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Report to the British Columbia Ministry of Forests and Lands as part of the project,
Landscape analysis for conservation of CWH biodiversity and
old-growth habitat attributes - A generic planning tool &
Biodiversity analysis for integrated resource management in
Tofino Creek watershed, Clayoquot Sound

Generation of alternative sets of protected habitat, harvesting and silvicultural prescriptions for the conservation of biological diversity

> *"We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."* Aldo Leopold from *A Sand County Almanac*

Problem statement:
There is more than one way to conserve biological diversity across landscape units of temperate coastal forest in British Columbia. There are strategies which emphasize more intensively preserved fragments surrounded by high-impact harvesting and silviculture. Other strategies can focus on more severe prescriptions and constraints across landscape units with smaller proportionate areas in protected cores, buffers and corridors. Each strategy has different implications for environmental, social and economic costs and benefits. Methods of identification of a range of options for the conservation of an area's biodiversity, provide a powerful tool for integration of these concerns with other non-timber values as well as with commodity values to provide an optimal balance between development and conservation / preservation (Ingram 1989). In order to make such an approach workable for forest land use planners in British Columbia, new adaptations of geographic information systems and development of new software modules are needed.

Implications for the research design of Phases 2 & 3 of the Tofino Creek Biodiversity Study:
1. There is more than one way to conserve biodiversity and related old-growth attributes across landscape units in the CWH Zone.

2. The variables in conservation strategies involve the proportion of area in protected old-growth forest, the quality of the habitat, the amount of long-term management that will be required for protected sites, and the amount of mitigative prescriptions for harvesting and silviculture.

3. Analyses of the spatial distributions and sensitivity of key old-growth attributes along with information on potential trade-offs within conservation strategies can provide the basis for generation of alternative sets of protected habitat, harvesting and silvicultural prescriptions - all which can maintain minimum and socially acceptable levels of conservation of local biodiversity.

4. In order to develop such planning procedures, geographical information system-driven computer modules are necessary.

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This is one of three background papers for the research design for Phases 2 & 3 of the Biodiversity Study of the Tofino Creek Watershed, Clayoquot Sound of the British Columbia Ministry of Forests and Lands, the Tofino Creek Steering Committee and the Departments of Forest Resources Management and Plant Science of the University of British Columbia. In conjunction with the research design, two complimentary projects are proposed: 1. Landscape analysis for conservation of CWH biodiversity and old-growth habitat attributes and 2. Biodiversity analysis for integrated resource management in
Tofino Creek watershed, Clayoquot Sound.

The landscape analysis proposal is to develop a generic forest land use planning tool for the conservation of biodiversity and will emphasize development of a computer module for use with a geographic information system - eventually to be applicable to any landscape-level spatial unit with some old-growth forest in the Province. This project is envisioned to have a time span of five years with the emphasis, in the first three years, on the data sets from the Tofino Creek Watershed and with additional case studies, involving other researchers, added in the final two years.

The biodiversity analysis of the Tofino Creek watershed is intended as the first case study for the development of the biodiversity planning module. The Tofino Creek watershed is proposed for a three year inventory, analysis and monitoring program for the following reasons. 1. The watershed has a modest and workable total area (<5,000 hectares). 2. The watershed, though partially logged, still supports significant old-growth and biodiversity values. 3. Without a rapid and intensive study in the coming year, many of these old-growth and biodiversity values could be severely compromised at the landscape level.

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A procedure to integrate requirements for in situ conservation of biological diversity with comprehensive land use planning

A major obstacle to effective habitat conservation programmes is one that land use planning may be able to overcome: the problem of translating global concerns into plans that include the "preservation of genetic diversity" (World Conservation Strategy, IUCN, 1980).

There are a number of ways with which to balance concerns for immediate economic benefits with conservation. As Barbier states, "The general objective is to maximize the goals across all these systems through a dynamic and adaptive process of trade-offs."

An approach to comprehensive planning for the in situ conservation for biological diversity, can emphasize incremental blocking of land uses and habitat conservation. Protection of unique and fragile amenities, which are difficult to quantify, can best be considered at the earlier phases of land use decision-making. Since requirements for productivity-related resources afford more flexibility, they can be worked in after initial decisions.

The approach to comprehensive land use planning explored in this proposal recognizes that a wide range of land use configurations and supporting activities can allow for socially desirable levels of conservation of biological diversity and margins of security. In the initial phase of land use planning, where the most vulnerable and strategic sites can be removed from further consideration for consumptive land use, a range of possible approaches to conservation of biological diversity are possible.

A strategy, which reflects political priorities and social and economic forces, can be chosen from a number of possible scenarios. After the alternatives are evaluated and one chosen, as part of a review of qualitative resources, the second step in land use planning, involving a complete balance of requirements for a range of economic and social needs and more quantifiable variables, can be considered.

Opportunities for conservation planning based on minimum requirements of sensitive species

Except for a few recent efforts, there have been only two types of approaches to integration of habitat into regional land use planning. Both have been ineffective for the in situ conservation of biological diversity. Sites with particularly important and recognized biological values can be removed from consideration for consumptive land use at various stages in planning. This has been referred to as the incremental approach to conservation planning. The second type of integration of habitat conservation into land use decision-making is the default pattern where the scraps of land, which are under little or no pressure for consumptive use, allow for maintenance of the habitat which is necessary for maintenance of local biological diversity.

Underlying these dominant approaches has been the fact that rarely have concerns for habitat been given comparable weight to those for consumptive economic development. A few methods have recently emerged which better value biological resources. An approach was proposed by Balser et al. (1981) where there are three separate rankings of categories for conservation and site selection involving geological, botanical and zoological factors.

While alternative scenarios (Gilpin 1987) have been used in wildland allocation for over

two decades, precise requirements for sites and minimum areas, for conservation of biological diversity, have rarely been set.

Instead of comparison of the appropriateness of competing uses of sites, it is more workable to take larger planning units (Cifuentes 1984, Gay 1984) and to set acceptable minimum levels of conservation for all amenities (Gregerson 1981). While this approach to trade-offs might favour biological conservation over short-term economic development, it can provide opportunities for identification of the range of configurations of consumptive and non-consumptive uses.

