystem and provide food resources or shelter no longer available from native plants because the relevant native plants have been eliminated.

There seems little point in expending scarce resources to remove weeds that do not threaten the future of any element of biodiversity or geodiversity in your protected area. There are some introduced plants that have been around so long that they occur in low numbers everywhere in suitable habitat dominated by natives and do not appear to suppress native species richness. Many of these species would be impossible to eliminate from even very small areas without destroying the intermixed natives or causing damage to other assets.

The highest priority in weed control, after the new invaders, should be given to species that threaten biodiversity and geodiversity. Among these, weed species that are still in a state of expansion and those that can be most cheaply eliminated should have highest priority; but all should be controlled to the degree necessary to maintain or improve the critical conservation values. There are relatively few such damaging weeds that can be permanently eliminated from large areas. Control, rather than elimination, is usually the aim of action.

Options for weed control

Techniques for dealing with weeds include biological control, herbicide sprays, cutting, slashing, replanting with native species, controlled burns to selectively target weed seedlings, and hand clearing. An effective combination is to remove weeds and then replant with vigorous native species to prevent reinvasion.

Herbicides. Herbicide application is a widely used approach to controlling agricultural weeds and is also employed in protected areas, particularly on species that have clumped or localized distributions. This management option is usually expensive. Where a decision is made to employ herbicides, particular care is required in planning and implementation to minimize damage to non-target species, including aquatic species and soil biota.

Over-planting. Small areas with dense infestations of weeds can be difficult to convert back to native vegetation unless the natives can be used to shade them out or to steal the resources they need for growth. Local soil, seed and cuttings should be used for propagation to avoid the introduction of new weeds and pathogens.

Hand weeding can be highly effective with scattered weeds among predominantly native vegetation. This requires weeds that can be relatively easily killed using hand tools and cheap or voluntary labour. Native litter placed on disturbed ground encourages native regeneration.

Grazing or burning, or grazing and burning, can be used to control some weeds. The combination of burning, followed by grazing, can be more effective than either one of the methods used in isolation.

Mechanical removal may work for some weeds in very limited areas with good access. Steam treatment can be highly effective, but can only take place near roads, as with most mechanical techniques.

Introduction of new organisms for biological control is initially a highly expensive option if the proper controls on introductions are followed, and has a low success rate.

Engage with the community. The source of your weed problem may be the nursery in the nearby settlement that is selling your weed. You may need to talk with the local community to remove weed species from nurseries and gardens.

Weed control should be part of a protected area management plan, with actions taking into consideration the biology of the weed species involved (see Case Study 16.3).

Managing introduced plant pathogens

Plant pathogens are fungi, bacteria, viruses or prions that kill or damage plants. Like weeds, these have transgressed the boundaries or biotic realms and regions – in this case, with largely unconscious human help. Once introduced, they are almost impossible to eliminate as their symptoms usually postdate their presence. Their rate of spread can be slowed through strict quarantine measures; but it is difficult to impose these measures and to get all to conform to them. It seems that some plant species will depend upon cultivation in pathogen-free settings for their future on the planet.

In the hope that local populations of susceptible species will evolve resistant genotypes if the spread of the pathogen is slowed sufficiently, managers should be aware of the symptoms of

