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DESIGN OF NATURAL AREA PRESERVES IN HAWAI'I

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ABSTRACT

Preserves, especially in Hawai'i, must be protectable and manageable. Elements in preserve design include defining objectives, determining minimal area requirements, identifying external threats, and identifying management activities to be conducted. Biological, economic, and social priorities must be considered. There is no substitute for detailed ecological knowledge and practical experience, but ecological compromises are essential. Land use on surrounding areas, successional processes, and life expectancies of preserves must be seriously considered, as well as special problems such as large or migratory animals. In Hawai'i, threats from introduced organisms, destruction and fragmentation of native ecosystems, and the abundance of rare taxa make decisions about preserve objectives and design especially critical. Intensive management of established preserves and accumulation of sufficient knowledge to accomplish this effectively and efficiently are crucial.

INTRODUCTION

The most challenging topic in natural area preservation is preserve design. The design of an area is the arena in which ecological knowledge is integrated with economic and social issues, and a project is developed that achieves not only the preservation objective but is practical. Acquisition and management issues must be considered as well as biological aspects of the preserve.

The challenge of preserve design extends to the scientist. What kind of area is required to protect the selected element(s)--size, shape, and habitat? Theoretical concepts, such as the theory of island biogeography (MacArthur and Wilson 1967) exist, but knowledge about ecosystems or the ecology of species in question is more critical to preserve design.

An ecologist's perspective on elements of preserve design for natural areas is the topic of this paper. Population biology and genetics contribute substantially to design, particularly where preserves are focused on threatened and endangered species, but this is covered by Schonewald-Cox (this volume). Aspects of design considered in this paper include size, shape, and ecological content and setting. Special preservation problems are identified, including those created by wide-ranging species and aquatic habitats. Difficulties unique to Hawai'i, for example, the number and scale of threats from alien species, are also discussed.

I regret that much of this paper is general and provides limited specific guidance for projects in Hawai'i. Unfortunately, guides almost always have to be general because of the diversity of preservation objectives, as well as differing biologic, economic, and social circumstances; ultimately, each project has a unique solution. There are, furthermore, not many preservation options in Hawai'i--potential reserve areas are limited in size and number. Some humility is also in order, since I am a mainlander advising a very competent group of island conservationists on how to do the job.

PRINCIPLES IN PRESERVE DESIGN

Steps in preserve design include definition of objectives, determination of area requirements (with consideration for disturbance patterns and succession), identification of external threats, identification of management activities, and design of a preserve unit that is protectable and manageable.

Definition of Preserve Objectives

The most important single principle in preserve design is identification of the objectives of the preserve, and the more precisely objectives can be defined, the better. What elements are the objects of the preservation effort? Is a specific organism to be protected, or an entire ecosystem? If the objective is related to preservation of a species, is the purpose to protect a viable population, a segment of a population, or a piece of critical habitat? If the objective is to preserve an ecosystem, is the objective to maintain a vignette of the present or some past condition, or is it to perpetuate the dynamics of the ecosystem and natural processes? This is a more difficult issue than it might seem. It is at the root of many discussions and disagreements on management objectives in national parks. In Hawai'i the importance of the time perspective has been highlighted by comparative analyses of the effects of Polynesian and Caucasian immigrations.

Inadequate definition of objectives has, in my opinion, caused more problems in design and management of preserves than any other single issue. On Federal lands the problem appears to result from a tendency to view preserves as static rather than dynamic ecosystems; major management problems, as well as drastic differences of opinion as to appropriate activities, often result. For The Nature Conservancy, the objective (often unstated) of simply preserving an attractive and available tract of land was a common, early problem and sometimes resulted in preserves of low ecological value or with unmanageable boundaries, or both.

Determination of Minimal Area

How large an area is required for a preserve? This is probably the question most frequently raised, whether by land managers, fund raisers, biologists, or the public. The answer varies because so many factors are involved--objectives of the preserve, ecology of the object elements, the nature of the surrounding landscape, and other factors.

In general, the preserve area must be large enough to encompass a viable biological unit. This may be defined as minimal population levels of a specific organism or a complete example (all trophic levels, perhaps) of an ecosystem. The size may be large, as is often the case with a forest, or may be quite small, as with some hot springs ecosystems. For whole ecosystems, areas are sought where modern human influences are minimized and a large array of natural processes is maintained.

