14.

RESTORATION OF NATIVE ECOSYSTEMS

Charles H. Lamoureux

ABSTRACT

There is little published information on "near-natural" ecosystems and their restoration. Ecosystem restoration involves the setting of a date to indicate a restoration point (e.g., 1778 for the National Park Service in Hawai'i) and presupposes some knowledge of ecosystem status at the target date and time. In Hawai'i, knowledge of past conditions is usually precluded by the rapidity and magnitude of recent changes. However, some restoration efforts based largely on removal of alien organisms have resulted in recovery of ecosystems that are largely native but lack components and processes destroyed in the past by alien organisms including man. No cost estimates for ecosystem restoration in Hawai'i are available as yet. Efforts devoted to prevention of the degradation of prime examples of near-natural and natural Hawaiian ecosystems should at least be equal to restoration efforts.

INTRODUCTION

The concept of "restoration" of an ecosystem implies that certain relatively recent changes are being reversed or that the ecosystem is reverting to what it was at some former time. Ecosystems may range from completely natural ones to those wholly induced by human activities, but the term "restoration" connotes that the recent changes which led to the present condition were in some way undesirable, and that the changes which will now be made will restore some state more desirable than the present, at least in the view of some human stewards.

This paper describes some of the concepts involved in ecosystem restoration, indicates the difficulties involved in undertaking such projects, and reviews some of the efforts at native ecosystem restoration in Hawai'i.

VARIOUS CONCEPTS OF ECOSYSTEM RESTORATION

In nature a number of landscapes (and ecosystems) exist. Duffey (1970) suggested categorizing these as:

1. natural landscapes, unmodified by human activity,
2. near-natural landscapes, with primarily native plants and animals, in areas used by humans, but so far as known, never subject to any major change in land use,
3. semi-natural landscapes, such as pastures and heathland, which have developed as a consequence of human cultural activity and land-use, and
4. artificial landscapes, such as strip-mined areas and areas reclaimed from the sea (e.g. polders in the Netherlands), which are wholly anthropogenic.

Nearly all of the literature on the restoration of ecosystems deals with methods that can be employed to grow something (almost anything) on artificial landscapes. Some good examples of recent work on strip-mined areas were reported by Goodman (1974), Cook (1976), and Hutnik and Davis (1976). Hutchinson (1974) also discussed the natural restoration of ecosystems on ancient spoil-heaps and mine tailings in Great Britain.

Less has been published on the restoration of semi-natural landscapes. Papers on this subject have tended to emphasize the need to use such tools as grazing and burning to maintain these ecosystems at a successional disclimax (Harrison 1974; Kumari 1974; Miller and Watson 1974; and Putwain, Gillham and Halliday 1982).

Although an important objective of many conservation activities is the restoration of near-natural landscapes, much less information has been published on this subject. Two reports of this type deal with the restoration of seagrass communities (Thorhaug and Austin 1976) and tropical high-forests (Kio 1981). Thus the papers presented at this symposium will contribute much-needed information.

PROBLEMS IN ADEQUATELY CHARACTERIZING ECOSYSTEMS

If one is to undertake the restoration of an ecosystem, it is important to know as much as possible about both the present state of the ecosystem and its past history. Yet such information is rarely available for any ecosystem. The reasons for this lack of information are:

1. Few natural ecosystems of any reasonably large size have been adequately described. While species lists for vascular plants and vertebrate animals are usually available, and biomass data for these groups of

organisms are sometimes available, almost no data are usually reported on lower plants, invertebrate animals, fungi, terrestrial algae, or prokaryotes. Even when such information is compiled at present, little or no information on past conditions is available.

2. Natural ecosystems, even those usually described as "stable," are really dynamic and constantly changing. Among the reasons for this are:

(a) the individual species in the ecosystem are continually evolving,

(b) loss of species from, and recruitment of species to, the ecosystem are continually occurring,

(c) successional changes may be occurring,

(d) there may be long-term changes in both climatic and edaphic factors in the ecosystem.

Even with these limitations, it still seems to be generally desirable to attempt to accomplish projects in ecosystem restoration. However, project planners should recognize the difficulties involved in such an undertaking, and recognize that as a practical matter the detectable restoration is likely to be limited to changing the proportions of certain higher plants and vertebrate animals in the ecosystem.

