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Monitoring the biological diversity of Galiano Island, Canada: A landscape approach to conservation planning

abstract

Galiano Island is one of the Gulf Islands on the south coast of Pacific Canada. The island is less that 20 km across the Strait of Georgia from the city of Vancouver. While there are tremendous pressures for suburbanization, there continues to be strong support to maintenance of the wildland character of the island along with continued by highly regulated timber harvesting. This paper is presented to give an example of how concerns for the conservation of local biological diversity can be reconciled with these often opposing pressures for land use. In terms of biodiversity conservation, we use a "landscape approach" emphasizes management of ecosystem and biogeographic **processes** and cognizance through mapping key attributes over time.

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Introduction

The Gulf Islands and southeastern Vancouver Island comprise the northern margin of the Coastal Douglas Fir Zone 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.

Today on the Gulf Islands, there is little frost or snow, relatively modest precipitation at between 70 and 90 cm of annual rainfall, and a propensity for long periods of summer drought. At this latitude, and because of the rain shadow created by the Olympic Mountains to the southwest, summer precipitation is highly variable with years of virtually no precipitation for 6 months and other years summers with some cool damp weather in every summer month.

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, *Pseudotsuga menziesee**** and western hemlock, ***, tend to dominate on more cooler and damp sites. Because of glaciation, the islands have complex shorelines and riparian matrices (Forman and Guidron...). The shallow marine areas are some of the most diverse and productive on Earch. 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 the local biological diversity (biodiversity) and fragmenting the landscape. Galiano Island is an example of a small island facing such pressures when natural ecosystems are still relatively intact and where there is a considerable range. Galiano, like many other small islands, is also subject to freshwater shortages which can have an impact on the local biodiversity.

The conservation of biological diversity has become generally recognized as a necessary component of an ecologically sustainable landscape or community (IUCN, UNEP, WWF 1991, Zonneveld and Forman 1990). The question of how to balance the conservation of biological resources with their sustainable use is of critical importance to the long term health of ecosystems and species, including humans, throughout the world. Today it is evident that the conservation and sustainable use of biodiversity needs to be addressed on all lands, public and private. Land use planners and managers need to make decisions today which will affect the long term health and integrity of the biotic and abiotic environment. The purpose of this paper is to lay the conceptual basis for finer-scaled and highly tiered system of land use zoning, monitoring and subsequent management which will insure the persistence of all elements of local biological diversity while maximizing the options for human activities and sustainable economic development.

The emerging disciplines of conservation biology and landscape ecology are providing new or modified ecological principles on which tools and techniques for conserving biological diversity are being developed (Decker et al. 1991, Scott et al. 1990, Hudson 1991). The common factor to any approach which aims to conserve biodiversity through protection and sustainable use is the need for accurate and current information on which to base and evaluate decision-making. This can be done by developing a monitoring system which aims to record and detect changes in the distribution and condition of landscape level elements such as habitats, communities and land use types.

The conservation of biological diversity as criteria in land management in the Gulf Islands of Pacific Canada

A standard operational definition of biodiversity that is simple and comprehensive for use in land use planning and management has not yet been developed (Noss 1990). Biodiversity is a term which generally refers to the variety of life and its processes (IUCN, UNEP, WWF 1991). One recent definition developed by the Society of American Foresters (1992) is more comprehensive:

> "Biological diversity refers to the variety and abundance of species, their genetic composition, and the communities, ecosystems, and landscapes in which they occur. It also refers to ecological structures, functions, and processes at all of these levels. Biological diversity occurs at spatial scales that range from local through regional to global".

For convenience, biodiversity can be divided into several levels of biological organization (McNeely et al. 1990, OTA 1987, Noss 1990, Salwasser 1991). The landscape level is more recent and is being discussed in conjuction with land use planning and management (Noss 1991).

Genetic diversity relates to intra-species diversity. It maintains variability among individuals within a population as well as between populations of a particular species. Genetic variety enables species to adapt to different environmental conditions and changes over large landscapes.

Species diversity is considered to be a measure of the richness and abundance of plant and wildlife within an area. The primary aim of management is to maintain viable populations of all plant and animal species in perpetuity throughout their geographic ranges. Such populations are considered to be viable (Soule' 1987).

Community (ecosystem) diversity refers to the compositional, structural and funtional variety of biological communities and their physical environments. Examples would include species richness and abundance, snags and other structural elements, and ecosystem production and succession.

Landscape diversity refers to the variety of biological communities and habitat types and their distribution in time and space. This has emerged from Whittaker's (1972) concept of *gamma diversity*. Attributes such as patch size, heterogeneity, and connectivity have important influences on the composition, composition, and viability of species.

The different levels of organization are closely related. Species diversity is dependent on the conservation of ecosystems while ecosystems may require certain keystone species for their long term productivity and resilience. Genetic diversity enables populations to adapt to changes in their environment.