Case Study 16.3

Management of two invading woody plants in the Everglades, Florida, US

The Everglades National Park in Florida consists of an extensive complex of wetlands and pine barrens and is closely adjacent to intensively developed areas. Two major woody weeds that have invaded the park are the Brazilian pepper (*Schinus terebinthifolius*) and the Australian paperbark (*Melaleuca quinquenervia*). A first stage in managing the populations of any weed is understanding its ecology and distribution. With Brazilian pepper, it has proven possible to detect dense populations using hyperspectral imagery, but not possible to use such imagery to locate isolated trees (Lass and Prather, 2004). This species has been shown to prefer human-disturbed sites with relatively high phosphorus levels (Li and Norland, 2001). At one such disturbed site within the Everglades National Park, 4000ha of abandoned agricultural land, which had been subjected to break-up of the limestone layer and fertilizer additions, complete soil removal proved necessary to prevent the reinvasion of the species and to enable its replacement with native wetland plants (Dalrymple et al, 2003). The paperbark is a wetland species, pre-adapted to Florida's conditions. It has proven so invasive, totally displacing native plants, that a biological control, *Oxyops vitiosa*, was introduced to chew on developing new season foliage. This it has done, with the surprising outcome of no less foliage, but 36 times less reproduction (Pratt et al, 2005).

various introduced pathogens. For example, the cinnamon fungus (*Phytophthora cinnamomi*) preferentially attacks certain shrub species, but has little effect on sedges or grasses, so can easily be deduced to be present. Diversion of tracks and area closures may slow down the spread of root pathogens, such as the cinnamon fungus, from spot infestations.

Managing animals

The conservation of vertebrate animal species has been the major reason for the establishment of a large proportion of the protected areas of the world. Yet, most of the individual animals and species of animals in protected areas are invertebrates. Invertebrates play a critical role in ecosystem functioning, with the survival of particular invertebrate species often being critical for the survival of plant and vertebrate species, and are important to conserve for themselves as major elements of biodiversity.

While there is some argument over whether predators normally have much of an influence on the populations of their natural prey, there is little doubt that herbivores can have substantial influence on the nature of vegetation, and that introduced predators can cause extinctions of their new prey, as with the extinction of rails (family *Rallidae*) on Pacific Ocean islands with the introduction of the Polynesian rat (*Rattus exulans*). Different animals have different tastes in foodstuffs, creating the possibility of manipulating the ecosystem to favour the most conservation-significant elements of biodiversity and geodiversity by varying the populations of particular animals. To serve this end, translocation, induced reduction of existing populations and induced increase of existing populations are options.

Translocation

The translocation of vertebrate carnivores can be used to reduce populations of species that threaten other species. For example, canines prey on the young of the fox (*Vulpes vulpes*), a species that threatens medium-sized native mammals.

Translocated herbivores can eliminate invasive non-native plants, promote diversity in native vegetation and prevent tree thickening. For example, the loss of elephants from the savanna system is likely to lead to tree thickening, given their role in tree destruction. The introduction of diseases and their vectors can be effective in nature conservation, as with the introduction of a flea to transport *Myxomatosis* between rabbits on sub-Antarctic Macquarie Island.

Animal welfare considerations have induced some research organizations to seek novel diseases to induce sterility in target populations without killing them. This is highly dangerous research that should be discontinued. The animal that is an ecologic and economic disaster in some countries is a precious native in others, and humans have not been particularly effective in stopping diseases transgressing national boundaries.

Translocation is an extreme form of manipulation, to be undertaken only after thorough research and deliberation. Conservation goals will usually be better achieved through management measures that adjust the sizes of populations of species already present in reserves, rather than introducing new ones.

Adjusting animal population downwards

Large vertebrate animals that inhabit open country can be efficiently and specifically culled by shooting either from helicopters or on the ground. The Judas technique is often effective in locating groups of social animals such as goats in country unsuitable for shooting from helicopters. A member of the species is captured and released with a radio transmitter attached. They find a herd, which is subsequently conveniently located and dispatched. Shooting is undertaken by rangers in many protected areas, and in others licensed or authorized shooters may be involved in culling operations (see Case Study 16.4).