Related but contrasting concerns in biological conservation: Diversity and productivity

Biological diversity and ecosystem productivity are only two sets of inter-related criteria for which habitat is conserved. Conservation of biological diversity requires a minimum level of productivity. "The preservation of genetic diversity is directly related to the maintenance of ecological processes. Failure to manage ecological processes results in the inevitable loss of genetic material, which is both our insurance policy and investment portfolio for the future." (Jacobs 1984)

Loss of living components of ecosystems can impair certain niches and associated processes (Ehrlich and Mooney 1983) as well as more tangible economic resources. Maintenance of socially acceptable levels of productivity will not necessarily conserve satisfactory levels of biological diversity, but scenarios which involve minimum levels of conservation of biological diversity will, more likely, not require the extensive and pervasive programmes for maintenance of biosphere processes.

A fundamental difference conservation planning goals for biological resources in contrast to those for productivity is that loss of diversity is irreversible. Productivity of natural resources and ecosystem processes can be decreased and then be increased over time if certain levels of air, soil and water quality can be maintained. Once an element of biological diversity is extinguished, it can not be increased in the human time-scale.

Precision becomes a preoccupation in both goal-setting and evaluation in programmes of in situ conservation of biological diversity. Socially desirable levels of ecosystem productivity, and related output of natural resources and services, can be tentative as related to economic aspirations especially in areas which are rich in natural resources and with low human numbers. In contrast, such relaxed approaches to maintenance of biological diversity, regardless of the intensity of land use and configurations of habitat protection, are more prone to be ineffective.

Thresholds for the in situ conservation of local biological diversity should be part of coordinated solutions to what Randall (1986) termed the "problem of allocating biotic resources." And for the environmental planner this translates into a specialized exercise involving analysis of both land sensitivity and land capability.

Alternative strategies which could provide a basis for integration of concerns for in situ conservation of biological diversity into land use planning

The emerging field of landscape ecology was proposed by Naveh (1970, 1984) as the key to attainment of ecologically compatible development. Principles of land use planning for areas

with severe ecological constraints must respond to the complex relationships within social and natural systems (Ayyad and Lang 1984).

In his essay on the contribution of biosphere reserves to "self-sustained development", suggested that the central obstacle to its attainment is the lack of integration of natural and social factors with operational goals for land stewardship. Adaptive management which "seeks to prescribe how to model prospective development in order to reduce uncertainties was proposed by Hilborn (et al. 1980). Unfortunately, much ecological sensitivity analysis (Cooper and Zedler 1980) has not often allowed for flexibility in decision-making because of the jumble of conservation objectives which are involved.

The notion of ecological determinism (McHarg 1966, 1969) can be interpreted in contradictory ways. An erroneous position, which was prevalent in the 1970s, was of "the ecology" - a sort of vulgar optimization. This static conception has lead to assumptions that human development, per se, was environmentally damaging and that only a small number of land use configurations could allow for nature conservation. There is more than one acceptable future ecology for an area and more than one set of possible networks of protected areas for the conservation of local biological diversity.

Concerns for various factors can more precisely interject at various points in a progression of development planning and land use decision-making that in previous efforts to "design with nature." Throughout a planning exercise, such incremental approaches might be no less comprehensive than those which depend on gestalt decision-making.

The focus of this procedure is less on optimized values (Pearse 1969, Swartzman and Van Dyne 1972, Bammi and Bammi 1975) where it is possible to produce compromises which are ultimately unsatisfactory for a range of environmental concerns. Emphasis is on insurance of minimum levels of conservation of biological resources and other qualitative amenities regardless of the pressures for economic expansion. Optimization can come later in the land use planning exercise through evaluation of possible alternatives. This is a departure from conventional trade-off analysis (Brown 1981) where the focus of decision-making is on contests between protection of natural amenities and consumptive land use. The overall form, which equally satisfactory conservation measures can take, is the focus of this procedure.

The choice is not between effective and ineffective conservation. Instead, it is possible to choose from a portfolio of measures the combination which is most capable of satisfying the full range of human needs while maintaining biological resources and other wildland-related amenities.

Such an uncompromising approach, to working concerns for conservation of biological diversity into decision-making frameworks, is necessary because of the nature of the resource. Precise objectives, such as minimum habitat requirements of focal species, can represent the limits to compromise but in a manner that allows for relative flexibility.

Alternative sets of interventions for the conservation of biological diversity

The need for a model which identifies trade-offs between possible sets of conservation measures. All planning is based on forms of predictive models. A land use plan is the product of

objectives, criteria and data. How these things are worked to form a certain plan is the result of a particular set of predictions resulting from perpetually incomplete data.

Determination of different sets of possible measures, which could maintain minimum levels of biological diversity, can employ a powerful but structurally simple model. The paradigm which is proposed relies on trade-offs between land allocation, habitat quality, management and mitigation and is based on three trade-offs.

Paradigms in habitat protection

The modern conception of nature conservation has been dominated by the island metaphor (Cole 1981). This has usually involved a dichotomous approach where there are areas which are natural and those which are not. Emphasis for in situ conservation is usually on space and general characteristics, such as area, as derived from interpretations of the theory of island biogeography (MacArthur and Wilson 1967).

The insulate concept laid the basis for examination of the regional context of fragments of natural habitat and respective, landscape change and ecological impacts. Unfortunately, it has often allowed for a preoccupation with area, rather than with the inter-relationships of sites and the more subtle aspects of local environmental quality.

This is not to suggest that spatial criteria are not important in planning networks of protected areas. Rather, these are only superficial indicators of a number of habitat factors for which it is less easy to generalize. It is the identification of these more qualitative requirements which provide flexibility for formulation of a range of potentially satisfactory conservation programmes.

The metaphor of the old-growth reserve as an island is giving way to that of the boundary of a reserve as part of an assemblage of membranes or filters (Schonewald-Cox and Bayless 1986); ones which are highly sensitive to the interplay of external and internal forces. In their essay on the role of protected habitats in Italy, Giacomini and Romani (1978) described a shift from parks as "protectionist instruments" to "elements of total planning." They view parks as open systems and stated that, "attempts to create or operate on a park considering it as a closed system are destined to failure."

Along with allocation of space, two other sets of planning interventions determine the performance of protected natural areas: management of both human influences and biota within reserve boundaries and regulation of external land use activities which could degrade potential habitat. The nature of particular membranes results from the the contrast between the boundaries and the landscapes which link and separate networks or clusters (Gregg 1983) of reserves.

