Biological Conservation **18** (1980) 241–255

AFTER PRESERVATION: PHILOSOPHICAL AND PRACTICAL PROBLEMS OF CHANGE†

PETER S. WHITE & SUSAN P. BRATTON

Uplands Field Research Laboratory, Southeast Region Department of Interior, Great Smoky Mountains National Park, Twin Creeks, Gatlinburg, TN 37738, USA

ABSTRACT

Even after land is legally protected, ecological change continues to affect species and ecosystems. Changes vary from natural to human-caused, from beneficial to detrimental, and from manageable to impossible to manage. Management can be approached on two levels: (1) an ecosystem-community ('process-oriented') level and (2) a species-population ('species-oriented') level. Management on these two levels sometimes conflicts. Key changes in reserves include: natural and human disturbance, manipulation of fire regimes, succession, imbalance of animal populations (e.g., elimination of large predators and population fluctuation of grazers), population and genetic change of rare species, introduction of exotics, pollution of air and water, interference with hydrologic regimes, and increased visitor pressure. Man-caused changes and poor management are still the greatest threats to nature reserve systems.

A preservationist 'hands-off' legacy, while idealistic and philosophically attractive, may contribute to lack of firm leadership in reserves by biologists and managers. Because the effects of humans are now omnipresent, some form of management (if only to regulate visitor impact) usually is necessary. Dealing with ecological change requires statement of preservation goals, priorities, and clear policy on key issues; in addition, resource inventory, monitoring, and management-oriented research are required.

INTRODUCTION

The preservation of species and ecosystems begins with the battle to protect the lands on which they occur (Smithsonian Institution, 1975; Nature Conservancy,

† The opinions expressed are those of the authors and should not be taken as statements of United States National Park Service policy.

Biol. Conserv. 0006-3207/80/0018-0241/$02·25 © Applied Science Publishers Ltd, England, 1980
Printed in Great Britain

1975), but legal protection itself does not guarantee continued survival of either species or ecosystems. In a long-term, evolutionary sense, extinction, speciation, and community change are inevitable; much more important to preservationists, however, are the short-term changes due to natural processes and human influence that occur within, and outside, reserve boundaries. The natural world is not static; hence, we must be reconciled to change or attempt to correct, guide, or prevent change. The changes that reserves experience vary from natural (e.g., windfall of senescent trees) to those that are directly human-caused (trail widening); from those that are beneficial (natural disturbances which maintain the open habitats in forested landscapes necessary for light-demanding species) to those that are obviously detrimental (elimination of native species by introduced diseases); from those that are impossible to manage (e.g., landslides) to those that are manageable (e.g., fire). Management, necessary in many situations, nonetheless itself extends human influence in a natural world that preservation seeks ideally to keep free of human influence.

Two paradoxes are apparent: (1) our goal is to preserve systems that must change and (2) managing for preservation itself introduces human influence into natural systems even when its sole purpose is to correct or prevent human-related damage. Human influence, planned or not, direct or subtle, today is unavoidable, even in remote wilderness areas (e.g., the spread of pesticides in wind-blown agricultural dust and the influence of air pollution far from its source). Reserves themselves, by their relative naturalness and increasing scarcity in a developed world, attract visitors. Some form of visitor management, at least, is imperative.

Natural preservation poses philosophical and practical problems. The purpose of this paper is to organise and discuss the major issues, controversies, and dilemmas of nature reserves—those that arise after legal protection is obtained. While no single set of solutions can apply to every situation, it is our conviction that preservationists ought to face these issues as directly as possible and establish firm policy guidelines early in a reserve's history. All too often administrative inertia and lack of clearly-thought-out priorities hinder preservation goals, despite the otherwise good intentions of biologists and managers.

CONSERVATION OR PRESERVATION?

Historically, conservation and preservation in the USA were distinct and partially antagonistic. The former sought wise harvest of natural resources that were being ruthlessly exploited in the early 1900s. Long-term use of renewable resources was seen as economically more rewarding than quick profits and erosion of the resource. Conservationists were motivated by economics and oriented toward a few valuable and 'game' species, or such goals as slowing soil erosion and protection of water supplies.

Preservationists, on the other hand, sought to protect wild lands from any economic use or development. Preservationists did not have specific management goals and usually did not select any single species or resource as more important than others. Natural ecosystems were seen as self-maintaining units that needed only protection from human influence to remain as they were.

The following discussion is directed toward preservation rather than conservation in the historic sense of the terms. Nonetheless, we feel that preservationists must identify resources preserved and that conservation-type management may be necessary to ensure that the protected land functions as a reserve. This compromise of idealistic preservationist goals is unfortunate. Its necessity stems from the artificiality of reserve boundaries, conflicts in reserve resources, and ongoing human influence. The early goals of preservation ought always to be kept in mind, however, and given a choice, preservationists ought always to move with caution and err on the side of naturalness (Owen, 1972). On the other hand, the history of preservationists as guardians only has left us with a certain reluctance to take an active role when resources are deteriorating (see the discussion in Stone (1965) of the contrast between the preservation-oriented National Park Service and the conservation-oriented Forest Service in the USA).

