A BIODIVERSITY PRIMER

FOR ONTARIO

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A BIODIVERSITY PRIMER

What is Biodiversity?

Biodiversity, or natural riches, is a new term that describes something very old.
-- Alfredo Ortega, Ph.D., NW Biological Research Centre, Mexico

Definitions of biodiversity are, well…diverse. Taken literally and simply, it's the variety of life. Taxonomists spend entire careers studying just that. Taken most broadly, it's *our collective life support system* (OBS, 2005). Getting from there to here is the story of this primer, and the rationale for preserving Ontario's, and the world's, biodiversity.

Ontario's Biodiversity Strategy (OBS) adopts the definition of biodiversity that is used in the *Canadian Biodiversity Strategy* and the *United Nations Convention on Biological Diversity:*

> *Biodiversity is 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 a part; this includes diversity within species, between species and of ecosystems.*

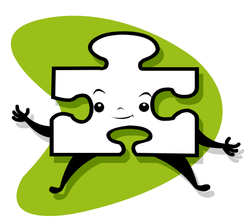
There are a couple of key points here. First, biodiversity is scalable. It exists at the level of genes within populations, populations within species, species within communities and ecosystems, ecosystems within landscapes, landscapes within bioregions, and so on. And there are important aspects to biodiversity at each of those levels. Second, biodiversity is a key element of ecology and ecosystems – without the connections it creates, things fall apart.

So the first challenge of biodiversity is just getting your head around what it means, and what its implications are. But before most people are willing to invest that kind of time, we need to briefly address the second challenge: "Who cares?"

Why care about biodiversity?

Good question. After all, it's all "out there" somewhere, and doesn't touch our daily lives…or does it?

***You* are a piece of biodiversity.** You're alive, aren't you? Then you're a piece of the puzzle – part of biodiversity. The same things that affect bugs, trees and fish can affect you too. Think *ozone depletion.*



by permission, Guy Gagne, artist

Everything's connected. What all that biodiversity does affects you…somehow. And what you do affects everything else. That can be a good thing! Just think – everything we do either uses natural resources or returns them as waste, and the amount of land and resources needed to do that, for a population or a person, is called an *ecological footprint*. We all can do things that make *our* personal footprints smaller.

by permission, Phil Testemale, artist

Natural systems created through biodiversity do things for you…for free! Things like air conditioning, flood control, plant pollination, pest control, soil aeration, and water filtration and storage. These things would cost a lot if we had to use technology to do them. They're called *ecosystem services.* Did you know that wetlands are worth more than CD$20,000/hectare/year, just sitting there doing their thing?

***You* have to live with what gets left behind.** They say that we don't inherit the earth from our parents, we borrow it from our children. If you're one of those kids, you just might want to know what you'll be getting back. If you're a parent or grandparent, what's your environmental legacy going to be? Either way, what you do now matters greatly to the future quality of life.

Biodiversity on the level.

Genetic diversity. It's what fuels evolution – the variability among individuals within a species, based on variations in genes, that natural selection can act on. That variability increases the chance that a species will adapt to changing environmental conditions or impacts, since some individuals will be able to handle that change much better than others. The more individuals you have, the greater the chance of variation, or the *deeper* the *gene pool*. And woe to those who end up in the shallow end – populations or species with a small number of individuals have limited variability and thus limited ability to respond to change, creating a downward spiral that's hard to pull out of. This is why species at risk can be so difficult to rehabilitate. And once you get below a certain number of individuals, based on reproductive potential, it is effectively impossible. Genetic variation is the cornerstone of all biodiversity.

Population diversity. While we often talk about species, what we generally see and interact with are populations – distinct groupings of species members that have a limited exchange of genetic information among the groups. While they can reproduce together, they don't often do so. As a result, the genetic differences across populations tend to increase, even though the variability within any population (because it's smaller) may be less than across the species as a whole. This allows species to fit like keys into local environments while offering a broad range of differences to any large-scale change. Also, because of the relative isolation, local impacts on one population may not be felt by another. A crude but conservative first approximation estimates about 220 populations per species (Hughes, et. al, 1997), which puts the total number of populations world-wide into at least the low billions.

Siscowet, or "fat" lake trout.

Normal, or "lean" lake trout. By permission, Gina Mikel, www.scientificillustrator.com.