The implications of concerns for biological diversity for land management on the Gulf Islands are relevant to all of the more undisturbed islands with Mediterranean-type ecosystems. The biotic composition of Galiano Island is only 10,000 year old and there are only a few rare and disjunctive distributions and there are no endemics. The most vulnerable species and habitats are along the shoreline or in extremely xeric or extremely mesic conditions and to some extent this dynamic represents the biogeographic patterns of post-glacial colonization: from the north and from the extensive summer drought / fire climax mosaics of California and Oregon. Given the small sizes of the habitat units and the climatic fluctuations, the vegetation mosaics on the Gulf Islands have been highly dynamic.

Recent aboriginal presence has tended to favour the more Mediterranean-type vegetation through controlled burning - particularly of the oak woodlands. Over the last century, infrastructure, housing, fire suppression and limited sheep grazing have tended to obliterate the xeric communities and degrade the mesic communities. The continued logging of the large conifers, mainly the dominant forest species, Douglas fir, *Pseudotsuga Menziesi* (***sp.***), has had a neglible impact on elements of local biological diversity except for the few on this island that are dependent on large tree structures and dead wood. The landscape matrix of this long and narrow island is a thin membrane of shore, estuary, and wetland ecosystems which are extremely narrow, spatially, and are easily punctured by housing, roads, wells and enhanced drainage.

Island landscape ecology

Island landscapes in the Pacific Northwest region of North America are characterized and dominated by aquatic-terrestrial ecotones (marine, freshwater, wetlands, riparian) and upland forest ecosystems. At a landscape scale, maintaining biodiversity on islands requires conserving a variety of ecosystem types (communities, habitats, and corridors) in a variety of conditions (i.e. succession and disturbance states).

The emerging concepts of landscape ecology provide a basis for developing a landscape-level monitoring program on coastal islands. A landscape is a heterogeneous land area composed of repeating clusters of interacting ecosystems or landscape elements (Forman and Godron 1986). This definition can be expanded to include the coastal-zone which dominates island landscapes. The coastal-zone has been defined as a region of interaction between terrestrial, atmospheric, and marine systems (Ray 1991). In a recent paper on coastal-zone biodiversity patterns, Ray (1991) has argued for the development of a land and seascape ecology for the coastal zone. A description of the coastal zone is outlined in the section on ecosystems.

Landscape elements have been defined as "the basic, homogeneous, ecological unit, whether of natural or human origin, on land at the scale of a landscape" (Forman and Godron 1986). In this study, landscape elements or ecosystems represent one level of organization and includes freshwater and marine ecosystems. Ecosystems are classified as the largest relatively homogeneous units within a landscape. Within ecosystems is the habitat and community level. For example an estuarine ecosystem might contain marsh, eel grass, and mudflat habitats and communities. The next level of resolution is the habitat element and species level. Examples include wildlife trees (snags, large live trees) and endangered and threatened species.

The coastal zone is a dominant feature of island ecosystems. It is the interface between land, sea, and air which surrounds all islands. The coastal zone is an ecotone, characterized by high productivity, diversity, and interconnections between adjacent ecosystems. It extends from the outer edge of the continental shelf to the inland extent of the tidal or spray zone. Geomorphologists and some marine biologists (Ray 1991) consider the coastal zone to include the coastal plains, the relict ocean bottoms which are now above the sea level.

Ray (1991) has proposed a conservation-oriented coastal zonation system to help explain patterns of biodiversity. The zones are derived from spatially and geomorphically based units which can be divided into five basic types.

<u>Terrestrial Units</u>

(1) Uplands: They are not technically part of the coastal zone, but have an important

influence on the coastal zone because of their freshwater discharge.
(2) Coastal Plains: These are freshwater areas, which used to be sea bottoms. They are now covered with sediment and are located above the sea level.
(3) Tidelands: They are bounded by the the inland limit of saline and springtide waters.

Marine Units
(4) Shoreface Entrainment Volume: This area extends seaward from the low-tide shoreline. It is always covered by seawater and is sometimes characterized by sands moving around with the changing wave conditions.
(5) Offshore Entrainment Volume: This unit is bounded by the outer extent of the continental shelf and the shoreface entrainment volume. The outer limit of the continental shelf is around the 200 m depth.

Watersheds can be of three types in coastal zones: simple, compound or complex. A simple watershed would consist of an extensive tideland area draining into the shoreface entrainment volume. Examples include mangroves, marshes, and mudflats. Complex watersheds are characterized by flowing water draining from the coatal plains or uplands and having a direct affect on the offshore entrainment volume. There are many variations between these two extremes. On some smaller islands which have no permanent streams or rivers, hydrological interchanges are dominated by nonpoint flow, tides and storms (Ray 1991). Galiano Island is such an island although it does not experience the types of storms common to oceanic islands. Although coastal zones are characterized by many types of ecosystems, watersheds, and geomorphology, the land/seascpe coastal unit system allows for comparisons to be made between different shorelines.