In their "multidisciplinary boundary model", Schoewald-Cox and Bayless 1986 developed the concepts of the administrative boundary and the generated edge. The former is a mapped construct while the latter is an ecological gradient either inside and outside the reserve. The generated gradient has width in contrast to the administrative boundary and is often degraded wildland or the buffer zone around a natural core. Too often this edge zone is usually well within the administrative boundaries.

Different combinations of allocation, management and mitigation could be ascertained to satisfy a set of objectives for maintenance of biological diversity (Slayter 1974). Protected area membranes are part of the regional, landscape mosaic where habitats and populations are perpetually expanding or diminishing. In ideal situations, it is possible to confine impacts of land use activities to levels which are similar to those of dynamic, natural factors. The research on ecotones by Hansen, di Castri and Naiman (1988) suggests that regional networks of protected habitat can function as "differentially-permeable membranes that facilitate some ecological flows but impede others."

Recognition of the inter-relatedness of management, mitigation and allocation for reserve performance has emerged over the last two decades. In a paper on conservation of macropods in reserves in western Australia, Main and Yadov (1971) emphasised the relationship of reserve size to requirements for management.

Almost a decade earlier, Leopold et al. (1963) provided the rationale for active management by suggesting that few of the protected habitats in the United States were sufficiently large to be self-regulatory ecological units. This biological concept was expanded by Pyle (1980) to include social contexts when he stated that, "The fewer and less intense the hostile pressure from outside the reserves, the larger the area set aside, the lower the number of visitors and the friendlier the social climate in which the reserve exists, the greater its defensibility and manageability."

Implications of influences, which are external to membranes, have only recently been explored. Soule' (1984) suggested reserve designs which make interiors "immune to changes in land use practice in the surrounding regions" such as where entire watersheds are protected. The equally promising possibility, of making land use activities, such as harvesting and silviculture, compatible with conservation requirements, through mitigation of negative impacts of practises, provides another set of opportunities for generation of alternatives for biological conservation.

An expanded paradigm for environmental planning for the in situ conservation of biological diversity

The island paradigm for habitat conservation has probably never provided the basis for effective conservation. It is impossible to confirm this though numerous historical accounts suggest that early reserves, which have remained protected into the modern period, were once more diverse in species.

The intended capabilities of protected habitat have become more explicit through modern biology. Recognition of the loss of biological resources in preserves is so recent that little has yet been done to counteract detrimental forces. The long-term impacts of fragmentation and adjacent land uses were not understood and therefore not considered in reserve design. In addition, a growing number of impacts of land use activities and technologies have become impossible to control.

The paradigm which is explored in this manual is centred on the inter-relationships between conservation measures, available at the district and regional levels, and the nature of interventions necessary to insure the continued survival of full assemblages of local biological

diversity. These inter-relationships can be expressed in three trade-offs.

The area / regulation trade-off

In conservation of genetic diversity in natural ecosystems, and the processes which maintain it, there is a general relationship between the total area in protected habitat and the level and nature of the ecosystem management which is necessary. Regulation is both management within designated reserves and regulation of land use in adjacent areas to avert negative impacts.

Greater regulation would accompany less total areas in reserves to satisfy minimum conservation requirements for certain complexes of organisms. A greater spatial allocation of protected habitat might require less regulation in order to accomplish the same conservation objectives.

The basis for this trade-off is that designation of protected area, per se, is not the only determinant of whether the respective site will continue to support prescribed sets of organisms. The viability of a site, in terms of the requirements of certain organisms, can be interrupted or even permanently impaired, over time, without regulation which mimics natural processes or controls insidious anthropogenic change. No amount of internal or external management can maintain populations when certain numerical and spatial habitat requirements are unmet.

The recent work of Janzen (1983), in the neotropics, has tended to confirm the area-regulation trade-off. He has noted that, "As areas of conserved pristine forest are reduced in size they are increasingly susceptible to significant immigration of animals and plants from nearby anthropogenic secondary successional habitats." Susceptibility often necessitates management or mitigation - or the allocation of more protected habitat for an extended buffer.

It is in consideration of the two end points, the relationship between area and regulation can be explored. The amount of flexibility which would be available depends, in large part, on the population structure, niche and habitat requirements of assemblages of species and the nature of cyclical change and resilience to disturbance in associated ecosystems.

The area / regulation trade-off poses some new opportunities for making protection of biological diversity compatible with development planning. At one end of the axis of trade-offs is the possibility of reserves so large that on-going requirements for maintenance and regulation might be attractively low. At the other extreme, economic expansion could be so well integrated with networks of multi-purpose, protected areas, through on-going management and mitigation, that the total area allocated solely for purposes of conservation of biological diversity could be modest.

The economic dimensions of the area / regulation trade-off involve both traditional land uses and pressures for expansion of modern economic pursuits. The more negative and pervasive the regional ecological impacts of land use activities, the greater the requirements for management and mitigation or total allocation of space for protected natural areas. However, there are biologically and socially derived limits to the possibilities for allocation of reserves and regulation. While these constraints may be fluid, and change with the level of social development, decisions made today will largely determine the range of future options.

The area / site quality trade-off

In the creation of networks of protected areas, for conservation of local biological diversity, some combinations of sites could be more efficient, in terms of allocation of space. Some sites have habitats which support lower densities of selected species. Larger areas are required to satisfy minimum requirements for populations.

Some sites hold larger numbers of species and focal taxa than others. When sites of high concentrations are protected, it may be possible to keep the total area in reserves lower than if conservation efforts were for sites of "poorer quality." With rare species where often only a few sites exist, options for site selection are more limited.

The area / site quality trade-off suggests that there are trade-offs between the total area, which could be allocated to a network of reserves, and the capabilities of sites to support targeted complexes of organisms. If the sites with the highest quality of habitat are not chosen for protection, but instead are converted to consumptive uses, the total area of habitat, which will become necessary to protect the biological diversity of the district, will increase.

In a modelling phase of a land use planning exercise, the total area needed for a district network of protected areas would diminish if sites with configurations of more spatially efficient and secure habitats were chosen. The extremes of the axis of the area / site quality trade-off could vary greatly depending on the habitat requirements of the set of targeted organisms, the distribution and overlap patterns of populations, and the nature of the pressure for expanding consumptive land use. Determination of the axis of trade-offs, between necessary area and site quality, for particular biotic districts and harvesting and conservation contexts, is useful in a number of ways.