Extreme population variability can, however, be a double-edged sword. For example, lake trout in Ontario's Great Lakes were once incredibly diverse. There were at least 15-20 different forms of lake trout recognized by commercial fishermen before sea lamprey invaded. These fish differed in where they were found, when they spawned, and in their appearance. They were given such names as blacks, redfins, yellowfins, paper bellies, fats, humpers and sand trout. Undoubtedly, the number of genetically distinct populations was much higher. However, even all this diversity could not stand up to over-harvest, sea lamprey predation and loss of habitat, particularly inshore rubble shoals required for spawning. Catches plunged to 10% of original yield in Lake Superior and basically nothing in the other Great Lakes. And when conditions were improved and it came time to try and reintroduce lake trout, results were disappointing in all but Superior, where enough wild populations survived to make a decent comeback. All those discrete

Researcher holds a 25-year-old wild lake trout from Stannard Rock, Central Lake Superior (United States Geological Survey).

lake trout stocks had evolved for a reason: reproductive success of lake trout in each area. The fish were in effect "tailor-made", but many of those stocks have disappeared forever. It will take much time and effort to find and test stocks which may or may not be reasonable replacements.

Species diversity. Basically, all the different types of living things found in a certain habitat, ecosystem or area. World-wide, we've identified more than 1.4 million species (Wilson, 1992), but estimates vary radically, from 5 to 30 million as conservative, and up to 100 million on the outside. 14 million appears to be an estimate that shows up commonly in the literature (Global Biodiversity Assessment, 2001 Summary). Over 30,000 species have been identified in Ontario (Sutherland, 2006), including:

- more than 1000 fungi
- more than 4,800 plants
- over 20,000 invertebrates (insects, spiders, etc.)
- More than 700 vertebrates
    - more than 160 fish
    - about 60 reptiles and amphibians
    - more than 470 birds
    - more than 80 mammals

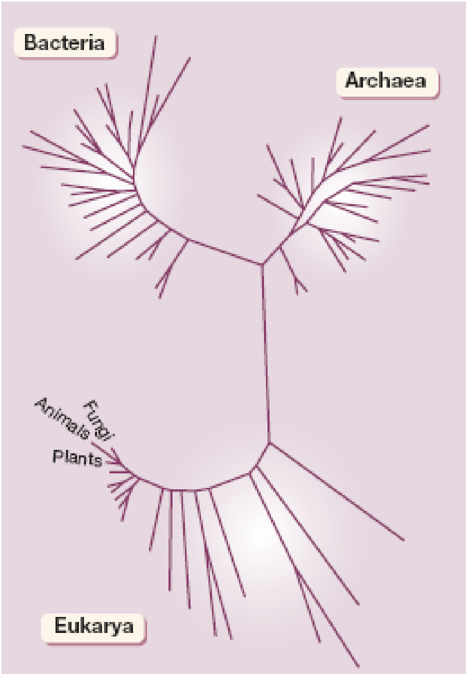
This compares to the following global breakdown (KY Afield, 1997; CFM, 1997):

- 35,000 micro-organisms
- 70,000 fungi
- 273,000 plants
- 875,000 invertebrates (insects, spiders, etc.)
- 42,000 vertebrates
    - 19,000 fish
    - 10,500 reptiles and amphibians
    - 9,000 birds
    - 4,000 mammals
- 105,000 other animals

These lists hugely under represent microorganisms, which are poorly known and poorly studied in most parts of the world. This known lack of understanding contributes greatly to the wide variation in total species estimates.

"On the tree of life…visible life consists of barely noticeable twigs. This should not be surprising — invisible life had at least three billion years to diversify and explore evolutionary space before the 'visibles' arrived. – Sean Nee

