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Indicators of biological diversity & landscape processes for land use simulation on islands

abstract

The purpose of this paper is to explore the utility of biodiversity indicators for integration of concerns for conservation of nature into broader frameworks for development planning on islands. The increasing commitments of governments to conservation of species, threatened habitats, and wild species with genetic resources requires new planning frameworks which are better based on site and population data as well as the principles of landscape ecology. The needs for more precise and comprehensive decisions over natural sites are examined. The potential utility of indicator species or focal taxa, to guide spatial planning and to lay a basis for the development of ecotourism are outlined as is a typology of indicators of representiveness, vulnernability and exploitation pressures and respective conditions within the landscape. Island ecosystem are review in terms of indicator species and related landscape features. A range of applications to spatial planning frameworks involving protected area cores, buffers, corridors and barriers are reviewed. Applications for some islands in the Pacific Rim are described.

Just as the pressures for economic and social development continue for the world's small islands so to will those for more comprehensive and secure nature conservation - particularly in ways which enhance the tourist base. How can we conserve and restore natural areas on islands and somehow make peace with the forces which inevitably require more building construction, infrastructure and pollution? It will not be easy - even in the increasingly abused name of "eco-tourism." The is only more careful, spatially precise and ecologically cognizant land use planning with a vision of eco-development (McElroy and de Albuquerque 1990).

The planning that there has been for small islands in the post-World War II period was largely ineffective or an outright disaster in terms of survival of sensitive species and habitats. In addition, entire island landscapes were transformed the losses of elements of natural and cultural diversity - features key to post-modernist development strategies as increasing numbers of tourists shy away from areas where the "sense of place" has been obliterated.

Within protected areas, facilities siting and zoning in master plans have often been of limited capacity to control threats to the sensitive and narrow shore zones. One of a number of problems was the lack of knowledge of the land base and in the development of policies and types of measures that can be easily linked to data bases. Concerns for biological diversity are particularly daunting and perhaps if we can develop a new planning paradigm that services these particular environmental concerns it may be possible to more carefully respond to other parameters with their inevitable social and economic dimensions.

Biological diversity and conservation planning on islands:
The need for fine-scaled knowledge of landscape elements

Conservation on small islands is increasingly problematic for a plethora of reasons. There are few areas on any islands where there has not been significant degradation of shore areas. Adjacent shallow marine areas are increasingly prone to degradation as part of broader archipelago and coastal mainland marinescapes (Ray 1991). Upland areas of islands have always been particularly prone to habitat fragmentation but the technologies and intensities of land use in the late Twentieth Century have been especially deleterious especially because of the speed and intensity of new activities. Water shortages and climate change are often particularly deleterious for riparian zones which are often modest in terms of area. In recent decades, traditional communities on islands have become increasingly active, politically, and articulate in terms of their particular conservation and development needs.

In recent decades, a range of socially and economically based concerns for the conservation of biological diversity has emerged (Ehrlich and Mooney 1983, Norse et al. 1986, Callicott 1986, Ehrenfield 1988, Wilson 1988, Ehrlich 1988). At the same time, there is a growing awareness of the vulnerability of island ecosystems and landscapes to inappropriate expansion of economic and settlement activities (McEachern and Towle 1974, Dahl 1985) and the possible loss of respective biological resources (Moore 1983, Juvik and Juvik 1984, Crosby 1986, Vitousek 1988). While there is consensus that conservation of biological diversity requires the planning of networks of protected areas, there have been major gaps in theory and techniques for islands (Ingram 1989A) and the monitoring and management of cumulative impacts (Dickert and Tuttle 1985). In addition, there is the need to better integrate conservation planning into broader frameworks for land use planning on islands (Coccossis 1987, Council of Europe 1987, Hamnett 1990, McElroy and de Albuquerque 1990) in order to attain "sustainable development" (Redclift 1987).

Possibilities for determining generic-type minimum requirements as related to the size and connectivity of zones of natural habitat and cultural landscapes will probably be unresolved indefinitely and planning decisions must be based on analyses of particular islands, respective biota and threats. Only a series of typologies of potentially viable conservation interventions, as related to island geomorphology, ecosystem structure, habitat configurations and cultural factors, is possible.

Landscape indicators and conservation planning

One of the major gaps in a theory of environmental planning for the conservation of biological diversity is in choice and use of "indicator species" (Noss 1990) for decision-making (Day 1989) and, in particular, for choice of habitat for protection. The presence of certain plants, animals, invertebrates or communities could signal that respective sites are worth protection as natural areas. Where complete preservation is not possible or economic and politically acceptable, the sensitivity of particular indicators could guide the formulation of acceptable thresholds of land use. Such "bioindication" (Zonneveld 1983) can provide the basis for "ecological planning" and indeed can become central design concepts for new developments.

Indicator or focal species can be worked into sampling frameworks, related to the persistence of respective populations, which can then be used for landscape analysis and the subsequent development of options for protection of sites within district-wide networks (Noss and Harris 1986, Ingram 1989A). There are numerous steps involving surveying and inventorying of local biological diversity, "gap analysis" (Burley 1988, Scott et al. 1990), development of criteria for conservation and land use planning, and ongoing monitoring, management and regional regulation.

There are still nagging questions about the utility of indicator species to guide the conservation of local biological diversity and the methods necessary to link information on these species to site and regional-scale decision-making. The steps between choice of a suite of focal species (or taxa where taxonomies are unresolved) and landscape analysis, for determination of viable networks of reserves, are still poorly explored and there are few successful examples.

Landscape ecology and the vocabulary for spatially oriented and finely scaled conservation measures

The emerging science of landscape ecology (Forman and Godron 1986) may provide a sufficiently rigorous theoretical framework to effectively use indicators. Such landscape approaches to wildlife and ecosystem management may constitute a sufficient vocabulary to identify landscape relationships that satisfy conservation requirements on more of an indefinite basis. However, the applications of such canons as:

cores, island biogeography (MacArthur and Wilson 1967, Diamond 1971, Diamond 1972, Diamond 1975, Faeth and Connor 1979, Connor and McCoy 1979, Cole 1981, and patch dynamics (Pickett and Thompson 1978);

buffers (Wiens et al. 1985, Schonewald-Cox and Bayless 1986, Roberson-Vernhes 1989), edges (Hansen et al. 1988) and regional matrices (Giacomini and Romani 1978, Janzen 1983, Noss and Harris 1986);

corridors (for connectivity) (Allen and Starr 1982, Fahrig and Merriam 1985, Groome 1990, Mwalyosi 1989, Wolski 1990, Harrison 1992) and

barriers to invasions of alien species will vary radically with landscape structure, biogeography and the choice of indicator species.

A biodiversity indicator functions, therefore, to guide the choice of habitats, sites and indefinite and prescribed conditions for the best formalization of these functional categories of conservation. The composition of suits of indicators should vary in terms of conservation criteria, perceived threats to biological diversity, and the interpretation of principles of landscape ecology. For example, the importance of the shore/riparian matrices to landscape connectivity may increase on small islands. Conservation planning on islands must maintain and create these types of habitat conditions within the context of various unwieldy zoning and land management programmes. Such planning systems must eventually be diversified and made more adaptive if they are ever to be effective for conservation of local biological diversity.

The difficulties of conservation of biological diversity on islands

Scientific interest in islands and endemism goes back to the beginnings of the modern concepts of evolution, speciation and biogeography. Charles Darwin acknowledged the role of isolation as early as 1844 (Darwin 1909). While the richness and vulnerability of island ecosystems shaped the modern paradigms of biogeography and conservation, subsequent approaches have tended to discount the unique requirements of these same archipelagoes.

The vulnerability of an island's biota to change tends to increase with spatial and temporal isolation. Island endemics often occur away from shore areas. Since the post-Pleistocene fluctuations in sea level, there may not have been sufficient time for recolonization back into previously inundated areas especially for highly localized species associated with stable types of forest habitat. Biota of mountainous islands are vulnerable through climatic change which often cause populations to be particularly marginal, unstable and therefore under particularly active selection pressures.

The concept of disharmonious biota has been employed in consideration of terrestrial zones of island ecosystems. This derives from the earliest formulations of the equilibrium theory of island biogeography (MacArthur and Wilson 1967, Connor and McCoy 1979). Rates of colonization and extinction might eventually balance as a function of the total area of land-mass and isolation (Diamond 1971, Faeth and Connor 1979). Where colonization is particularly slow, there are lags in attaining an intrinsic saturation point. On islands, this can be complicated by the continued speciation of the organisms which have already become successfully established.

The ecological boundaries of islands are not limited to shores and shallow marine areas. Rather than simply a barrier, a shoreline is a zone of overlap between terrestrial and marine food webs and involves a distinct and added set of habitat types. The shape of these habitat units are usually long and narrow and therefore prone to breakup in times of environmental change.

Intensification of impacts of habitat fragmentation on islands.

Portions of island biota have some dependence on mature successional stages and relatively undisturbed sites (Ingram 1989A). Modern alterations of island forests are producing changes which are often not comparable to those of natural processes nor impacts from traditional societies. Urbanization and tourist development can obliterate shore ecosystems and create barriers with negative impacts. The scales (Noss and Harris 1986, Meentemeyer and Box 1987) and rates of modern change are often much greater. The tracts of primary forest that remain are often degraded on an indefinite basis due to expansion of edges and decreasing size of habitat units.