Ecologists put their knowledge to work when determining the necessary size and shape of a preserve. Information on the natural history of the ecosytem or species in question is the most important part of this design effort. As mentioned, there are some ecological models that can be used to help quantify the size of area or size of population needed. Island biogeographic theory (MacArthur and Wilson 1967) is proposed as a basis for preserve design (Sullivan and Shaffer 1975), although many urge caution in use of an "insufficiently validated theory" (Simberloff and Abele 1976), and others warn against direct comparisons of island data and isolated patches of habitat on continents (Terborgh 1974). Other models make it possible to calculate distances required to eliminate external climatic influences on the interior environment of a forest stand. Home ranges of animals can be used to calculate the size of the reserve required; Sullivan and Shaffer (1975) provided some examples for predators, and Franklin and Trappe (1968) proposed a minimal size based on small mammal populations.

General models are no substitute, however, for extensive and accurate information on the ecological life history of a target organism or the structural and compositional patterns characteristic of an ecosystem. Knowledge of successional processes--paths and rates of change and the processes driving these changes--is essential but often lacking. Disturbances are an essential part of most ecosystems. What types, frequencies, and intensities of disturbance are characterized as "normal" or as catastrophic components of the ecosystem of concern?

The ecological analyses must also consider the current naturalness of the ecosystem in question as well as potential threats to that naturalness. What have been the effects of past human activities--for example, prevention of wildfire or introduction of alien organisms such as goats and pigs? What is the potential for additional unnatural impacts on organisms, processes, or structures characteristic of the ecosystem?

Some philosophical considerations make clear that the earlier comments on size are of limited usefulness; major compromises with the ideal are inevitably necessary. First, no area on earth is free of significant human influences. Modern man has caused changes everywhere. Second, it is rarely possible to have complete examples of an ecosystem. Major components have been effectively lost from ecosystems--for example, the passenger pigeon and American chestnut in the deciduous forests of eastern North America, and the buffalo from the shortgrass prairies. Hunting pressure and large home range requirements generally make it impossible to incorporate natural populations of larger mammals (ungulates or carnivores) in our preserves. Third, the scale of disturbances characteristic of many ecosystems in their primitive state generally cannot be accommodated in preserves. Catastrophic wildfire on the scale of thousands of acres and at intervals of several centuries is characteristic of the Douglas-fir forests of the Pacific Northwest. In these forests, minor disturbances that create compositional and structural diversity within the basic forest fabric (for example, bark beetles, root rots, and windthrow) can be incorporated within a preserve, but the prime catastrophe that resets these ecosystems requires a series of preserves and a patience with stochastic natural processes.

Most natural area preserves therefore involve major compromises. Varying degrees of human influences must be accepted, although designs can attempt to minimize this. On many Federal Research Natural Areas, natural populations of larger vertebrates have been written off. Hunting, fishing, and trapping are uncontrolled in U.S. Forest Service reserves and allowed but controlled in many U.S. Fish and Wildlife Service reserves. Ungulates and large predators are fully protected only in national parks, and even those areas may be under threat--witness the possible legalization of hunting Roosevelt elk in Olympic National Park, Washington, by native Americans. Similar compromises exist in many state areas and The Nature Conservancy reserves.

This is not to say that such compromises are necessarily fatal flaws in a preserve's design. Indeed, many ecosystems appear to function quite satisfactorily in the absence of ungulates or large carnivores. My objective is merely to point out that such compromises are inherent in most preserves and that puritanical posturing is, therefore, inappropriate. All reserves miss the ideal to at least some degree; it is a question of where the line for ecological compromise is drawn on a particular project.

Physical elements of size and shape are susceptible to analysis once preserve objectives are defined, ecology of the elements of interest are analyzed, and compromises with the ideal are accepted (explicitly or implicitly). The area must be large enough to essentially eliminate edge effects. It should be large enough to incorporate the patterns of structural diversity (for example, gaps) and compositional diversity characteristic of the ecosystem. The size should be sufficient to handle the natural disturbances inherent to the functioning ecosystem; an area sufficient to accommodate the disturbances that reset the ecosystem to an earlier successional state may be beyond possibility, as mentioned earlier.

The current or anticipated state of the lands surrounding the proposed reserve is a very important consideration in determining the size of the required tract. Will the reserve be an isolated tract in a matrix of ecologically contrasting lands? This can be a very critical issue when major structural contrasts are involved (e.g. between old-growth forest and clearcut lands) or when surrounding lands contain threats to organisms of interest (e.g. domestic pets may threaten some microtine or bird populations in a reserve located in an urban environment).