Poisoning has the disadvantage that it tends to be less species specific than shooting in its lethal outcomes, with secondary poisoning and biological accumulation being typical problems. However, poisons can kill animals that are impossible to control by shooting. Successful poisoning of an undesirable animal must affect its population more than that of its competitors and prey. This can be achieved by the use of chemicals that induce a higher mortality in the target animal than in others, as is the case with 1080 poison in Western Australia, where the native

Case Study 16.4

Elimination of cats on the sub-Antarctic Marion Island, South Africa

The introduction of cats (*Felis catus*) by human beings has been thought to have caused the extinction of large numbers of species, these extinctions having been concentrated on islands. Feral cat elimination attempts have been successful on at least 48 islands, ranging from Baja California to the tropics, to the sub-Antarctic. The success rate has been greater on small than on large islands. The largest island from which cats have been eliminated is Marion, a 290 square kilometre sub-Antarctic island belonging to the Republic of South Africa. The elimination was the result of a 19-year programme, the first stage of which was research on the impacts of cats and the characteristics of the cat population. This was followed by the development of a management policy and the selection of methods of control. The feline panleucopaenia virus was released in 1977 and its effects were monitored. This proved an insufficient measure by itself, so a second method of control, hunting at night, was trialled, then fully implemented, while its effects and that of the disease continued to be monitored. The combined effects of these two control measures proved insufficient for elimination of the species. In a final assault, trapping and poisoning were used. By 1991, no cats survived on Marion Island.

Sources: adapted from Bester et al (2002) and Nogales et al (2004)

animals are adapted to the active ingredient, which occurs in local plants, while introduced animals are not. Alternatively, the form of presentation or application of the bait can be used to eliminate or minimize mortality in non-target species.

Adjusting animal populations upwards

Managers may wish to increase the populations of particular animal species as part of recovery from endangerment, or to achieve a particular management purpose, such as the control of a weed species. The key to increasing the population of any animal species is the recognition and correction of the factor or factors that limit an increase in numbers. These may operate to limit fecundity, as with DDT-induced thinning of bird shells, or relate to mortality in the juvenile or later stages of life, as with long-line kills of female albatrosses. There may be particular temporal pinch points that control the overall population, such as the amount of food available in a particular season or the number of nest sites available in spring. The population may succumb to diseases at particular population densities or be subject to increased predation once more readily available as a food source in an environment. Population regulation is sometimes complex and its causes are not always easily determinable, as may be seen in the account of the Gould's petrel (*Pterodroma leucoptera*), an endangered species found nesting on small coastal islands off the Australian state of New South Wales (see Case Study 16.5).

Animals have been threatened by infrastructure within reserves. Vehicles are a major cause of mortality of threatened species, although large windows in visitor centres present their own dangers for birds. Sewerage ponds seem to be more of a resource for water birds and animals than a threat. Poorly designed gates installed to secure sensitive caves have, in some cases, proven disastrous for bat populations through restricting nocturnal flights for feeding and the return of this energy to cave ecosystems as guano – a situation that potentially raises the risks of insect predation for park vegetation or local croplands.

The best option to solve these problems is to withdraw tourist traffic and/or infrastructure to sites outside the protected area. Where this option is not possible, traffic can be slowed within reserves through the use of 'speed humps' and avoiding long straights. Animal overpasses and underpasses can lower mortality but, in most cases, need to be combined with barrier fencing to be effective and are highly expensive.

Many threatened species have their populations limited by predation from other animals, usually, but not always, by introduced species. The solution lies in reducing the numbers of the

Case Study 16.5

Recovery of an endangered species: Gould's petrel

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The Gould's petrel is Australia's rarest endemic sea bird. The only place it breeds in the world is on two small islands at the entrance to Port Stephens, New South Wales. The vast majority of the birds nest in rock cavities on the rugged rainforest-covered slopes of Cabbage Tree Island, and a dozen or so pairs nest on nearby Boondelbah Island.

The first comprehensive census of the Gould's petrel was undertaken in 1982. The initial survey revealed some disturbing facts. Fewer than 300 pairs nested, and breeding success was drastically low (less than 20 per cent). Surveys repeated in each of the subsequent two years yielded similar results. It was also found that the population had declined by more than 25 per cent during the past two decades. The causes of the species' demise were poorly understood.

