Ecological Concepts, Principles and Applications to Conservation

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Bio Diversity BC
CONSERVING THE VARIETY OF LIFE

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About this document

The purpose of this document is to provide a primer on the concepts and principles that support cooperative actions to conserve B.C.'s rich biodiversity. As a companion piece to *Taking Nature's Pulse: The Status of Biodiversity in British Columbia*, this document is intended to stimulate public discussion about how best to identify and implement priority actions for biodiversity conservation in this province.

This document was prepared by Biodiversity BC, a partnership of government and non-government organizations with a mandate to produce a biodiversity strategy for British Columbia.

Biodiversity BC Partner groups:

- B.C. Ministry of Agriculture and Lands,
- B.C. Ministry of Environment,
- Canadian Parks and Wilderness Society (representing environmental non-government organizations),
- Ducks Unlimited Canada,
- Environment Canada,
- Habitat Conservation Trust Foundation,
- Metro Vancouver (representing the Union of British Columbia Municipalities),
- Nature Conservancy of Canada,
- Pacific Salmon Foundation,
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- The Nature Trust of British Columbia.

This document consists of three parts:

1. **What is biodiversity?:** a definition of biodiversity and its value;
2. **Ecological concepts and principles:** general understandings and assumptions about biodiversity; and
3. **Application of ecological concepts and principles:** ways to maintain biodiversity including what can be done and how to do it.

1 What is Biodiversity?

1.1 Defining Biodiversity

The Canadian Biodiversity Strategy defines biodiversity as “the variety of species and ecosystems on Earth and the ecological processes of which they are a part – including ecosystem, species, and genetic diversity components.”

The United Nations Convention on Biological Diversity provides a similar definition for biodiversity: “the variability among living organisms from all sources including, inter alia [among other things], terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.”

In short, the term is used to refer to life in all its forms and the natural processes that support and connect all life forms. Biodiversity is not easily defined because it is more than just the sum of its parts, as all of its elements, regardless of whether we understand their roles or know their status, are integral to maintaining functioning, evolving, resilient ecosystems. Complex concepts such as biodiversity are often easier to grasp if reduced to their component pieces. While this approach does not give a complete picture of how these pieces interact and combine to create biodiversity, it helps us understand different aspects of biodiversity.

The *levels of organization* of biodiversity include ecosystems, species and genes.

- An **ecosystem** is a dynamic complex of plant, animal and microorganism communities and non-living (abiotic) elements, all interacting as a functional unit. An ecosystem’s character changes as community members and physical contexts change, sometimes crossing a threshold of tolerance within the system that results in its inability to return to its previous form.

- **Species** are a complete, self-generating, unique ensemble of genetic variation, capable of interbreeding and producing fertile offspring. They (and their subspecies and populations) are generally considered to be the only self-replicating units of genetic diversity that can function independently.
- **Genes** are the working units of heredity; each gene is a segment of the DNA molecule that encodes a single enzyme or structural protein unit. Genetic diversity is the foundation of all biodiversity. Genetic variation permits populations to adapt to changing environments and continue to participate in life's processes.

Three primary *attributes* of biodiversity are composition, structure and function.[1]

- **Composition** is the identity and variety of an ecological system. Descriptors of composition are typically lists of the species resident in an area or an ecosystem and measures of composition include species richness and diversity of species.
- **Structure** is the physical organization or pattern of a system, from habitat complexity as measured within communities to the pattern of habitats (or patches) and other elements at a landscape scale.
- **Functions** are the result of one or more ecological and evolutionary processes, including predation, gene flow, natural disturbances and mycorrhizal associations as well as abiotic processes such as soil development and hydrological cycles. Examples of functions include predator-prey systems, water purifications and nutrient cycling.

Each of these attributes is multi-scalar and incorporates both spatial and temporal dynamics. As a result, these attributes may also be examined at different scales including regions, landscapes and ecosystems.

Figure 1 provides examples of some of the linkages between the primary components and attributes of biodiversity.

FIGURE 1. **EXAMPLE OF BIODIVERSITY COMPONENTS AND ATTRIBUTES**

COMPONENT/ATTRIBUTE	COMPOSITION	STRUCTURE	FUNCTION
Ecosystem	Ecosystems in an area	Patch size	Connectivity
Species	Species richness in an area	Abundance	Predator/prey dynamics
Genetic	Number of unique genes in a population	Relative abundance of each unique gene in a population	Adaptation

1.2 The Value of Biodiversity to Humans

Biodiversity is the foundation of a vast array of ecosystem services essential for human well-being (see Figure 2).[2] Ecosystems support all forms of life, moderate climates, filter water and air, conserve soil and nutrients and control pests. Species (animal and plant) provide us with food, building materials, energy and medicines. They also provide vital services such as pollination, waste assimilation, water filtration and distribution of seeds and nutrients. Genetic diversity enables us to breed higher-yield and disease-resistant plants and animals and allows the development or natural evolution of breeds and races that thrive under a variety of environmental conditions.[3] For instance, genetic variability in a species allows adaptation over time to changing climatic conditions. The cultural services that ecosystems provide include recreational, aesthetic and spiritual values that are vital to individual and societal well-being.

Key public concerns about human impacts on biodiversity include effects on rates of extinction, future options, productivity of ecosystems, and loss of economic opportunities.[4] Retaining a variety and abundance of individuals and species permits the adaptability that sustains ecosystem productivity in changing environments and promotes further diversity (future adaptability and options), thereby potentially sustaining desirable economic and environmental opportunities and maintaining future options for the benefit of human communities.

In addition, many people believe that all life forms have an intrinsic value and that humans have a moral obligation to protect them and ensure that they survive for their own sake apart from their potential value to future human generations.[5]

FIGURE 2. THE CONTRIBUTION OF BIODIVERSITY TO HUMAN WELL-BEING[6]

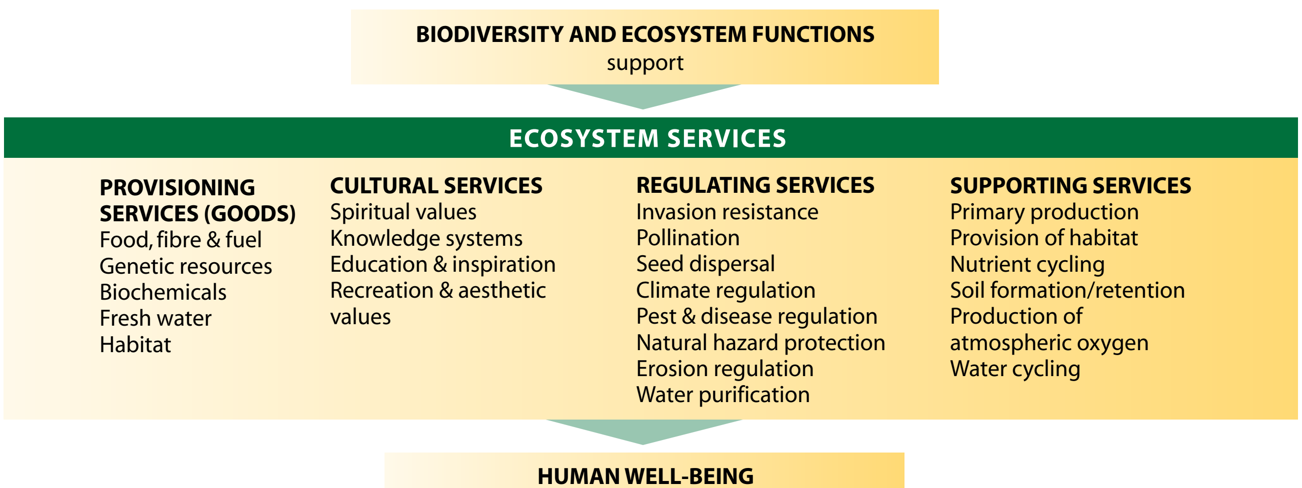

Figure 3 provides an overview of the ecological concepts and principles discussed in section 2 and their application as discussed in section 3. Ecological concepts are general understandings (or facts) about ecosystems and ecosystem management. Ecological principles are basic assumptions (or beliefs) about ecosystems and how they function that are informed by the ecological concepts. Ecological principles use ecological concepts (which are understood to be true) to draw key conclusions that can then guide human applications (section 3) aimed at conserving biodiversity.