The management / mitigation trade-off

The third trade-off is concerned with an internal dimension of the first. With a set of reserve boundaries and a total area for a network of protected areas, there is also a dynamic inter-relationship between the types and levels of management (internal) and mitigation (harvesting and silvicultural prescriptions that are external to protected stands of old-growth forest) which could be employed. With more management, less mitigation would be necessary. The opposite would also be true.

There are limits to the plasticity of the trade-offs between management and mitigation especially in terms of what is politically feasible and which does not offset costs of habitat conservation on to local communities (Thompson et al. 1986). There are even more intrinsic constraints related to the biophysical characteristics of the protected areas and surrounding districts and the types of adjacent land use activities.

Management involves various forms of substitution of ecosystem processes and social control and is often an expensive means to cope with undesirable aspects of the expansion of land use in a district. By contrast, mitigation is preemptive and directed at the social, economic and technological dimensions of land use.

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Management is implicitly an active affair which involves the substitution or reinforcement of natural processes and policing of human activities. In contrast, mitigation involves specific forms of restraint on what is usually an expanding set of regional land use activities. While regulation of land use, outside of reserves, is by no means passive intervention, its implementation is usually at the administrative and legislative levels and functions to be preemptive.

The temporal dimensions of management and mitigation measures can be quite different. The level of mitigation employed in the earlier phases of conservation programmes often determines the extent of the management which will become necessary for years to come. However, the opposite is not true. The mitigation regimen largely creates the context from which arise requirements for management.

In conservation planning, there is an opportunity to decide on the general balance of management and mitigation measures or rather of preemptive versus more adaptive and internal approaches. The extremes of this third dimension of trade-offs are tied to the feasibility of various kinds of control over sites and the social climate for imposition of limitations on land use activities. The need for management and mitigation is determined by the nature, intensity and duration of the regional economic development or of broader trends in environmental degradation.

Eight strategies of environmental planning for the in situ conservation of local biological diversity

The trade-offs comprise three dimensions of variation in style for the planning of regional networks of protected areas. The extremes of each axis can be combined to form eight distinct strategies which maintain minimum levels of of the requirements of the habitat indicators of biological diversity. A number of less extreme configurations of measures are also available.

Such strategies provide opportunities for relating conservation planning back to social and economic policy. They force conservation and harvesting and silviculture planning to be viewed as one in the same. For a conservation plan to be successfully implemented it must support the chosen style of harvesting and silviculture.

The policy issues which are embodied in this set of possible approaches to programmes of conservation and economic expansion, involve regulation of economic expansion. Insular strategies are predicated on the stance of minimum impingement on economic activities outside of protected areas. In contrast, mitigative approaches involve greater restriction in economic activities but could quite possibly allow for some exploitation over greater total area.

The eight strategies provide a basis for determination of divergent approaches to links between decision-making for harvesting and silviculture and conservation. The island paradigm often involves a more laissez-faire approach to land use planning while the membrane requires structures for regional coordination and must influence, more directly, consumptive land use activities. If economic expansion is given earliest consideration in land use planning, the range of possibilities for biological conservation is narrowed. The opposite is also true.

Biodiversity conservation strategy 1: minimum portion of district in protected habitat with high

levels of regulation - random and often poor quality of sites - regulation largely within boundaries of protected areas

This situation has often resulted with protected habitat establishment and is the most common manifestation of the island metaphor in nature conservation. Pressures for expansion of land use are great, the total area of the protected habitat is minimal, the quality of most of these sites is poor, networks of reserves are left with an on-going burden of requirements for heavy regulation and manipulation. This is the maximum management option which jeopardizes biological conservation for future generations.

Biodiversity conservation strategy 2: minimum portion of area of district in protected habitat with high levels of regulation - poor site quality - regulation largely of external land use

The configurations of protected areas in this strategy might be similar to that in strategy 1 but there would be a major difference in decision-making for regional land use. From the earliest phases of planning, regulation would emphasize preemptions of negative impacts from land use outside of the reserves and there would be minimal, direct manipulation of ecosystems within protected areas.

This is the maximum mitigation (harvesting and silvicultural prescriptions) option which would allow land use activities throughout much of the district as well as for laissez-faire approaches to management but would require heavy regulation of human activities.

Biodiversity conservation strategy 3: minimum portion of area of district in protected habitat with high levels of regulation - high quality of habitat of sites - regulation largely within boundaries of protected areas

This strategy is similar to that of strategy 1 and its island metaphor but is less problematic for on-going management because the habitat which has been allocated is of better quality and tending to be smaller in area. Management activities can be more focused on particular sites. This type of high quality park system option has sometimes been proposed for the creation of systems of protected areas which are attractive for wildlife tourism.

Biodiversity conservation strategy 4: minimum portion of area of district in protected habitat with high levels of regulation - high quality of habitat of sites - regulation is largely in areas outside of protected areas

This strategy is similar to that of strategy 2 but the requirements for mitigation (harvesting and silvicultural prescriptions)s might be more workable as the sites which are protected are less problematic. Land use expansion could be relatively pervasive but regulatory measures for land use would be precise and well-monitored.

This, the maximum area in mitigation (harvesting and silvicultural prescriptions)s option would require planning apparatuses which could maintain tight controls for an indefinite period.

Biodiversity conservation strategy 5: high portion of district in protected habitat as required with

minimum regulation - poor quality of habitat of sites - regulation largely within boundaries of protected areas

In contrast to strategies 1 through 4, the ones which follow are viable in settings where pressures for expansion of consumptive land use are less severe. Highly site-specific land use expansion is envisioned as in the case of mining and infrastructure installation.

Negative impacts of land use would bleed into reserves but, due to the extent of protected habitat, could be offset through management in edge zones. This is the maximum spatial management of internal buffer zones option.

Biodiversity conservation strategy 6: high portion of district in protected habitat as required with minimum regulation - poor quality of sites - regulation is largely outside of boundaries of protected areas

Conservation activities would emphasize control of large territories, often with inclusion of redundant or marginal habitat types and regulation of land use activities outside of protected areas. Of the 8 strategies, this one relies on the most fluid and least obtrusive boundaries between zones of habitat preservation and consumptive land use. This is the maximum spatial regulation of buffer zones around protected old-growth cores.