Reserves are established for a variety of reasons or become multiple-purpose as their use increases. Typical motives for preservation are listed in Table 1. When the

TABLE 1
REASONS FOR PRESERVATION

1.	Preserving pristine ecosystems; representative ecosystems; unusual ecosystems; species; geological formations or landforms; historic or archeological sites; watersheds; scenery; islands of naturalness in a developed world
2.	Providing buffer areas, breeding areas, or refuges for species which are exploited in surrounding lands; providing for educational use; scientific research; recreation
3.	Maintaining natural heritage

preservation of different resources is in conflict (e.g., historic or recreational resources versus rare species) a system of priorities must be worked out. Preserving rare species and pristine ecosystems will usually be at the top of the list. There may be cases where even these goals conflict; for example, if human influence must be extended into pristine areas to save a rare species from extinction. Preservationists should be aware of reasons for preservation and priorities if conflicts arise.

AFTER PRESERVATION

Changes occur within reserves because of natural processes and human influence. The most widely reported changes are listed in Table 2. Two kinds of natural change occur in relation to: (1) the dynamics of environment and communities (e.g., succession and natural disturbance) and (2) the dynamics of populations and the genetic structure of populations (e.g., island biogeographical considerations and selection in reserves). Dealing with both kinds is complicated by consideration of reserve size and isolation. The two kinds of change also suggest two levels of management: (1) managing on the ecosystem, community, and natural process level and (2) managing on the species and population level. Species and process management may sometimes be in conflict.

After discussion of natural changes, we will return to human influence in reserves, the greatest threat.

TABLE 2
AGENTS OF CHANGE AND COMMONLY REPORTED PROBLEMS IN RESERVES

Natural dynamics in environment and communities—
1. Natural disturbance eliminates some communities, maintains others, initiates or sets back succession.
2. Successions are ongoing and development of closed communities threatens the existence of species dependent on open habitats.

Natural dynamics in rare species populations—
3. Rare species may be lost from reserves; this danger is related to population size and isolation, species' natural history, and reserve size and isolation.

Human-influenced changes—
4. Top predators have been reduced or eliminated, open habitat in forested communities has been increased. The result is a tendency for larger than normal populations of herbivores and overgrazing or browsing.
5. Elimination of other influential animals (e.g., beaver in areas of eastern US).
6. Introduction of exotic animals, pests, and diseases.
7. Fire suppression has allowed build-up of fire fuels, increased fire danger, and potential loss of fire-dependent species.
8. Air and water pollution, water table changes, control of flooding, river meandering.
9. Visitor pressure, including developments such as roads, trails, campsites.

Natural dynamics of species and communities

Ecosystems are dynamic—always structurally so and often also compositionally fluctuating (Raup, 1941; Watt, 1947; Churchill & Hanson, 1958; Vogl, 1974; Henry & Swan, 1974; White, 1979). Those dynamics are initiated by environmental fluctuation (Ehrlich *et al.* 1972; Albertson & Tomanek, 1965), natural disturbance (Raup, 1941; Churchill & Hanson, 1958; Gómez-Pompa, 1971; Henry & Swan, 1974; Kozlowski & Ahlgren, 1974; Vogl, 1974), species senescence (Foster, 1977), or other intra-community characteristics (Watt, 1947). Successions are initiated in some cases, set back to earlier stages in others (Stout *et al.*, 1975). Species are adapted to temporal pattern as they are to spatial gradients (Pickett, 1976; Austin, 1977). Regional biotic pools are rich in dynamics-dependent species and communities.

For many kinds of temporal pattern there may be no management option—for example, such disturbances as windstorm, ice-storm, frost-heaving of soils, environmental fluctuations, and landslides. In other cases, management may be possible—for example, fire, coastal erosion and deposition, and alluvial erosion, deposition and flooding, though not always desirable. Costly schemes of disturbance suppression have been attempted (Brown, 1961; Mutch, 1970; Johnson *et al.*, 1976; Schroeder *et al.*, 1976) but often result in increased vulnerability to subsequent disturbance. The basic problem of preserving systems that are naturally dynamic has been discussed by Stone (1965), Westhoff (1971), Owen (1972), Smith (1976), and Dolan *et al.* (1978). Management based on intrinsic vegetation dynamics has been proposed for flooding (Franz & Bazzaz, 1977) and fire (Wright, 1974; Kessell, 1976).

Reserves are established either in a state of secondary succession initiated by human influence (e.g., logging, agriculture, stock grazing, and human-set fires) or as natural wilderness areas in which shifting natural disturbance (the disturbance regime) and succession interplay. Reserves may also contain a mixture of these two states. The following are common dilemmas of management of systems in ecological flux.

The clearest situation occurs when a wilderness reserve is large enough to contain a mosaic of community states, such that there is a dynamic equilibrium shifting patches of mature vegetation, successional states, and recently disturbed areas (Heinselman & Wright, 1973; Wright, 1974). Such a system remains stable as long as disturbance regime remains constant in over-all expression. At the other extreme lie cases where reserve size is small relative to disturbance scale and the full range of compositional fluctuations may be experienced locally. An example is the effect of hurricanes and windstorms in a large reserve like Great Smoky Mountains National Park, where severe blowdowns may affect individual watersheds but do not occur parkwide. Almost all the mature timber in Harvard Forest, by contrast, was blown down in a single hurricane in 1938.

In the case of wilderness areas and natural disturbance, the following questions must be answered: (1) Should all natural disturbances be allowed free rein if they conflict with other resources (e.g., if fire threatens a particularly old stand or a rare species)? (2) In cases where succession is eliminating disturbance-dependent species, should natural disturbances be mimicked to maintain such species or should there be an attempt to arrest succession and hold the landscape in a mosaic of static states of varying maturity? (3) Should we re-introduce species lost through local catastrophe? (4) Should we attempt to manage long-term climatic, geologic, or successional trends? Complications involve the spread of disturbances or their effects beyond reserve boundaries (e.g., a natural fire in a reserve threatening neighbouring private lands).