FIGURE 3. OVERVIEW OF CONCEPTS, PRINCIPLES AND APPLICATIONS

ECOLOGICAL CONCEPTS

ECOSYSTEM CONCEPTS

- Levels of biological organization
- Native species
- Keystone
- Population viability/ thresholds
- Ecological resilience
- Disturbances
- Connectivity/fragmentation

ECOSYSTEM MANAGEMENT CONCEPTS

- Coarse and fine filter approach
- Risk is an inherent aspect of decision-making
- Adaptive management
- Ecosystem-based management
- Protected area

ECOLOGICAL PRINCIPLES

- Protection of species and species subdivisions will conserve genetic diversity
- Maintaining habitat is fundamental to conserving species
- Large areas usually contain more species than smaller areas with similar habitat
- All things are connected but the nature and strengths of those connections vary
- Disturbances shape the characteristics of populations, communities, and ecosystems
- Climate influences terrestrial, freshwater and marine ecosystems

APPLICATION OF ECOLOGICAL CONCEPTS AND PRINCIPLES

COARSE AND FINE FILTER APPLICATIONS

- Use coarse and fine filter approaches
- Representation, in a system of protected areas
- Retain large contiguous or connected areas
- Maintain or emulate ecological processes
- Manage landscapes and communities to be responsive to environmental change
- Manage towards viable populations of all native species
- Preserve rare landscape elements, critical habitats and features, and associated species
- Minimize the introduction and spread of invasive alien species that disrupt ecological resilience and population variability

PLANNING APPLICATIONS

- Set objectives and targets for biodiversity in plans
- Manage biodiversity at multiple levels of biological organization and multiple time and spatial scales
- Incorporate spatial and temporal approaches to land use that are compatible with an area's natural potential
- Avoid land uses that convert natural ecosystems and restore damaged ecosystems
- Avoid, mitigate or as a last option compensate for the effects of human activities on biodiversity
- Employ adaptive management of natural resources to maximize learning
- Given that humans are a powerful agent of change, make science based decisions

2 Ecological Principles

2.1 Ecological Concepts

Ecological concepts are general understandings (or facts) about ecosystems and ecosystem management.

- **Ecosystem concepts** provide a foundation for developing ecological principles in section 2.2 and applications in section 3.
- **Ecosystem management concepts** are basic tools that can be applied to support some of the applications in section 3 that relate to planning.

The following pages define each concept (additional definitions are provided in the glossary) and provide examples to put them in context. The definitions are ordered to follow the levels of biological organization from populations to species, ecosystems and landscapes, taking into account the fact that ecosystems contain both biotic and abiotic components–that is to say, not only living organisms and their relationships but also non-living elements such as soil and hydrological cycles.

2.1.1 Ecosystem Concepts

Concept 1

Levels of biological organization (genes, populations, species, communities, ecosystems, landscapes, regions). Life is dynamic and involves multi-scale ecological patterns and processes.[7] Although each scale is important, the interdependence of scales needs to be understood and assessed in order to conserve biodiversity.

The cross-scale nature of ecosystems includes ecological processes that operate from centimeters and days to hundreds of kilometers and millennia and collectively affect biodiversity.[8] In a forest, for example, this ranges in increasing scale from physiological processes that affect the life history of leaves, competition between plant species in a clump or gap that affect populations, disturbance and predation processes that influence the composition and structure of a community, to climatic processes that influence landscapes and regions. Each of these scales interacts with their finer/faster and coarser/slower neighbouring scales resulting in hierarchies and adaptive cycles that have been referred to as a *panarchy*.[9]

CONCEPT 2

Native species are those that naturally exist at a given location or in a particular ecosystem – i.e., they have not been moved there by humans.[10] For example, cedar and salmon are native to B.C.; Scotch broom and brown bullhead are introduced species that are not native to B.C. and have invaded some local ecosystems. Native plants, animals, fungi and microbes co-evolved over time to form a complex network of relationships. They are the foundation of natural ecosystems that sustain biological diversity. However, B.C. is a relatively new landscape due to glaciation that covered most of the province several thousand years ago. Given the short evolutionary scale for species, B.C. has few endemic (i.e., unique to B.C.) species.

Non-native species (or alien species) move into an ecosystem as a result of humans having moved them at some point or having removed a natural barrier (e.g., the removal of a natural barrier to fish passage). *Invasive alien species* have the potential to displace native species and threaten ecosystems or species with economic or environmental harm.[11] Invasive alien species can be particularly damaging since they are not subject to natural predators and diseases that keep populations of native species in check. Some invasive aliens cause a fundamental change in ecosystem composition, structure and function. For example, the spread of Eurasian watermilfoil in freshwater ecosystems in B.C. (introduced primarily on boat trailers) has clogged gravel spawning beds used by salmon on the coast and has also resulted in substantial increases in the release of phosphorus in Okanagan lakes.[12]

CONCEPT 3

A keystone species, ecosystem or process has a disproportionate influence on an ecosystem or landscape such as the role beavers play in altering the hydrological characteristics of streams and wetlands.

- *Keystone species* have effects on biological communities that are disproportionate to their abundance and biomass. The loss of keystone species results in broader community or ecosystem-level effects.[13] A keystone species interacts with other species through predation, symbiotic dependencies such as plant-pollinator relationships, or ecosystem modification (e.g., cavity nesters, beaver impoundments).

In B.C.'s coastal temperate rainforests, wild salmon species are often considered an important keystone species as they add marine nitrogen to freshwater and terrestrial ecosystems and are an important food source for many animals, including grizzly bears that drag the carcasses of salmon into the forest, adding beneficial nitrogen into forest soils where it is limited.[14] Another example is sea otters that feed on sea urchins, which in turn feed on kelp. By limiting the number of sea urchins, the sea otter promotes the development of kelp forests which in turn provide habitat for fish and invertebrate species. When hunting wiped out the sea otter from the B.C. coast, the kelp forests disappeared from many areas.[15]

- *A keystone ecosystem* is particularly important because it provides habitat for a large portion or critical elements of an area's biodiversity.[16] Riparian ecosystems near streams, lakes and wetlands are considered keystone since they cover a relatively small area yet support a disproportionately large number of species.[17] Estuaries are also a keystone ecosystem because of their disproportionately large influence relative to their size and abundance.[18]
- *A keystone process* is fundamental to the maintenance of an ecosystem. For example, fire plays a vital role in maintaining open ponderosa pine forests and grasslands in B.C.'s dry interior. Pollination is another keystone process.[19]

CONCEPT 4

Population viability/thresholds. "Viability" in this context refers to the probability of survival of a population/species in the face of ecological processes such as disturbance. When the amount of habitat available declines below the "extinction threshold", a population/species will decline and eventually disappear;[20] in addition to habitat for particular populations, a species' survival depends on maintaining healthy genetic variability. Species-level details about movement, behaviour and life history traits demonstrate that threshold responses vary by species and can be difficult to detect.[21] Unfortunately, the demographic data required to estimate viability are known for less than 0.01% of the species in B.C. Although extinction is normal in natural ecosystems, present rates of extinction have been accelerated by human activities.