Biodiversity conservation strategy 7: high portion of district in protected habitat as required with minimum regulation - high quality of habitat of sites - regulation largely within boundaries of protected areas

Strategy 7 may be the ideal approach to minimize the need for expensive management while still relying on the island metaphor. Needs for on-going manipulation and policing would be largely be preempted by the high quality core areas being surrounded by the extensive areas to accomplish this.

Broad territorial monitoring is key to allocation of the scarce resources available for management. This approach can be thought of as the more viable island metaphor option.

Biodiversity conservation strategy 8: high portion of district in protected habitat with high quality sites with minimum regulation - regulation largely outside the boundaries of protected areas

Like strategy 6, the edges between zones of habitat protection and land use expansion are subtle and often layered in numerous buffer zones. The higher quality of the sites and the relatively large portion of the district in reserves would mean that pressures for land use expansion need not dominate site selection and that, in turn, it is feasible to place restrictions on land use activities in areas outside of the reserves.

This strategy is the conservation membrane with maximum security option. In the last decade of the Twentieth Century, this approach to habitat conservation seems the most efficient and secure in terms of long-term balancing of cost, benefits and risks. Unfortunately, it is also the most utopian for most situations, at the present time.

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Phases in the procedure for integration of old-growth habitat conservation and preservation into forest land use planning

Using the minimum requirements of the focal habitat of biotic districts, along with cause - effect linkages and analysis of management fields as tools and the trade-offs as the framework, it is possible to devise a procedure for generation of multiple strategies for integration of concerns for biological diversity into comprehensive land use planning. The following is one possible procedure which can be constructed to employ these techniques.

Phase 1 DELINEATION OF THE BIOTIC DISTRICT

Phase 2 INVENTORY OF SPECIES

Phase 3 SELECTION OF FOCAL TAXA / SENSITIVE SPECIES

Phase 4 DETERMINATION OF REQUIREMENTS OF FOCAL TAXA / SENSITIVE SPECIES

It is possible to develop an automated approach similar to Starfield and Bleloch's (1983) expert system and Kessel's (1977, et al. 1982) wildland fire management procedure.

Phase 5 MAPPING OF DISTRIBUTIONS OF FOCAL TAXA / SENSITIVE SPECIES AND HABITAT AND POPULATION FACTORS RELATED ASSOCIATED REQUIREMENTS FOR PERSISTENCE

There are three approaches to organisation of biogeographical data: point-locality mapping, mapping of intrinsic features, such as habitat types, and synthetic approaches involving grids or other artificial delineations (Morse et al. 1981). This third approach is the most commonly favoured (Rowe and Sheard 1981, Nagy and Wagle 1979). A set of grids could be drawn over the map of the biotic district which would correspond to "cruising" transects. Each grid-cell would be sufficiently small in represented area to be considered a homogeneous unit of habitat.

Phase 6 DEVELOPMENT OF OLD-GROWTH ATTRIBUTE SAMPLING FRAME

Based on the compilation of the habitat requirements, specific types of old-growth attributes, as related to particular species (mainly trees and shrubs) under specific landform and successional conditions, can be identified.

Phase 7 GAP ANALYSIS OF CAPABILITIES OF INOPERABLE AREAS FOR THE CONSERVATION OF ELEMENTS OF LOCAL BIOLOGICAL DIVERSITY

Before new protected areas can be proposed, any which exist should be analyzed in terms of what relevant habitat is already protected. This has been termed gap analysis by Burley (1988). The prospects of these sites for maintenance of such diversity elements, in the long-term, could be assessed in the impact simulation phase.

Phase 8 EVALUATION OF QUALITY OF SITES FOR POTENTIALLY VIABLE HARVESTING AND SILVICULTURAL METHODS

The priority areas for both wildland conservation, for values other than biological diversity, and for alternative methods of harvesting and silviculture could be evaluated (Hopkins 1977). Each site could be rated for appropriateness of wildland designation regardless of habitat information. A rating system for other wildland values, such as visual quality, as well as extractive resources could be mapped.

Phase 9 EVALUATION OF QUALITY OF SITES FOR HABITAT CONSERVATION

Each landscape cell is evaluated in terms of the presence and extent of requirements of the focal taxa. The sites involving more species and minimum requirements and more densities or preferred habitat attributes are considered higher quality. A number of the most obvious and efficient configurations of protected area allocations and regulation could be identified.

Phase 10 EVALUATION OF THE POSSIBLE REGULATORY MEASURES IN TERMS OF EFFECTIVENESS AT MAINTENANCE OF THE MINIMUM REQUIREMENTS FOR POPULATIONS AND HABITAT AND MINIMIZING CONSTRAINTS ON HARVESTING AND SILVICULTURE

The subset of protected area categories and management and mitigation (harvesting and silvicultural prescriptions) measures, which would be most secure and effective, can be identified for particular species, requirements and settings within the district.

Phase 11 IMPACT SIMULATION FOR INITIAL CONFIGURATIONS OF PROTECTED OLD-GROWTH CORES, BUFFERS AND RELATED CONSTRAINTS (INCLUDING SILVICULTURAL AND CONSERVATION MEASURES)

The prospective negative cause-effect linkages, between land use activities and minimum requirements, can be compiled and quantified. The environmental factors related to the sensitivity of sites to certain practices and transfer of primary impacts to protected habitat can be mapped. Potential responses of habitat in particular sites to certain regimens of land use-induced disturbance can be simulated through scalars.

This phase relates minimum requirements to land use activities. Three pathways of choices could be made from determinations of habitat loss for the initially proposed reserves. Negative relationships between activities on certain sites and populations of sensitive species in nearby areas (Forman 1982, Rice 1978) could then be quantified by use of gradients.

The potentially lost habitat could be removed from further consideration, for protection, and substitute habitat could be located as with the island approach. In contrast, limitations on adjacent land use (mitigation) and measures to intervene in ecosystem processes to control habitat degradation (management) could be simulated. The limits to these responses, as related to the extremes of the three trade-offs, could be determined.

Phase 12 EXPANSION OF CONFIGURATIONS OF CONSERVATION MEASURES TO INCLUDE TRADE-OFFS INVOLVING REGULATION .

Management and mitigation (harvesting and silvicultural prescriptions) activities would be simulated to lessen or compensate for negative impacts of adjacent land use. Since the viability of protection on certain sites could improve with increased or heavy management and mitigation (harvesting and silvicultural prescriptions) measures, less area for additional protected natural areas might be necessary. Or it might be preferable to allocate larger total area in reserves, with more buffers, and to dispense with potentially unwieldy regulation.