A research project was initiated to identify the causes responsible for reproductive failure. As expected, the rate of nest failure was exceptionally high. More alarmingly, however, was the discovery that nesting adults were dying in relatively large numbers. Many petrels perished after becoming entangled in the sticky fruits of the birdlime tree (*Pisonia umbellifera*). The most prevalent cause of mortality, however, was predation by pied currawongs (*Strepera graculina*) and, occasionally, Australian ravens (*Corvus coronoides*). These predators would kill both chicks and nesting adults to feed their own developing young.

Experimental recovery actions were implemented immediately before the 1993 to 1994 breeding season. Poisoning destroyed birdlime trees within the breeding grounds of the Gould's petrel. Follow-up measures prevented new plants establishing from seed. Shooting reduced pied currawong numbers. Their nests were located and destroyed, along with any eggs and young. Ongoing monitoring of the petrel population revealed an immediate rise in the number of petrels incubating eggs and a marked improvement in breeding success. The culmination of these factors was a fourfold increase in fledgling production. Breeding success now regularly exceeds 55 per cent, and in most years more than 300 young fledge (see Figure 16.1).

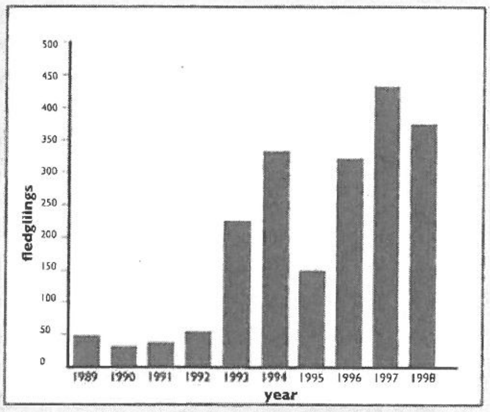

Figure 16.1 Number of Gould's petrel fledglings produced on Cabbage Tree Island, New South Wales, for ten seasons, 1989–1998 (years refer to commencement of breeding season)

Clearly, the threats posed by the birdlime tree, pied currawong and Australian raven were able to be ameliorated by appropriate management intervention. The question remained, however, as to why these unusual threats arose, particularly on an island essentially remote from the influences of people. The answer lay in the changes to the vegetation wrought by rabbits since their introduction to Cabbage Tree Island in 1906.

The Gould's petrel breeds in two deep rainforest-covered gullies on the western slopes of Cabbage Tree Island. Rabbits had destroyed much of the rainforest understorey. Without adequate concealment, nesting petrels have been exposed to predators. The sparseness of vegetative cover also makes the petrels more vulnerable to entanglement in the fruits of the birdlime tree. An intact understorey captures many of these fruits before they fall to the ground. Fruits caught up in vegetation pose little or no threat to petrels moving about the forest floor.

It was considered that the requirement for long-term control of pied currawongs could be eliminated if rabbits were eradicated and the understorey given the opportunity to re-establish. Rabbits were successfully eradicated. The procedure involved the sequential use of three mortality agents: *Myxomatosis*, rabbit calicivirus and poisoning. Significant changes in the vegetation of Cabbage Tree Island were evident within just weeks of the last rabbit being removed. Before implementing recovery actions, fewer than 50 young fledged each year. During the late 1990s, reproductive output had risen to 300 young per annum. Following this success, an attempt to establish a second viable colony on Boondelbah Island was initiated and 100 nest boxes were established there between 1999 and 2000. Two hundred chicks were transferred and all but five successfully fledged, with some returning to breed. In 2002 to 2003, 12 nest boxes were occupied and five eggs were laid. Surveys in 2001 to 2002 found that, in total, there were 1000 birds breeding with 450 young being produced per annum (NSW NPWS, 2003).

threatening species. This has been highly successful in recovering threatened bird species in New Zealand, where predators have been eliminated from small islands to which the species have been translocated.