In the case of secondary succession after human impact, choices are also involved: (1) Should there be an attempt to recreate virgin landscape communities (Leopold *et al.* (1963) suggested a return to pre-Columbian states of US National Park vegetation and stasis there; Garcia Dory (1977) suggested re-establishment of native vegetation types after intense human landscape use in Spain)? (2) Should there be an attempt to influence direction and rate of succession? (3) Should preservation maintain anthropogenic or historic states of communities (Green, 1972; Haber, 1973; Lindsay & Bratton, in press, *a* and *b*)? The latter dilemma is particularly important in Europe where man and his grazing animals have long been important in vegetation composition and elimination of these anthropogenic influences results in community change and species loss.

Dynamics of populations and genetic structure of populations

Problems of area and geographical isolation apply to reserves themselves, to rare habitats within reserves, and to small populations within habitats (Hooper, 1971; Terborgh, 1974; Willis, 1974; Diamond, 1975). The number of species at equilibrium in a reserve or habitat is a function of reserve size and isolation (ecological contrast (Diamond, 1975) with surroundings is treated here as an aspect of isolation). Species differ in their susceptibility to local extinction and in their ability to recolonise from other areas (Diamond, 1975), and may therefore need separate management actions (Terborgh, 1974). Within any reserve it is likely that there will be species rare enough to suffer random extinctions (Hooper, 1971; Bonnell & Selander, 1974) due to small population size.

Hooper (1971) has proposed the following alternatives faced with species loss due to the above problems: (1) no attempt to save rare species; (2) actively maintain several reserves for populations and suitable habitats within normal dispersal distance of the species (see also Drury (1974) for recommendations as to optimal sub-population division); (3) actively manage for a large (i.e., larger than normal) population size within a single reserve (e.g. Dring & Frost, 1971; Jeffrey, 1971); (4) breeding, cultivation, and constant re-introduction (Wayre, 1969; Rawes & Welch, 1972; Drury, 1974; Thompson, 1974, 1976).

The danger of loss of species has been seen as one of the most powerful rationales for preservation because species represent a critical genetic resource (Akintola & Sanford, 1969; Frankel, 1970; Melville, 1970; Gómez-Pompa *et al.*, 1972; van de Kasteele, 1974). Preservation itself has been seen as the persistence of genes in time (Frankel, 1970). Certainly natural extinction cannot be avoided in the long run, but a major goal of reserves should be to eliminate human-caused extinctions—the last several hundred years have seen drastically increased extinction rates due to the effect of people (Miller & Botkin, 1974; Smith, 1976).

Preservationists should not only be aware of the danger of extinction of taxonomic species, but, more fundamentally, of the danger of loss of unique gene pools, and genetic shifts in populations due to human influence. Preservation management itself may alter genetic structure of populations both by influencing environment (Berry, 1971; Owen, 1971) and through maintenance of isolated homogeneous habitats with strong inbreeding (Drury, 1974). The latter situation may lead to specialisation, conservatism, and a drop in genetic variability—Drury (1974) recommends splitting single populations into several separate, but not totally isolated, sub-populations.

There are mixed opinions as to the potential for genetic drift in small populations. Berry (1971) suggested that drift hardly ever occurs; Hooper (1971) warned that populations must be close enough together so that occasional immigration could balance drift potential in small populations. Small populations are not necessarily low in genetic variability (Berry, 1971; Drury, 1974), although Bonnell & Selander (1974) reported a case where this was true.

Basic questions suggested above are: (1) With what genetic level should we be concerned (e.g., species, subspecies, variety forms, persistent hybrids, chance hybrids, and/or local and apparently unique genotypes (Hardin, 1977))? (2) Should we manage taxa actively (e.g., manipulate population size or divide populations into subpopulations)? (3) Should we create zoos, breeding programmes, gardens, and seed banks? (4) Should a reserve be an ark (i.e., should we re-introduce extirpated species or introduce species with no historical precedence in the area)? (5) Should we introduce genotypes that are local in origin if some remnant population exists that is capable of rebounding? (6) Should we maintain local genotypes whose existence may be the result of anthropogenic impacts (e.g., the local genotypes maintained by grazing sheep and cattle on chalk grasslands in England (Wells, 1969))? (7) Should we manage for maximum diversity as a top priority? (8) Should we try to monitor and/or minimise our own management-produced selective pressures? (9) What levels of genetic change or population decline should be regarded as critical and therefore requiring more active management (Hooper, 1971)? The need for population biology studies of rare species is clear (e.g., Dring & Frost, 1971; Namkoong & Roberds, 1974).

The greatest threat

The human influence, whether direct or indirect, is the greatest threat to preservation goals. Direct impacts on ecosystems and species include visitor use of reserves and the roads, trails, and developments that are constructed for them. Many reserves are established with an inherent contradiction—they are designed both to protect natural, largely human-free, systems and to provide for public enjoyment of wilderness (whether recreational or contemplative) (Stone, 1965). Indeed, it is often explicitly stated that preservation will put wild lands under common ownership and make enjoyment by present and future generations possible. Such a situation is, of course, preferable to private ownership, development, and exploitation, but there is danger in reserves becoming like the tragedies of the commons described by Hardin (1968). Management is needed to ensure protection of reserves from over-use.