Phase 13 GENERATION OF THE 8 STRATEGIES

Phase 14 ANALYSIS OF ALTERNATIVES AND CHOICE OF ONE STRATEGY OR PREFERENTIAL RANKING OF THE STRATEGIES

Computation and simulation

The quantitative evaluation of sites and the formulation of conservation strategies would require a number of computations. It is necessary to scan considerable geographic data to determine which landscape cells could best meet habitat requirements for assemblages of focal taxa. The habitat involving high concentrations of characteristics, related to minimum requirements, would be identified and priorities determined (Phase 9). Unless decided otherwise, as based on Phase 8, these higher quality sites would be the first choices for protection.

One of the most difficult tasks in computation is simulating possible protected areas (Phase 11) and decisions including additional conservation measures (Phase 12).

It is necessary to qualify cause-effect linkages: to determine which prospective protected sites would be vulnerable to degradation. It is necessary to quantify cause - effect linkages through multi-dimensional scalars.

A site search function to identify additional areas with desired habitat characteristics and / or substitute sites, which might be of lower quality but would be less sensitive or prone to degradation can be employed for the island approaches. A regulatory measures search function could search for forms of management and mitigation (harvesting and silvicultural prescriptions) which would lessen the extent of habitat degradation. A number of algorithms, from other types of geographical information systems, could be developed.

Potential uses of a procedure which identifies sets of conservation alternatives

There are numerous steps between the identification of options for harvesting, silviculture and old-growth conservation of biological diversity; the choice of one configuration; and its integration into a comprehensive land use plan. The procedure, in this manual, can be employed in a number of different ways depending on the situation.

Three key determinants for use are: the extent to which the biological diversity of a district

has been imperiled; the extent of the powers to determine and coordinate land use and its regulation; and the nature of cause-effect linkages between land use practices and ecological impacts.

Settings where multiple strategies for habitat protection for conservation of biological diversity could be employed

At a number of stages in regional planning, alternative scenario generation and evaluation could be employed as a modular tool as part of larger exercises. There are four principle roles which alternative conservation measures could play in comprehensive land use planning.

Different but equally viable conservation paths could be used to identify crucial sites for protected designation from those available for exploitation. This could be particularly relevant to pristine regions with pressures for large-scaled, economic development. In these frontier settings, with rapid infusion of human population and technology, comprehensive decision-making is key to averting degradation of environmental quality at the regional level.

Such a method for determination of possibilities for conservation could also be used for determination of whether a certain harvesting and silviculture plan would allow for conservation of biological diversity. If there is a sincere governmental commitment and accompanying institutional structure for habitat protection, and economic objectives for a proposed harvesting and silviculture had already been set, generation of strategies could be used to ascertain whether a specific proposal would be acceptable.

Another use of the procedure could be employed for the identification of divergent styles of resource development and district programmes of protected areas. This could be employed where the overall style of harvesting and silviculture and conservation has not yet been set. This would be the most ideological use of the strategies: demonstrating that habitat conservation is workable as part of land use expansion and that certain options for economic development are more ecologically compatible than others.

As well as for use in large-scaled land use and conservation decisions, such strategies could be used to identify measures for incremental expansion of systems of protected areas as part of finer-scaled exercises for maintenance of biological diversity. As scenario generation occurs further along in the process of modification of the natural landscape mosaic, the irreversible ecological changes which result will preclude certain options. Consequently, the range of potential solutions for satisfaction of both pressures for conservation and certain forms of harvesting and silviculture will narrow.

Analysis of the most crucial areas for biodiversity conservation in the early stages of forest land use planning

Alternative strategies have been used in environmental planning for site and resource-related decision-making for over two decades. What makes this procedure new is that variability within strategies is limited to the combinations and intensities of conservation measures for the conservation of biological diversity and does not embody concerns for other amenities and

social needs. Decisions for these other factors would be made independently of this scenario generation. Conservation of biological diversity is only part of one level of environmental considerations in a more complex process of trade-off-related decisions for sites within the a district.

Certain areas are so rich in biological diversity and so sensitive to loss that a case can be made to limit all forms of modern human disturbance or certain classes of land use activities. In a regional planning exercise, certain biotic districts could be identified on the basis of richness or vulnerability and then could be removed from consideration for certain types of land use expansion such as commercial timber harvesting or mining.

Highly vulnerable districts could be evaluated in terms of the conservation strategies which would be available. If the range of possibilities was too narrow and the level of necessary habitat protection not practical, it may be desirable to zone for less detrimental land uses, such as non-consumptive tourism.

Evaluation of potential impacts of a cutting permit on biodiveristy

Development plans in remote, rural areas with low human densities have too often been imposed from the outside with implication to local communities left unexplored. In debates over whether to accept or reject rigid project designs, a procedure could be employed to determine whether there would be losses in elements of regional biological diversity.

The harvesting and silviculture plan could be super-imposed over the various configurations of possible habitat protection to determine if there is any compatibility with requirements of conserving biological diversity. Such evaluation can determine whether or not a proposed project involves a socially-acceptable margin of security from negative impacts(Fischhoff et al. 1981). The social, economic, political and administrative implications of compatible strategies could then be considered.

If potentially negative impact are identified, this information could lay the basis for redesign of the harvesting and silviculture proposal. Such trade-offs, between harvesting, management and conservation, could be integrated directly into the next, the multiple criteria (Zionts and Wallenius 1976, Voogd 1983) phase of the land use planning exercise.

Choices of styles of harvesting and habitat conservation styles in forest land use planning

Sometimes land use planning decisions can be made in a political economic context where pressures for population and economic expansion are not desperate. Where a number of divergent sets of priorities can be compared, the ones which would be compatible with certain strategies for the conservation of biological diversity, could be linked. Such conservation-of-biological-diversity "paths" (Lovins 1979) or transition strategies (Sachs 1984) could become symbolic in local political processes.

Where the first use of the procedure is district-oriented and the second is site-oriented, this focus is on economic and environmental policy. There are a number of possible steps between the strategies and local concerns for harvesting and silviculture. Key policy issues are inevitably

viewed in terms of the benefits or costs especially for poor, rural people or revenue-hungry provincial governments. Yet the real advantages to local economies of the conservation of biological diversity are long-term in nature.