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 characterized by distinct zonation patterns that are common throughout the world. The zones include the supratidal, intertidal, and subtidal zones. The interdital zone can be further broken down into the upper, middle, and lower intertidal zones. Each zone is home to a distinct variety of species associations. Tidepools are characteristic of rocky shores, especially in the lower zones. Tide pools can be separated from the ocean for up to 10 hours at a time in the upper intertidal zone. Species living in tidepools are adapted to a surviving within a range of environmental conditions.

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. Diversity is greatest in the more environmentally stable subtidal zone.

Estuaries are semi-enclosed coastal waters where saltwater and freshwater meet. The distribution of species is determined in large part by salinity. Estuarine ecosystems are composed of several biological communities that are linked together through the food chains and mineral cycles. The most common biotic communities on the west coast with temperate climate are:

Salt marshes are tidal wetlands which are dominated by grasses and occur within an estuarine ecosystem. Salt marshes are one of the most productive marine habitats and contain an abundance of species. **Mud flats** are common in the intertidal zone of protected coastal areas. Mud flats commonly extend from the low marsh zone into the subtidal zone. They are dominated by large areas of muddy sand. **Sea (Eel) Grass Communities** occur in the subtidal zone of estuarine ecosystems. Examples include eel grass which commonly occur around Galiano Island. Eel grasses grow in patches in the muddy sand and are important to a variety of benthic species.

From a coastal ecosystem point of view, the maintenance of biodiversity in the coastal zone is dependent not only on man's activities within the coastal zone but also upland and in the pelagic or offshore ocean. Ongoing loss and degradation of estuaries and their communities has resulted in estuaries being considered a wildlife habitat of major concern in the Georgia Depression Ecoprovince (British Columbia Environment 1991). Threats include industrial and logging activities in coastal regions.

Table 1:
Examples of Land Use Activities Causing Impacts on the Islands in the Pacific Northwest

	PRIMARY LOCATION OF ACTIVITY		
LAND USE ACTIVITY	UPLAND	COASTAL	OFFSHORE
Logging	X	X	
Log transport / infrastructure	X	X	
Settlement	X	X	
Oil Spill		X	X
Pollution from Boats		X	X
Toxic Chemicals	X	X	X
Sewage, Septic Tanks	X		
Saltwater Intrusion		X	
Pesticide	X	X	
Fertilizer	X	X	
Recreation/Tourism		X	
Mining	X	X	
Roads		X	
Powerline Corridors		X	

Terrestrial activities such as logging, development, agriculture, and tourism can greatly impact shorelines. In addition, offshore marine pollution, overharvesting, and tourism can also put pressure on the coastline. Due to its immense popularity, the coastal zone and its biodiversity will continue to require special attention if representative portions are to remain high in productivity and diversity. This is crucial on small islands which have a high coastal zone to terrestrial upland ratio and have a limited water-retaining capacity (Beller et al. 1990).

The island membrane: hydric and mesic corridors

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 safegarding of water supplies. Islands are especially vulnerable to droughts and erosion of material into the sea because of their limited water-retaining capacity and their relatively small catchments (Beller et al). Population pressure, whether seasonal or year around, from tourism or settlements, stress the limited water supply and expose aquifers to saltwater intrusion.

Aquatic and terrestrial ecosystems are closely associated, primarily through the hydrological cycle. Water functions as a biological transport system, linking one ecosystem to the next (Schreiber et al. 1987). Nutrients are thus transported while waste products are washed away. Freshwater ecosystems can be divided into three categories: lentic, lotic, and wetlands.

Lotic ecosystems are characterized by flowing water carrying nutrients and other materials downstream. The primary input of energy comes from adjacent vegetation and soil. Lotic ecosystems include rivers, streams, and riffles. Flow rates vary from slow meandering rivers to rapids. The main types of flowing water ecosystems on the smaller islands of Coastal Southern British Columbia are seasonal streams.

On Galiano Island, streams become evident for up to a few days after a rainfall (Van Vleet et al. 1989). In most cases they remain dry all summer. Because of the close links between land and water, the integrity of lotic ecosystems and their biotic communities is dependent upon the condition of the adjacent terrestrial ecosystems. The interface between terrestrial ecosystems and aquatic ecosystems is known as a riparian zone or corridor. Riparian zones are recognized to be very important to aquatic and terrestrial species and communities and are discussed below.

Lentic or still water ecosystems are associated with lakes and ponds. Lakes can be divided into three categories based on the content of nutrients: oligotrophic, eutrophic, and mesotrophic lakes. Ponds are discussed below in the section on non-tidal wetlands. **Oligotrophic lakes** are nutrient-poor and contain relatively few species. **Eutrophic lakes** on the other hand are nutrient-rich and contain an abundance of species. **Mesotrophic lakes** are somewhere in between these two extremes and represent the majority of lakes. (***clarify for Galiano) Lakes and ponds also display horizontal zonation, similar to the coastal zone.