The kinds of users to be expected in reserves are listed in Table 3. Because of the naturalness and scarcity of reserves in developed landscapes, they are experiencing increased visitor pressure, a trend that seems to be worldwide (Boden & Ovington, 1973; Simmons, 1973; Brotherton, 1975; Garcia Dory, 1977; Slater & Agnew, 1977). Visitors may disturb an area directly (e.g., trail erosion, air pollution by automobile traffic, firewood gathering, changes in animal behaviour), but also through political pressure (e.g., opinions about landscape aesthetics, locations of trails and campsites, fishing, gathering of edible plants, etc.). Some groups may exert political pressure although they do not directly use the park lands *per se* (e.g., hunters who view parks as significant reservoirs of animals for adjacent lands open to hunting; and construction companies who view land near reserves in terms of potential for second home development).

TABLE 3
VISITORS TO RESERVES

1.	Biologists, plant or animal collectors (whether casual or research oriented)
2.	Other scientists, such as geologists, archaeologists
3.	Field trips of university groups, schools, and nature groups
4.	Recreation and wilderness seekers including technical rock climbers and cavers
5.	Gardeners, fishermen, hunters, and gatherers of edible or medicinal plants (with permission or poachers without permission)
6.	Sightseers and organised tour groups

The promise of some kind of development or access to reserves is often made; indeed, nature groups fighting to protect various areas propose nature centres, trails, scenic roads, and other developments because they attract public support and increase public awareness of the need for reserves through their educational value.

The basic question that must be asked for all the kinds of visitors listed in Table 3 is: How much use is compatible with preservation goals? Other questions concerned with direct visitor impacts are: (1) Should we allow/regulate collection of plants, animals, archaeological artefacts, rocks and minerals (Huxley, 1974)? (2) Should we allow collection of ornamental, medicinal, or edible plants (including the option of allowing collection of fruits only)? (3) Should we allow firewood gathering? (4) Should we allow fishing or hunting (e.g., to control populations that are not at present naturally regulated)? (5) Should we set up reserves within reserves—i.e., special protection areas (as in Japan (Simmons, 1973)) or wilderness designation—which have more stringent protection than other areas within the preserve?

Indirect human impacts can be dramatic and difficult to control; the cause of such impacts may be far removed from disturbed sites. Unfortunately they cannot be controlled by simply limiting the number of people in a reserve.

These impacts include the introduction of exotic pests, diseases, plants, and animals, the decline of large native predators, extirpation of other animals which modified habitats (e.g., buffalo, beaver, in the USA), previous history of logging, agriculture, suppression of natural fires and/or air and water pollution and modification of hydrologic regimes. Some of these impacts are local in origin; in other cases the cause lies beyond reserve boundaries and control may be impossible (e.g., hydrologic changes influencing a preserved wetland). In particular, air pollution from combustion of fossil fuels and the spread of pesticides in windblown agricultural dust has reached even remote and superficially pristine wilderness areas.

Major issues to be faced with regard to indirect human impacts are: (1) Should we eliminate exotics and prevent cultivation of exotics in reserves? (2) Should we exercise control of herbivore populations where top predators have been eliminated (Owen, 1972)? (3) Should we try to re-establish large predators? (4) Should we re-establish other native species whose disappearance is documented historically? (5) What kind of fire management is appropriate? (6) What kind of monitoring scheme is appropriate?

Changes experienced by reserves: summary and examples

The major threats experienced by reserves are listed in Table 4. No attempt has been made to list them in order of importance; indeed, reserves will differ in the relative importance of each threat. The list represents the factors which potentially alter ecosystems and contribute to species loss, but it should be pointed out that these 'threats' may potentially increase habitat types and species number as well (e.g., natural disturbance). The significance of the threats will vary with reserve size, internal heterogeneity, and isolation. Finally, the perceived significance of threats is a function of perception of the importance of the different resources recognised in the reserve.

TABLE 4
MAJOR THREATS TO SPECIES AND ECOSYSTEMS IN RESERVES

1. Imbalance in animal populations (e.g., herbivore overpopulation)
2. Introduction of exotic pests, diseases, animals, and plants
3. Natural disturbances
4. Suppression of natural disturbances
5. Succession
6. Natural fluctuations in small populations
7. Air and water pollution
8. Human-caused changes in hydrologic regime
9. Visitor pressure: campers, hikers
10. Internal development to accommodate visitors
11. Scientific researchers (e.g., collectors)
12. Gardeners, gatherers, hunters, and fishermen
13. Unresponsive or ill-prepared preserve administrations
14. Lack of management priorities and plans
15. Lack of monitoring data and research options
16. Political pressure

Our experience in Great Smoky Mountains National Park (GRSM), USA, demonstrates the need for addressing clearly both practical and philosophical problems of preservation. GRSM has been a National Park for ca. 40 years—we have outlined in Table 5 what we consider the major issues that have arisen during those years (see also Bratton & White, 1980). While the papers cited in Table 5 address the specific problems and their possible solutions, we would like simply to underline the fact that here preservation requires more than passive guardianship. Although the establishment of GRSM protected 200,000 ha of forest land (much of it unlogged and unfarmed), threats to species and habitats have persisted. There are