A species may be declining because a successional stage in the vegetation is in decline. This is relatively easily reversed if the species depends upon early successional stages, but is less easily reversed if it depends upon old growth. In this case, there may be some chance of increasing the numbers of the species if the resource that it depends upon in old growth can be replaced artificially, as with nest boxes that substitute for nesting hollows.

Managing the impact of people on natural environments

Some people maltreat protected areas or see them as an opportunity to make a living at the expense of their natural values (threats to protected areas from human activities, such as pollution, are considered in Chapter 9). Others can love protected areas to death through:

- defoliation and erosion of camping areas;
- trampling and vehicle impacts;
- polluting with their wastes;
- unconsciously introducing pathogens, weeds and pests;
- disturbing animals through misplaced kindness or accident; or
- accidentally starting fires.

Critical concepts in understanding when and where people need to be managed are resistance and resilience. For example, a vegetation type is highly *resistant* if the act of a large number of people walking on it does not cause its death. The vegetation type is *resilient* if death is caused, but recovery is rapid. Different degrees of resistance and resilience interact to determine how much human pressure of any type can be placed on an ecosystem before it collapses, irreversibly, into another less desirable state. These concepts have been used by managers for many purposes, such as locating tracks, determining the need for toilets at camping areas and assessing the need for access restrictions.

When does a human-induced change become unacceptable? This is a critical question in the management of natural values. The worst type of threshold to set is a proportional one. Proportions are essentially arbitrary, so are easily shifted as a result of political pressure. For example, if a threshold was that the natural vegetation cover be removed from no more than 1 per cent of a protected area, and a new ecotourism resort proposal came up that would take removal to 1.02 per cent, the threshold may be shifted to 1.025 per cent and those who objected would be mocked. The best types of thresholds are 'no' ones that relate to the values for which the protected area is most significant: for example: 'providing tourist facilities should cause no irreversible changes to landforms and soils at the century time scale'.

Options for mitigating trampling damage

There are basically three options to prevent trampling causing irreversible and expanding damage to ecosystems and aesthetic naturalness:

1. reducing the number of tramplers to carrying capacity (politically difficult);
2. restricting tramplers to small hardened lines (can be immensely expensive); and
3. separating tramplers from the natural (can be immensely expensive).

Rationing can take place by privilege, booking, cost or lottery, or some combination. All of these techniques have been used to control access to back country in the US and elsewhere. Alternatively, removing tracks from maps, obscuring track entrances and periodic closures are all potential approaches.

Management costs can be minimized by not bothering too much about easily reversible damage, like that in some boggy areas, where the discomfort might prevent people going further. However, the cheapest option is not necessarily the best in the long term – some of the more expensive forms of track and campsite construction, such as stone steps, not only blend in better with their surroundings than cheaper forms, such as boardwalks and wooden camp platforms, but also last much longer, with lower maintenance costs.

Options for preventing the introduction or spread of new organisms by users of protected areas

Codes of practice are one mechanism that has been used to mitigate the undesirable effects of park users. They can be effective in reducing reversible or gradually incremental damage. However, they are of little use for preventing the unwitting introduction of new organisms because they are never universally adopted among users, and it takes only one introduction to establish a potentially damaging organism in a new place. For hygiene to be effective, it must be compulsory and policed. Vehicles, camping equipment, clothes and boots must be cleaned, requiring easily used cleaning stations outside the protected area, or within the protected area when leaving an infested or infected area. This is very expensive. Prevention of access to those parts of a protected area from which a disease could be spread by people is an alternative. However, to be effective, such quarantining requires a high level of policing or unanimous social support.

Options to reduce disturbance of animals

Recognizing the high likelihood that the feeding of animals within protected areas will result in harm to people, animals or ecosystems, most jurisdictions ban, or highly regulate, this activity. Nonetheless, people are still injured or killed as a result of illegal feeding, prompting the shooting or translocation of the most aggressive individuals of potentially lethal species. Access to areas important for the breeding of animals is often also regulated in order to ensure that people are not there at times of the year when their presence could cause high levels of mortality, or, if present, do not disturb the animals.