The concept of *minimum viable population* refers to the smallest isolated population having a reasonable chance of surviving over time despite the foreseeable effects of demographic, environmental and genetic events and natural disturbances. Therefore, in smaller populations, the reproduction and survival of individuals decreases, leading to a continuing decline in population numbers. This effect may be due to a number of causes such as inbreeding or the ability to find a mate, which may become increasingly difficult as population density decreases.

CONCEPT 5

Ecological resilience is the capacity of an ecosystem to cope with disturbance or stress and return to a stable state. The concept of ecological resilience is consistent with the notion that ecosystems are complex, dynamic and adaptive systems that are rarely at equilibrium; most systems can potentially exist in various states. Moreover, they continually change in unpredictable ways in response to a changing environment.[22] This concept measures the amount of stress or disruption required to transform a system that is maintained by one set of structures and processes to a different set of structures and functions.[23] A resilient ecosystem can better withstand shocks and rebuild itself without collapsing into a different state.

Ecosystem change can occur suddenly if the resilience that normally buffers change has been reduced. Such changes become more likely when slow variables erode. Slow variables include the diversity of species and their abundance in the ecosystem, and regional variability in the environment due to factors such as climate. All of these variables are affected by human influence.

Both functional diversity and response diversity are important to maintain ecological resilience. Functional diversity is the number of functionally different groups of species and consists of two aspects: one that affects the influence of a function within a scale (see 'levels of biological organization' above) and the other that aggregates that influence across scales.[24] Response diversity is the diversity of responses to environmental change among species contributing to the same ecological function and provides adaptive capacity given complex systems, uncertainty and human influence.[25]

In a rangeland, for example, functional diversity increases the productivity of a plant community as a whole, bringing together species that take water from different depths, grow at different speeds, and store different amounts of carbon and nutrients. Response diversity enables a community to keep performing in the same way in the face of stresses and disturbances such as grazing and drought.[26]

CONCEPT 6

Disturbances are individually distinct events, either *natural* or *human-induced*, that cause a change in the existing condition of an ecological system.[27] Disturbances can be described in terms of their type, intensity, spatial extent, frequency and other factors.

- *Natural disturbances* include wildfire, flood, freshet, lake turnover, drought, windthrow, and insect and disease outbreaks. Some "natural disturbances" may be responding to human-caused climate change – a current example is the mountain pine beetle epidemic in the interior of the province. Extreme natural disturbance events often characterize an ecosystem and ensure the presence of some species. Disturbance is critical to maintaining the richness of systems (e.g., riparian ecosystems) or rejuvenating them.

- *Human-induced disturbances* in terrestrial ecosystems include, for example, timber harvesting, road building, and rural and urban development. Human-caused aquatic disturbances include damming, water extraction from rivers and streams, wetland drainage and pollution. Some of these human-related disturbances cause lasting changes that can fundamentally alter ecosystems and modify our approach to ecosystem management. For example, to reduce fire damage on property and in forests, the management response is to reduce the size and intensity of forest fires, which truncates the range of disturbances of ecosystems.
- *Biological legacies* are the elements of a pre-disturbance ecosystem that survive to participate in its recovery. They are a structural consequence of the selective filter that the disturbance process imposes on the ecosystem. Biological legacies are critical elements of ecosystem dynamics across a broad range of ecosystems studied. Examples are large fish in freshwater systems or standing live and dead trees in forests, which are common within the perimeter of a wildfire and play critical roles in the establishment of new forests and in sustaining biodiversity.

The term "natural range of variability" (NRV) is used to describe naturally occurring variation over time of the composition and structure found in a system, resulting in part from sequences of disturbances.[28] This has traditionally been estimated in North America by examining the variations that occurred during the centuries prior to European settlement. The longer the time frame over which the variability is calculated, the more variability is included. Infrequent catastrophic events are sometimes excluded from the NRV estimates, although, as noted above, such events can be influential in characterizing and sustaining ecosystems. The traditional activities of First Nations are often considered part of the NRV as their actions were typically part of the ecosystem for hundreds to thousands of years.

Climate change will play an important (though not the only) role in future changes to the NRV. The current rate of rapid climate change has the potential to shift ecosystems out of the range of conditions they experienced historically. As a result, the past will become an increasingly unreliable guide for estimating the current and future NRV for an area. Alternatively NRV could be estimated using climate models, however, it should be recognized that a time lag would be expected as the composition and structure of an ecosystem shifts due to changes in the NRV.

CONCEPT 7

Connectivity/fragmentation is the degree to which ecosystem structure facilitates or impedes the movement of organisms between resource patches.[29] What constitutes connectivity is scale-dependent and varies for each species depending on its habitat requirements, sensitivity to disturbance and vulnerability to human-caused mortality.[30] Connectivity allows individual organisms to move in response to changing conditions, such as seasonal cycles, a forest fire or climate change. Loss of connectivity results in fragmentation. The degree and characteristics of natural connectivity vary with differences in landscape type.[31] Humans can impact connectivity and cause fragmentation in ways that can adversely affect biodiversity.

Connectivity and fragmentation are both important contributors to ecosystem function and processes. For example, some habitat types (e.g., caves, bogs, cliffs) may be ‘naturally’ fragmented; others (e.g., streams, riparian habitat) are essentially linear; and others are often distributed in large blocks or patches. A key management challenge is how to deal with habitats that existed naturally in large patches but which, as a result of human activity, have been converted into much smaller, sometimes isolated patches. Another challenge is to reduce ‘unnatural’ connectivity to naturally fragmented and isolated habitats so that the unique species they support are not displaced by invading species.

2.1.2 ECOSYSTEM MANAGEMENT CONCEPTS

The ecosystem concepts described in section 2.1.1 help inform basic *ecosystem management concepts* that, in turn, support some of the applications in section 3 that relate to planning.

CONCEPT 8

Coarse and fine filter approach. Concept 1 (levels of biological organization) notes that there are recognizable but varying degrees of aggregation and association among species and the processes they create. Coarse and fine filter approaches build on that concept. “*Coarse filter*” is a metaphor to express the idea that by conserving the ecological communities of a given region, the majority of species will be conserved. The coarse filter approach refers to the management of landscapes through a network of protected areas, and management practices in the surrounding matrix that attempt to emulate and conserve natural ecological processes within the NRV. “*Fine filter*” is a metaphor to express the idea that some species, ecosystems and features need to be conserved through individual, often localized efforts (this is called the fine filter approach) because they fall through the mesh of the coarse filter. An example is a species of conservation concern that relies on a particular habitat feature within an ecosystem for survival where the feature is not normally conserved by a coarse filter approach. Some ecologists consider the retention of biological legacies following disturbances, such as live and dead trees, and coarse woody debris in forested landscapes, as a "*medium filter*" approach that conserves stand (or site) level biodiversity.[32]

CONCEPT 9

Risk is an inherent aspect of decision-making. Given the complexity and variability evident in Concepts 1, 4, 5 and 6 above, we can never be wholly certain of the consequences of a management action. Risk is the potential for loss or damage resulting from a particular action or decision. Risk assessment takes into consideration two elements: (1) the likelihood of an event occurring; and (2) the magnitude of the consequences should that event occur. Risk assessment is a formal appraisal of these two elements. Risk management is the process of weighing the assessed risks against the expected benefits to make the "best" decision. Uncertainty is directly related to risk, for example, because an increase in uncertainty can result in a higher perception of risk.[33]