TABLE 5

MAJOR PROBLEMS AND LESSONS OF 40 YEARS OF PRESERVATION AT GREAT SMOKY MOUNTAINS NATIONAL PARK (GRSM), USA

1. Elimination of large predators: mountain lion, wolf, golden eagles, bald eagles, peregrine falcons. (Mountain lion sightings are increasing and may indicate a small remnant population.)
2. Elimination of other animals with large ecosystem effects: beaver. (Recently beaver are becoming re-established; this seems to be an invasion of animals re-introduced near the Park.)
3. Locally large deer populations and overbrowsing effects on tree reproduction (Burst & Pelton, in press). (This problem is due to absence of large predators and maintenance of open habitats in large historic zone.)
4. Exotic pests and diseases: *Endotheca parasitica* has all but eliminated *Castanea dentata*, a former forest dominant (Woods & Shanks, 1959); *Adelges piceae* currently severely endangers *Abies fraseri*, a forest dominant (Johnson, 1977); *Caratocystis ulmi* threatens *Ulmus* spp.
5. Exotic species: European wild boar is severely impacting native vegetation, soils, and water quality (Bratton, 1975, 1977).
6. Anthropogenic fire along Park boundaries and suppression of natural fire have caused community changes (Kuykendall, 1978).
7. Succession on grassy balds threatens a rare and possibly anthropogenic habitat type, a unique population of hybrid, azaleas, and scenic vistas (Lindsay & Bratton, in press, *b*; Lindsay 1977, 1978).
8. Gardeners and gatherers threaten native plants, especially *Panax quinquefolium* and members of *Orchidaceae*.
9. Managers are faced with the dilemma of either introducing non-local genotypes of mountain lions and brook trout or attempting to manage the slow recovery of remnant native populations.
10. Reserves as arks: *Geum radiatum* and *Parnassia asarifolia* seed were collected and grown in TVA gardens; *Parnassia* plants were transplanted back into GRSM on sites where the seed had been taken (Robert Farmer, pers. comm.).
11. Visitor pressure causes trail erosion, damages to campsite areas, impacts on air and water quality (Bratton *et al.*, 1978).
12. Developments for visitation, such as roads, parking areas.
13. Drainage changes: channelisation was carried out in several wetlands; a sinkhole pond was bulldozed for better recreation. These practices have been stopped.
14. A section of stream was poisoned with rotenone to remove 'rough fish'; exotic trout were introduced. Smoky Mountain mad tom *Notorus baileyi* is presumed extinct due to this management action (Etnier, 1978).
15. Major academic research has been carried out in GRSM, but management problems were not addressed.

no known management options for some of these problems, at least on the local level (e.g., No. 4). Other problems have management solutions which are now being acted on (e.g., Nos. 8, 11, 12). Still others have management options which are still being debated (e.g., Nos. 1, 2, 3, 5, 6, 7, 9, 10). Presumably environmental impact statements would halt some problems listed in the table (e.g., Nos. 13 and 14). We feel that the need to formulate policy on preservation issues is more than academic. Such formulation is needed to ensure that the Park functions to preserve what was originally intended.

A PRESCRIPTION

Preservationists often subscribe, at least subconsciously, to the idea that reserves should contain mature, stable ecosystems. Even in areas with histories of previous disturbance, natural succession is seen as re-establishing such stable states. A reserve might therefore simply have as a policy the directive 'to protect the native flora', with no policy on natural population fluctuations (including natural extinction) or on natural disturbances (such as fire). Where change is not anticipated, policies may be established hurriedly or after the fact. Probably the most difficult problem is that managers are often oriented toward static systems even where natural disturbance is integral to communities they would like to preserve. If no clear policies have been established, controversy is sure to be generated—e.g., when artificial population control (hunting or trapping) is necessary in a man-free wilderness area or when controlled burning must be used near a recreation or scenic area. The only preventative to these difficulties is firm, well-established policy. Unfortunately, controversy and administrative inertia can result in paralysis or drastic limitations to management alternatives, especially when an attempt is made to choose policy after a problem has arisen. Policy decisions are not often simple. Research is imperative, but many dilemmas are simply a matter of conceptualised priority, not absolute fact. Preservationists are urged to think through such issues early in their efforts.

The problems with ecological change discussed in previous sections of this paper suggest some basic elements of policy formation in reserves (Table 6). The aims of

TABLE 6
A BASIC PRESCRIPTION FOR RESERVES

1. State aims of preservation explicitly
2. Identify and list resources preserved
3. Place resources in order of priority to guide resolution of conflicts
4. State management goals
5. Design decision-making systems, allowing for periodic review
6. Set policy on:
   natural disturbances and succession (especially fire)
   re-establishment of natural communities
   re-establishment of historic communities
   re-creation or maintenance of anthropogenic communities
   re-introduction of native species
   exotic species
   rare species
   genetic level of management
   control of animal populations that may be out of balance
   visitor impacts including developments for visitors
7. Set up a monitoring programme
8. Identify and place in order of priority problems for research
9. Carry out management-oriented research
10. Review priorities, policies, and initiate management programme

preservation should be stated explicitly (Owen, 1972). The resources preserved should be identified and listed (Meijer, 1973). Resources should be given an order of priority to guide the resolution of conflicts between them. Management goals should be described and questions concerning fluctuations in reserve ecosystems have to be faced rather than avoided. Changing politics, within and outside reserves, affect their functioning (Garcia Dory, 1977). The internal decision-making structure should be clearly organised. The inevitability of ecological change and the potential for sudden shifts in ecosystem composition (e.g., the invasion of an exotic) indicate that flexibility should be designed into the managerial system, with allowance for periodic review of policy.