Freshwater or non-tidal wetlands are closely associated with lakes and streams and are generally areas of high organic matter productivity (Imes 1990). Because of the variety of wetlands, there is no standard definition for wetlands. A functional definition used by the Ministry of Forests (Meidinger and Pojar 1991) refers to wetlands as "lands that are wet enough or inundated frequently enough to develop and support a distinctive natural vegetative cover that is in strong contrast to the adjacent matrix of better drained lands". There are five basic classes of wetlands in Canada: bogs, fens, marshes, swamps, and shallow open waters. All five types of freshwater wetlands occur on Galiano Island, although not extensively.

Shallow open waters are commonly referred to as ponds and sloughs, this type of wetland is composed of permanent and shallow water with less than 10% vegetation cover on the surface.

Marshes are permanently or seasonally innundated with nutrient-rich water. The water level in marshes fluctuates throughout the year and vegetation cover is extensive. **Fens** are characterized by an accumulation of more than 40 cm of well to poorly decomposed non-sphagnic peat. Waters in fens are more mineral-rich and less acidic than in bogs.
Swamps are wooded wetlands which are rich in minerals and nutrients. They have more dissoved oxygen than fens and are able to support a 25% or greater tree or tall shrub cover.
Bogs are composed of poorly to moderately decomposed *Sphagnum*-derived peats. The upper layer is often raised above the groundwater layer and is strongly acid and nutrient poor.

Riparian zones are the interface between freshwater aquatic and terrestrial ecosystems (Gregory et al. 1991). A riparian zone ecotone can be defined at different scales (Hunter 1990). At the smallest scale, it simply refers to a narrow band of land bordering the edge of a stream or lake. At a larger scale it includes the stream's bank and floodplain which experience periodic flooding. At the largest scale it refers a strip of land (biotic communities and physical environment) that has a significant influence on a stream or lake ecosystem.

This last definition is more comprehensive and is appropriate for an ecosystem or landscape perspective of riparian corridors (Bickford and Dymon 1990). The riparian corridor includes the stream, its bed, banks, floodplains, transition zone (between wetlands and uplands) and the adjoining uplands. This perspective stresses the importance of the links between land and water in the riparian zone. Riparian corridors connect a variety of ecosystems throughout a landscape by facilitating the movement of water, nutrients, sediments, and organisms. Like other land-water edge habitats, riparian zones provide important ecological funtions and are high in species diversity.

Forest communities

Coniferous forest ecosystems dominate the terrestrial landscapes of the Pacific Northwest. On coastal islands, the maintenance of forest ecosystems on the edges of aquatic ecosystems is critical to the conservation of coastal and freshwater wildlife habitats and ecological processes. For humans, it is also of great importance for the maintenance of freshwater supplies, especially in the summer where drought conditions are common.

(***expand on Krajina references***) Galiano Island is completely within the Coastal Douglas-fir zone of the biogeoclimatic classification system. Although no survey of Galiano Island has been done using the BCE system, some of the environmental resources of the island have been inventoried and mapped (Clement 1978, Eis and Craigdallie 1980). There are 6 landscape units and 10 vegetation units on the island. As noted by Eis and Craigdallie (1980), "The landscape units are a composite expression of all environmental and ecological factors and express similarity within the general environment"

Geomorphic types on Galiano Island

1. Solid bedrock
2. Broken rock
3. Shallow soils
4. Deep mineral soils
5. Poorly drained mineral clays

6. Wet organic soils
7. Bogs, fens and marshes
8. Lakes

Vegetation associations of Galiano Island
1. Nootka Rose - early hair grass - rock outcrop
2. Garry oak - hairy honeysuckle - California fescue
3. Oceanspray - colluvial rubble
4. Broad-leaved stonecrop - scarp
5. Alaska brome grass - Rhacomitrium moss - rock outcrop
6. Pacific madrone - hairy honeysuckle - dull Oregon-grape
7. Coast Douglas-fir - salal - Pacific trailing blackberry
8. Western red cedar - red alder - western sword fern
9. Red alder - American skunk cabbage - common lady fern
10. Wetland

Only recently has there coalesced strategies and guidelines for maintaining biodiversity in forest management lands in the region and they are largely experimental. None, so far, have been oriented to the region's islands and drier areas within this its driest zone. The guidelines are important for Galiano Island where over half of the island because of the need for careful management of timber harvesting and have some of the elements proposed by Hunter 1990, Hansen 1990, and Probst and Crow 1991. Some of the emerging concepts can be integrated into a biodiversity monitoring and management program. Landscape and stand level attributes are discussed in the indicator/monitoring section and include:

Landscape Components:	Stand Components:
. age structure	. plant age diversity
. forest community diversity	. plant species diversity
. spatial heterogeneity	. snags and large fallen trees
. fragmentation	. canopy structure
. edge/interior habitat	. pools and riffles

Classification of landscape units

Landscape classification is an essential prerequisite to any type of landscape evaluation (Blankson and Green 1991). Several landscape level surveys have been done on Galiano Island in the late 1970's and early 1980's (Clement 1978, Eis and Craigdallie 1980). The purpose of these surveys were to assist land use planners in making decisions relating to the growing pressures for housing and recreation on the island. This information is a useful starting point or baseline from which to develop a ecological monitoring program.