The size, shapes and formation patterns of patches and gaps within successional mosaics is particularly central in determining the sensitivity to fragmentation (Temple and Wilcox 1985, Wilcox and Murphy 1985, Harris 1985) of particular archipelagoes. Similarly, there are variable regimens of disturbance and ecotones (Schonewald-Cox and Bayless 1986, Hansen et al. 1988) which enter in to the equation of "intrinsic vulnerability" of loss of species from fragmentation.
Cultural factors that exacerbate sensitivity to fragmentation can then be analyzed in terms of:
a. the extent of traditional modification of ecosystems;
b. prospects for the use of technologies and respective intensities and sites across landscape units and regions (Giacomini and Romani 1978, Janzen 1983);
c. prospective species introductions (Vitousek 1988); and
d. long-term demands for tourism and recreation.

A long-term threat, to the continuing evolution and the prospects for successful management of island biotas, is that of the disruption of patterns of colonization across entire archipelagoes. There is a similarity, here, with networks of protected habitat. As natural habitats and respective populations on mainlands and adjacent islands decline, the functional distance / time factor increases for potential recolonization. Maintenance of connectivity, no matter how tenuous are the colonization pathways, should therefore be a major criteria in planning protected areas within archipelagoes.

Insularization is compounded by inevitable catastrophes and stochastic losses, including problems in environmental regulation and the implementation of conservation planning, which destabilize already unstable systems. Human beings are making virtually all islands more "oceanic" and oceanic islands are relatively depauperate and derive much of their global significance, in terms of biodiversity, from the organisms that have persisted and evolved over long periods of relative stability - a stability that has not been afforded by human beings even where there are well-protected reserves.

The history of the impacts of human beings on the organisms on islands, particularly species which are terrestrial, is one of ecological disaster. Few islands on Earth have not loss species with the initial phases of settlement of *Homo sapiens*. The structure of many island ecosystems tend to be especially vulnerable to displacement by invasions of alien species (Vitousek 1988). Island forms are often pre-disposed to extinction.

The responses of shore zones to land use vary with a wide range of practices and biophysical settings, and in the case of the impacts of sediment transport, can have divergent impacts between temperate and tropical ecosystems. There are a number of types of ecological degradation, where tropical biota are more sensitive, such as with the lowering the concentrations of oxygen in marine areas and loss of atmospheric ozone.

There are a number of key pathways for the synergistic transmission of disturbances from terrestrial areas to adjacent marine zones and a more modest set for transfer of source perturbations in marine areas up onto land. Terrestrially derived disturbances often involve the soil mantle, alterations of fresh-water regimens and the deposition of suspended sediment in the sea. Even for the many small streams which usually carry the bulk of freshwater on small islands, such extended freshwater and marine watershed pathways may have a central influence on entire island ecosystems.

The impacts of terrestrial activities, on adjacent and down-stream marine ecosystems, can be devastating. Coral reefs are particularly sensitive to erosion from on-shore activities including road building, timber removal and building construction as well as from pollution. Because of pressures for logging, coral reefs adjacent to islands with high timber values are particularly vulnerable in the coming decade.

Landscape indicators for monitoring biodiversity and conservation planning on forested islands

The presence and condition of certain species have provided opportunities to make inferences on a wide array of ecological conditions. In his review of ecological impact assessment, Westman (1985) had the most realistic concept of the potential importance of such a focal taxa concept to conservation of biological diversity when he suggested that, "if impact analysts can identify keystone species in a food web, studies of the effect of the proposed impact can be more sharply focused on these species, with considerable gain in research efficiency. The implications of species as foci have been further explored in conservation planning by Wright and Hubbell (1983).

The indicator species focal taxa concept involves a jumble of notions. Keystone species (Paine 1966) are those which exert influences over other members of their ecological communities out of proportion to abundance. A limitation in the use of compilations of focal taxa for determination of persistence of an area's biological diversity is that organisms chosen can too often be those which are most obvious, most attractive, least difficult to find, and best known. There are a number of uses of focal taxa in land use planning. The use of such species for planning habitat protection programmes for the *in situ* conservation of local biological diversity can lay the basis for: choice of sites for protected natural areas (Spellerberg 1981); organization of priorities for analysis of habitat quality; monitoring the effectiveness of established networks of protected areas; prescriptions for land management within protected areas; and regulation of potentially damaging land use activities in areas adjacent to protected habitat.

There are three types of indications which focal taxa can provide in environmental planning for the *in situ* conservation of biological diversity on islands.

1. There are species which are **representative** of complexes of organisms and associated environmental factors.
2. Some taxa are more **vulnerable** to extirpation because of environmental and ecological changes which result from land use practices.
3. A third type of indicator is not so much derived from natural factors as a number of pressures for and from human **exploitation**.

A single organism can qualify for more than one category of indicator.

Representative and vulnerable species can be argued to qualify on the basis of intrinsic biological characteristics. Unfortunately, what is known about the species, in an area, is quite uneven and there are invariably science-derived and socially-derived biases. The notion of "representative species" (Darwin 1844 (1909)) emerged along with the modern concept of natural selection and speciation. But a number of contradictory and overlapping concepts become evident. Two divergent types of representative species can be employed. The first group are primarily dominant plants with key associates. These species represent the major vegetation types though in super-rich, humid tropical settings additional criteria must be employed to determine a manageable subset. The second type of representativeness involves key elements of coadapted complexes of organisms (Frankel and Soulé 1981). Maintenance of these species, within a network of reserves, can sometimes indicate the persistence of entire assemblages. If such a species persists in an area, an assumption can be made that other species, in the respective complex, are also surviving. In a sense, ever species represents a unique set of ecological relationships and therefore suits of representative species must if only for workability not represent "ecological redundancy" (Walker 1992).

Species which are prone to local disappearance or extinction have been the subjects of much of the concerns for conservation of biological diversity. Vulnerability results from two convergent sets of factors: the nature of the impacts of prospective land use expansion and an particular predisposition, of an organism, to disappearance.

There are organisms with at least one of a number of characteristics such as: rarity, large-sized; low rates of reproduction; highly specific requirements for reproduction as in the case of some tropical perennial; population dynamics determined by internal regulation at levels near carrying capacity; and slow to recover from catastrophic losses. These species have been labelled *K*-selected species (MacArthur and Wilson 1967, Pianka 1970).

Species can also be vulnerable solely because of systematic deterioration of habitats and niches through pollution, climatic change (Peters and Darling 1985), species losses and introductions. Species can be vulnerable because of certain human activities, land use activities and technologies. These organisms, too, can be identified as foci especially when there is clear documentation of the vulnerability of some aspects of ecological requirements and life history to human-induced disturbance.

The third category of indicators are those wild populations which are or could be utilized for direct human benefit and which can be termed economic or exploited species. Some of these organisms or certain genotypes are prone to disappearance because of factors related to their exploitation. Wild species, no matter how extensive in distribution, are prone to loss of intra-specific variability through habitat and population loss. Maintenance of some unexploited populations, for procurement of genetic material and research, is worthwhile. These are species which may never be directly utilized but which could provide a basis for an introduction of new domesticates or which could be employed to improve already existing crops or stocks.

Protected habitat, where economic species persist under natural conditions, is important for a number of reasons. A species protected from over-exploitation has its continued existence assured. A full range of selection factors and local genomes could be maintained. Certain genotypes which are particularly valuable for exploitation could be particularly well-maintained. Rarer genes, some of which may be key to the continuing evolution and adaption of the wild populations and which might one day be useful for the improvement of domesticates, can be protected.

Traditional economic activities usually involve a large number of wild and semi-domesticated species. In contrast, industrial societies have relied on a smaller number of species which produce highly profitable commodities. These two patterns of exploitation of biological resources were recognized by Dasmann (1975) when he differentiated self-reliant, ecosystem-based and often tribal communities from modern, "biosphere" society which is integrated into the "global economy" (Norgaard 1988).

A wild species, which has a recognized potential for contributing germplasm for improvement of a domesticated plant or animal; which could contribute to a new domestication; or which could be exploited in a new or expanded form potentially holds genetic resources. There are three kinds of genetic resources. There are wild species which are within genepools of domesticated species and which could contribute genetic material for crop or stock improvement. There are wild species which could be potentially domesticated (Plotkin 1988). And there is a much larger group of multi-purpose species (Ng 1985), many of which are plants and invertebrates, which can be exploited, *in situ*, or introduced and managed as self-perpetuating populations for a range of benefits.

Minimum requirements such as habitat attributes and population levels which may indicate the persistence of the indicator species

Landscape attributes linked to indicator species are tools for use in the evaluation of a site's capabilities of supporting minimum requirements for habitat and populations. Minimum requirements are a form of prediction for the persistence of indicator species and of the complexes of organisms of which they are a part. If the full set of minimum requirements of all of the focal species of a district are maintained within protected habitat, the local biological diversity can be assumed to be adequately conserved. The minimum requirements concept, as a technique in environmental planning, emerged from the "safe minimum standards" approach (Bishop 1978) to public decision-making involving endangered species.

The concept of persistence of an organism with a large part of its associated alleles and habitat, within a particular district, involves a number of separate but overlapping goals. Each of these has a different role in determination of requirements. There are three major conditions which the minimum requirements should guarantee: resilience to niche and habitat-related change including catastrophe, fitness and the ability to adapt and continually evolve, and maintenance of any additional, desired level of intra-specific variability as related to utilization by human beings. A set of minimum requirements is a compilation of computations as based on these goals.