CONCEPT 10

Adaptive management. As a formal response to the presence of uncertainty and risk, adaptive management is a systematic learning process that formally plans and monitors the outcomes of decisions to improve our ability to better manage natural resources given uncertainty. The options to improve decision making with incomplete knowledge include: (1) "trial and error", in which initial choices are a 'best guess' with later choices chosen from a subset that gives better results; (2) "passive adaptive" where one model is assumed to be correct; and (3) "active adaptive" where multiple alternate models are linked to policy choices.[34] Passive adaptive management can provide an effective means of identifying the best (or at least better) practices among existing practices. Active adaptive management can play a particularly important role by incorporating uncertainty in a dynamic system[35] and thus providing greater learning opportunities for stakeholders, scientists, managers and citizens. The concepts of risk and uncertainty are inextricably linked to adaptive management, where learning is a key output in support of continuous improvement in decision-making.[36]

CONCEPT 11

Ecosystem-based management (EBM). EBM can be defined as "an adaptive approach to managing human activities that seeks to ensure the coexistence of healthy, fully functioning ecosystems and human communities. The intent is to maintain those spatial and temporal characteristics of ecosystems such that component species and ecological processes can be sustained, and human wellbeing supported and improved."[37] Thus EMB is not only necessarily place-based but also takes into account two opposing value systems (intrinsic ecosystem value vs. value to humans). There are many definitions of EBM and several include both socio-economic and biological considerations.[38]

CONCEPT 12

Protected area. Protected area in this context refers to any area that has some form of protection and typically has a minimal human footprint. In B.C. that would include all federal or provincially designated parks and protected areas as well as many areas that are managed primarily for biodiversity. Examples are National Wildlife Areas, Wildlife Management Areas, riparian reserve zones, old growth management areas, wildlife habitat areas and ungulate winter ranges. Some private lands protected through acquisition or agreement would also qualify.

Protected areas are often the core of a coarse filter approach to conservation. However, they also can serve other conservation roles. Protected areas are used for fine filter purposes (e.g., to protect a population of a rare species or a significant landform); to provide connectivity; to serve as benchmarks; and/or to provide for research and education opportunities.

2.2 Ecological Principles

Ecological principles are basic assumptions (or beliefs) about ecosystems and how they function and are informed by the ecological concepts described in section 2.1 above. Ecological principles build on ecological concepts (which are understood to be true) to draw key conclusions that can then guide human applications (section 3) aimed at conserving biodiversity.

PRINCIPLE 1

Key supporting concepts: **Population viability/thresholds; levels of biological organization**

Protection of species and species' subdivisions will conserve genetic diversity.[39]

At the population level, the important processes are ultimately genetic and evolutionary because these maintain the potential for continued existence of species and their adaptation to changing conditions. In most instances managing for genetic diversity directly is impractical and difficult to implement. The most credible surrogate for sustaining genetic variability is maintaining not only species but also the spatial structure of genetic variation within species (such as sub-species and populations). Maintenance of populations distributed across a species' natural range will assist in conserving genetic variability. This ensures the continuation of locally adapted genetic variants. Retaining a variety of individuals and species permits the adaptability needed to sustain ecosystem productivity in changing environments and can also beget further diversity (future adaptability). This will be particularly important given climate change; for example, the genetic potential of populations at the northern edge of their range in B.C. may be particularly important to help facilitate species adaptation to changes. Species that are collapsing towards the edge (versus centre) of their range and disjunct populations (where a local population is disconnected from the continuous range of the species) are also particularly important to consider, given climate change, in order to conserve genetic diversity and enable adaptation.

PRINCIPLE 2

Maintaining habitat is fundamental to conserving species.

A species habitat is the ecosystem conditions that support its life requirements. Our understanding of habitat is based on our knowledge of a species' ecology and how that determines where a species is known to occur or likely to occur. Habitat can be considered at a range of spatial and temporal scales that include specific microsites (e.g., occupied by certain invertebrates, bryophytes, some lichens), large heterogeneous habitats, or occupancy of habitat during certain time periods (e.g., breeding sites, winter range areas). Therefore conserving habitat requires a multi-scale approach from regions to landscapes to ecosystems to critical habitat elements, features and structures.

Key supporting concepts:
Levels of biological organization; connectivity/fragmentation; native species

PRINCIPLE 3

Large areas usually contain more species than smaller areas with similar habitat.

The theory of island biogeography illustrates a basic principle that large areas usually contain more species than smaller areas with similar habitat because they can support larger and more viable populations. The theory holds that the number of species on an island is determined by two factors: the distance from the mainland and island size. These would affect the rate of extinction on the islands and the level of immigration. Other factors being similar (including distance to the mainland), on smaller islands the chance of extinction is greater than on larger ones. This is one reason why larger islands can hold more species than smaller ones. In the context of applying the theory more broadly, the "island" can be any area of habitat surrounded by areas unsuitable for the species on the island.[40] Therefore a system of areas conserved for biodiversity that includes large areas can effectively support more viable populations.

Key supporting concepts:
Population viability/thresholds; protected area; coarse and fine filter approach

PRINCIPLE 4

All things are connected but the nature and strength of those connections vary.

Species play many different roles in communities and ecosystems and are connected by those roles to other species in different ways and with varying degrees of strength. It is important to understand key interactions. Some species (e.g., keystone species) have a more profound effect on ecosystems than others. Particular species and networks of interacting species have key, broad-scale ecosystem-level effects while others do not.

The ways in which species interact vary in addition to the strengths of those interactions. Species can be predator and/or prey, mutualist or synergist. *Mutualist species* provide a mutually beneficial association for each other such as fungi that colonize plant roots and aid in the uptake of soil mineral nutrients. *Synergistic species* create an effect greater than that predicted by the sum of effects each is able to create independently.

The key issue is that it is important to determine which among the many interactions are the strong ones because those are the ones toward which attention needs to be directed.

Key supporting concepts:
Levels of biological organization; keystone ecological processes

PRINCIPLE 5

Key supporting concepts:
Disturbances; connectivity/ fragmentation

Disturbances shape the characteristics of populations, communities, and ecosystems.

The type, intensity, frequency and duration of disturbances shape the characteristics of populations, communities and ecosystems including their size, shape and spatial relationships.

Natural disturbances have played a key role in forming and maintaining natural ecosystems by influencing their structure including the size, shape and distribution of patches. The more regions, landscapes, ecosystems and local habitat elements resemble those that were established from natural disturbances, the greater the probability that native species and ecological processes will be maintained. This approach can be strengthened by developing an improved understanding of how ecosystems respond to both natural and human disturbances, thus creating opportunities to build resilience in the system. For example, high frequency, low intensity fires have shaped ponderosa pine ecosystems while low frequency, high intensity fires have shaped lodgepole pine ecosystems. Maintaining these ecosystems means restoring fire and/or designing management practices such as harvesting to reduce the differences between a managed landscape and a landscape pattern created by natural disturbance.

Since ecosystems can change dramatically at the site level due to natural disturbances, considering their composition and structure of habitats at the landscape-level may be more useful. For terrestrial ecosystems, this means taking into account:

- species composition;
- the amount and patch size distribution;
- the variety and proportion of seral stages of terrestrial habitat from young to old; and
- the diversity of within community structure (e.g., a variety of amounts of snags and coarse woody debris within forest stands).