Where there is a push for immediate economic benefits, the nature of the land use decisions and subsequent strategies can be linked to concerns for specific biological resources such as totem species and community types with local and international identification. Choices of strategies become linked to more comprehensive, alternative planning strategies (Painho 1987) involving competing emphases such as tourism versus industrial development or community-based forestry as opposed to corporate logging concessions.

As for settings with "downward spirals" (Thompson et al. 1986) of regional environmental deterioration, the whole process of strategy identification can seem a luxury. But it is only in the exploration of the widest set of options that we can sometimes find solutions to the inevitably "wicked problems" (Rittel and Webber 1973) of competition over resources and space.

Evaluation of the effectiveness of the existing network of protected areas and subsequent determination of priorities for expansion

In many of the areas of the world, where large tracts of natural habitat remain, there are presently some kinds of protected areas. In some cases, these programmes have already been effective at maintenance of the biological diversity of a district under projected land use-induced disturbance.

Scenarios can be used to determine whether present conservation programmes are effective. In this use of the procedure, as a basis for evaluation of the actual conservation within networks of protected habitat, gaps identified lead to proposals for additions to park systems. In some instances, it might be determined that the existing networks of protected areas are so ineffective, that it might be better to expansion of systems of ecological and genetic reserves.

Some limitations on employment of multiple strategies for the conservation of biological diversity through comprehensive, land use planning

> "The model assumes some abstract planners with clear goals.
> But conservationists are themselves part of society, rooted
> in particular social groups and self-selected by ideological /
> cultural criteria, with their own politics and vulnerabilities
> to external and internal pressures. The self-awareness of the
> conservation planning / managing community is a possible protection
> against built-in error. So, what will be the typical patterns of
> insights and blindnesses, commitments and opportunisms?"
> (Richard Levine 1988)

In his essay on environmental management in the Third World, Bowander (1980) identified three prerequisites for effective problem-solving and implementation. It is necessary to quantify the

long-term results of programmes of environmental management. Standards of evaluation should be explicit. Siting decisions must be information-based.

Some limitations to the usefulness of alternative strategies are derived from potential abuse by decision-makers. Politically acceptable aspects of a number of sets of measures could be muddled to produce what could appear to be viable choices but which are incapable of satisfaction of district-wide conservation criteria. Superficial aspects of strategies could be used to gain acceptance for a comprehensive planning exercise, for the in situ conservation of biological diversity, without understanding how it could support or detract from other goals for conservation of biota, wildland and other natural resources as well as for those for economic expansion and social development.

The most immediate potential for misuse of this procedure is when a government opts for less area in protected status and protection of poorer quality habitat and thus externalizes the bulk of the costs of conservation on to future governments. In these harvesting and silviculture settings, only relatively self-regulating units of protected habitat, with reliance on the island paradigm, can withstand severe pressures for liquidation of old-growth forests.

Use of strategies to highlight a politically expedient plan for harvesting, silviculture and conservation path could lead to simplistic interpretations which could inhibit programme harvesting and silviculture in the long-term. The linking of the most attractive scenario to a vision of development, in a manner which is cognizant of long-term environmental costs and benefits, is advantageous until such an approach, in turn, becomes orthodox, inflexible or looses public favour.

The real value of a generic planning tool for the conservation in biological diversity is in empowering a range of societal and sectoral groups to begin to precisely consider the the requirements for habitat conservation and through this process come to perceive of a wider range of options for both conservation / preservation and economic activities deriving from the forests of British Columbia.

references and selected readings

Ayyad, M. and G. Lang. 1984. Ecological bases for planning in regions with severe ecological constraints. In Ecology in Practice. Volume 1 Ecosystem Management. 210 - 233. Paris, Unesco.

Balser, D., A. Bielak, G. De Boer, T. Tobias, G. Adindu and R. S. Dorney. 1981. Nature reserve designation in a cultural landscape incorporating island biogeography theory. Landscape Planning 8: 329 - 347.

Bammi, D. and Bammi, D. 1975. Land-use planning: An optimizing model. OMEGA - International Journal of Management Science 3(5): 583 - 594.

Bowonder, B. 1980. Environmental management and the third world. Science and Public Policy. June 1980: 185 - 197.

Brown, T. C. 1981. Tradeoff Analysis in Local Land Management Planning. Fort Collins, Colorado, USDA Forest Service (General Technical Report RM - 82).

Burley, F. W. 1988. Monitoring biological diversity for setting priorities for conservation In Biodiversity. E. O. Wilson

(editors). 227 - 230. Washington, D. C., National Academy Press.

Cifuentes, M. , C. MacFarland, R. and R. Morales. 1984. Strategic planning of national or regional systems of biosphere reserves: A methodology and case study from Costa Rica. In Conservation, Science and Society. 93 - 120. Paris, Unesco - UNEP.

Cole, B. J. 1981. Colonizing abilities, island size, and the number of species on archipelagoes. American Naturalist 117(5): 629 - 638.

Cooper, C. F. and P. H. Zedler. 1980. Ecological assessment for regional development. Journal of Environmental Management 10: 285 - 86.

Ehrlich, P. R. and H. A. Mooney. 1983. Extinction, substitution and ecosystem services. BioScience 33(4): 248 - 254.

Fischhoff, B., S. Lichtenstein, P. Slovic, S. L. Derby and R. L. Keeny. 1981. Acceptable Risk. London, Cambridge University Press.

Forman, R. T. T. 1982. Interaction among landscape elements: A core of landscape ecology. In Perspectives in Landscape Ecology. S. P. Tjallingii and A. A. de Veer (editors). 29 - 34. Wageningen, Netherlands, Pudoc.

Giacomini, V. and V. Romani. 1978. National parks as open systems: An Italian overview. Landscape Planning 5: 89 - 108.

Gilpin, M. E. 1987. Spatial structure and population vulnerability. In Viable Populations for Conservation. M. E. Soule' (editor). 125 - 139. New York, Cambridge University Press.

Gregersen, H. M. 1981. forestry. In Tropical Forests: Utilization and Conservation. F. Mergen (editors). 108 - 124. New Haven, Connecticut, Yale School of Forestry and Environmental Studies.

Gregg, W. P. 1983. Multiple - site biosphere reserves for better management of regional ecosystems. (on file) United States Department of the Interior National Park Service, Washington, D. C.