Buffers become particularly important when there are major contrasts or incompatibilities between preserves and surrounding lands. By maintaining an environment more compatible with preserve objectives, while still allowing a variety of other uses, buffers can provide transitions wherein undesirable influences of surrounding lands are diffused. Buffers can drastically reduce the area necessary within a preserve proper and may, in fact, be the only way to develop a design that is biologically, economically, and socially acceptable. Obviously, much larger preserves may be needed where circumstances dictate that any buffers must be included within the preserve, as many Federal land managers insist.

Some consideration of boundaries is necessary, as the topographic nature of reserve boundaries may overshadow the importance of size and shape alone. In mountainous regions, boundaries placed along major topographic breaks, such as ridge lines, can result in effective isolation of even small tracts from surrounding lands. By carefully selecting topographic boundaries, smaller viable reserves may be possible than if legal lines are selected as boundaries.

Complete watersheds are particularly advantageous as reserve units. They utilize topographic boundaries that are well defined in many landscapes. Watersheds have integrity as ecological units although some organisms may move in and out. They provide for fully protected aquatic ecosystems because the source areas for the surface water bodies are incorporated within the preserve. Watersheds also tend to incorporate considerable habitat diversity by their very nature (for example, the presence of environmental gradients of soil, topography, and elevation). Incorporation of habitat diversity may actually be a much more important criterion in the design of a preserve than its overall size.

<u>Management Programs</u>

The management program for a preserve is also an important consideration in preserve design. The preserve must be protectable and manageable, quite aside from considerations outlined in the previous section. Walt Matia, head of The Nature Conservancy's Stewardship Program, strongly emphasized this aspect of design in my discussions with him. For example, if prescribed fire is to be part of a management program, the preserve must be designed so that burns can be implemented; such programs may not be viable on a small, prairie preserve located in urban surroundings.

It is essential that the nature and intensity of management programs be identified during the design process. What activities will be necessary: burning, hunting, trapping, or grazing? What size and shape of preserve is necessary for the implementation of these activities?

Protection is a specific management element that must be considered even where no overt manipulative activities are planned. Are the boundaries identifiable? What is the risk of loss to destructive forces from outside the area? And how can this be minimized? Windthrow is a common threat, for example, in natural areas of large trees in the Pacific Northwest. The threat of blowdown can be minimized by considering patterns of storm winds and selecting windfirm topographic locations for boundaries.

In all cases, preserve design must incorporate specific considerations of proposed management activities and the size and shape necessary for the implementation of those activities.

SPECIAL PROBLEMS IN PRESERVE DESIGN

Large and Migratory Animals

Animals that are large or migratory, or both, present special problems in preservation that are generally not appropriately handled in the context of strict nature preserves or Research Natural Areas. Many ungulates, top carnivores, birds, and marine mammals are among those that present problems (see Terborgh (1974) for examples). The role of preserves with such animals is generally confined to protection of key habitats for breeding, migration, or wintering. Such preserves are generally only effective in the context of comprehensive management programs (for example, those developed by the U.S. Fish and Wildlife Service for threatened or endangered species). These programs typically involve management of the animals throughout their ranges and on all types of lands, and even international agreements. Natural populations of ungulates and predators are sometimes protected in national parks although even parks may lack sufficient size for some species. Restrictions on hunting in parks are also under increasing pressure, and changes in rules could further reduce locales for studying unhunted populations of many species.

Any preserve for large or wide-ranging animals must fit into the context of a larger species conservation effort to be effective. Natural area preserves will generally play limited, although sometimes critical, roles. Simply preserving such species may tax human society, let alone maintaining natural populations of such species.

Aquatic Ecosystems

Preserve design for aquatic ecosystems or organisms can be very difficult. The watersheds of these ecosystems would ideally be included in a preserve so that a natural hydrologic regime could be maintained along with the chemical and physical properties of the water itself. This is sometimes possible with streams, ponds, and other relatively small aquatic features. In reality, such control is rarely possible with larger aquatic ecosystems--rivers, large lakes, and estuaries. Our larger national parks and wilderness areas provide us with the few significant natural examples of such types. Even in these cases some external influences can still significantly modify natural conditions --for example, acid rain in the case of poorly buffered lakes and ponds.