It is important to recognize that for some less mobile species, distribution of habitat is potentially as influential as amount of habitat (i.e., patch size; connectivity).

PRINCIPLE 6

Climate influences terrestrial, freshwater and marine ecosystems.

Climate is usually defined as all of the states of the atmosphere seen at a place over many years. Climate has a dominant effect on biodiversity as it influences meteorological variables like temperature, precipitation and wind with consequences for many ecological and physical processes, such as photosynthesis and fire behaviour. For example, major temperature fluctuations in surface waters in the Pacific Ocean due to El Nino climatic events can influence weather and significantly warm temperatures throughout much of B.C. This in turn can increase some wildlife populations or impact the migration timing of some migratory bird populations.[41] Another example of the effect of climate is the loss of large populations of native B.C. oysters due to cold temperatures in the 1900s; similarly, cold periods can kill fish in lakes.

Because of the key role of climate, rapid climate change profoundly changes ecosystems.[42] For example, climate change enables population outbreaks in some species and likely contributed to the mountain pine beetle epidemic in B.C. due to successive warm winters. Alterations to stream flow and timing of freshet resulting from climate change affects fish and waterfowl. A critical question therefore is: How should anticipated climate changes influence current conservation decisions so that ecosystems remain resilient in the future?

Key supporting concepts:

Ecological resilience; disturbances

3 Application of Ecological Concepts and Principles

The applications described below provide ways of applying the ecological concepts and principles in order to conserve biodiversity. No single application will be sufficient – each approach ideally needs to be operating in conjunction with others. The applications are grouped into those that primarily relate to:

- **coarse and fine filter applications**: techniques to help conserve biodiversity; and
- **planning applications:** techniques to promote biodiversity conservation using planning tools and adaptive management that continuously improves our understanding of what needs to done and how this can be more effectively delivered over time.

3.1 Coarse and fine filter applications:

APPLICATION 1

Use coarse and fine filter approaches.

Key supporting concept:
Coarse and fine filter approach

Coarse filter approaches include the management of landscapes through a network of representative protected areas and management practices in the non-protected matrix that attempt to emulate natural ecological processes with composition and structure falling within the natural range of variability. Large-scale coarse filter approaches – at the levels of ecosystems and landscapes – are the only reasonable way to conserve the overwhelming mass – the millions of species – of existing biodiversity. Vertebrates and vascular plants make up a very small portion of biodiversity, and the vast majority of other species remain unknown. Many of the smaller organisms, including invertebrates, fungi and bacteria, provide critical ecosystem functions such as decomposition and nitrogen fixation; and contrary to some beliefs, many of these organisms are vulnerable to human impacts. Because there are simply too many species to handle on a species-by-species basis, the only practical way to conserve most biodiversity is to focus on the protection and management of ecosystems and landscapes.[43] The assumption is that if the key attributes of ecosystems and landscapes are managed within the natural range of variability, the species associated with those ecosystems and landscapes can be maintained.

Coarse filter approaches can be applied in a manner that focuses conservation efforts where they most matter – for example, by identifying those ecosystems or regions with a high number of endemic species (unique to that ecosystem or region) where a high percent of the original habitat has been lost.[44] This can help focus conservation efforts where they are likely to protect the most species that are vulnerable to habitat loss.[45]

Fine filter approaches focus on ecosystems, features and species, including species and ecosystems of conservation concern that may not be adequately protected through 'coarse filter' management approaches. The ecosystems, features and species that are not conserved by coarse filter approaches may be critical to maintaining biodiversity. For example, coarse filter efforts may not conserve small habitats or ecosystems such as a bald eagle nest or a cave. Although coarse filter or ecosystem approaches to species conservation are essential, they must often be supplemented by fine filter approaches.

APPLICATION 2

Key supporting concepts: **Protected area, coarse and fine filter approach**

Ensure representation in a system of protected areas.

Protected areas, including those managed primarily for biodiversity conservation and those managed for a wide range of sustainable uses, are extremely important, especially in environments where biodiversity loss is occurring as a result of ecosystem loss or alteration. An important conservation goal is to represent the diversity of ecosystems or enduring features within a system of protected areas. Proportional representation may be a good starting point with the actual level or amount of representation varying depending on factors such as rarity and sensitivity. Providing protected areas sufficiently large to represent predator-prey systems may also result in some ecosystem types having higher levels of representation than other types.

Despite efforts to increase the number and size of protected areas, the current system in most jurisdictions is not sufficient for conservation of all (or even representative) components of biodiversity, in part due to lack of representativeness. The variation across marine and freshwater ecosystems is even less protected than terrestrial ones due in part to a focus on terrestrial ecosystems and perhaps also jurisdictional issues. Marine protected areas can provide striking examples of the potential synergies between conservation and sustainable use, since appropriately placed ones can significantly increase the fishery harvest in adjoining areas.[46]

In addition to direct conservation benefits, protected areas provide invaluable natural benchmarks to assess our success in emulating natural conditions in other areas. Assessing the natural state of some ecosystems (such as long-lived forests) can be very difficult and is greatly influenced by spatial and temporal scale – now a moving target with climate change. Consequently, the natural benchmark values of protected areas are very important.

"Gap analysis" is a technique used in many jurisdictions in North America, including B.C., to assess ways to improve representation in the protected area and reserve system. The technique overlays ecosystem units or other more enduring units within existing protected areas to assess "gaps" in representation.[47] In B.C. terrestrial representation has used the Ecoregion and Biogeoclimatic Ecosystem Classification systems. There are also nearshore,[48] marine[49,50,51] and freshwater ecological classification systems that can be used to assess representation.[52]

APPLICATION 3

Retain large contiguous or connected areas.

Key supporting concepts:
Connectivity/fragmentation; protected area; ecosystem-based management

Unlike many jurisdictions in the world, B.C. still has relatively large areas of "wild" ecosystems where natural or near-natural ecological processes such as predator-prey dynamics remain largely intact.[53] The large contiguous and connected areas that support these natural ecosystems provide critical habitat for a wide variety of species. These areas are valued locally, provincially, nationally and globally, and efforts have been made to map and characterize them by various organizations and agencies. Protected areas and the natural and semi-natural matrix, where they exist, can be combined to retain large contiguous or connected areas.

Natural matrix conditions occur in *de facto* natural areas that are not specifically dedicated to the protection of biological values but in their current state contribute significantly to biodiversity conservation. In terrestrial ecosystems, this includes large areas where resource development (like timber harvesting) is not occurring or expected to occur, usually due to economic or physical inoperability. These areas, however, could be used for consumptive uses in the future if the value of the resource increases sufficiently or the technology becomes available to access them more economically.

Protected areas are generally too small to maintain mobile species such as large carnivores which require large home ranges, and therefore it is critical to consider what happens outside of protected areas. Therefore, retaining large contiguous or connected natural areas is important to conserving species with large home ranges. Large connected areas may also be the best way to address the conservation of biodiversity in this era of rapid climate change.

Efforts have been made in B.C. to recognize and conserve some of these large contiguous areas, such as the Muskwa-Kechika area in northeastern B.C. These unique values have also been recognized in several northern and coastal Land and Resource Management Plans (LRMPs). Regional connectivity strategies intended to provide for species migration between protected areas are provided in some LRMPs. It is also important to implement these strategies and to monitor their effectiveness.

To enable large areas to be connected, one important management practice is to mitigate barriers to species migration due to obstacles such as highways by providing opportunities for the safe passage of fish and wildlife.