Hansen, A. J., F. di Castri and R. J. Naiman. 1988. Ecotones: What and why? Biology International 17: 9 - 46. In A New Look at Ecotones: Emerging international projects on landscape boundaries. F. di Castri, A. J. Hansen and M. M. Holland (eds.). Paris, International Union of Biological Sciences.

Hilborn, R., C. S. Holling, and C. H. Walters. 1980. Managing the unknown: Approaches to ecological policy design. In Biological Evaluation of Environmental Impacts. 103 - 113. Washington, D.C., U.S. Fish and Wildlife Service, Report OBS-80/26.

Hopkins, L D. 1977. Methods for generating land suitability maps: A comparative evaluation. AIP Journal October 1977: 386 - 400.

Ingram, G. B. 1989. Planning district networks of protected habitat for conservation of biological diversity: A manual with applications for marine islands with primary rainforest. Ph. D. dissertation in Environmental Planning. On file, University of California at Berkeley.

IUCN. 1980. World Conservation Strategy: Living resource conservation for sustainable development. Gland, Switzerland, IUCN - UNEP - WWF.

Jacobs, P. 1980. Environmental planning and rational use. In Sustaining Tomorrow: A strategy for world conservation and development. F. R. Thibodeau and H. H. Field (editors). 77 - 85. London, University Press of New England.

Janzen, D. H. 1983. No park is an island: Increase in interference from outside as park size decreases. Oikos 41: 402 - 410.

Kessel, S. R. 1977. Gradient modeling: A new approach to fire modeling and resource management. In Ecosystem Modeling in Theory and Practice. C. A. S. Hall and J. W. Day (editors). 575 - 606. New York, John Wiley.

Kessell, S. R., R. B. Good, and M. W. Potter. 1982. Computer Modelling in Natural Area Management. Canberra, Australia, Australia National Parks and Wildlife Service.

Leopold, A. S., S. A. Cain, C. M. Cottam, I. N. Gabrielson and T. L. Kimnball. 1963. Wildlife Management in the National Parks. (on file) United States Department of Interior National Park Service, Washington, D. C.

Levine, Richard. 1988. letter to Gordon Brent Ingram, October 21, 1988. on file, Department of Population Sciences, School of Public Health, Harvard University, Cambridge Massachusetts. on file, The University of British Columbia.

Lovins, A. B. 1979. Soft Energy Paths: Towards a durable peace. New York, Harper and Row.

MacArthur, R. H. and E. O. Wilson. 1967. The Theory of Island Biogeography. Princeton, New Jersey, Princeton University.

McHarg, I. L. 1966. Ecological determinism. In Future Environments of North America. F. F. Darling and J. P. Milton (editors). 526 - 538. Garden City, New York, The Natural History Press.

McHarg, I. L. 1969. Design With Nature. Garden City, New York, Doubleday - Natural History Press.

Main, A. R. and M. Yadov. 1981. Conservation of macropods in reserves in western Australia. Biological Conservation 3(2): 123 - 133.

Morse, L. E., M. S. Henifin, J. C. Ballman, and J. I. Lawyer. 1981. Geographical data organisation in botany and plant conservation: A survey of alternative strategies. In Rare Plant Conservation: Geographical data organisation. L. E. Morse and M. S. Henifin (editors). 9 - 29. Bronx, New York, New York Botanical Garden.

Nagy, G. and S. Wagle. 1979. Geographic data processing. Computing Surveys. 11(2): 139 - 181.

Naveh, Z. 1970. The conservation of ecological diversity of Mediterranean ecosystems through ecological management. In The Scientific Management of Animal and Plant Communities for Conservation. E. Duffey and A. S. Watt (editors). 605 - 622. London, Blackwell Scientific.

Naveh, Z. 1984. Landscape Ecology: Theory and application. New York, Springer-Verlag.

Painho, M, J. G. Fabos and M. Gross. 1987. Alternative Plan Formulation: The application of a programming model in landscape / land use planning. Amherst, Massachusetts Agricultural Experiment Station.

Pearse, P. H. 1969. Principles for allocating wildland among alternative uses. Canadian Journal of Agricultural Economics 17(1): 121 -131.

Pyle, R. M. 1980. Management of nature reserves. In Conservation Biology: An evolutionary perspective. M. E. Soule and B. A. Wilcox (editors). 319 - 328. Sunderland, Massachusetts, Sinauer Associates.

Randall, A., 1986. Human preferences, economics, and the preservation of species. In The Preservation of Species: The value of biological diversity. B. G. Norton (editor). 79 - 109. Princeton, New Jersey, Princeton University Press.

Rice, R. M. 1978. The effects of forest management on erosion and sedimentation due to landslides. In Proceedings of Eighth World Forestry Congress, Jakarta, Indonesia. 1978. III: 320 - 332.

Rittel, H. W. and M. M. Webber. 1973. Dilemmas in a general theory of planning. Policy Sciences 4: 155 - 169.

Rowe, J. S. and J. W. Sheard. 1981. Ecological land classification: A survey approach. Journal of Environmental Management 5(5): 451 - 464.

Sachs, I. 1984. Developing in harmony with nature: Consumption patterns, time and space uses, resource profiles, and technological choices. In Ecodevelopment: Concepts, projects, strategies. Oxford, England, Pergamon.

Schonewald-Cox, C. M. and J. W. Bayless. 1986. The boundary model: A geographical analysis of design and conservation of nature reserves. Biological Conservation 38: 305 - 322.

Slayter, R. O. 1974. Ecological reserves: Size, structure and management. In A National System of Ecological Reserves in Australia. Fenner (editor). Canberra, Australia (Australian Academy of Science Report No. 19).

Soule', M. E. 1984. Applications of genetics and population biology: The what, where and how of nature reserves. Conservation, Science, and Society. 252 - 264. Paris, Unesco - UNEP.

Swartzman, G. L. and G. M. Van Dyne. 1972. An ecologically based simulation - optimization approach to natural resource planning. Annual Review of Ecology and Systematics. 3: 347 - 398.

Thompson, M., M. Warburton and T. Hatley. 1986. Uncertainty On a Himalayan Scale: An institutional theory of environmental perception and a strategic framework for the sustainable development of the Himalaya. London, Milton Ash Editions.

Voogd, H. 1983. Multicriteria Evaluation for Urban and Regional Planning. London, Pion Limited.