GOALS AND OBJECTIVES OF ECOSYSTEM RESTORATION

As we discuss the restoration of native ecosystems at this symposium, the objectives seem really to be the conservation of natural and near-natural ecosystems; the protection of rare, threatened, or endangered species in these ecosystems; and in some cases the restoration of semi-natural ecosystems to the near-natural state. These are basically the objectives of most conservation activities in national parks and natural areas, and it seems useful to consider what previous workers have stated as appropriate goals for such activities. Elton (1958) indicated that one of the chief aims of conservation should be the retention or replacement in the landscape of the greatest ecological variety, while Berry (1974) urged retention of the greatest genetic variety. One or both of these goals have been given by most subsequent authors, including Duffey and Watt (1971), O'Connor (1974), Polunin and Eidsvik (1979), and Foster (1980). Stankey (1982) described the need for developing management systems to aid in reaching these goals.

When planning for ecosystem restoration it is necessary to choose some date in the past to indicate the point to which the ecosystem should be restored. For the U.S. National Park Service this date was chosen by the Leopold Committee in 1963: "As a preliminary goal, we would recommend that the biotic associations within each park be maintained, or where necessary recreated,

as nearly as possible in the condition that prevailed when the area was first visited by the white man" (Barbee 1976). Barbee went on to describe the philosophical problems facing the park manager in Hawai'i if one must manage resources to include Polynesian introduction but exclude those which are post-Cook. At least this policy provides the clearly stated goal that ecosystem restoration projects in Hawaiian national parks should aim at restoration to the state prevailing in January, 1778 (if only we knew what that was).

EFFORTS AT ECOSYSTEM RESTORATION IN HAWAI'I

Most efforts at ecosystem restoration in Hawai'i have involved the use of exclosures; these have been discussed thoroughly in the paper by Loope and Scowcroft (this volume). However, a few more projects have extended beyond the boundaries of exclosures, and these warrant mention.

One such project was the restoration of Laysan Island, in the northwestern Hawaiian Islands. In the early years of this century the vegetation of Laysan was devastated by rabbits. Most of the native flora disappeared (and 3 of the 5 endemic land birds became extinct). Efforts to replant the Island were made in the 1920's with a wide range of plant materials both native and alien (Christophersen and Caum 1931; G.P. Wilder, n.d.). Studies made in the 1960's (Lamoureux 1963) revealed that the ecosystem had been restored to the extent that most of the plants which had previously occurred there were again there, and most of the planted species, both those native to the main Hawaiian Islands and the alien species, had not survived. While there were originally a few local endemics, some of which probably survived the devastation as buried seeds, many reestablished species were fairly widely distributed coastal plants that may well have colonized naturally since 1923. The endemic avifauna fared much worse than the higher plants. Nothing was known of the insects before the devastation, so no comparisons were possible. There is little evidence to suggest that human activities contributed in any substantial way to the restoration of the Laysan ecosystem in the 35 years after the rabbits were removed.

Other projects involved areas in the main islands of the Hawaiian group. In the mid-1930's, after studying the vegetation of the southeastern corner of O'ahu, Egler (1939) proposed that, in the absence of continued disturbance, native Hawaiian plants would eventually replace the alien plants which at that time dominated the area. This hypothesis has never been tested since many of Egler's study sites have been replaced by houses. However, Hatheway (1952) arrived at similar

conclusions based on his research in Mokule'ia, northwestern O'ahu. Twenty years after Hatheway established his plots, they were relocated and restudied by Wirawan (1972). He found that in some plots the proportions of native and alien plants had remained essentially unchanged, while in some other plots the proportion of aliens had increased. He concluded that the 20-year interval was perhaps not long enough to permit adequate testing of the hypothesis. The question remains unanswered.

The removal of goats from Hawai'i Volcanoes National Park was enhanced by the appearance of conspicuous undescribed endemic Canavalia in an exclosure, as described by Loope and Scowcroft (this volume), and subsequent studies have been made (Mueller-Dombois, 1979, 1981; Mueller-Dombois and Spatz 1975) of the vegetation changes in the lowland areas of the Park after relaxation of goat foraging pressure. This is a situation opposite to that described earlier, in which grazing was used to restore certain European ecosystems to the stage desired for conservation (Kumari 1974) by preventing the normal sequences of succession from occurring. In the Hawai'i Volcanoes case, succession has proceeded rapidly following goat removal. At the present time certain alien plants are dominant in the succession in much of the area, but the climax stages are as yet not evident.

While one study suggested that pig digging in grasslands on Mauna Loa greatly increased the percentage of alien species in communities which had formerly had more native species (Spatz and Mueller-Dombois 1975), other studies in rain forest areas have yielded inconclusive results to date (Loope and Scowcroft, this volume); however, there is evidence in at least some plots of recovery of native species.