After initial inventory, monitoring of reserves resources should be established (Dawkins, 1971; Johnson & Bratton, 1978; Bratton, in press). It is impossible to remove human influence from reserves—we must monitor both indirect and direct impacts, as well as natural changes that may be taking place, and we must do this both in systems that are perceptibly changing and those that are not. Such monitoring will aid the identification and priority of problems for research. Basic management-oriented research is required (Owen, 1972). Financial limitations may force tight priority settings in such research; an academic tendency for infinite data collection with few management implications should be avoided in the case of reserve-funded research.

After preliminary research is completed, a management programme can be established. The available data should be adequate to identify (1) sensitive systems, areas which are liable to change with very minor environmental fluctuations, (2) disturbance-dependent systems, areas where material man-caused disturbances are a primary factor in ecosystem function, (3) sensitive species, those species whose populations can be easily modified, and (4) species in flux, those species undergoing natural or man-caused changes in population structure or genetics. Monitoring must continue and be integrated into management action, and research which investigates the dynamics of systems should be conducted as an ongoing managerial process.

Active management in reserves is necessary if only because of the permeating human influence (Miller & Botkin, 1974); however, we agree wholeheartedly with Owen's (1972) opinion that management be kept at a minimum. In general, a 'hands-off' preservationist policy is now impossible, but many ecosystems may be essentially self-maintained and not endangered. Such systems need only continued protection. Manipulation, in other cases, seems necessary (Owen, 1972), depending, of course, on preservation goals. We stress here the need for resource identification, and the clear statement of goals, priorities, and policies. In essence, many of the dilemmas and choices are philosophical and judgements necessarily subjective. Nonetheless, there are clear practical problems that develop because of lack of both firm guidelines and administrative structure for coping with resource problems (e.g., as simple an issue as no policy on the cultivation of exotic plants around reserve buildings leading to introduction of species which may become invaders of native vegetation). Many reserves already have such policies and have research programmes and active management; we hope that the biologists, administrators, and managers of newly-created reserves will follow that lead.

REFERENCES

AKINTOLA, G. A. & SANFORD, W. W. (1969). The problem of biochemical conservation: a preliminary study of phenolic compounds in the leaves of *Afzelia africana* as an example. *Biol. Conserv.*, **1**, 233–5.

ALBERTSON, F. W. & TOMANEK, G. W. (1965). Vegetation changes during a 30-year period in grassland communities near Hays, Kansas. *Ecology*, **46**, 714–20.

AUSTIN, M. P. (1977). Use of ordination and other multivariate descriptive methods to study succession. *Vegetatio*, **36**, 165–76.

BERRY, R. J. (1971). Conservation aspects of the genetical constitutions of populations. In *The scientific management of animal and plant communities for conservation*, ed. by E. Duffey and A. S. Watt, 177–206. Oxford, Blackwell Scientific Publications.

BODEN, R. W. & OVINGTON, J. D. (1973). Recreation use-patterns and their implications for management of conservation areas. *Biol. Conserv.*, **5**, 265–70.

BONNELL, M. L. & SELANDER, R. K. (1974). Elephant seals: genetic variation and near extinction. *Science, N.Y.*, **184**, 908–9.

BRATTON, S. P. (1975). The effect of the European wild boar, *Sus scrofa*, on Gray Beech Forest in the Great Smoky Mountains. *Ecology*, **55**, 1356–66.

BRATTON, S. P. (1977). The effect of the European wild boar on the flora of the Great Smoky Mountains National Park. In *Research and management of wild hog populations*, ed. by G. W. Wood, 47–52. Georgetown, SC. Belle W. Baruch Forest Science Institute of Clemson University.

BRATTON, S. P. (in press). Information storage and population monitoring within Great Smoky Mountains National Park. In *Proc. of the Symposium, Geographical data organization for rare plant conservation, New York Botanical Garden*, November, 1977.

BRATTON, S. P., HICKLER, M. G. & GRAVES, J. H. (1978). Visitor impact on back-country campsites in the Great Smoky Mountains. *Environ. Mgmt*, **2**, 431–42.

BRATTON, S. P. & WHITE, P. S. (1980). Rare plant management– After preservation, what? *Rhodora*, **82**, 49–75.

BROTHERTON, D. I. (1975). The development and management of country parks in England and Wales. *Biol. Conserv.*, **7**, 171–84.

BROWN, W. L. (1961). Mass insect control programs: four case histories. *Psyche*, **68**, 75–111.

BURST, I. L. & PELTON, M. R. (In press). Some population parameters of the Cades Cove deer herd, Great Smoky Mountains National Park. *Proc. Ann. Conf. Southeastern Ass. Fish and Wildlife Agencies, Hot Springs, Virginia*, 32nd.

CHURCHILL, E. D. & HANSON, H. C. (1958). The concept of climax in arctic and alpine vegetation. *Bot. Rev.*, **24**, 127–91.

DAWKINS, H. C. (1971). Techniques for long-term diagnosis and prediction in forest communities. In *The scientific management of animal and plant communities for conservation*, ed. by E. Duffey and A. S. Watt, 33–44. Oxford, Blackwell Scientific Publications.

DIAMOND, J. M. (1975). The island dilemma: lessons of modern bio-geographic studies for the design of nature reserves. *Biol. Conserv.*, **7**, 129–46.

DOLAN, R., HAYDEN, B. P. & SOUCIE, G. (1978). Environmental dynamics and resource management in the U.S. National Parks. *Environ. Mgmt*, **2**, 249–58.