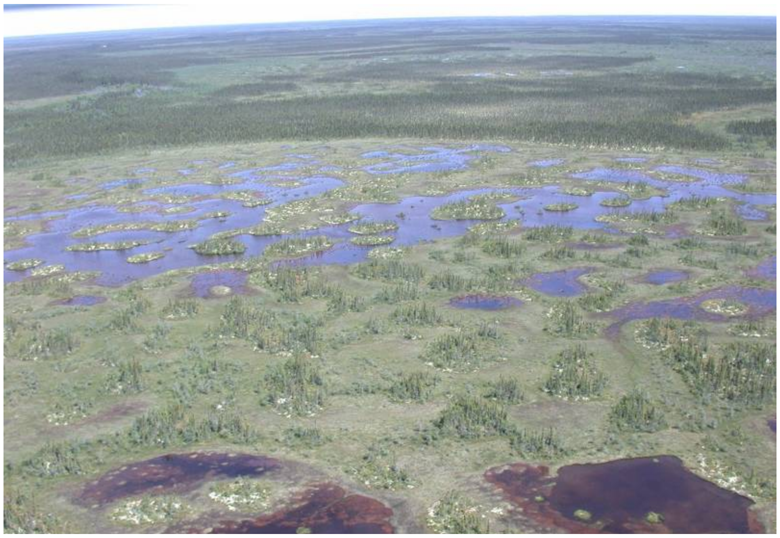
At right, line length represents the degree of divergence in RNA, an important indicator of biodiversity, among bacteria, archaea (bacterial relatives found first in extreme environments) and eukarya (cellular organisms including plants and animals) (Nee, 2004; also diagram).



Species diversity, however, is more than just the number of species in a given area, habitat or ecosystem (richness). Obviously, biodiversity differs between an area that contains 99% of one species and 1% of 99 others, and one that contains 1% each of 100 species (evenness) (Purvis & Hector, 2000). Whether you're looking at the number of individuals or biomass will also make a big difference. And some species' importance can be out of line with either numbers or biomass, for example *keystone species*. There can also be great differences in species composition or biomass over time. The point is, biodiversity, even species diversity, cannot be reduced to a single number. There are dimensions to diversity. Many of them.

Species diversity can also be greatly affected by physical variability in the ecosystems where they live. Differences in temperature, light, substrate, structure and chemical composition combine to create slightly to greatly different physical niches in a heterogeneous landscape. Each species of a diverse mix performs better in a particular niche, and the system becomes more productive as more and more niches are filled (Tilman, 2000).

Ecosystem diversity is the variety of ecosystems within a landscape or region, and the basic principles of biodiversity apply here as well, only the scope of impact and response is much larger. It is at this level that the interactions and links among species, and the consequences of those links become evident.



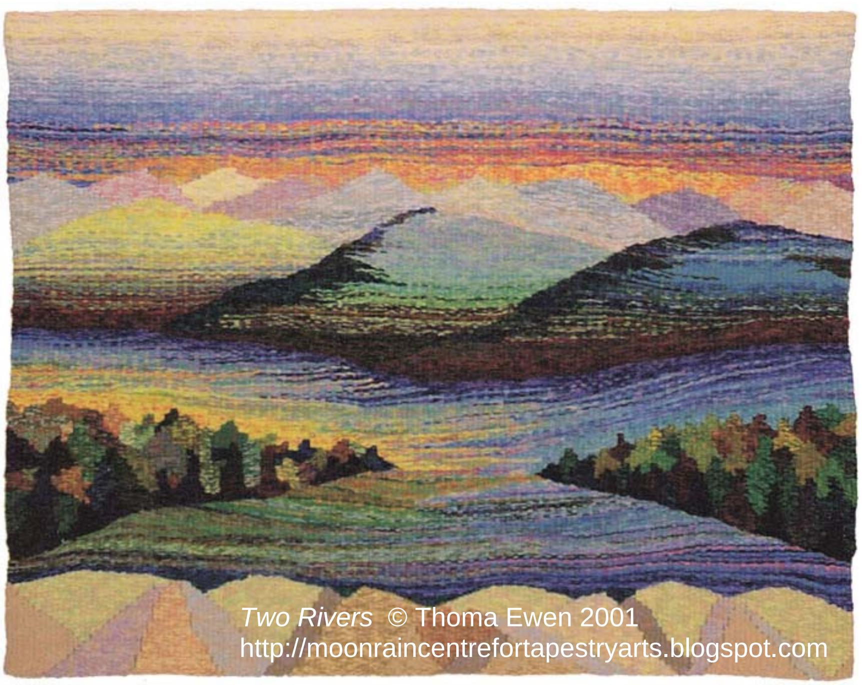
Ecosystem Diversity within the Hudson Bay Lowlands. Photo by permission, OMNR.