It had long been suspected that sheep and other feral herbivores were responsible for a decline in mamane (Sophora chrysophylla) forests; so it had been predicted that the removal of these herbivores would result in restoration of this forest ecosystem. However, there was little scientific evidence for this. Recently, papers (Scowcroft 1983; Scowcroft and Giffin 1983; Scowcroft and Sakai 1983) have provided data which support these hypotheses and demonstrate that ecosystem recovery and an increase in cover by native species occur once the herbivores have been removed in this forest type.

The most conspicuous effort in Hawai'i in reintroducing a native species to the wild in order to restore a conspicuous component of an ecosystem is the nene (Nesochen sandvicensis) restoration project. It has

been demonstrated that nene can be bred in large numbers in captivity and released into the wild where they can feed and reproduce. However, there is a high mortality rate in the wild, and the wild population at present can be maintained only by continual reintroductions of captive-reared birds. Research is under way to determine what is happening to birds after release. The most recently published study (Stone, Hoshide, and Banko 1983) did not confirm the hypothesis that predators such as mongooses, feral cats, feral dogs, or pigs play a critical role in reducing wild populations of nene, but the study included only a small number of birds in only one part of the species range. In sum, the factors limiting restoration of the nene are still unknown but probably are complex (Stone et.al. 1983).

COSTS OF ECOSYSTEM RESTORATION

It is difficult to determine costs and benefits of ecosystem restoration. Thorhaug and Austin (1976) gave costs of planting seagrasses from seed in areas where the original cover had been destroyed. Their cost estimates ranged from about $21,000 to $140,000 per hectare depending on density of planting, and they concluded that restoration was feasible at those costs.

Gosselink, Odum, and Pope (1974) worked in the opposite direction and attempted to determine the economic value of the tidal marsh. They concluded that when all uses of the marsh are considered, including direct production of fish and shellfish, its value in assimilating waste, and its gross primary productivity, its total social value was in the range of $50,000 to $80,000 per hectare.

I am unaware of any comparable figures that have been developed for Hawaiian ecosystems, or of any cost/benefit studies that have been undertaken on the value of native ecosystems. While it would be possible to estimate costs to date for removal and exclusion of goats from Hawai'i Volcanoes National Park, or for the nene restoration project, neither project is yet completed, and it is premature to attempt to develop even relatively simplistic cost/benefit ratios.

CONCLUSIONS

While few ecosystem restoration projects have yet proceeded far enough in Hawai'i to enable workers to predict their probable outcomes, results to date suggest that the following sorts of manipulative techniques will need to be used in conducting them:

1. Removal of non-native herbivores and prevention of their re-introduction.

2. Removal of non-native predators and prevention of their re-introduction.

3. Removal or drastic control of alien plants, at least those determined by study to form significant components of the ecosystem.

4. Replanting with rare native plants which are as genetically similar as possible to those which formerly inhabited the area.

5. Restocking with rare native animals which are as genetically similar as possible to those which formerly inhabited the area.

6. Preventing, or at least slowing, detrimental changes in the ecosystems before, during, and after restoration. (This may well be the most difficult task of all.)

Even when all these techniques are fully employed it will probably not be possible to reach a goal such as that of restoring ecosystems in national parks to late eighteenth century stages, simply because we don't know what these were; it is likely that many species then present have become extinct already anyway. This does not mean that such efforts should not be undertaken, but does suggest that equal efforts should be devoted to prevention of further degradation of Hawaiian ecosystems.

LITERATURE CITED

Barbee, R.D. 1976. Ecological park management: a manager's perspective. Proc. 1st Hawaii Volcanoes Natl. Park Nat. Sci. Conf., 35-38. Honolulu: Univ. Hawaii.

Berry, R.J. 1974. Conserving genetical variety. In Conservation in practice, ed. A. Waron and F.B. Goldsmith, 99-115. London: John Wiley Sons.

Christophersen, E., and E.L. Caum. 1931. Vascular plants of the Leeward Islands, Hawaii. B.P. Bishop Mus. Bull. 81.

Cook, C.W. 1976. Surface-mine rehabilitation in the American West. Environ. Conserv. 3(3):179-183.

Duffey, E. 1970. Conservation of nature. London: Collins.

Duffey, E., and A.S. Watt, eds. 1971. The scientific management of animal and plant communities for conservation. Oxford, England: Blackwell Sci. Pub.

Egler, F.E. 1939. Indigene vs. alien in the development of arid Hawaiian vegetation. Ecology 23(1):14-23.

Elton, C.S. 1958. The ecology of invasions by animals and plants. Oxford, England: Methuen.

Foster, R.B. 1980. Heterogeneity and disturbance in tropical vegetation. In Conservation biology, ed. M.E. Soule and B.A. Wilcox, 75-92. Sunderland, Mass.: Sinauer Assoc., Inc.