APPLICATION 4

Key supporting concepts: **Ecological resilience; disturbances**

Maintain or emulate natural ecological processes.

Natural ecological processes shape ecosystems and should be maintained where possible; this includes disturbance regimes, hydrological processes, nutrient cycles and biotic interactions that also shape evolutionary processes. Maintaining ecological processes helps ensure that dynamic natural ecosystems continue to function and can promote ecological resilience. Natural ecological processes (both biotic and abiotic) should be continued, where practical, by minimizing human interference. Where interference occurs, human actions should try to emulate those processes.

For example, society no longer tolerates some types of disturbances, such as wildfire, where valued timber resources could be damaged or human property or life could be threatened. Yet wildfire is one of the key natural disturbances for most terrestrial ecosystems in B.C.'s interior. In these cases, emulating disturbance regimes through human actions, like forest harvesting, becomes a necessary surrogate. To be most effective, these practices should emulate the natural pattern of leave patches and dead wood as well as removing the fibre that would have been lost to naturally occurring fire. Restoring fire in the ecosystem through the use of prescribed fire is an important tool but may not be cost-effective or appropriate for many ecosystems in B.C. Other examples of perturbations to natural processes include the regulation of water flows by dams constructed to control floods or provide water for irrigation in the drier parts of the year. The release of water at critical times such as during fish migration can help mitigate these downstream impacts.

APPLICATION 5

Key supporting concepts: **Ecological resilience; disturbances**

Manage landscapes and communities to be responsive to environmental change.

Disturbances are a key source of environmental change. Natural disturbances can significantly affect ecosystems through agents such as insect and disease outbreaks, wildfires, flooding and drought. Ecosystems typically adapt to these disturbances in due course and recover naturally when they occur. However, the cumulative effects of climate change, increased human settlement and use and other agents of change such as invasive alien species can stress ecosystems to the point where they cannot recover from disturbances or recover at a rate that is unacceptably slow. It is therefore an important principle of planning to create conditions under which ecosystems can absorb disturbances and remain resilient.[54] Most importantly, that means ensuring that the full complement of existing species and processes is maintained so the ecosystem can heal itself, and avoiding placing so much stress on a local ecosystem that it is unable to recover naturally.

Climate change, to cite one example of human-induced stress, is likely to alter the historic NRV. Actions to facilitate the adaptation of biodiversity and ecosystems to climate change may include the development of ecological connectivity.[55] In addition to maintaining connectivity where they can be identified, and given that most of B.C. remains under Crown ownership, one effective and available strategy is to manage the matrix so that it resembles natural conditions, thereby making it less hostile and more permeable to dispersing organisms. Actions that recognize that 'the matrix matters'[56] can help facilitate connectivity in the landscape, including the movement of organisms between protected areas.[57]

Atypical catastrophic disturbance events such as floods, fire and insect infestation can occur unexpectedly. Contingency or emergency planning for such disasters can not only save human lives and property but also can help ensure our response facilitates ecosystem recovery and does not inadvertently exacerbate impacts on biodiversity. For example, salvage harvesting activities in areas affected by the mountain pine beetle should consider retention strategies that provide biological legacies needed to help ensure species persistence. It is also important to mitigate the impacts of increased harvesting and road building on forest fragmentation and watershed hydrology, including stream flow and stream quality. When dealing with unexpected yet consequential events, it is vital to consider how our response might assist or harm biodiversity.

As discussed under Concept 5 (ecological resilience), the natural ability of ecosystems to respond to disturbances is particularly important for ecosystem renewal and reorganization. A range of responses provides adaptive capacity in a world of complex systems, uncertainty, and human-dominated environments that contributes to the resilience of desired ecosystem states following disturbance and management. Ecosystems with high response diversity provide a buffer that helps prevent system collapse due to decisions that may have uncertain outcomes. In some examples, a decrease in response diversity is associated with a higher level of disturbances such as when toxic chemicals are released into a lake that eliminate bacteria that are critical to maintaining the nitrogen cycle.[58]

APPLICATION 6

Key supporting concepts: **Native species; population viability/thresholds; coarse and fine filter approach**

Manage towards viable populations of native species.

Maintaining viable populations of all native species helps ensure that extinction thresholds are not reached. Most thresholds become apparent at a point where it is too late to intervene. Therefore providing habitats that sustain populations well above minimum viable populations lessens the risk of extinction. It is generally more expensive to recover a population that is threatened or endangered than it is to avert population collapses caused by crossing threshold levels.

Providing viable populations of a species well distributed across its natural range (or across the appropriate environments dictated by climate changes) helps ensure that genetic variability within populations is conserved. This may be particularly important given evolving conditions, such as climate change that can affect a species.

The best strategy to "keep common species common" is through coarse-filter approaches that represent native ecosystems in protected areas while encouraging management practices in the surrounding matrix that maintain the composition, structure and function of natural ecosystems. These efforts will help ensure that natural patterns and abundance of habitat and associated native species remain viable.

APPLICATION 7

Key supporting concepts: **Keystone; disturbances; coarse and fine filter approach**

Preserve rare landscape elements, critical habitats and features, and associated species.

We often recognize distinctive features in an area that are uncommon but to which other organisms respond. We tend to give these features different names such as "rare landscape elements," which include ecological communities of conservation concern that are identified in B.C. by the Conservation Data Centre. 'Critical habitats' are geographic areas that are essential to conserve species of conservation concern or the maintenance of viable populations. Examples include forested areas that provide arboreal lichen needed by mountain caribou for their winter survival and estuaries that provide critical habitat for salmon fry as they gradually adjust to the increased salinity of water in the open ocean as well as to new food resources and predators. 'Critical features' are components of habitat that are needed to help conserve species of conservation concern and maintain viable populations. Examples include clean gravel for spawning cutthroat trout, wildlife trees used by cavity nesters, and caves used by bats. Biological legacies are critical features that remain on a site or landscape after a natural disturbance and can be 'lifeboats' that facilitate the persistence of species. For forested ecosystems, these legacies include live and dead trees and coarse woody debris.

Coarse-filter approaches may not be sufficient to preserve rare or critical elements, habitat and features that may be essential to conserving biodiversity. Consequently, it is important to assess whether fine-filter "gaps" in conservation occur despite coarse-filter efforts.

Appropriate management practices can help ensure the persistence of landscape elements, critical habitats and features. An example is urban development planning that designs and secures riparian conservation zones to maintain fish habitat and wildlife corridors. In forestry, wildlife trees retained following harvesting can provide habitat for cavity nesting birds, while large pieces of coarse woody debris may be important to maintaining rodent populations that are a key component of the predator-prey food chain in many landscapes.

The coordinated, planned location of rare landscape elements, critical habitats and features along with other reserves and designations for conservation across the landscape helps optimize conservation efforts while minimizing impacts on resource use.

APPLICATION 8

Minimize the introduction and spread of invasive alien species that disrupt ecological resilience and population variability.

Key supporting concepts: **Native species; keystone; ecological resilience, population viability.**

Some invasive alien species can out-compete native species, thereby lowering the population levels of native species and impacting their viability. The reduction in native species caused by invasive alien species can in turn impact the food chain that supports other forms of native species. For example, the spread of knapweed in over 40,000 hectares of B.C.'s grasslands and open forests has reduced their forage potential by up to 90%. If left unchecked, knapweed could spread to over 1 million hectares of grassland and open forests in B.C.[59] Another example is the introduction of alien fish species that can eliminate native amphibian populations in small lakes. The key management lessons here, repeated over and over in recent decades are: do not willfully introduce alien species (never assume they will be beneficial), and intervene early to eradicate them once their presence is known.