Also, less diverse and productive ecosystems, such as coldwater streams or small lake trout lakes, fit within and contribute to the functioning and productivity of larger areas such as their bioregions. Everything has its place.

The importance of being connected.

Connections. Everyone has them. Being "well-connected" means a lot in our society. It means everything in nature. Think *Web of Life* – trite but true. All those species and populations, in isolation, accomplish little. It's only when they link up that things begin to happen, systems begin to work, things get done. And generally (as we shall see), the more biodiverse things are, the more links there are, the better things function (Tilman, 2000).

Consider a woven hanging or rug that uses many colours and strands to create a picture. If each colour represents a species and each strand an individual, then the picture can represent the functions created by the interactions of species and individuals. Landscape patterns viewed from a distance look similar, a natural analog. When new, the rug can be stretched and pulled (within limits) and it will spring back into "shape", as will a diverse natural system. However, if it gets worn and torn with use, losing strands here and there, perhaps whole colours, not only do the images (functions) begin to go, but stretching to the same degree may now break more strands, and the rug/system won't return to its previous shape.



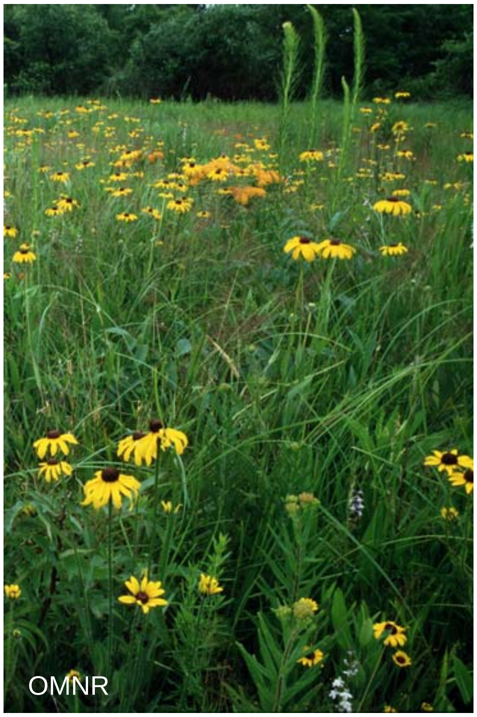
Two Rivers © Thoma Ewen 2001
http://moonraincentrefortapestryarts.blogspot.com

I know what you're thinking – this sounds like intuitive science, right? It *looks* like it should work that way, but does it? What do we actually know? First, biodiversity is in some ways very new science, although it's supported by years of study in related fields (ecology, genetics). The term wasn't coined until 1986. *Biological diversity* precedes it by only 6 years (Wikipedia: biodiversity), and it has been "a principal focus of scientific inquiry" for less than 15 years (Tilman, 2000). So sure, there are still lots of uncertainties, and the complex, interactive, chaotic nature of the subject makes it hard to study, but some generalities are emerging from a rapidly developing body of scientific literature:

- greater biodiversity leads to greater productivity in plant communities;
- greater biodiversity reduces the relative size of productivity fluctuations brought on by seasonal change;
- greater biodiversity leads to greater nutrient retention in ecosystems;
- greater biodiversity leads to greater ecosystem stability (i.e. returns quickly to an equilibrium; often expressed as total biomass);
- ecosystem processes are less stable or reliable at lower diversity levels;
- greater biodiversity leads to greater resistance to invasion;
- greater biodiversity leads to greater resistance to disease.
- removal or addition of any species can lead to pronounced changes in community composition and structure. (Tilman, 2000; McCann, 2000)

So biodiversity is often a reasonable measure of ecosystem function, and is integral to it.

One way to visualize the stability of diverse systems is to picture (or actually view) a diverse meadow and a manicured lawn containing nothing but one variety of grass. Imagine the relative impact of removing one important species from each system.



Nature, in most cases, also seems to abhor monocultures. Consider the time, effort and money it takes to maintain the lawn on the right versus the natural meadow on the left.

The importance of ecosystem functions.