Goodman, G.T. 1974. Ecological aspects of the reclamation of derelict land. In Conservation in practice, ed. A. Waron and F.B. Goldsmith, 251-264. London: John Wiley Sons.

Gosselink, J.G., E.P. Odum, and R.M. Pope. 1974. The value of the tidal marsh. Cent. for Wetland Resour. Pub. No. LSU-SG-74-03. Baton Rouge, La.: Louisiana State University.

Harrison, C.M. 1974. The ecology and conservation of British lowland heaths. In Conservation in practice, ed. A. Waron and F.B. Goldsmith, 117-129. London: John Wiley Sons.

Hatheway, W.H. 1952. Composition of certain native dry forests: Mokuleia, Oahu, T.H. Ecol. Monogr. 22(2):153-168.

Hutchinson, J. 1974. Land restoration in Britain--by nature and by man. Environ. Conserv. 1(1):37-41.

Hutnik, R.J., and G. Davis, eds. 1976. Ecology and reclamation of devastated land. Vol. 1. New York: Gordon and Breach.

Kio, P.R.O. 1981. Regeneration methods for tropical high-forests. Environ. Conserv. 8(2):139-147.

Kumari, E. 1974. Man-made ecosystems and nature conservation, with special reference to Matsulu Bay, Estonian SSR. Environ. Conserv. 1(1):31-36.

Lamoureux, C.H. 1963. The flora and vegetation of Laysan Island. Atoll Res. Bull. 97.

Loope, L.L., and P.G. Scowcroft. Vegetation response within exclosures in Hawaii: a review. [This volume]

Miller, G.R., and A. Watson. 1974. Heather moorland: a man-made ecosystem. In Conservation in practice, ed. A. Waron and F.B. Goldsmith, 145-166. London: John Wiley Sons.

Mueller-Dombois, D. 1979. Succession following goat removal in Hawaii Volcanoes National Park. Proc. 1st Sci. Res. Natl. Parks Conf., 1149-1154. San Francisco: Natl. Park Service.

Mueller-Dombois, D. 1981. Vegetation dynamics in a coastal grassland of Hawaii. Vegetatio 46:131-140.

Mueller-Dombois, D., and G. Spatz. 1975. The influence of feral goats on the lowland vegetation in Hawaii Volcanoes National Park. Phytocoenologia 3(1): 1-29.

O'Connor, F.B. 1974. The ecological basis for conservation. In Conservation in practice, ed. A. Waron and F.B. Goldsmith, 87-98. London: John Wiley Sons.

Polunin, N., and H.E. Eidsvik. 1979. Ecological principles for the establishment and management of national parks and equivalent reserves. Environ. Conserv. 6(1):21-26.

Putwain, P.D., D.A. Gillham, and R.J. Holliday. 1982. Restoration of heather moorland and lowland heathland, with special reference to pipelines. Environ. Conserv. 9(3):225-235.

Scowcroft, P.G. 1983. Tree cover changes in mamane (Sophora chrysophylla) forests grazed by sheep and cattle. Pac. Sci. 37(2):109-119.

Scowcroft, P.G., and J.G. Giffin. 1983. Feral herbivores suppress mamane and other browse species on Mauna Kea, Hawaii. J. Range Manage. 36(5):638-645.

Scowcroft, P.G., and H.F. Sakai. 1983. Impact of feral herbivores on mamane forests of Mauna Kea, Hawaii: bark stripping and diameter class structure. J. Range Manage. 36(4):495-498.

Spatz, G., and D. Mueller-Dombois. 1975. Succession patterns after pig digging in grassland communities on Mauna Loa, Hawaii. Phytocoenologia 3(2/3): 346-373.

Stankey, G.H. 1982. The role of management in wilderness and natural-area preservation. Environ. Conserv. 9(2):149-155.

Stone, C.P., H.M. Hoshide, and P.C. Banko. 1983. Productivity, mortality, and movements of nene in the Kau Desert, Hawaii Volcanoes National Park, 1981-1982. Pac. Sci. 38(3):301-311.

Stone, C.P., R.L. Walker, J.M. Scott, and P.C. Banko. 1983. Hawaiian goose research and management--where do we go from here? Elepaio 44(2):11-15.

Thorhaug, A., and C.B. Austin. 1976. Restoration of seagrasses, with economic analysis. Environ. Conserv. 3(4):259-267.

Wilder, G.P. n.d. Notebooks and letters. Dep. Botany, Univ. Hawaii, Honolulu.

Wirawan, N. 1972. Floristic and structural development of native dry forest stands at Mokuleia, N.W. Oahu. M.S. Thesis, Univ. Hawaii, Honolulu.