Invasive alien species are considered the second-most serious factor responsible for the extinction of native species and loss of biodiversity, worldwide, after habitat loss. Climate change is expected to increase the capacity of existing invasive alien species to invade natural ecosystems and to allow new invasive alien species to establish in B.C.[60]

The Invasive Plant Strategy for B.C.[61] recommends solutions for the "top ten" challenges to invasive plant management in B.C. including improving cooperation, providing necessary resources, enacting legislation, improving compliance, increasing management effort, coordinating a system for early detection and eradication, establishing a comprehensive inventory, ensuring a regional approach is taken, improving technical expertise and undertaking coordinated research.

3.2 Planning Applications

Conservation of biodiversity cannot be effectively achieved without understanding the needs of, and consulting with, users of lands and waters to achieve solutions that conserve biodiversity. This requires proactive planning approaches (or tools) for biodiversity that can be effectively integrated with existing strategic and local-level planning processes.

APPLICATION 9

Key supporting concepts: **Keystone; ecosystem-based management; adaptive management**

Set objectives and targets for biodiversity in plans.
Managing by objectives is key to conserving biodiversity. If we don't know "where we want to go", how can we assess success or failure? For example, at the strategic level, in order to keep common species common and prevent loss of native species, three broad objectives could include:

- representing the range of natural ecosystem types in protected areas;
- providing the amount and distribution of habitats important to sustain native species; and
- ensuring that the abundance and distribution of native species are not substantially reduced by human activities.

Measurable indicators (such as the abundance of an indicator species) need to be developed in order to monitor whether management objectives are being attained and provide needed "red flags" in situations requiring corrective action. Forest certification systems generally include the specification of criteria and indicators, as well as measurable targets, including those for biodiversity conservation, in order to facilitate monitoring and reporting, and to promote continuous improvement.

Objectives, indicators, and targets for biodiversity should be documented in sustainable management plans that support resource use activities. Monitoring has to be an integral part of the planning process. Implementation monitoring assesses whether the targets are being achieved. Effectiveness monitoring assesses whether the targets support the objectives and, if they don't, provides insight on how the targets should be adjusted.

APPLICATION 10

Key supporting concepts: **Levels of biological organization; ecosystem-based management; adaptive management**

Manage biodiversity at multiple levels of biological organization and multiple time and spatial scales.[62]
Planning processes at a variety of scales can provide the objectives needed to guide management, and cost-effective monitoring (not only at local but also at very large scales) can provide the feedback needed to improve the objectives or targets or to determine how they are being implemented. This includes planning at the regional,

landscape and ecosystem level. Examples of such planning in B.C. include Sustainable Resource Management Plans, site plans for specific resources uses, water use plans, and urban planning.

APPLICATION 11

Incorporate spatial and temporal approaches to land use that are compatible with an area's natural potential.

Key supporting concepts:
Ecosystem-based management

The natural potential of areas to support biodiversity varies: some areas support a wide variety of species, others support rare species, and still others support relatively few yet common species. Similarly, the natural potential of areas to support agriculture, timber production and other human uses also varies. Providing a mix of land uses, ranging from a conservation emphasis to extractive use emphasis, that is consistent with an area's natural potential helps to ensure that societal goals to conserve biodiversity, while providing goods and services, can be simultaneously and sustainably attained. Providing this mix can be accomplished by "zoning" areas in plans – for example, through the resource management zones identified in LRMPs.

Two general opportunities exist for incorporating biodiversity conservation into management practices in sectors such as agriculture, forestry, fisheries and urban development. First, management activities that promote the complexity of biodiversity can often be more economical than alternative approaches that simplify biodiversity. For example, regenerating a diversity of species that emulates natural composition following harvesting can increase ecosystem resilience to forest pests such as bark beetles, thereby better maintaining commercial timber supply. Second, strategies that promote the intensification of production rather than the expansion of the total area of production can allow more area for conservation. For example, some urban development allows housing to be more concentrated, thereby protecting more green space than is possible through an approach that allows urban sprawl to occur, displacing critical habitat (e.g., by draining wetlands).

APPLICATION 12

Avoid land uses that convert natural ecosystems and restore damaged ecosystems.

Key supporting concepts:
Disturbances; connectivity/fragmentation; ecosystem-based management; risk in decision-making

Natural ecosystems provide the habitat necessary to maintain biodiversity. Land uses that convert natural ecosystems over large areas or critical habitats (such as rare Garry oak ecosystems, wetlands or estuaries) can, in turn, significantly degrade biodiversity. This includes impacts that disrupt abiotic processes that include soil erosion or altering the level of the water table. Because many areas developed for urban and agricultural uses are rich biologically, special efforts, for example through careful urban planning, are needed to avoid further loss to critical habitats.

Where ecosystems have been converted or degraded, ecosystem restoration efforts should be made. Ecosystem restoration, however, is generally far costlier than protecting the original ecosystem and it is rare that all of the biodiversity and services of a system can be restored.[63] Nevertheless, in small areas restorative activities can be very effective in recovering biodiversity in damaged ecosystems. Recent restoration activities in B.C. have focused on a number of key areas including:

- Restoration of ecosystems in urban and urban fringe areas with high human impact – for instance, Garry oak ecosystems on Vancouver Island.
- In-stream riparian and slope stabilization work aimed at restoring the carrying capacity of watersheds for both anadromous (sea-going) and resident fish populations. Populations of the various Pacific salmon species have been a particular focus.
- Restoration of fire to ecosystems where frequent fire historically had a key ecosystem maintenance role. These projects have typically involved thinning of over-dense stands and re-introduction of fire at appropriate scales and intensities.
- Restoration of areas where major impacts, such as mine tailings piles, have eliminated most or all natural ecosystem components and functions.[64]

Restoration in B.C. is increasingly moving from restoration after the fact to restoration as a planned and integral part of resource management and development activities.[65]

APPLICATION 13

Key supporting concepts:
Ecological resilience; disturbances; risk in decision-making

Avoid, mitigate or, as a last option, compensate for the effects of human activities on biodiversity.

Improved valuation techniques and information on ecosystem services tells us that although many individuals benefit from the actions and activities that lead to biodiversity loss and ecosystem change, the costs borne by society of such changes is often higher. Even in instances where our knowledge of benefits and costs is incomplete, the use of the precautionary approach (requiring assurance that harm will not occur) may be warranted when the costs associated with ecosystem change may be high or the changes irreversible.[66] In these cases, actions that may cause irreversible damage, such as species loss, should be avoided.

When decisions are made that adversely impact ecological processes and biodiversity e.g. creation of reservoirs for flood control and hydro-electric generation, the impacts should be minimized and any residual impact should be mitigated. If impacts can not be fully mitigated, then compensation for the impact should be completed in off site areas to ensure resilient ecosystems that maintain biodiversity.

APPLICATION 14

Employ adaptive management of natural resources to maximize learning.

Key supporting concept:
Adaptive management; ecosystem-based management; risk in decision-making

Our current knowledge and ability to manage natural resources for biodiversity is full of uncertainty, especially with regard to natural environmental variability, human impacts on the environment, understanding of ecosystem processes, and variations in social and political goals.[67] The short-term impacts of human activity on a few species have been well described, but long-term impacts on the vast majority of species (e.g., invertebrates) are poorly known. In B.C., recognized knowledge limitations[68] include:

- many species have not been described scientifically (e.g., many invertebrates);
- species ecology including habitat requirements;
- ecological processes; and
- long-term impacts of human activity such as climate change.