Integration of island biodiversity analysis into conservation and development planning

There are many ways to use biodiversity indicators depending on the technical and political context. The following steps represent a generic progression though additional steps and linkages to other conservation and development concerns are inevitable.

step 1.island-wide biogeographic and ecological inventory;
step 2.choice of focal taxa;
step 3. determination of the types of minimum requirements for each focal taxon for long-term survival on respective islands;
step 4. translation of minimum requirements into tangible elements which can be surveyed, inventoried and monitored across landscape units;
step 5.political decisions on the interpretation of constraints on both land use expansion and conservation;
step 6.generation of conservation and development scenarios;
step 7.public review of conservation and development alternatives;
step 8.politically based choice of an alternative;
step 9.initial implementation of expanded conservation and consolidation within the local national political and economic context; and
step 10.on-going monitoring and evaluation, adaptive management and inevitable revision of conservation plan.

The use of the biodiversity indicators approach to conservation planning will differ radically with biogeography, ecosystem structure, island landscape configurations, formation of cultural landscapes, land ownership and political structures and land use planning frameworks (Ingram 1989A). The following are a range of examples to illustrate key differences and commonalities.

The first example is with temperate rainforest and is considered in depth. However, it is relatively low in biological richness. The summer drought, temperate example, Galiano Island, is higher in biological richness but has less extreme environmental gradients and has been heavily disturbed by logging and recent settlement. The example of the island off-shore of New Guinea is perhaps saturated with biological diversity to the point where both surveying and any major changes in the landscape mosaic would be problematic.

Burnaby Island, *Skwa-ikungwa-i, Haida Gwaii*: A temperate rainforest island

This example is of the potential use of indicators under optimal administrative conditions, a large park, and with relatively low and well-documented levels of biological richness. The South Moresby, *Haida Gwaii*, area of the northern coast of British Columbia was considered over a long-term research effort on the sensitivity of the local biological diversity (Ingram 1981, Ingram 1989A) and Burnaby Island, *Skwa-ikungwa-i*, was the focus from 1985 to 1990. The area became the centre of one of the most protracted and acrimonious conflicts over competing proposals for logging and wildland preservation (South Moresby Resource Planning Team 1981 & 1984) in Canadian history (May 1990). Indeed, the nature of subsequent Canadian efforts to preserve wildlands and habitat have been shaped by the struggle over the South Moresby. In mid-1987, negotiations began to declare the entire area a National Park and a concept was developed for the South Moresby National Park Reserve in 1988. Unfortunately, the record of Parks Canada suggests that expanded tourism and facilities, as well as intensifying harvesting of marine resources, will continue to threaten elements of local biological diversity (Ingram 1989B).

The Queen Charlotte Islands lie to the west of the northern coast of British Columbia mainland and to the south of southeastern Alaska. The islands have a cool, maritime climate. Annual rainfall, on much of the islands, exceeds 200 cm. Much of the vegetation of the Queen Charlotte Islands consists of temperate rainforest in mature successional phases. A small number of coniferous tree species predominate and often grow to spectacular age and dimensions. There are over 600 species of vascular plants on the islands (Calder and Taylor 1968).

Three post-glacial processes led to the unique biota and ecological relationships on the Queen Charlottes. Endemic species spread from the refugia. Most species colonized the islands via a temporary land bridge which linked the northeastern corner of Graham Island to the mainland approximately 10,000 years B.P. The relatively few species, which successfully colonized, thrived in a depauperate flora and fauna and evolved to adapt to and to take advantage of the numerous broad and vacant niches. The climatic phase which followed the glacial retreat, the Hypsithermal (Heusser 1960) of 8,500 to 3,000 before present, was warmer than today and there was colonization of plant species which have persisted in sheltered pockets at sea level.

The Haida people were the sole inhabitants of the Queen Charlotte Islands until the archipelago was annexed in the mid-Nineteenth Century. Human occupation probably extended back to be fore the retreat of the last glacial period and given the nature of the recolonizations and ecosystem formations, the present landscapes are cultural in nature (Fladmark 1975). Today, there is a mixed population of settlers, Haida and temporary workers though few people live in the vicinity of the National Park Reserve and Burnaby Island. Haida communities exploited both the marine and terrestrial resources of the islands on a subsistence basis though surplus was usually accumulated.

The lack of large metal tools for cutting trees kept disturbance of the vegetation composition limited to that from gathering understorey species and infrequent felling of large cedar trees for the crafting of canoes. After World War II, the export of timber and fish products increased dramatically. Three large, integrated forest companies had, at one point, control over 41% of the land area of the Queen Charlotte Islands.

There are 4 terrestrial, biogeoclimatic zones in the Burnaby Island area: the coastal western hemlock zone, *CWHg*, the superhumid, coastal cedars-pine-hemlock zone, *CCPH*, (Pojar and Annas 1980), the mountain hemlock zone, *MH*, and alpine tundra. Within these zones, are a number of associations (Lewis 1982). The terrestrial vegetation of over 90% of the Burnaby Island area is dominated by coniferous forest. There are a number of physiognomic types in the Burnaby Island area: salt marsh; beach strands; Sitka spruce forest near shores; alluvial meadow forest; deciduous woodland with red alder, *Alnus rubra*; alpine; various association of western hemlock, Sitka spruce and red cedar; bogs, fens and marshes; and forests of yellow cedar and mountain hemlock at higher elevations.

Representative species have been grouped under a number of simple categories: marine, marine freshwater, terrestrial and the terrestrial marine interface. In the case of plants, the most dominant species of vegetation types have been identified. For vertebrates, predators at the higher trophic levels have been identified. This approach to representativeness neglects the detrital food webs, and such groups as terrestrial invertebrates. Unfortunately, there are currently insufficient ecological data on which to base the choice of taxa associated with the lower levels of detrital food webs.

A number of species are closely associated with kelp beds of the algae species, *Nereocystis luetkeana* and *Macrocystis integrifolia*. The Burnaby Island area is rich in species of marine mammals. Most of these are highly mobile and though sensitive to regional environmental degradation, are difficult to consider at the level of habitat requirements within the biotic district. The more sedentary sea otter, *Enhydra lutris*, was exterminated in the Queen Charlotte Islands in the Nineteenth Century and has been described as a keystone species in areas with kelp, sea urchin, and abalone.

There are a number of species which are associated with eel grass, *Zostera marina*. This marine angiosperm can occur at the mouths of rivers which empty into protected bays and inlets and where there is low salinity. Two sedges on the Queen Charlotte Islands are confined to saline marshes and therefore can be valuable indicators: *Carex glareosa* and C. *lynbyei*. Of the two saltmarsh types described by Lewis (1982), the dominant species, the grass, *Deschampsia cespitosa*, is the dominant in the *S1* type and the pigweed, *Salicornia pacifica* is indicative of the *S2* type.

Because of their economic importance and sensitivity to degradation of freshwater environments, there is a substantial body of research on salmonids. The species which occur in the

Burnaby Island area are: pink, *Oncorhynchus gorbuscha*; chum, O. *keta*; and coho, O. *kisutch*. There are a number of bird species which require estuarine conditions. Some of the most representative species of these food webs may be the great blue heron, *Ardea herodias* and the Canada goose, *Branta canadensis fulva*.

The freshwater ecosystems of the Burnaby Island area are relatively modest in comparison to other areas of the Queen Charlotte Islands. Maintenance of the spawning habitat of the anadromous fish species: pink salmon, *Oncorhynchus gorbuscha*; chum salmon, O. *keta*; and coho salmon, O. *kisutch*, are indicative that the associated complexes or organisms are relatively intact.

The requirements of birds which nest on lakes such as the red-throated loon, *Gavia stellata*, the common loon, *Gavia immer*, the Pacific loon, G. *pacifica* and yellow-billed loon, G. *adamsii* could be indicative of the requirements for a range of vulnerable elements in the lacastrine ecosystem. Of the loon species, perhaps the red-throated, *Gavia stellata*, has the most dependable presence on Burnaby Island (Reimchen and Douglas 1984).

Survival of the local species of alcids, may be indicative of the maintenance of a range of marine and terrestrial conditions and minimum levels of productivity. The species present include: rhinoceros auklet, *Cerorhinca monocerata*; tufted puffin, *Lunda cirrhata*; common murre, *Uria aalge*; pigeon guillemot, *Cepphus columba*; Cassin's auklet, *Ptychoramphus aleuticus*; and ancient murrelet, *Synthliboramphus antiquum*. Similarly, the persistence of the river otter, *Lutra canadensis*, might indicate the maintenance of key overlaps of terrestrial, marine, and estuarine food webs.

The harlequin duck, *Histrionicus histrionicus*, has a wide range of requirements for both marine and terrestrial habitat including key feedings areas near Alder Island and areas for reproduction near fast-moving mountain streams. Two of the birds of prey in the South Moresby area play key roles in the interface of the terrestrial and marine food webs: bald eagle; *Haliaeetus leucocephalus* and Peregrine falcon, *Falco peregrinus pealii*.