DRING, M. J. & FROST, L. C. (1971). Studies of *Ranunculus ophioglossifolius* in relation to its conservation at the Badgeworth Nature Reserve, Gloucestershire, England. *Biol. Conserv.*, **4**, 48–56.

DRURY, W. H. (1974). Rare species. *Biol. Conserv.*, **6**, 162–9.

EHRLICH, P. R., BREEDLOVE, D. E., BRUSSARD, P. F. & SHARP, M. A. (1972). Weather and 'regulation' of subalpine populations. *Ecology*, **53**, 243–7.

ETNIER, D. A. (1978). *Report on the search for spotfin chub* (Hybopsis monacha) *and Smoky mad tom* (Noturus baileyi) *in the Little Tennessee River System, North Carolina*. University of Tennessee, Department of Zoology, Knoxville, TN. (Unpublished report).

FOSTER, R. B. (1977). *Tachigalia versicolor* is a suicidal neotropical tree. *Nature, Lond.*, **268**, 624–6.

FRANKEL, O. H. (1970). Genetic conservation of plants useful to man. *Biol. Conserv.*, **2**, 162–9.

FRANZ, E. H. & BAZZAZ, F. A. (1977). Simulation of vegetation response to modified hydrologic regimes: a probabilistic model based on niche differentiation in a floodplain forest. *Ecology*, **58**, 176–83.

GARCIA DORY, M. A. (1977). Covadonga National Park, Asturias, Spain. Its history, conservation interest and management problems. *Biol. Conserv.*, **11**, 79–85.

GÓMEZ-POMPA, A. (1971). Posible papel de la vegetación secundaria en la evolución de la flora tropical. *BioTropica*, **3**, 125–35.

GÓMEZ-POMPA, A., VASQUEZ-YANES, G. & GUERARO, S. (1972). The tropical rain forest: a nonrenewable resource. *Science, N.Y.*, **177**, 762–5.
GREEN, B. H. (1972). The relevance of seral eutrophication and plant competition to the management of successional communities. *Biol. Conserv.*, **4**, 378–84.
HABER, W. (1973). Conservation and landscape management in Germany, past, present, and future. *Biol. Conserv.*, **5**, 258–64.
HARDIN, G. (1968). The tragedy of the commons. *Science, N.Y.*, **162**, 1243–8.
HARDIN, J. W. (1977). Vascular plants: introduction. In *Endangered and threatened plants and animals of North Carolina*, ed. by J. E. Cooper, S. S. Robinson and J. B. Funderburg, 56–63. Raleigh, North Carolina State Museum of Natural History.
HEINSELMAN, M. L. & WRIGHT, H. E. JR, (Eds.). (1973). The ecological role of fire in natural conifer forests of western and northern North America. *Quaternary Research*, **3**, 317–8.
HENRY, J. D. & SWAN, J. M. A. (1974). Reconstructing forest history from live and dead plant material—An approach to the study of forest succession in southwest New Hampshire. *Ecology*, **55**, 772–83.
HOOPER, M. D. (1971). The size and surroundings of nature reserves. *The scientific management of animal and plant communities for conservation*, ed. by E. Duffey and A. S. Watt, 555–61. Oxford, Blackwell Scientific Publications.
HUXLEY, A. (1974). The ethics of plant collecting. *Jl R. hort. Soc.*, **99**, 242–9.
JEFFREY, D. W. (1971). The experimental alteration of a *Kobresia*-rich sward in Upper Teesdale. In *The scientific management of animal and plant communities for conservation*, ed. by E. Duffey and A. S. Watt, 79–89. Oxford, Blackwell Scientific Publications.
JOHNSON, K. D. (1977). *Balsam woolly aphid infestation of fraser fir in the Great Smoky Mountains.* MS thesis, University of Tennessee, Knoxville.
JOHNSON, W. C. & BRATTON, S. P. (1978). Biological monitoring in UNESCO Biosphere reserves with special reference to the Great Smoky Mountains National Park. *Biol. Conserv.*, **13**, 105–15.
JOHNSON, W. C., BURGESS, R. L. & KAEMMERER, W. R. (1976). Forest over-story vegetation and environment on the Missouri River Floodplain in North Dakota. *Ecol. Monogr.*, **46**, 59–84.
KESSELL, S. R. (1976). Gradient modeling: a new approach to fire modeling and wilderness resource management. *Environ. Mgnt*, **1**, 39–48.
KUYKENDALL, N. W. III. (1978). *Composition and structure of replacement forest stands following southern pine beetle infestations as related to selected site variables in the Great Smoky Mountains.* MS thesis, University of Tennessee, Knoxville.
KOZLOWSKI, T. T. & AHLGREN, C. E. (Eds.). (1974). *Fire and ecosystems.* New York, Academic Press.
LEOPOLD, A. S., CAIN, S. A., COTTAM, C., GABRIELSON, I. N. & KIMBALL, T. L. (1963). Wild life management in the national parks. Advisory Board on Wildlife Management appointed by the Secretary of the Interior. *Trans. N. Am. Wildl. nat. Resour. Conf.*, **28**, 28–45.
LINDSAY, M. M. (1977). Management of grassy balds in Great Smoky Mountains National Park. *USDI, National Park Service, Uplands Field Research Lab, Management Rep.*, No. 17, 67 pp.
LINDSAY, M. M. (1978). The vegetation of the grassy balds and other high elevation disturbed areas in the Great Smoky Mountains National Park. *USDI, National Park Service, Uplands Field Research Lab, Management Rep.*, No. 26, 150 pp.
LINDSAY, M. M. & BRATTON, S. P. (In press,*a*). Grassy balds of the Great Smoky Mountains: their history and flora in relation to potential management. *Environ. Mgmt.*
LINDSAY, M. M. & BRATTON, S. P. (In press, *b*). The vegetation of grassy balds and other high elevation disturbed areas in the Great Smoky Mountains National Park. *Bull. Torrey bot. Club.*
MEIJER, W. (1973). Endangered plant life. *Biol. Conserv.*, **5**, 163–7.
MELVILLE, R. (1970). Plant conservation and the red book. *Biol. Conserv.*, **2**, 185–8.
MILLER, R. S. & BOTKIN, D. B. (1974). Endangered species: models and predictions. *Am. Scient.*, **62**, 173–81.
MUTCH, R. W. (1970). Wildland forest and ecosystems—a hypothesis. *Ecology*, **51**, 1046–51.
NAMKOONG, G. & ROBERDS, J. H. (1974). Extinction probabilities and the changing age structure of redwood forests. *Am. Nat.* **108**, 355–68.
NATURE CONSERVANCY (1975). *The preservation of natural diversity: a survey and recommendations.* Final report for US Department of the Interior Contract No. CXOCA-5-040. Arlington Virginia, Nature Conservancy.
OWEN, D. F. (1971). Species diversity in butterflies in a tropical garden. *Biol. Conserv.*, **3**, 191–8.
OWEN, J. S. (1972). Some thoughts on management in National Parks. *Biol. Conserv.*, **4**, 241–6.
PICKETT, S. T. A. (1976). Succession: an evolutionary interpretation. *Am. Nat.*, **110**, 107–19.
RAUP, H. M. (1941). Botanical problems in boreal America. *Bot. Rev.*, **7**, 147–248.
RAWES, M. & WELCH, D. (1972). Trials to recreate floristically-rich vegetation by plant introduction in the northern Pennines, England. *Biol. Conserv.*, **4**, 135–40.