While adaptive management is recognized as important for dealing with problems associated with high levels of uncertainty, success in implementing it has been low.[69] Some current adaptive management processes rely too heavily on linear models, discount non-scientific knowledge and do not incorporate policy processes that could support cooperation among various stakeholders.[70] In certain situations passive management may be appropriate and highly informative when there is a high confidence in the ecosystem response or when there are strong regulatory or institutional constraints; however, in practice passive adaptive management often evolves into "trial and error."[71] Other weaknesses include lack of the monitoring needed to provide the learning necessary for continuous improvement.

Some of the key characteristics of active adaptive management include[72]:

- recognize there is a large amount of uncertainty in processes and events;
- develop a few alternate models or sets of explanations;
- select the policies or practices to be implemented;
- define key management and other actions at the necessary scale; and
- incorporate scientists, stakeholders, politicians and citizens in the learning process.

To promote learning and continuous improvement in the face of risk and uncertainty, a key management premise is 'not to do the same thing everywhere' by treating management as an experiment and testing innovative approaches. For example, evaluating different configurations and widths of riparian buffers in freshwater systems to emulate post-fire patterns in interior forests in B.C. to create diversity and improve learning.

As adaptive management can be expensive, implementing adaptive management should be targeted to operations that provide opportunities to learn the most and inform management.

The *adaptive management* cycle supports continuous improvement and consists of the following steps:

- *define*: setting objectives and targets;
- *design:* planning actions based on existing objectives and targets, knowledge, technology and inventory;
- *implement:* acting based on those plans;
- *monitor*: checking the effects of those actions; and
- *evaluate*: assessing the results of implementation actions which can lead to new knowledge;
- *adjust*: revising targets or planning actions where needed to better meet objectives;[73]
- *incorporate:* incorporating results into future management decisions.

APPLICATION 15

***Key supporting concept:* Levels of biological organization; ecosystem-based management**

Given that humans are a powerful agent of change, make science-based decisons.

Biodiversity provides the natural capital needed to sustain human well-being, and is currently under profound stress from human use and human-driven climate change. It is clear that our efforts today to conserve biodiversity will help ensure its values are passed on to future generations, and that the need for action is urgent.

We need to start by examining the impacts of decisions at all scales – local, regional and global and develop integrated approaches. Decision-making for biodiversity should be neither top-down nor bottom-up – rather, considerations need to be mindful of impacts at multiple scales. The objectives provided provincially, strategically and tactically for biodiversity conservation should provide context to local decision-making. At the same time, learning from local decisions, including the application of innovative approaches, may result in modifying higher level objectives to be more congruent with effective biological conservation practices on-the-ground.

For example, on the east coast of Canada, cumulative local decisions to fish for Atlantic cod by targeting large individuals have led to a human-induced genetic evolutionary shift to small-sized cod. Indications are that it may be very difficult to recover the genetic diversity of cod populations following depletion.[74] Noting these trends locally and early by monitoring impacts could have informed higher level decisions to change fishing regulations and avert these long-term genetic impacts. This example illustrates how humans can be powerful agents of natural selection and how decision-making informed by science and sound monitoring can produce decisions that work for the good of biodiversity and of the long-term interest of communities that depend on its conservation.

A global concern is rapid climate change, that will have significant implications to biodiversity conservation. Our decisions or actions locally to reduce emissions in our household and in our community can, through cumulative actions of many individuals and many communities, help to reduce the rate of climate change. These local actions can augment needed regulatory and policy changes that are actively under consideration in B.C. and other jurisdictions. The existing and potential impacts of climate change illustrate more than any other current issue the relevance of the slogan “think globally, act locally”, but the same holds true for any other human activity with the potential either to diminish or enhance the value of biodiversity in our province.

Glossary

Adaptation: any feature of an organism that substantially improves its ability to survive and leave more offspring. Also, the process of a species' or a population's genetic variability changing due to natural selection in a manner that improves its viability.

Alien species: a species occurring in an area outside its historically known natural range as a result of intentional or accidental dispersal by humans (i.e., movement of individuals) or direct human activities that remove a natural barrier (e.g., creation of a fish ladder to allow fish to move past a waterfall). Also known as an *exotic* or *introduced* species.

Biota: the animal and plant life of a region.

Carbon sequestration: the processes that remove carbon from the atmosphere. Natural carbon sequestration processes include plant growth. A variety of means of artificially capturing and storing carbon, as well as enhancing natural sequestration processes, are being explored in an effort to mitigate global warming due to climate change. Many of these efforts are associated with the Kyoto Protocol to the United Nations Framework Convention on Climate Change, which is an amendment to the international treaty on climate change, where mandatory targets for the reduction of greenhouse gas emissions are assigned to signatory nations.

Climate variability: variations in the mean state and other statistics of climatic features on temporal and spatial scales beyond those of individual weather events. These often are due to internal processes within the climate system. Examples of cyclical forms of climate variability include El Nino Southern Oscillation (ENSO) and Pacific Decadal Variability (PDV). Climate change is a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended time period (typically decades or longer). Climate change may be due to natural forces including changes in solar radiation and volcanic eruptions, or persistent human-induced changes in atmospheric composition or in land use.

Community: an integrated group of living organisms inhabiting a given part of an ecosystem.

Conservation concern: globally or provincially critically imperilled (G1 or S1), imperilled (G2 or S2), or vulnerable (G3 or S3). Species of global conservation concern are ranked G1 to G3. Species of provincial conservation concern are ranked S1 to S3.

Ecological processes: actions or events that shape ecosystems such as disturbances, predation, competition, nutrient and element cycling such as carbon sequestration.

Ecosystem: is a dynamic complex of plant, animal and micro-organism communities and their abiotic environment, all interacting as a functional unit.

Endemic: found only in a specified geographic region.

Gene: the functional unit of heredity; the part of the DNA molecule that encodes a single enzyme or structural protein unit.

Gene flow: the transfer of genes from one population or locality to another.

Genetic variability: the variety and relative abundance of genes within a particular species, variety, or breed.

Habitat: the natural environment in which an organism normally lives.

Hybridization: crossing of individuals from genetically different strains, populations, or species.

Indicator species: a species whose status provides information on the overall condition of the ecosystem or of other species in that ecosystem.

Landscape: an expanse of territory with characteristics that set it apart from other areas (e.g., watersheds).

Matrix: the complex of natural, semi-natural and domesticated lands and waters in the landscape within which protected areas are embedded.

Organism: an individual plant or animal.

Patch: in landscape ecology, a particular unit with identifiable boundaries that differs from its surroundings in one or more ways.

Population: a group of individuals with common ancestry that are much more likely to mate with one another than with individuals from another such group.

Restoration: the return of an ecosystem or habitat to its original community structure, natural complement of species, and natural functions.

Selection: natural selection is the differential contribution of offspring to the next generation by various genetic types belonging to the same populations.

Species: in most living organisms, each species generally represent a complete, self-generating, unique ensemble of genetic variation, capable of interbreeding and producing fertile offspring.

Species diversity: a function of the distribution and abundance of species.

Species richness: the number of species within a specified area.

Stability: a function of several characteristics of community or ecosystem dynamics, including the degree of population fluctuations, the community's resistance to disturbances, the speed of recovery from disturbances, and the persistence of the community's composition through time.

Sustainable use: the management of human interactions with genes, species, and ecosystems so as to provide the maximum benefit to the present generation while maintaining their potential to meet the needs and aspirations of future generations.

Notes

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