Based on the data which is presently available, it is difficult to identify vertebrate species which represent particular forest communities. Most of the vertebrates on the Queen Charlotte Islands have relatively wide ecological amplitudes. A number of bird species are associated with mature successional phases of forest: the northern saw-whet owl, *Aegolius acadicus brooksi*; the Steller's jay, *Cyanocitta stelleri carlottae*; and the hairy woodpecker, *Picoides villosus picoides*. All of the raptors in the Burnaby Island area exploit terrestrial species: bald eagle, *Haliaeetus leucocephalus*; sharp-shinned hawk, *Accepiter striatus perobscurus*; red-tailed hawk, *Buteo jamaicensis*; and Peregrine falcon, *Falco peregrinus pealii*.

A complex set of forest and successional mosaic indicators was compiled (Ingram 1989A). This was based on the previous outline of terrestrial vegetation, the following representative species are indicated for each association. Criteria for designation of a species as vulnerable from regional environmental change can be based on body size, reproductive vulnerability and other aspects of life history (Whitehead 1970), and ecological amplitude (Webb et al. 1967). A designation of vulnerability can be based on of the following criteria.

There are species which are vulnerable largely because they are rare or occur in very low densities (Elton 1975, Terborgh 1974, Terborgh and Winter 1980). These species are susceptible to disappearance because the scale of landscape alteration in comparison to total habitat is so extensive that the minimum habitat which is required for persistence is easily jeopardized. Within their ranges, endemic taxa may not be rare but local disappearances pose a greater threat to the continued existence of the species.

Organisms, such as vertebrates with large-sized bodies and low population densities, tend to be vulnerable to disappearance because of a combination of high intake requirements and low numbers (Frankel and Soulé 1981). Organisms which are at higher trophic levels, tend to be particularly specialized and therefore sensitive to losses of disruptions of food webs and habitats (Eisenberg 1980). Many high level predators can be categorized as both representative and vulnerable. *K*-selected species are often associated with narrow ecological amplitudes and mature successional phases and therefore are prone to disappearance when these conditions are altered (Myers 1983).

Migratory species are often highly reliant on certain sites and food resources in precise time periods. Because of their mobility they are often considered rare in particular districts even though their levels of resilience and requirements for survival are different.

Vulnerable species have been grouped into categories of endemic and rare species and those which are intrinsically sensitive to general forms of disturbance, logging or recreation. Under endemic and rare taxa are: plant species which are truly endemic to the Queen Charlotte Islands, plant species which are rare in British Columbia and southeastern Alaska or which have disjunctive distributions, and vertebrate subspecies which are endemic to the Queen Charlotte Islands.

Species vulnerable to general forms of disturbance are those which are *K*-selected or which occupy precarious niches which disintegrate as a result of introduced species or marine pollution. Species vulnerable to logging are those which require habitat mosaics which contain certain configurations of mature forest or which require habitats which are generally prime sites for logging. Species which are vulnerable to non-consumptive recreation, are those which occur in the vicinity of shore areas and which are effected by trampling and the presence of humans.

The level of endemism on the "Canadian Galapogos" (Foster 1984) is high for northwestern North America. The biogeography of the mosses and liverworts of the Queen Charlotte Islands suggest that there have been areas available for continuous colonization for several million years. A portion of the mosses and liverworts on the islands are "persistent remnants." The dispersal patterns of bryophytes on the islands are particularly limited because most reproduction is vegetative. Consequently 17 bryophyte species were identified though most are not identifiable except by a very small number of specialist botanists.

There are a number of rare vascular plants that occur in the southern Queen Charlotte Islands with habitats similar to those in the Burnaby Island area (Straley et al. 1985). There are also species associated with glacial refugia and are therefore endemic to the Queen Charlotte Islands or the islands and the Brooks Peninsula of Vancouver Island. There are a number of hypsithermal relicts which are associated with limestone substrate along shore cliffs (Roemer and Ogilvie 1983, Banner et al. 1983).

There is an endemic sea flea, *Paramoera carlottensis*, which occurs in brackish tidepools in the South Moresby. The one endemic Homoptera species on the Queen Charlotte Islands is a spittlebug, *Aphrophora regina* (Hamilton 1982). There are 2 species of carabid beetle which are endemic to the Queen Charlotte Islands and which occur in the South Moresby (Kavanaugh 1988): Louise Island carabid beetle, *Nebria louiseae*; and Queen Charlotte alpine carabid beetle, *Nebria haida*. There is a geometrid moth, *Xanthorhoe clarkeata*, which is endemic to parts of the alpine zones of the Queen Charlotte Islands (Ferguson 1987). However, it is doubtful if it occurs in the small area of alpine on the mountain summit.

There are three subspecies of birds which are unique to the islands: the northern saw-whet owl, *Aegolius acadicus brooksi*, the Steller's jay, *Cyanocitta stelleri carlottae*; and the hairy woodpecker, *Picoides villosus picoides*. There are bird species which are so uncommon in the area that they have been listed, by the Committee on the Status of Endangered Wildlife in Canada, as rare: the red-necked grebe, *Podiceps grisegena* and the sand-hill crane, *Grus canadensis tabida*. There a number of subspecies of land mammals which are endemic to the Queen Charlotte Island and which occur in the Burnaby Island area: the pine marten, *Martes americana nesophila* (Giannico 1986); the ermine, *Mustela erminea haidarum*; the black bear, *Ursus americana carlottae*; and the river otter, *Lutra canadensis periclyzomae*. There are two subspecies of shrew, *Sorex monticolus*, which occur on the Queen Charlotte Islands. One subspecies, S. m. *prevostensis*, is known only from Kunghit Island of the South Moresby area, which is to the south of the Burnaby Island, and may well occur further north. The other subspecies also occurs on the mainland and is neither endemic nor rare. One of the 3 species of bat, which occur on the Queen Charlotte Islands, the Keen long-eared bat, *Myotis keenii*, is rare with its few recorded populations limited to the Pacific coast of North America. The Steller sea lion, *Eumetopias jubatus*, is relatively rare, throughout much of its range, as is the still-absent, sea otter, *Enhydra lutris*, where it has survived and recolonized.

Most of the organisms of the Queen Charlotte Islands are well-adapted to disturbance through being post-glacial colonizers. The species in this category are jeopardized largely because of their ecosystem positions. The major threats to these species are alien species, marine pollution, and the excessive harvesting of marine food resources.

Red cedar, *Thuja plicata*, is vulnerable to browsing by the introduced, black-tailed deer (Pojar and Broadhead 1984). Deer populations can increase rapidly after clearcutting but then decline catastrophically as seral phases of even-aged stands progress. Cedar seedlings are often browsed to the ground in lean periods. In his analysis of the impact of introduced deer on the understorey, Lewis (1982) listed the following species, with roles in the shrub layer, which are also being jeopardized: huckleberry, *Vaccinium parvivolium*; oval-leaved huckleberry, *Vaccinium ovalifolium*; skunk cabbage, *Lysichiton americanum*; sword fern, *Polystichum munitum*; salmonberry, *Rubus spectabilis*; salal, *Gaultheria shallon*; and deer fern, *Blechnum spicant*. In the late 1960s, Haida informants suggested to Turner (Turner and Levine 1971) that highbush cranberry, *Viburnum edule*, and wild strawberry, *Fragaria chiloensis*, had already became "very scarce" where deer have become numerous.

The one native amphibian, the toad, *Bufo boreas*, tends to be displaced in areas where the introduced Pacific tree frog, *Hyla regilla*, has invaded (Green and Campbell 1984). Without monitoring and protection of the habitat, which is least prone to invasion, the toad could disappear from the South Moresby area.

Significant portions of the populations of colonial nesting birds and alcids, on the Queen Charlotte Islands, might disappear through severe levels of coastal industrialization, introduced predators, and increased wilderness recreation (Kaiser and Lemon 1987). The species under this category which occur and nest in the South Moresby include: common murre, *Uria aalge*; pigeon guillemot, *Cepphus columba*; marbled murrelet, *Brachyramphus marmoratus*; ancient murrelet, *Synthliboramphus antiquus*; Cassin's auklet, *Ptychoramphus aleuticus*; rhinoceros auklet, *Cerorhinca monocerata*; tufted puffin, *Lunda cirrhata*; and horned puffin, *Fratercula cornibulata*.

There are few, typically *K*-selected mammals on the Queen Charlotte Islands. The marten, *Martes americana*, the extirpated sea otter and the extinct, Dawson caribou have some of these characteristics as they relate to vulnerability.

Exploited species are those with importance to the Haida, species which have had commercial value in the post-contact period, and those which have potentially significant genetic resources. Since a great number of species were traditionally utilized by the Haida, those included under focal taxa are only the ones which have been particularly important to economic activities as well as to health and cultural expression. The species which have been exploited as commodities, over the last century, are limited to a small number of timber and marine, food species. There are a number of species which could provide genetic resources.
The Haida have traditionally utilized a number of plant and animal resources in the Burnaby Island area. Traditional use patterns have changed over the last century and the range of species which are exploited has diminished. In the 1970s, there was a modest reversal of this trend and renewed

interest in traditional resources.

Perhaps the list of resources which were owned (Blackman 1976) by particular lineages are indicative of the resources which were particularly important or in short supply. Patches of fireweed, cinquefoil, bog cranberry, and crabapple (Turner and Levine 1971) had well-delineated hierarchies of users and use titles. Of the wide array of exploited vertebrates, salmon streams, halibut banks and sea bird nesting sites were similarly owned.