SCHROEDER, P. M., DULAR, R. & HAYDEN, B. P. (1976). Vegetation changes associated with barrier-dune construction on the Outer Banks of North Carolina. *Environ. Mgmt*, **1**, 105–14.

SIMMONS, I. G. (1973). The protection of ecosystems and landscapes in Hokkaido, Japan. *Biol. Conserv.*, **5**, 281–9.

SLATER, F. M. & AGNEW, A. D. Q. (1977). Observations on a peat bog's ability to withstand increasing public pressure. *Biol. Conserv.*, **11**, 21–7.

SMITH, R. L. (1976). Ecological genesis of endangered species: the philosophy of preservation. *Am. Rev. Ecol. Syst.*, **7**, 33–5.

SMITHSONIAN INSTITUTION (1975). *Report on endangered and threatened plant species of the United States.* Submitted to the 94th Congress, 1st session, Serial No. 94-A. Washington, DC, United States Government Printing Office.

STONE, E. C. (1965). Preserving vegetation in park and wilderness. *Science, N.Y.*, **150**, 1261–7.

STOUT, B. B., DESCHENES, J. M. & OHMANN, L. F. (1975). Multi-species model of a deciduous forest. *Ecology*, **56**, 226–331.

TERBORGH, J. (1974). Preservation of natural diversity. The problem of extinction prone species. *BioScience*, **24**, 715–22.

THOMPSON, P. A. (1974). The use of seed-banks for conservation of populations of species and ecotypes. *Biol. Conserv.*, **6**, 15–19.

THOMPSON, P. A. 1976. Factors involved in the selection of plant resources for conservation as seed in gene banks. *Biol. Conserv.*, **10**, 159–67.

VAN DE KASTEELE, S. (1974). Conservation of wild *Lilium* species. *Biol. Conserv.*, **6**, 26–31.

VOGL, R. J. (1974). Effects of fire on grasslands. In *Fire and ecosystems*, ed. by T. T. Kozlowski and C. E. Ahlgren, 139–94. New York, Academic Press.

WATT, A. S. (1971). Factors controlling the floristic composition of some plant communities in Breckland. In *The scientific management of animal and plant communities for conservation*, ed. by E. Duffey and A. S. Watt, 137–52. Oxford, Blackwell Scientific Publications.

WAYRE, P. (1969). The role of zoos in breeding threatened species of mammals and birds in captivity. *Biol. Conserv.*, **2**, 47–9.

WELLS, T. C. E. (1969). Botanical aspects of conservation management of chalk grasslands. *Biol. Conserv.*, **2**, 36–44.

WESTHOFF, V. (1971). The dynamic structure of plant communities in relation to the objectives of conservation. In *The scientific management of animal and plant communities for conservation*, ed. by E. Duffey and A. S. Watt, 3–14. Oxford, Blackwell Scientific Publications.

WHITE, P. S. (1979). Pattern, process and natural disturbance in vegetation. *Bot. Rev.*, **45**, 229–9.

WILLIS, E. O. (1974). Populations and local extinctions of birds on Barro Colorado Island, Panama. *Ecol. Monogr.*, **44**, 153–69.

WOODS, F. W. & SHANKS, R. E. (1959). Natural replacement of chestnut by other species in the Great Smoky Mountains National Park. *Ecology*, **40**, 349–61.

WRIGHT, H. E., Jr. (1974). Landscape development, forest fires, and wilderness management. *Science, N.Y.*, **186**, 487–95.