There are several ways of organizing the information into a useful classification system, each designed to achieve specific objectives (Blankson and Green 1991). Oulined here is a hierachical landscape classification system for Galiano Island which is adapted from several sources (Marsh 1991, Dunn et al. 1991) and is based on the information about land use, habitats, and communities which occur on the island (Table 2).

The **first level** represents the landscape element/ecosystem level, based on overall structure and general land use/land cover. Each unit is a relatively homogeneous area of land. The **second level** breaks down the ecosystems into some common habitat and land use types. The **third level** gives more specific information on sites, habitats, and communities for natural and modified ecosystems. Ecotones, the transition zones between ecosystems, are also included and are discussed in detail in the section on the island matrix. Each level in the table provides increasing resolution. This landscape matrix provides a framework for selecting indicators to monitor ecosystem diversity and condition.

Table 2:
ECOSYSTEMS AND ECOTONES ON GALIANO ISLAND

Level 1	**Level 2**	**Level 3**	
I. TERRESTRIAL ECOSYSTEMS			
Cultivated systems	Cropland		
	Pasture		
Built systems	Residential		
	Commercial		
	Industrial		
	Transportation		
	Utilities		
Degraded systems	Gravel pits		
	Other systems		
Forest and woodland ecosystems	Coniferous forest		
	Deciduous forest		
	Mixed forest		
Grass/Scublands			
II. AQUATIC ECOSYSTEMS			
Freshwater ecosystems	Lotic (stream)		
	Lentic (lake)		
	Non-tidal wetland	Shallow open waters	
			Marsh
			Swamp
			Fen
			Swamp
			Bog
Marine Ecosystems	Bay & estuary	Tidal marsh	
			Mudflat
			Sea (eel) grass
	Rocky shore		
	Sandy beach		
	Cobblestone beach		
III. ECOTONES			

Land-water ecotones	Lotic (riparian)	
		Lentic
		Wetland
		Coastal-zone
		Groundwater

The Galiano Island matrix: Land-water ecotones

Aquatic-terrestrial ecotones are of vital importance to many species, communities, and ecosystems. They have also played a critical role in the socio-economic development of mankind. Their desirability as a place of commerce, habitation, and recreation has resulted in a world wide loss and degradation of natural coastal and riparian habitats.

An ecotone has been defined as a "zone of transition between adjacent ecological systems, having a set of characteristics uniquely defined by time and space scales, and by the strength of the interactions between adjacent ecological systems" (di Castri et al. 1988). Land-water ecotones are important for a number of ecological reasons. They are often high in productivity and biodiversity, especially species and genetic diversity, relative to their surroundings (Risser 1990, di Castri and Hansen 1992). Ecotones are also important in regulating the flows of energy,water, organisms, nutrients, and materials between ecosystems (Risser 1990, Thorne-Miller & Catena 1991, Wiens 1992). In this way they connect a variety of ecosystems across a landscape.

In landscape ecology, the matrix is defined as the dominant element in a landscape. On small coastal islands in southwestern British Columbia, forests and coastal ecosystems are the dominant elements. From a functional point of view, land-water ecotones are of critical importance to the integrity of island ecosystems. This includes freshwater-terrestrial ecotones, such as riparian and wetland ecotones. On the inhabited coastal islands, forests become fragmented through settlement patterns and logging practices.

The matrix of an island such as Galiano includes all of its land-water interfaces (Ingram 1992). The matrix connects all of the surficial hydrological systems and their associated plant communities. Unlike a mainland marix, an island matrix is made up of a series of connecting ecotones/corridors and patches (Figure 5). Island matrices can be monitored to provide valuable information on the condition and human impacts on these ecologically important areas.

Terrestrial-aquatic ecotones can be divided into several categories. These may be useful for identifying and focusing management attention on the segments of the matrix which are being threatened by human activities. The main categories of land-water ecotones are outlined below.

Mesic and hydric ecotones

Lentic ecotones are the interfaces between water bodies (i.e. lakes and ponds) and adjacent terrestrial patches. The structure and species composition of the ecotone depends on shore slope, water level fluctuations, and depositional and erosional processes (Pieczynska 1990).

Lotic (riparian) ecotones are the edges between streams and rivers and their adjacent terrestrial ecosystems.

Wetland ecotones are more complex than lotic and lentic ecotones. Holland et al. (1990) identify four types:

tidal upland-wetland ecotone;
tidal wetland-open water ecotone;
inland upland-wetland ecotone; and
inland wetland-open water ecotone.