Food plants include: seaweeds, *Macrocystis integrifolia* and *Porphyra perforata*; spiny wood fern, *Dryopteris austriaca*; sword fern, *Polystichum munitum*; skunk cabbage, *Lysichitum americanum*; rice root, *Fritillaria camschatecensis*; greyberry, *Ribes bracteosum*; black currant, *Ribes laxiflorum*; crabapple, *Pyrus fusca*; cloudberry, *Rubus chamaemorus*; salmonberry, *Rubus spectabilis*; thimbleberry, *Rubus parviflorus*; creeping raspberry, *Rubus pedatus*; salal, *Gaultheria shallon*; oval-leaved huckleberry, *Vaccinium alaskaense*, oval-leaved huckleberry, *Vaccinium ovalifolium*; red huckleberry, *Vaccinium parvifolium*; bog cranberry, *Vaccinium oxycoccus*; lingonberry, *Vaccinium vitis-idaea*; red elderberry, *Sambucus racemosa*; strawberry, *Fragaria chiloensis*; and highbush cranberry, *Viburnum edule*. Medicinal plants include: licorice fern, *Polypodium vulgare*; dwarf juniper, *Juniperus communis*; yew, *Taxus brevifolia*; false lily-of-the-valley, *Maianthemum dilatatum*; false hellebore, *Veratrum eschscholtziiii*; eel grass, *Zostera marina*; devil's club, *Oplopanax horridum*; black twinberry, *Lonicera involucrata*; highbush cranberry, *Viburnum edule*; snowflower, *Moneses uniflora*; bog adder's-mouth orchid, *Malaxis paludosa*; waterlily, *Nuphar luteum*; cinquefoil, *Potentilla pacifica*; fireweed, *Epilobium angustifolium*. Plants used in technology include: bull kelp, *Nereocystis luetkeana*; yellow cedar, *Chamaecyparis nootkatensis*; red cedar, *Thuja plicata*; western yew, *Taxus brevifolia*; and stinging nettle, *Urtica dioica*.

Shellfish and other edible invertebrates include: geoduck, *Panope generosa*; California mussel, *Mytilus californianus*; butter clam, *Saxidomus giganteus*; abalone, *Haliotis kamtschatkana*; octopus, *Octopus dofleini*; edible blue mussel, *Mytilus edulis*; sea cucumber, *Parastichopus californicus*; green sea urchin, *Strongylocentrotus droebachiensis*.

The coming of modern, Canadian society has brought a spectacular narrowing of the range of utilization of local biological resources. For all practical purposes, exploitation is limited to a small number of timber trees, fish and shellfish. Only, the following species are utilized commercially at the present time: Sitka spruce, *Picea sitchensis*; western hemlock, *Tsuga heterophylla*; red cedar, *Thuja plicata*; and yellow cedar, *Chamaecyparis nootkatensis*. A growing number of species of fish and shellfish are harvested in the waters of the Burnaby Island area including salmon: pink, *Oncorhynchus gorbuscha*; chum, O. *keta*; and coho, O. *kisutch*. Species with genetic resources of local, regional and international significance include: western yew, *Taxus brevifolia*; red alder, *Alnus rubra*; crabapple, *Pyrus fusca*; all the *Vaccinium* species including V. *uliginosum*; *Ribes* spp.; *Fragaria chiloensis*; and salmon: pink, *Oncorhynchus gorbuscha*; chum, O.

keta; and coho, O. *kisutch*.

Implications for conservation planning on Burnaby Island, *Skwa-ikungwa-i*

The compiled list of indicators suggests that a large portion are very much a reflection of the inventorying priorities and the nature of the perceived threats. The minimum requirements that are suggested from the limited life history and distribution data that is available also suggests a highly fluid set of tools. The advantage of this situation is that additional research is stimulated and it will be difficult for a set of indicators to be enshrined and use uncritically. But the disadvantage is that the science is open to scrutiny to the point where it will become ignored in the face of more blatantly political forces.

characterization of minimum requirements in terms of protected area cores

Many of the sensitive habitats are associated with small sites with shores, cliffs, bogs and alpine. Destruction of any these relatively rare ecosystems could be detrimental to persistence. The shore and riparian zones form weak, narrow matrices that are easily punctured and truncated. There are a small number of strategic nodes such as the area of extensive estuary and salt marsh, *K'iit*.

While there are considerable area of mature forest mosaics, and relatively low biotic reliance on those resources, there are few areas which are large and contiguous and while represent a range of forest types and environmental gradients. In addition, many areas lack certain key habitat characteristics.

We can therefore envision a network of protected area cores involving much of the shore line, all of the alpine and bog areas, some of the more permanent edges, and tracts of forest which include entire watersheds but which invariably extend beyond single geomorphic units.

characterization of minimum requirements in terms of protected area buffers

With so many of the requirements involving a full range of successional phases, buffer areas may be relatively large and complex. However, buffers as filters around nodes and portions of the shore riparian matrices will probably be relatively ineffective. Given the steep topography, unstable landforms (Swanson et al. 1988) and the small, shallow marine areas, buffers to mitigate cause-effect linkages such as those originating with disturbance of the soil mantle, should also prove to be relatively ineffective.

The human activities that might be acceptable in buffers under the current concept(s) for the South Moresby National Park Reserve could include: buildings, trails, transportation and facilities infrastructure, traditional gathering, commercial harvesting of marine resources, scientific experimentation. All of these activities could create or maintain edges and these edges will need to be carefully sited to minimize unacceptable levels of fragmentation.

characterization of minimum requirements in terms of protected area corridors

Corridors could have some of the activities that are acceptable for buffers but must also function to maintain connectivity. Again, the weak shore riparian matrices are the key for connectivity but most of these areas should be allocated to core reserve. An additional shore corridor might function to widen the functional matrix by allowing some human activities but at cautious levels.

characterization of minimum requirements in terms of protected area barriers

Barriers, one of the least explored conservation planning concepts, become central topics for conservation planning in the area. The outlying islands will prove key for maintenance of some populations that are less impaired by introduced species such as raccoons. Natural barriers can be augmented. The bluffs have a similar function. There may be some utility in actually minimizing connectivity to adjacent parts of Burnaby and Moresby Islands. And an additional phase to creating barriers on the outlying islands is to manage the habitat to make it relatively inhospitable or hazardous.

If numerous herbaceous species and shrubs are to persist in the area, as well as possibly some associated vertebrates and traditional gathering areas, fencing is necessary. The shape and size of these "fragments" should reflect island biogeography theory. The extend of the effectiveness of such barriers should be determined.

Parks Canada and the Haida Nation will probably only develop a monitoring framework after various political questions are answered. A complete compilation of indicators must await those resolutions. Certainly, the framework is far more site and ecosystem-specific than their current approaches to park planning.

Galiano Island - An example of a humid, Mediterranean-type forest mosaic

If we take the same approach as was used on the cool and wet north coast of Pacific Canada and apply it to a more southerly setting, a few key variables emerge. On Galiano Islands, one of the Gulf Islands near Vancouver, Canada there is a higher level of species diversity but also, as with many summer-drought ecosystems, a higher level of natural disturbance. In this case, it is related to climatic fluctuations, summer drought and wildfire. Conserving biodiversity is much more about managing disturbance regimens and minimizing water deficit. The problem of feral animals destroying regenerative capacities is every present as well. At the same time, the Indian communities have a less articulated relationship with traditionally exploitation of plant and animal species.

The concept of an island mosaic emerges: dynamic yet sufficiently balanced to support most species. Indicators can be a reflection of what is unique and distinct of the conditions and sites which are in most short supply: the extremes of microclimate and patterns of standing biomass. In this case both the xeric sea bluffs and Garry oak, *Quercus garryana*, woodlands are vulnerable without periodic fire and high fuel levels (from long periods of fire suppression) in coniferous forests could be apocalyptic for some tree cover. This latter problem is further complicated by the ongoing invasion of broom, *Scoparius* spp., which tends to overwhelm oak savannah and other open ecosystems - especially after hot fires.

The Gulf Islands and southeastern Vancouver Island comprise the northern margin of the *Coastal Douglas fir Zone* (Province of British Columbia Ministry of Forests 1988) which extends south to California. This area has the mildest climate in Canada and is the most northerly example of a "sub-humid Mediterranean" ecosystem being at roughly the latitude of Paris. They key factor here is that there is a extended summer drought which makes the area prone to wildfire. Wildfire and aboriginal burning tended to add an additional structuring to the landscape above the geomorphic units. Biogeographically, however, the Gulf Islands are more similar to the Channel Islands off the northwest coast of France as both were strongly altered in the glacial periods.

These islands harbour the northern extension of numerous plant species in the biogeographical zone, *Oregonia*, which extends from California to another 200 kilometres to the north. This climate produces classically fire climax forest mosaics. On Galiano Island, Garry oak, *Quercus garryana*, woodland occurs on xeric, south-facing bluffs while forest dominated by Douglas fir tend to dominate on more cooler and damp sites. Because of glaciation, the islands have complex shorelines and riparian matrices The shallow marine areas are some of the most diverse and productive on Earth. The area has a tremendously productive and diverse set of ecosystems though because of the brief period since the last glacial inundation (at least 10,000 years B.P.) is still relatively depauperate in species. The north end of Galiano has some of the most important archaeological sites in southwestern Canada and the island has seen human occupation for nearly all of the last 10,000 years.