An alternative to direct control is to have all or part of the watershed or source area for the aquatic ecosystem managed under a regime consistent with the preservation objectives. This may prove to be the most desirable approach (economically, socially, or both), even when complete watershed control is feasible. This may mean having a part of the watershed within a less restrictive conservation category (for example, a park) or even dedicated to a consumptive but compatible use, such as production of water for a municipality or irrigation district. The key is to develop cooperative management programs for watersheds that will insure the integrity of the water supply for aquatic ecosystems. Hawai'i is pioneering in these approaches.

Another essential design element for aquatic preserves appears to be direct control of the aquatic habitat and the immediate environs. Preservation objectives can often be at least partially achieved with control of only the water body and adjacent shores; this may mean a lake, pond, marsh, or a reach of river or stream and the adjacent terrestrial areas. The objective is the control of the interface between land and water, particularly where major interactions or transfers between land and water are occurring. Examples of such interactions include overland flows of water, provision of protective cover and litter by riparian plants, and transfer of woody debris to the aquatic ecosystem.

Succession

Preservation of some ecosystems is simply not possible in the narrow sense of perpetuating a community of a given composition or structure because of successional processes. We tend to think of an ecosystem as being in a dynamic equilibrium with an environment, including the disturbance regime. A sere is initiated by a catastrophic event, proceeds through a series of ecological stages (often differing in composition, structure, and cycling processes), and is eventually reset to an initial condition by another disturbance episode, with the pattern repeating ad infinitum. This is a simple but useful general model for many combinations of ecosystems and disturbance regimes.

Ecosystems representative of primary succession (that is, developing on freshly created surfaces) often cannot be maintained. Such ecosystems are the consequence of unique events--a volcanic eruption or glacial retreat--that cannot be readily duplicated by humans. Such seres can only be understood and allowed to proceed with minimal human interference. Examples of such ecosystems are not always obvious at first glance. A good example may be some of the 'ohi'a (Metrosideros polymorpha) forests in Hawai'i, a topic discussed in detail by Mueller-Dombois (this volume). Some of these forests are a consequence of an episode of vulcanism that provided conditions suitable for their establishment. The forests have developed, site conditions have been altered, and senescence has occurred. Development of forests of similar structure may have to await another volcanic eruption. Similar circumstances may exist with Metrosideros forests that have developed on tephra soils in New Zealand.

The point in preserve design and management is to recognize that there may be situations where ecosystems cannot be maintained, even with human intervention. There are other circumstances that also produce this result--for example, where relict communities or organisms are encountered that are no longer capable of regenerating themselves on a site. We need to be aware of these limitations.

Life Expectancies and Risk Spreading

There is relatively little basis, as far as I know, for judging life expectancies of preserves of any size, but some observations may be useful:

1. Most losses of preserves have been a consequence of social, not physical, processes.
2. Losses of Federal preserves have tended to be inversely related to difficulty of establishment; for example, congressionally established areas (national parks, wilderness areas) have been quite stable while Research Natural Areas (which are established by agency regulations) have varied depending upon agency commitment and the complexity of their establishment process.
3. Losses of The Nature Conservancy preserves have most often been the result of an upgrading process and reflect poor initial selection or design, or both.
4. Erosion of natural ecological values rather than outright loss of preserves has been most common.

One issue in the design of preserve systems has been the relative merit of few larger or many smaller preserves. Strong cases have been made in the scientific literature for the importance of large preserves, particularly by individuals interested in larger vertebrates (Sullivan and Shaffer 1975). As a plant scientist I have tended to favor smaller and more widely dispersed preserves.

Any overall conservation strategy obviously must and will include a range of sizes. Large areas are clearly essential to some objectives, as already noted. It would be imprudent to put all of our conservation eggs into a very few baskets, however, if we don't have to. A series of smaller areas has the particular advantage of reducing the danger of loss; that is, it spreads the risk. This can also be a genetically advantageous strategy by incorporating greater genetic diversity of many organisms. I have strongly favored a series of modest Research Natural Areas for Douglas-fir (Pseudotsuga menzesii) in the Pacific Northwest over 1 or 2 large tracts to incorporate more of the geographic and genetic variability and to reduce the chance of losing a large proportion of the reserved forests to a single catastrophe.

Fortunately, the strategies of a few large versus many small reserves are rarely mutually exclusive. Where conflicts do arise theoretical models will not substitute for judgment and prudence in the decision process.