Groundwater ecotones are the interfaces between groundwater and surface water. They play an important role in the landscape by regulating energy and water flow between adjacent systems (Gilbert et al. 1990). If there is significant sea level rise, these surface and sub-surface saltwater/freshwater ecotones will be altered drastically and under the combined pressures of housing construction, outdoor horticulture and road building, respective areas and populations are the most vulnerable.

Coastal zone ecotones

Because of the steepness of many shorelines, adjacent terrestrial and marine ecological units are remarkably narrow and in long, narrow strings form the coastal zones. Ecotones practically abutt ecotones which makes these communities particularly vulnerable to shore development and subsequent fragmentation and sea level rise.

Forest succession ecotones and associated landscape elements

Based on some of the wildlife habitats of major concern in the Georgia Depression Ecoprovince (British Columbia Ministry of the Environment 1992), the following habitats are of major concern for persistence species and current levels of habitat diversity.

Dead and downed woody material

A. Loss due to harvesting of old-growth forests and prescribed burning on cutover lands. Stand-tending activities in managed forests also a major impact.

B. Intensive silviculture and continued harvesting of older forests will lead to critical decline in some habitats. Needs to be included in a habitat diversity policy.

Mature trees on the edges of estuaries

A. Industrial and logging developments lead to destruction (e.g. sorting and dumping grounds).

B. Ongoing loss or degradation. Habitat protection will try to minimize impacts; purchase of estuarine lands, with rehabilitation, is ongoing.

Garry oak and arbutus woodland

A. Loss due to urban expansion.

B. Restricted to southern Georgia Depression Ecoprovince. Residention development is continuing habitat conversion; most remaining habitat occurs on private land.

Woodland and forest ecotones

Young Forest Successional Stages (dominated by herbs, shrubs or deciduous trees)

A. Elimination of young forest successional stages by acceleration to closed-canopy conifer plantations - through intensive silviculture, brushing and herbicide spraying. Result is loss of natural habitat diversity.

B. Need to better understand impact of habitat change especially on ungulate browse, berry supplies for grizzlies and black bears, bird nesting habitat and furbearer prey populations.

Mature/Old-Growth Forests

A. Loss due to forest harvesting; will not be replaced by intensive silviculture. The loss of old growth results in a lack of natural habitat diversity.

B. A major concern due to ongoing timber harvests. Need old-growth policy built into guidelines for habitat diversity. Preservation or deferment of ungulate winter ranges does not encompass full range of old-growth habitats. Fragmentation of older stands is a problem. Need to develop innovative ways of providing adequate old growth by such methods as extended rotation. Need information on amounts, sizes, distribution and type required for wildlife.

Riparian and wetland habitats

A. Losses due to urban, agricultural, and hydroelectric development; continual loss of older forests due to forestry practices.

B. Ongoing loss. Coastal fish-forestry guidelines should help in coastal areas. total protection of older forests needed in some watersheds. Much destruction of riparian habitat occurs on private land in Interior and is difficult to protect. Continue to seek co-operation from landowners.

A. Loss due to conversion to other uses of agricultural and urban development.

B. Encroachment will continue. Attempts to preserve or rehabilitate wetlands will continue; purchase of critical wetlands is ongoing.

A. Loss due to urban expansion, timber harvesting and shoreline development; stand-tending activities will have severe impacts on wildlife trees in managed forests.

B. Present WCB regulations for forest harvesting make solutions difficult. Habitat protection efforts are continuing - to get guidelines for wildlife tree management developed and accepted. Need to include wildlife trees in a habitat diversity policy and continue work in public education.

Critical patches and corridors

Information about the variety, patterns, and connectivity of ecosystem patches across the landscape is another important component of a biodiversity monitoring program (Salwasser 1991). Several types of patches are common to pacific coastal islands. Thses include: wetland patches, forest patches, and human ecosystem patches such as cultivated, built, and degraded lands. Some of patches are part of the island matrix (i.e. wetlands) whereas other are indirectly linked to them (i.e. upland ecosystems). The linkages can be provided by other patches or corridors. Corridors are similar to patches in composition, but have a different horizontal structure, being typically narrower. Like patches, corridors can be natural, modified, cultivated, built, or degraded based on their conditions (Appendix 4). Corridors can also be classified based on their origin. There are five basic types of corridors (Forman and Godron 1986, Barret and Bohlen 1991): disturbance, planted, regenerated, environmental resource, and remnant corridors. Corridors have received of lot of attention recently with respect to the conservation of biodiversity (Pace 1991, Harris and Atkins 1991). The planning and management of corridors is an attempt to maintain and restore natural landscape connectivity beneficial for biodiversity (Hudson 1991).

Implications of configuration of landscape elements for conservation planning and land management

The study of spatial patterns and variation is an important component of landscape ecological studies (Zonneveld 1990). Landscape patterns have important consequences regarding the maintenance of biodiversity and ecological processes (Dunn et al. 1990, Turner 1989, 1990). Landscape patterns refers to the number, size, and juxtaposition of habitats, communities, and land use types (Dunn et al. 1990).