Much of future Canadian population growth will be concentrated in coastal areas such as this and particularly in this mild southwestern region. The island is only 30 kilometres from the City of Vancouver which is rapidly growing and already the third largest in Canada. While there is only a year-round population of 850 people, on this long island which is roughly 20 by 5 kilometres, pressures for suburbanization are intensifying as well as a social commitment to maintenance of a full range of habitats and species and a productive base for timber production. Such pressures will force increasingly careful and site-specific decision-making which in turn press the local planning agency, Islands Trust, to develop a more ecologically based system of land use zoning. On the coastal islands of southwestern British Columbia, as in many other parts of the province, pressures for logging, settlement, and tourism are increasingly threatening natural habitat and fragmenting the landscape.

In coastal marine communities, there are is a wide range of ecosystems and biota as related to geomorphology, depths and water conditions. The shore communities of Galiano Island are relatively rocky with few sandy beaches or mud flats. These rarer communities become the focus for much of the conservation activities. Rocky shores are common as are tide pools. The rare, sand beaches provide habitat for marine and terrestrial species that are adapted to a hostile, shifting environment. Different plant and animal associations occur in subtidal, intertidal, and supratidal zones. Estuaries are semi-enclosed coastal waters with mixtures of saltwater and freshwater. Salt marshes are tidal wetlands which occur within an estuarine zones. The rare mud flats occur in protected coastal areas. A related community of eel grasses grow in patches in the muddy sand.

Because of the relatively dry nature of the climate and the mesic ecology of most of the plant species present, the Galiano matrix, indeed the islands's landscape ecology, is structured by the distribution of freshwater. In addition, the availability of freshwater will determine responses to the growing population and development pressures. The conservation and management of freshwater ecosystems is crucial for the long term maintenance of species and the safeguarding of water supplies. Islands are especially vulnerable to drought because of their limited water-retaining capacity and their relatively small catchments. Population pressure, whether seasonal or year around, from tourism or settlements, stress the limited water supply and expose aquifers to saltwater intrusion.

Based on some of the wildlife habitats of major concern in the *Georgia Depression Ecoprovince* (British Columbia Ministry of the Environment 1992), the following habitat features are of particular concern for persistence of species and maintenance of current levels of habitat diversity:
dead and down woody material;
mature trees on the edges of estuaries;
Garry oak and arbutus woodland and relate woodland and forest ecotones;
mature or "old-growth" coniferous forests; and
riparian and wetland habitats.

The Gulf Islands are remarkable in their special planning and conservation programmes which have evolved, divergently, from those on the islands of San Juan County in the adjacent United States. The following policies of the Islands Trust are particularly relevant to the current concept of the diversity of Galiano Island and potential threats (Islands Trust 1990):
1. prevent the disruption of natural wetlands;
2. preserve natural land forms of the islands;
3. restrict interference with the natural, dynamic processes of coast erosion and deposition;
4. encourage the conservation of the natural vegetation of the Trust Area generally and, in particular, protect from disturbance the following:
significant examples of representative plant communities;
special stands or individual trees due to scientific, scenic or historical interest;
examples of mature forest;
natural vegetation adjacent to the foreshore of the ocean;
natural vegetation around lakes, streams and wetlands; and
areas of significance to wildlife, such as eagle nesting trees;
5. conserve wildlife and to minimize the effects of human activities on it;
6. preserve wildlife habitat by:
preventing interference with rock islets used by wildlife;

protecting special trees, such as those used by herons or eagles;
encouraging forestry practices which will minimize negative impacts on habitat;
encouraging minimum habitat disturbance from development, by provision of large lots, retention of vegetation and trees, retention of wetlands and maintenance of contiguous areas of undisturbed land;

preserving marine mammal habitat; and
priority to the requirements of endangered species;
7. protect the marine life and ecology of Trust waters;
8. protect marine life habitat by:
prohibiting development which would destroy the spawning and rearing areas of herring and other marine mammals;
supporting the creation of underwater marine parks;
9. recognize the special significance of the coastal zone in the natural environment and the competing demands of human activities in this area by;
enacting special protective regulation governing development in the coastal zone; and including additional building setbacks on the waterfront;
10. recognize certain areas for special significance due to their natural physical, biological or aesthetic features and to:
enact special protective regulations to preserve special areas, such as requirements for protection of vegetation and lower residential density;
encouraging public acquisition of special natural areas;
11. enact that those areas designated on the Plan Map as special areas be subject to a large minimum lot size and that they be protected by:
requiring that areas for conservation, greenbelt or recreation be dedicated at the time of subdivision;
recommending that residential development be designed to minimize impact on the natural environment;
recommending that consideration be given to special areas in reviews of Community Plans; and
12. encourage the following forestry practices:
replanting areas after logging with more than one indigenous species; and
leaving buffer strips along roads, ocean front, streams, wetlands and lake shores.

The four functions of landscape indicators for conservation of biological diversity on Galiano Island are relevance to specific policies, power to detect trends, applicability through the planning and management unit, and understandability for local citizens and the broader public. The biodiversity indicator becomes a bridge, and sometimes a measure, of science, social values, and human needs. But how site-specific is the basis for decision-making, when it is necessary to review permit applications for building and infrastructure remains to be seen.

Based on a cursory review of possible indicators, a general divisions between those associated with dry/warm and wet/cool habitats emerges. Virtually all species associated with freshwater and estuarine habitats are vulnerable as are most associated with specific segments of ecotones across shore matrices. The biodiversity elements associated with the more naturally isolated and homogeneous forest fragments are probably the more resilient in terms of the impacts of development. Thus, the areas with the greatest pressures for development, the shore, which already are being altered by roads and houses, are the most in need of conservation intervention. Conservation priorities could thus include the more intact and diverse shore areas and the inland matrices which connect them.

Fergusson Island - An island with tropical rainforest in the southwest Pacific

Fergusson Island is the largest island in the D'Entrecasteaux Archipelago and one of the largest islands off of eastern New Guinea. It has an area of 1340 square kilometres with mountains which rise to 1830 metres. The island is particularly significant, biogeographically, as it has one of the most pristine mosaics of primary rainforest on a relatively large, off-shore island of anywhere on Earth.

The area has a poorly understood blend of Australian and Asian plants and animals. Data on the D'Entrecasteaux Islands was key in Diamond's original (1971, 1972) assertion of the dynamics of "saturation" in island biogeography (with its implication for reserve design). The area is also remarkable for its island endemics particularly its forest canopy and ground-dwelling birds and rare marsupials. Given the steep environmental gradients, the large tracts of primary rainforest and the relatively pristine coral reefs, the island is probably one of the most biological rich points on the planet. Nature-oriented tours emphasizing bird watching, with visits spectacular species such as the Goldie's Bird of Paradise, *Paradisaea decora* (Lecroy et al. 1980), began in the 1980s.

The traditional patterns of land tenure are largely intact but commercial logging began in 1988. As well as the loss of primary rainforest-dependent wildlife, massive-scaled logging can degrade adjacent shore and marine areas. The sedimentation from logging can harm the productivity of adjacent reefs. The complex mosaics of gardens, zones of gathering, and the myriad of subsequent successional patches and edges are being simplified with a probable loss of habitat and species diversity in low-lying areas.

The list of the vertebrates of Fergusson Island is largely based on the Rothschild bird expeditions of Fergusson and Goodenough Islands (Rothschild and Hartert 1896 and 1914) and the Fourth and Fifth Archbold Expeditions of 1953 and 1956-1957 (Brass 1959). The first collecting of mammals was in the late nineteenth century with 12 species initially identified (Thomas 1895). Before the Fifth Archbold Expedition, the island was "virtually unknown botanically" (Brass 1959).

The most extensive biological research in the area has been on the avifauna (Frith 1979). A list was compiled by Lecroy (et al. 1983), based on 1978 and 1979 field work in the area. Diamond (personal communication 1987) compiled a list of bird sightings in the area as based on the literature. There are, therefore, some severe gaps in the knowledge of the biota of Fergusson Island. Most of the endemic plants have neither been collected nor identified. Virtually nothing is known on the endemic invertebrates including the corals and the butterflies.

Such a poor state of knowledge makes the utility of focal taxa, as conservation planning techniques, at best, marginal. Yet, even with these limitations, it is still possible to compile a compelling and somewhat diverse list of species. If only because of the slightly greater pool of data on birds, and their extraordinary diversity on the island, this group becomes the metaphorical indicators for most assemblages of forest organisms. But this is risky especially for the survival on non-avian endemics and freshwater organisms. The exploited species are also problematic. The area has been heavily serviced by missions over the last century and traditional plant use, such as for medicinal, has declined.

Some types of indicator organisms for coral reefs such as dominant coral species and fish which are obligate coral predators have yet to be identified. The giant clam, *Tridacna* sp., is a partial indicator of deeper communities within coral reefs. The dugong, *Dugong dugon*, is dependent upon sea-grass beds and is therefore a reliable indicator of the grazing food web of this community type. The two major zones of the mangrove communities are dominated by *Rhizophora* spp. and *Bruguiera* spp. respectively. The Brahminy kite, *Haliastur indus*, may be a viable indicator for a range of shore ecosystems especially those involving mangroves.

There is a tidal stream community dominated by *Nypa fruticans*. The saltwater crocodile, *Crocodylus porosus*, may have some utility as an animal indicator of the integrity of the mouth of rivers and adjacent swamps. The freshwater crocodile, *Crocodylus novaeguineae*, may have some utility for indicating the maintenance of a range of lake and stream conditions. Similarly, the requirements of the rare, Great-billed heron, *Ardea sumatrana*, might be a viable representation of a range of stream and lake conditions.