PRESERVE DESIGN IN HAWAI'I

Hawai'i presents some incredibly difficult problems in preserve design, as many people already know. The first problem is the limited acreage of unmodified landscape--a problem that is not unique to Hawai'i. Much of Hawai'i has been converted to various human uses including recreation, urban and military developments, and agricultural production. Habitat destruction limits the possibilities for natural area preservation at the outset, especially at low elevations where almost no unmodified ecosystems exist.

Alien organisms are a huge and pervasive obstacle to preserving Hawai'i's natural diversity. Smith (this volume) estimates that there are 600 naturalized plants in Hawai'i, of which 86 are pests. Some of these plants, such as banana poka (Passiflora mollissima), strawberry guava (Psidium cattleianum), fire tree (Myrica faya), and Andropogon and other grasses, are very aggressive and readily displace native plants. Introduced animals include such conspicuous organisms as feral goats (Capra hircus), pigs (Sus scrofa), and feral sheep (*Ovis aries*) and the mongoose (*Herpestes auropunctatus*), as well as numerous less conspicuous animal species. Some of these animals function as vectors for alien plants while others prey directly on native fauna. Introduced diseases, such as avian malaria, have had major impacts on some groups of animals. Alien invertebrates continue to establish themselves and are having serious impacts on native insects and mollusks; some also serve as disease vectors.

Irreversible changes in Hawaiian ecosystems have resulted from the combined effects of ecosystem disturbance, introductions of alien organisms, and extinction of native organisms. For example, 120 native plants (11% of the flora) are known to be already extinct (Wagner, Herbst, and Yee, this volume). Environmental conditions (fire and soil hydrologic and nutrient regimes) have been drastically, and perhaps permanently, altered by alien organisms (Smith, this volume). It is, therefore, simply not possible to recreate complete examples of some ecosystems. It will also be extremely difficult to protect examples of some ecosystems from the continuing onslaught of aliens.

Ecosystems in Hawai'i are threatened in ways, and on a scale, that are beyond any in my North American experience. Entire ecosystems, not merely species or trophic levels, are threatened with extinction. Furthermore, such drastic potentials exist in the absence of any additional human disturbance. In many areas of the world, undisturbed ecosystems are resistant to the invasions of aliens; for example, Eurasian annual grasses will generally not replace native bunchgrasses in the steppes of the Pacific Northwest unless these ecosystems are disturbed by grazing. This is clearly not the case in much of Hawai'i where human intervention is essential to protect even undisturbed native ecosystems from aliens. The threat of banana poka exemplifies for me the ultimate nightmare--an alien species that is capable of invading intact rain forests and completely destroying them.

The excellent general scientific data base for the Hawaiian Islands is favorable to preservation efforts. Thanks to the efforts of many individuals and, especially, the Endangered Hawaiian Forest Bird Project, we have a good understanding of where key tracts of land are located, as well as the overall status of ecosystems and many species.

Conservation Triage

A critical step in preservation of Hawai'i's natural diversity would appear to be some decisions about overall objectives--a conservation triage. What should be the relative emphasis on ecosystems versus species?

The huge numbers of threatened and endangered species have been mentioned by several symposium speakers. How much effort should go toward keeping "basket cases" in existence? Is it better to focus on preservation of biological structures and processes (including evolutionary processes) as represented by the ecosystems? Or, should we increase preservation of some components --specific species? A sound system of ecosystem-oriented preserves will take care of many species, including species currently unknown to us. On the other hand, species are valuable as indicators and components of ecosystems and as rallying points for public conservation efforts, as well as having an intrinsic worth.

Another triage issue is purity versus practicality in preserve selection and design. As Holt and Fox (this volume) have suggested, emphasis may need to be on preserving the "best" available areas of specific ecosystems.

In this objective setting and in triage, as well as in carrying forward the actual preservation efforts, it is absolutely essential that the small community of scientists and land managers in Hawai'i cooperate. Continuing conflicts will ensure that the preservation effort will fall far short of its potential and need. A common front will make the need and priorities clear to the public and to the politicians. A fragmented scientific community and lack of long-range land use planning will confuse the issues and make it easy for opponents to defeat preservation efforts.

Acquisition and Intensive Management

The circumstances in Hawai'i necessitate new and creative solutions to preserve design, as biological issues are combined with the social and economic realities of land acquisition. Some new approaches to conservation problems have already been taken. The acquisition of conservation easements and development of cooperative management agreements on target lands and in buffer areas are good examples. Where but in Hawai'i would someone conceive of purchasing the right to be managerially responsible for someone else's watershed? With land ownership such a controversial issue in Hawai'i, it might be possible to arrive at long-term agreements with owners of critical conservation properties, agreeing to preservation in return for rights to use noncritical lands elsewhere.