In the case of Galiano Island as well as other coastal islands, the description of the number, shapes, distribution, condition, and trends of the ecosystem types identified and described above can provide valuable information for land use planning and conservation. The use of a GIS can greatly facilitate the task of mapping and overlaying ecosystem with land use patterns to determine areas of human impacts.

The long term monitoring and study of landscape patterns and their changes over time can help provide a better understanding about the functioning of the landscape and the relationship between landscape elements and elements of biodiversity. This area of landscape ecology moves away from a descriptive approach to a more experimental approach. Long term monitoring provides a link to an adaptive management approach (Walters 1986). Such an approach is based on testing hypotheses which are relevant to land use planning and management policies towards biodiversity. This allows management practices to be continually evaluated and adapted based on current information. The function of monitoring progresses from a descriptive task to a predictive tool.

The emerging concepts of landscape ecology provide a basis for developing a framework which can be used to implement such a biodiversity monitoring system. Monitoring biodiversity is a complex task which can be done at several different scales. A landscape level approach provides a framework for integrating additional information on species, populations, and ecosystem processes in the future.

In his initial phases of a review of the island landscapes of Clayoquot Sound, an area directly to the west on the ocean coast of Vancouver Island and with a more maritime climate, Prescott-Allen (1992) identifies three types of environmental monitoring which are needed to keep track of sustainable development.

> **Baseline monitoring** measures natural conditions in ecosystems and species at a certain point in time before certain disturbances and is a prerequisite to the other kinds of environmental monitoring.
>
> **State of the environment monitoring** is a kind of tracking of 1) the current condition of

ecosystems and species, 2) human impacts on ecosystems and species, and 3) actions to mitigate impacts.

Experimental monitoring is in order to understand and simulate ecosystems and species respond to particular stresses.

Biodiversity monitoring is closely tied to state of the environment monitoring, focusing on 1) **conditions** of selected elements of biodiversity, 2) **human activities or stress** which have an impact on biodiversity and 3) **management responses** to reduce the impacts on biodiversity (Environment Canada 1991, IUCN, UNEP, WWF 1991). Baseline monitoring is a necessary prerequisite, which for Galiano Island is partially complete.

This section will describe some desirable characteristics of indicators, which includes having a direct link to land use policies. The three types of indicators and examples of each are outlined and arranged in a framework matrix.

Planning and managing for the conservation of biodiversity is generally recognized to be more efficient through ecosystem management at the landscape level (Thomas 1992). This is only a first step, though, which combined with management at the other levels (genetic, species, community) increases the effectiveness of a conservation strategy.

From a landscape ecology perspective, monitoring involves the recording and detecting of changes at two scales, the landscape element or ecosystem scale and the landscape scale. At the ecosystem scale, certain attributes need to be detected which provide some information about the composition, structure, and condition of an ecosystem. At the landscape scale, attributes which provide information about the landscape as a whole and patterns of specific ecosystem types are selected.

Indicator functions for the Gulf Islands

The following policies of the Islands Trust are relevant to the current concept of the biversity of Galiano Island and potential threats (Islands Trust 1990).

A. ENVIRONMENTAL POLICIES

1. Fresh Water

3. To prevent the disruption of natural wetlands.

2. The Land Base

1. To preserve natural land forms of the islands.

6. To restrict interference with the natural, dynamic processes of coast erosion and deposition.

3. Vegetation

1. To encourage the conservation of the natural vegetation of the Trust Area generally and, in particular, protect from disturbance the following:

(a) Significant examples of representative plant communities.

(b) Special stands or individual trees due to scientific, scenic or historical interest.

(c) Examples of mature forest.
(d) Natural vegetation adjacent to the foreshore of the ocean.
(e) Natural vegetation around lakes, streams and wetlands.
(f) Areas of significatance to wildlife, such as eagle nesting trees.

4. Wildlife

1. To conserve wildlife and to minimize the effects of human activities on it.
2. To preserve wildlife habitat generally and, particularly, by:

(a) Preventing interference with rock islets used by wildlife.
(b) Protecting special trees, such as those used by herons or eagles.
(c) Encouraging forestry practices which will minimize negative impacts on habitat.
(f) 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.
(g) Preserving marine mammal habitat.
(h) Giving priority to the requirements of endangered species.

5. The Marine Environment

1. To protect the marine life and ecology of Trust waters.
2. To protect marine life habitat by:

(f) Prohibiting development which would destroy the spawning and rearing areas of herring and other marine mammals.
(h) Supporting the creation of underwater marine parks.

8. Special Areas

1. To recognize the special significance of the coastal zone in the natural environment and the competing demands of human activities in this area by:

(a) Enacting special protective regulation governing development in the coastal zone, including additional building setbacks on the waterfront.