The following are the major forest physiognomic types on Fergusson Island.

a. *FHS* - small-crowned trees on plains and fans - These communities have various dominants including a number of poorly identified dipterocarp species, as well as Intsia sp., *Casuarina* sp. and *Campnosperma* sp. sclerophyll scrub - These drier areas can best be represented by the dominant eucalypt species.

b. *FHs* - small-crowned lowland hill forest - There are a series of pure stands of Casurina sp., *Castanopsis* sp. and *Hopea* sp. and these are reliable dominants. However, the dominants of more mixed forest have not yet been determined.

c. lower montane forest - There are pockets of the relatively rare conifer, *Araucaria cunninghamii* and deciduous species. These are representative of some rarer types of lower montane forest. However, the dominants of the more mixed forest types have not yet been determined. There is a type of forest in the upper elevations of the hill forest which can be termed, cloud forest, and one of the dominants is a *Castanopsis* sp.

Certainly all of the *Ficus* spp., though not yet identified, should be considered keystone mutualists. Other mutualists have not yet been identified. A key group of mobile links, which are particularly sensitive to regional environmental change, are nomadic fruit-eating birds. These species require a number of different habitat types over wide environmental and ecological gradients. Their survival would be a significant indicator of the conservation of district-wide mosaics particularly in the highly diverse foothill forests. Three such species are the pink-spotted fruit dove, *Ptilinopus perlatus*; Nicobar pigeon, *Caloenas nicobarica*; and the Pied imperial pigeon, *Ducula bicolor*. Perhaps less sensitive but just as much mobile links are the other pigeons, *Ducula pinon* and D. *zoeae*, and the other fruit doves, *Ptilinopus viridis*, P. *aurantifrons*, and P. superbus.

The arboreal marsupial, *Dactylopsila tatei*, is a mobile link which is thought to spread the seeds of large, fruit-bearing forest trees. The black Dorcopsis wallaby, *Dorcopsis atrata*, is thought by local informants to be dependent on the fruit of a fig (*Ficus* sp.). There are birds which are primarily nectarivores such as the eastern black-capped lory, *Lorius hypoinochrous* (syn. *Domicella hypoinochrous*).

The freshwater crocodile, *Crocodylus novaeguineae*, is near the apex of the food chain in river, lake and swamp areas. The saltwater crocodile, *Crocodylus porosus*, has a similar position in estuarine ecosystems. The forest and shore-dwelling birds of prey recorded for the area include: crested hawk, *Aviceda subscristata*; black kite, *Milvus migrans*; Brahminy kite, *Haliastur indus*; white-breasted sea eagle, *Haliaeetus leucogaster*; New Guinea grey-headed goshawk, *Accipiter poliocephalus pallidimas*; variable goshawk, *Accipiter novaehollandiae pallidimus*; Gurney's eagle, *Aquila gurneyi*; and Peregrine falcon, *Falco peregrinus*. There are as least two large pythons on Fergusson Island and these are key terrestrial predators: Papuan python, *Liasus albertisii*, and Amethystines python, *Python amethistinus*.

In his study of avifauna compositions on the New Guinea island of Karkau, Diamond (1971) listed categories of species rarity. He linked these attributes to vulnerability to extinction on continental islands:

narrow habitat requirements;
large-sized territory;
tendencies to be unsuccessful competitors; and
species in only marginally suitable habitat.

For this study, the criteria for vulnerability for all species have been expanded beyond that of simple rarity to include:

large-sized, widespread species;
species with small geographic ranges;
species which are hunted;
habitat specialists; and
inexplicably rare species (Beehler 1981).

Two groups of birds were suggested by Diamond (personal communication 1987) on the basis of endemism: "the two species of birds of paradise endemic to Fergusson and one or more other southeastern island": curl-crested manucode, *Manucodia comrii*; trumpet manucode, *Manucodia keraudrenii*; and Goldie's bird of paradise, *Paradisaea decora*, and "subspecies endemic to Fergusson alone...or to Fergusson plus other southeast islands": variable goshawk, *Accipiter novaehollandiae pallidimus*; pheasant pigeon, *Otidiphaps nobilis insularis*; red-breasted fruit dove, *Ptilinopus viridis vicinus*; double-eyed fig parrot, *Opopsitta diophthalma virago* (syn. *Cyclopsitta* d. v.); buff-faced pygmy parrot, *Micropsitta pusio harteri*; Papuan boobook (owl), *Ninox theomacha goldii*; barred owlet nightjar, *Aegotheles cristatus* cf. A. *bennettii*; yellow-billed kingfisher, *Halcyon torotoro ochracea*; blue-breasted pitta, *Pitta erythrogaster finschii*; varied triller, *Lalage leucomela*; grey-headed cuckoo-shrike, *Coracina schisticeps vittata*; large-billed gerygone, *Gerygone magnirostris proxima*; golden whistler, *Pachycephala pectoralis fergussonis*; little shrike-thrush, *Colluricincla megarhyncha fortis*; and Papuan black myzomela, *Myzomela nigrita forbesi*. There are rare birds, such as the Great-billed heron, *Ardea sumatrana*, and the Gurney's eagle, *Aquila gurneyi*, which are recorded on Fergusson Island though are probably only present sporadically.

The biogeography and taxonomy of the mammals of the D'Entrecasteaux Islands is far from complete. There are gaps in taxonomic treatments and in collecting. The taxonomy of New Guinean rodents is far from complete. One of the two native rats, *Rattus mordax fergussoniensis* is endemic to Fergusson, Goodenough and Normanby Islands (Taylor et al. 1982). There is a arboreal marsupial, *Dactylopsila tatei*, endemic to Fergusson Island (Tyler 1979, Honacki et al. 1982). The black Dorcopsis wallaby, *Dorcopsis atrata* (van Deusen 1957), is one of the rarest and considered one of the most endangered marsupials (Tayler 1979). This wallaby is confined to small portions of Goodenough (IUCN / UNEP 1989) and Fergusson Islands.

The size and reproductive requirements of the giant clam, *Tridacna* sp., such K-selection attributes. There are social and physiological aspects of the *Dugong dugon* which require maintenance of stationary populations with relatively high rates of reproduction and low rates of adult mortality. On Fergusson Island, there are a number of bird "species of the forest interior...whose habitat disappears with logging" (Diamond 1987 personal communication): blue-breasted pitta, *Pitta erythrogaster finschii*; common golden whistler, *Pachycephala pectoralis*; little shrike thrush, *Colluricincla megarhyncha*; grey crow, *Corvus tristis*; Papuan black myzomela, *Myzomela nigrita forbesi*; dwarf honey-eater, *Toxorhamphus ilioliphus* (syn. *Oedistoma iliolophus*); tawny-breasted honey-eater, *Meliphaga flavescens* (syn. *Xanthotis flaviventer*); and puff-backed honey-eater, *Meliphaga aruensis*. The Goldie's bird of paradise, *Paradisaea decora*, also requires edges of relatively mature forest for display (Lecroy 1981, Lecroy et al. 1980, personal observations with Kalupi 1989). There are number of ground-dwelling, fruit-eating birds which are vulnerable to disturbance of the forest floor and the removal of fruit producing, canopy trees: Papuan black myzomela, *Myzomela nigrita forbesi*; Nicobar pigeon, *Caloenas nicobarica*; blue-breasted pitta, *Pitta erythrogaster finschii*; scrubfowl, *Megapodius freycinet*; and pheasant pigeon, *Otidiphaps* *nobilis insularis.*

There are a number of cavity nesting birds which require large, old trees for nesting and these species include: tawny-breasted honey-eater, *Meliphaga flavescens*; Blyth's hornbill, *Aceros plicatus*; sulphur-crested cockatoo, *Cacatua galerita*; eclectus parrot, *Larius roratus*; Goldie's bird of paradise, *Paradisaea decora*; buff-faced pygmy parrot, *Micropsitta pusio harteri*; Papuan boobook, *Ninox theomacha goldii*; barred owlet nightjar, *Aegotheles cristatus*; and yellow-billed kingfisher, *Halcyon torotoro ochracea*. The cuscus, *Phalanger orientalis intercastellanus* (Laurie and Hill 1954), and the arboreal marsupial, *Dactylopsila tatei* are cavity nesting in large trees associated with primary forest. There are a number of bird species which are only associated with primary forest and large tracts of disturbed forest probably involve psychological barriers which in turn intensifies the influence of fragmentation: golden whistler, *Pachycephala pectoralis fergussonis*; little shrike-thrush, *Colluricincla megarhyncha fortis*; Papuan black myzomela, *Myzomela nigrita forbesi*; pink-spotted fruit dove, *Ptilinopus perlatus*; blue-breasted pitta, *Pitta erythrogaster finschii*; grey crow, *Corvus tristis*; dwarf honey-eater, *Toxorhamphus iliolíphus*; tawny-breasted honey-eater, *Meliphaga flavescens*; Blyth's hornbill, *Aceros plicatus*; sulphur-crested cockatoo, *Cacatua galerita*; eastern black-capped lory, *Lorius hypoinochrous*; trumpet manucode, *Manucodia keraudrenii*; Goldie's bird of paradise, *Paradisaea decora*; and pheasant pigeon, *Otidiphaps nobilis insularis*.