Managing the natural aesthetic resource

The natural aesthetic resource incorporates the smell, sound, touch, taste, spirituality and view of natural phenomena and natural landscapes. The beauty of wild landscapes has long been a prime motivation for establishing protected areas. Beauty is, of course, in the eye of the beholder, and beholders are well known to vary in their perceptions. Most early national parks contained a juxtaposition of water and steep land, characteristics still dominant in the wild land art of most contemporary cultures. There also seems to be a high degree of cross-cultural constancy in the perception that a view of water from an open glade, through a partial vegetation screen, is to be desired, as it would have been in East Africa in the early days of our species. However, those who live on plains tend to appreciate their natural beauty as much as those who live in mountains appreciate the splendour of their habitat. We grow into landscapes by living in them and perceive a beauty, that may be unfelt by others, in familiar natural objects and scenes. Conversely, visual contrasts to familiar landscapes may be the major attraction for visitors to natural areas, such as the stunning limestone towers of the Ha Long Bay World Heritage Area in Viet Nam. City dwellers may be drawn to natural areas largely by the visual contrast with their normal habitat.

Management options to maintain or increase the natural aesthetic resource

It is impossible to avoid all negative impacts on the natural aesthetic resource if infrastructure and facilities are built within protected areas. The best option is not to build within them; but if developers are too powerful to resist, it may be possible to persuade them to spend a little extra money on disguise, or, at least, to have disguise as a design criterion. Disguise should relate to all of the senses. The aesthetic experience at the lookout may be visually outstanding; but if music can be heard and cooking food smelled, the feeling of being at one with the beauty of nature may evaporate.

The normal approach to natural aesthetic value management is highly utilitarian – the greatest scenic good for the greatest number. Trees are carefully culled in front of the lookout to leave the ones that hide the atomic power station in the valley below; roads are located to minimize views of scenic disruptions; visitor centres and car parks are built to blend into their surroundings. Quietness and solitude, as important components of the natural aesthetic experience, tend to be ignored, as does the need to preclude artificial light at night. If visitors want the full natural aesthetic experience, they must escape from roads, visitor centres and lookouts to more natural places, more remote from mechanized access and intrusive interpretation. Low standards of aesthetic management may still permit momentary gratification of visitors whose more lasting passions may lie elsewhere, but disappoint, disenfranchise and disillusion those with higher standards who are potentially the most committed and effective advocates for your reserve.

If one adopts the position that the natural aesthetic resource is independent of the number of people who might experience it in any one place, or that it is inversely related to this number, it is possible to quantify its potential loss from any development within or outside a protected area. Viewfields can be analysed. The greater the proportion of the viewfield that is occupied by human disturbance and artefacts, the lesser the natural aesthetic experience. If these variables are measured, then it is easy to calculate their relative losses from alternative development plans, inside or outside protected areas, or, alternatively, to measure the potential gains from road closure and rehabilitation (Kirkpatrick and Haney, 1980).

Managing remoteness

Remoteness of an area from human disturbance is an important consideration in terms of the potential for natural phenomena, such as functioning natural systems, to both persist in an undisturbed condition, and to impart a sense of the wildly primeval environment from which we have come as a species. The concept of wilderness is a Western cultural construct that may sometimes include pre-agricultural humanity as part of the natural landscape, but which excludes the artefacts of agricultural, industrial and post-industrial societies as elements of naturalness. The fact that some people find the concept offensive because they take it, often incorrectly, to imply that they or their ancestors did not use and influence land now designated as wilderness, does not reduce its usefulness in managing naturalness.