2. To recognize that certain areas have special significance due to their natural physical, biological or aesthetic features by:

(a) Enacting special protective regulations to preserve special areas, such as requirements for protection of vegetation and lower residential density.
(b) Encouraging public acquisition of special natural areas.

B. SOCIAL POLICIES

2. Residential Settlement

5. To 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:

(a) Requiring that areas for conservation, greenbelt or recreation be dedicated at the time of subdivision.
(b) Recommending that reidential development be designed to minimize impact on the natural environment.
(c) Recommending that consideration be given to special areas in reviews of

Community Plans.

3. Forestry

2. To encourage the following forestry practices:

(c) Replanting areas after logging with more than one indigenous species.

(g) Leaving buffer strips along roads, ocean front, streams, wetlands and lake shores.

Biodiversity indicators as derived from biogeography, ecosystem structure, impacts of land use and social derived criteria for conservation

To be effective and efficient, indicators must have certain characteristics. It is not always possible for each indicator to meet all of the criteria, but combined, the characteristics should all be represented. The four functions of landscape indicators for conservation of biological diversity on Galiano Island are the following:

1. relevance to specific policies,
2. power to detect trends,
3. applicability through the planning and management unit, and
4. enhancement of environmental knowledge and clarity for local citizens and the broader public.

Policy Relevance and the "policy-indicator linkage" (McRae 1990) is an essential characteristic from the point of view of decision-makers. An indicator should provide information about the implementation of policy objectives. The use of indicators with strong cause-effect linkages is related to policy relevance and is much more useful than indicators whose relationships are not well understood.

Indicators must provide the basis for detection of temporal and spatial trends in ecosystems and the direction of change (stable, improving, or deteriorating). This enables mitigation strategies to be focused on priority areas within a landscape.

Biodiversity indicators must be qualified in terms of particular spatial scales. Indicators can be selected to detect changes from the site level to the global level depending on the objectives. At the local level, the emphasis is on site and landscape level indicators. Some concern may be taken to select some indicators which can also be used comparatively within and cross regions.

The effective use of indicators depends on how well understood and perceived. Biodiversity indicators are for decision-makers and concerned citizens and therefore the imperatives of political effectiveness and implementation require that the reasoning behind the choice must be comprehensible to the general public and locally based users of the land.

In sum, good indicators can assist land use planners and managers in the decision-making process and allow resources to be allocated where they are most needed. Noss (1990) and Merigliano (1989) describe some additional, more specific criteria that can be used depending on the objectives of the monitoring program:

ability to provide early warning of change;

easy and cost-effective to measure, collect, assay, and/or calculate;
ability to differentiate between natural and human disturbance;
ability to reflect the condition of more than itself; and
capable of providing a continuous assessment over a wide range of stress.

Of the relevant policies of Islands Trust (1990), an alphanumeric code is used which to link the policies to the indicators given below. The code also corresponds to that found in the Islands Trust Policy document. Most of the indicators have a direct or indirect link to the policy objectives. Those that are directly linked are highlighted.

These indicators can provide information concerning the implementation of environmental policies and the status and trends of selected biodiversity indicators. Their usefulness needs to be evaluated periodically based on their value to decision-makers and concerned citizens, and on current scientific knowledge.

The following indicators for monitoring biodiversity are divided into three categories: 1) conditions of ecosystems, 2) human activities or stress, and 3) management responses and mitigation. Appendix 2 expands on the special habitats of concern on Galiano Island. Only the major habitat categories are given. In this way this framework can be used for other islands of the Coastal Douglas-fir zone.

Land use planning and management in the Gulf Islands can play an important role in the conservation of biodiversity. Some important principles are emerging from landscape ecology and conservation biology which combined with the technology of a GIS can serve to assist planners and managers in the decision-making process. Information is a key component in this process. A monitoring program which aims to provide current and up to date information on the status and trends of biodiversity can help fill this gap. From the point of view of decision-makers, an indicator should be policy relevant. This provides the basis for evaluating the implementation of policies relevant to the conservation of biodiversity. Several of the policies of the Islands Trust are directly related to the maintenance of biodiversity. Information on selected indicators can then be incorporated into a biodiversity data base that forms one of the modules used in the region's land use planning framework. The integration of the biodiversity database into a GIS can assist citizens and planners to better understand the consequences and impacts of actual and potential land use planning decisions on the regions biological diversity.

By setting objectives for the maintenance of biodiversity and for the sustainable use of biological resources, it is then possible to make land use decisions which are compatible with conservation goals. Goals which include thresholds or limits of acceptable change can then be established at different scales i.e. for ecosystems, individual sites, habitat elements, and special species.

Conclusions

A long-term commitment to monitor biodiversity is essential to better understand ecological sustainability. Increasing knowledge about the environment will enable decision-makers to plan and manage land and resources with greater confidence. This in turn can lead to potentially fewer land use conflicts as knowledge grows about the carrying capacity of local ecosystems.

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