Intensive management efforts are an overwhelmingly critical element of natural area preservation in Hawai'i--the "active management program" of Holt and Fox (this volume). Identification of problems and selection of management strategies have to be early and integral parts of preserve design--much more than is often the case with mainland preserves. It is obvious from the planning and resources that are going into the management programs on several of the new Nature Conservancy preserves, that this is known. I view Hawai'i as a leader in the field of active (versus passive) management of natural areas; things cannot simply be left alone, not even for short periods. Mainlanders have much to learn in this regard in natural area management.

Intensive management will take many forms, including activities to eliminate or control aliens, to reconstruct ecosystems, and to perpetuate processes. Some approaches to the eradication or control of alien species are fencing, hunting and trapping of animals; introduction of insects or diseases for biocontrol of plants; and mechanical or chemical removal of plants. L.L. Loope (pers. comm.) suggested that feral animal control appears the minimum management required for any land dedicated to preservation of natural communities of native biota in Hawai'i. Forest structures and compositions can be reestablished in efforts to reconstruct functional ecosystems. Silvicultural practices such as planting, thinning, and killing of trees (to create dead wood structures) may be appropriate. (Efforts to reconstruct natural forests on cutover lands in Redwood National Park, California, provide an example.) Scott, Kepler, and Sincock (this volume) have suggested activities that can be used to perpetuate natural reproductive, migratory, and selective processes --transplantation of organisms, manipulation of organisms in the wild, and captive propagation. Simulation of disturbance regimes is another managerial approach to perpetuating natural processes. Prescribed fire management is a typical activity on the Mainland, and some day simulating the effects of flooding on segments of floodplain communities along dam-tamed rivers may be done. Are there similar processes that need to be perpetuated or simulated in Hawaiian ecosystems? Could you imagine attempting to simulate the effects of a volcanic eruption?

In any case, the management programs will be as complex and sophisticated as those on intensively managed agricultural and forest lands. Small natural areas may receive the management attention currently given only to national parks. Dollars, trained personnel, and knowledge will be essential to these programs. More knowledge of the species and the ecosystems will be especially critical in order to design and monitor management activities. All parties--agencies, universities, The Nature Conservancy, and other groups --have to drastically increase efforts at generating the necessary information.

Such intensive management of natural areas I find both a scary and a humbling prospect. Scary, because we are more and more assuming a God-like role, carrying the burden of perpetuating ever-increasing numbers of ecosystems and species, presumably forever. It reminds me of the responsibilities mankind has assumed for safe storage of long-lived nuclear wastes. Humbling, because of the limited knowledge available for carrying out our tasks. I am convinced that we know a lot less about ecosystem structure and function than we think. As I recall the level of understanding that we had of old-growth coniferous forests in the Pacific Northwest just 15 years ago, I am amazed at how little we saw of what was before us. And how confident we were that we knew almost everything of importance! At that time no one suspected that over 50% of the energy produced by these forests typically goes into maintaining the below-ground portions of the ecosystems. No one knew that microbes in rotting wood are fixing significant quantities of nitrogen, or that non-growing season photosynthesis could constitute half or more than half of the yearly production on some sites. The examples could go on ad infinitum. My point is that we scientists and resource managers should repeat statements of fallibility to ourselves nightly, lest we begin to believe that our limited understanding of ecosystems is complete, let alone represents "truth."

Preserve design in Hawai'i will often require original approaches to landscape control and intensive management programs. Objectives must be well defined and prominent as various design alternatives and management strategies are considered. Land acquisition and passive management cannot substitute for clarity of purpose, as often seems to be the case on the Mainland.

CONCLUSIONS

Preserve design is a process that involves ecological, social, and economic considerations. Definition of objectives is paramount in both design and management of preserves. Sound scientific information on the ecosystems and organisms of interest is essential; ecological theory is no substitute for such knowledge. Any guidelines on size, shape, and other criteria must, of necessity, be general as each design problem is unique.

Preserve design in Hawai'i presents the most difficult problems because of pervasive disturbance, an abundance of aggressive and influential aliens, land-use conflicts, and land ownership issues. Solutions will require many and original alternatives to outright acquisition, such as purchase of easements and use of buffers with compatible land uses. Intensive management programs will be necessary because passive management will typically not preserve the elements of interest.

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