A useful indicator of remoteness is the time it takes a walker to reach a given area from the nearest point of mechanized access. However, care is required in the use of such measures. For some people, a mere four hours' walking or canoeing may be sufficient for them to need to spend the night sleeping among nature, an exciting prospect in protected areas with crocodiles, lions or grizzly bears, and a potentially spiritual experience in less megafauna-blessed areas. Others require greater time distances in order to be motivated to camp in the wild. If assessment is not based on faster, more capable walkers, then those people most committed to wilderness and its protection may find no wilderness in your putative wilderness zone. The absolute distance from human disturbances can also be measured. This relates to the dissipation of unnatural sounds and smells, and to the feeling of remoteness experienced by people, although again people differ in their perception of what constitutes an adequate distance to imply wilderness.

Restoration and rehabilitation

In 'damage control', protected area managers inevitably find themselves involved in efforts to restore the natural environment to something resembling a known past condition by:

- eliminating detrimental processes;
- repairing degradation;
- removing introduced species; or
- re-introducing species that have vanished.

A viable, well-handled restoration exercise can have enormous benefits; but a non-viable or poorly handled attempt can be enormously costly in both economic and environmental terms.

From a geomorphological perspective, the potential to restore a damaged site depends upon the nature of the landforms and the processes that formed them. Little damage may have accrued where the features are formed of solid rock. Hence, the solid rock walls that surround the artificial reservoir in Hetch Hetchy Valley, Yosemite National Park, in the US have not suffered due to wave action, but only merely discoloured by a temporary 'bath-tub ring' caused by the death of lichen growing on the rock, making restoration entirely viable. Conversely, where reservoir or riverbanks are formed from unconsolidated soft sediments, waves may cause significant damage to the structure of the perimeter landforms, and reservoir-level fluctuations may induce damaging landslides on surrounding slopes. However, in both situations landforms that are more than a few metres below the reservoir surface will not be eroded by wave action because the short wavelength of wind waves does not allow them to scour a lake bed at depth.

Construction of an artificial facsimile of a destroyed landform does not constitute restoration, which instead involves working with nature to effect recovery. There is no capacity for a damaged landform to heal itself if it is the product of geomorphological processes that no longer operate at the site due to changed climatic conditions, such as a moraine deposited by a glacier during the Pleistocene in an area that is now entirely deglaciated. Conversely, if the processes originally responsible for formation of the landform are still operating at the site, a degree of self-healing *is* possible. Careful assessment of all elements in the landform community is required. And it is infinitely better, and cheaper, not to allow damage to occur in the first place.

Many ecosystems will restore themselves after damage, providing the underlying environmental conditions have not been changed. In most situations in which conditions have been changed, revegetation, with species suited to the new conditions, will occur without any human intervention. Where damage has initiated positive feedback, as with an eroding track, intervention may be necessary to stabilize the substrate before natural recovery can occur. Some forms of human-induced damage can have highly detrimental effects on aesthetic naturalness. In these cases, restoration may take the form of artificial inputs of fertilizers and direct seeding, or planting, of native species.

Management principles

1. Managers need to determine the natural elements and processes that their protected area is most important in protecting, and give management priority to maintaining these elements and processes.
2. It is impossible to manage a damaged protected area back to its 'pristine' landscape, but it is possible to rehabilitate a site so that it recovers some of its natural values.
3. Management decisions should be based on sound science and knowledge, including local traditional knowledge.
4. In most circumstances, changes in management regimes should be experimental, using adaptive management processes, rather than comprehensive.
5. Managing natural heritage in protected areas must go beyond localized phenomena to include functioning natural systems.
6. Protected area managers should seek indicators that signal imminent danger to the important values of their area, and should follow an adaptive approach consistent with emerging threats and management needs.
7. All management interventions should be:
   - consistent with the strategic plan and conservation objectives;
   - based upon knowledge of the distribution of the area's key environmental assets; and
   - monitored to assess their impact on biodiversity and other protected area objectives.
8. Biodiversity conservation and viability of populations of key species often depend upon factors beyond protected area boundaries; therefore, protected areas should be managed as part of wider regions.

Further reading

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