On the reefs, there are corals which are vulnerable to suffocation and related maladies as an indirect result of sedimentation from logging. Their physical forms accumulate sediment, and these species are therefore vulnerable. Unfortunately, the species have yet to be identified in terms of latin binomials. The giant clam is also vulnerable to accumulation of sedimentation. The giant clam, *Tridacna* sp., is very attractive for harvesting by both local people and foreign operations. The coming of guns has contributed to the vulnerability of some species, particularly birds. In his notes on Fergusson Islands, Diamond (personal communication 1987) suggested that "big edible birds that are prime targets of shotguns" be included as focal species and listed the following: black-shouldered fruit pigeon, *Ducula pinon*; fruit pigeon, *Ducula zoeae*; pheasant pigeon, *Otidiphaps nobilis*; Blyth's hornbill, *Aceros plicatus*, (syn. *Rhyticeros* sp.); and scrubfowl, *Megapodius freycinet*.

The important wild food plants include: the two species of sago, *Metroxylon sagu*,, M. *rumphii*; and unidentified species of chestnuts, curry berry, and edible fern. The following birds are those which are most commonly hunted for food: Blyth's hornbill, *Aceros plicatus*; scrubfowl, *Megapodius freycinet*; sulphur-crested cockatoo, *Cacatua galerita*; and eclectus parrot, *Larius roratus*. The following mammals are hunted for food: the dugong, *Dugong dugon*; the cuscus, *Phalanger orientalis intercastellanus*; and the black Dorcopsis wallaby, *Dorcopsis atrata*. The Goldie's Bird of Paradise, *Paradisaea decora*, is a major cultural emblem and the male birds are still hunted for their plumes, for use in traditional dances, in the central part of Fergusson Island.

The linking of concerns for genetic resources and their conservation *in situ* as part of larger programmes for preservation of primary rain forest has been poorly explored. A number of wild species in the following genepools were identified including banana, *Musa* spp.; sugar cane, *Saccharum* spp.; mango, *Mangifera* spp.; taro, *Colocasia* spp.; and citrus including *Microcitrus australasica*; *Microcitrus warburgiana*; *Citrus macroptera*; *Monanthocritrus cornuta*; *Wenzelia tenuifolia*; and *Wenzelia dolichophylla*.

In such a setting, where there is so little inventory data and the taxonomic classifications are so tentative, the focus shifts to strategic areas of species richness and types of mosaics that might be sufficiently diverse as to support a wide range of genotypes. But even for forest species, it is difficult to generalize about such mosaics. If a specimen of a target species is found, it is still very difficult to generalize about respective distributions, life history, and ecology. The few samples that are found can be subjects to extensive laboratory scrutiny if there are the facilities for genetic analysis. But such evaluations usually require a large number of samples and individuals and few of these are possible in the low densities which usually occur in primary rain forest.

It is highly debatable if information on the location of certain individuals of genetic resource species should provide the basis for choice of protected areas even after years of field work. Inventorying and conservation can best focus on the stability-related refugia for species associated with primary rain forest and areas of more tightly situated and high contrast edges for other species. Individual trees must be identified and marked and certain buffers should be related to the spatial patterns of reproduction of particular species.

The best way to minimize risk is to slow the cutting of primary forest and to diminish maximum block size while increasing the minimum dimensions of forest fragments. An alternative might be to alter logging practices, as related to timber removal or road engineering, to lessen overall fragmentation and other impacts. In order to integrate timber harvesting into cultural mosaics of swidden and gathering, the control of invasions of alien grasses is necessary.

The archipelagoes of eastern Indonesia

If we take the biodiversity indicator "tools" and apply them to a range of archipelagoes, there is an expanded set of possibilities for conservation planning. A sort of island biodiversity carrying capacity can be determined with certain types of development and settlement patterns appropriate for certain types of islands ecosystems and land / marinescape mosaics. Vulnerability to fragmentation would probably be markedly different between different islands even in the same group. Unfortunately, these statements are postulates and by the time there is data to prove them, there will be greatly diminished habitat for conservation.

The smaller islands of eastern Indonesia, to the east of Bali and Borneo, represent the largest configuration, in terms of spread and combined area of terrestrial and shallow shelf, of archipelagoes with relatively intact natural vegetation on Earth (Ingram 1992). The biogeography of these archipelagoes is dominated by the Wallace Line (Raven and Gregory 1935, Lincoln 1975) to the west which separates the islands from mainland southeast Asia, and Weber's Line (Mayr 1944) to the east, which separates the archipelagoes from those with more direct influences from Australasia. Further to the east, the islands are essentially continental formations with strong linkages to the continental mainland of New Guinea-Australia. Within this massive region, there is a tremendous range of island formation processes, climates, ecosystem structures, and patterns of colonization, speciation, and local extinctions. Thus, conservation planning strategies which might work for one island may not necessarily be viable for even a similar and adjacent island.

A phase for determining biotic districts (Ingram 1989A) is necessary. Grouping can be based on island formation processes, Pleistocene land bridges and subsequent insularization, climate, ecosystem structure, and historical and social factors determining the formation of the cultural landscapes. Within biotic districts, there can be commitments to maintain certain populations and levels of conservation security and risk. District-wide indicators can then be chosen. A substantial portion of the subsequent suite of indicators can be species which are vulnerable because of their patchy or island-specific distributions. An initial set of conservation planning districts for the small islands of Wallacea, between Sulawesi, Bali, New Guinea and Australia, might be grouped as follows:
Lombok;
Sumbawa;
the islands between Sumbawa and Flores including Komodo;
Flores;
the islands east of Flores (Solor to Wetar);
Sumba, Sawu and Roti;
Timor;
Leti, Babar and the Tanimbar Islands;
the Kai, Watubela and Gorong Islands;
the Banda and Damar Islands;
Seram and Buru;
Sula, Sulabesi and Taliabu;
Halmahera, Bacan and Morotai;
the Talaud Islands;
the Western Papuan Islands; and
the Aru Islands.

These island planning units represent a wide range in terms of total areas of terrestrial and shallow marine ecosystems. The *alpha diversity* numbers, for example between Seram and the Talaud Islands, vary greatly. Vulnerability to intrinsic and human-induced saturation also varies radically. Thus, the context for use of indicators varies even between adjacent districts.

Across this region, there would be a portion of the representative indicators which would be the same species and probably a larger group of the same genera. There would also be a group of the same species and of the same genera that are vulnerable to certain general changes and another group vulnerable to specific technologies and land use practices. There would be a small number of species and genera that are traditionally harvested and another, smaller group that are exploited commercially across the region. The approach for identification of genetic resources involves a small number of genepools and genera with some endemics and broadly distributed species.

There might be a small number of indicators which are limited to particular districts and and singular islands which could be totemic either culturally or in terms of conservation planning. There would also be a group of island-specific species which might represent something about the processes and compositions of, for example, Lombok but not, in contrast, of neighbouring Sumbawa. The number of indicators would tend to be a function of the relationships of postulated saturation levels to potential threats but there are also probable correlations involving *alpha diversity* for each island, island age and formation, speciation and extinctions, and ecosystem structure. The nature of the suite of indicators, themselves, might be able to give clues to the subsequent range of viable conservation strategies and to trends in requirements for total area in protection, reserve management, regulation of land use in non-reserve areas, and connectivity.

Appropriate technologies for the integration of conservation and development planning

Certainly, in the 1990s, the use of geographic information systems linked with modules for simulation and the choice and evaluation of configurations of conservation measures is a prerequisite for planning and monitoring programmes. The use of remote sensing data for both terrestrial and marine areas is necessary and this can involve both black and white and colour aerial photographs and various types of satellite imagery of various spectral ranges and levels of resolution. But this is standard for conservation planning in virtually any setting.

For small islands with adjacent marine ecosystems, some additional types of data and techniques are important. There is a need for assessment and mapping at finer scales: between 1:10,000 and 1:1,000. New (colour) aerial photographs are usually necessary. The finer-scaled satellite imagery, involving the smaller pixel areas, is often useful. Field work can utilize the new satellite tracking systems especially in open shore areas.

Some global linkages are preferable as related to regional models for climate change and possible sea level rise. Perhaps the greatest needs for conservation planning technologies for island settings are spatially precise modelling and trade-off analysis software which have modules well-suited for long and narrow habitat units and for tracking attributes related to both terrestrial and marine areas. Graphic technologies for ease of community review of proposed plans are quickly improving especially those involving visual simulation. The need continues for technologies that can be easily maintained in remote islands settings, with few if any product-oriented technicians.

Conclusions

It will taken another decade to develop credible frameworks for use of landscape indicators for the conservation of biological diversity. There are additional steps to compilation and quantification, which must be developed and evaluated. It is necessary to develop new ways empirically verify the range of possible uses, indeed "indications," of particular species, thresholds for persistence and indeed more specific criteria for conservation and development. For islands, the most immediate uses for biodiversity indicators are in management of impacts of tourism, marine degradation, and timber harvesting and in regional and site planning.

The range of the needs for biodiversity indicators for integratation of conservation and development planning in light of the relatively permanent shift to "ecotourism" is expanding. The information and theoretical requirements for effective use of biodiversity indicators are daunting. However, these indicator techniques are crucial as part of decision-making which is becoming increasingly site-specific and complex in its ecological criteria and management objectives for an uncertain future of greater human population, pressures by prosperity, recreation and spiritual renewal, and in celebration of islands as unique points of natural and social evolution.

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