At least 40 per cent of the world's economy and 80 per cent of the needs of the poor are derived from biological resources. -- The Convention About Life on Earth (UN Convention on Biodiversity)

Again, it seems intuitive that ecosystem functions are a good thing. They keep our air and water clean, help regulate our climate, and provide us with sources of food, shelter, clothing and medicine. They do these things for us, and for all life, basically for the cost of leaving them alone. Sometimes, that means that they're free. More often, to keep them we have to forgo competing uses of that ecosystem, be it resource extraction, waste deposition or development of one sort or another (residential, recreational, transport, industrial). If we don't know the cost of losing ecosystem services, it's hard to determine the impact of such a loss compared to the benefits of competing uses, which are almost always known.

To deal with this conundrum, we now have two concepts: *ecosystem goods and services* (most often shortened to ecosystem services), and *natural capital.* Ecosystem services, according to the OBS, are *services that humans derive from ecological functions such as photosynthesis, oxygen production, water purification and so on. Natural capital,* then, is the ecosystem that produces the goods and services.

The table below (Costanza, et al., 1997) provides a listing of such services and functions. A more detailed list can be found in Appendix A.

Ecosystem Service	Ecosystem Functions	Examples
Gas regulation	Regulation of atmospheric chemical composition	CO_2/O_2 balance, O_3 for UVB protection, SO_x levels.
Climate regulation	Regulation of global temperature, precipitation and other climatic processes	Greenhouse gas regulation.
Disturbance regulation	Storage, damping and other responses to environmental fluctuations	Storm protection, flood control, drought recovery and other habitat responses, mainly controlled by vegetation structure and landforms.
Water regulation	Regulation of hydrological flows.	Water for agriculture, industry, transportation or power generation.
Water supply	Storage and retention of water	Storage of water in watersheds, reservoirs and aquifers.

Erosion control and sediment retention	Retention of soil within an ecosystem.	Prevention of soil loss by wind, runoff or other processes, storage of silt in lakes and wetlands.
Soil formation	Soil formation processes.	Weathering of rock and the accumulation of organic material.
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients.	Nitrogen Fixation, N, P and other elemental or nutrient cycles.
Waste treatment	Recovery of nutrients and removal or breakdown of excess nutrients and compounds.	Waste treatment, pollution control, detoxification.
Pollination	Fertilization of flowers.	Providing pollinators for the reproduction of plant populations.
Biological control	Population regulation.	Predator control; reduction of herbivory.
Refugia	Habitat for resident and transient populations.	Nurseries, migration habitat, over wintering grounds.
Food production	Production useable as food.	Fish, game, crops, nuts and fruits.
Raw materials	Production useable as raw materials.	Lumber, fuel, fodder.
Genetic resources	Sources of unique biological materials and products.	Medicine, products for materials science, resistant genes/strains, ornamental species.
Recreation	Opportunities for recreational activities.	Eco-tourism, sport fishing, hunting, hiking, camping.
Cultural	Non-commercial uses.	Aesthetic, artistic, educational, spiritual, scientific.

The average value of all these goods and services, estimated world-wide, is US$33 trillion per year. To put that into perspective, the global GNP, a measure of the productivity of all the world's economic systems, is around US$18 trillion per year (Costanza, et al., 1997). Some of the values are determined directly, e.g. sport fishing; others are determined by what it would cost to artificially replace the natural service, e.g. water storage and flood control. For example, when New York City's water fell below standards, the estimated cost to install a filtration plant was $6-8 billion, with annual operating costs of $300 million. Not surprisingly, the city opted to restore the natural capital in its watershed at a cost of "only" $660 million (ESA, 2000).

Freshwater wetlands, considered by some as "wastelands", are actually the second most valuable world ecosystem (behind coastal estuaries), with a value of well over CD$20,000/ha/year (Costanza, et al., 1997).

Over 100,000 different animal species provide free pollination services. One third of human food comes from plants pollinated by wild pollinators. The value *of pollination services from wild pollinators in the U.S. alone is estimated at four to six billion dollars per year.* – Ecological Society of America

The net benefits of protecting natural areas, or converting tilled lands to natural areas in the Grand River watershed here in Ontario are estimated on average to be almost $200.00/hectare/year. Estimates range up to $342.76/hectare/year, which exceeds the highest rental rates of $247.10/hectare/year for agricultural land (Olewiler, 2004).

Threats to biodiversity, or beware the HIPPO (or HIPPOC)

To keep every cog and wheel is the first precaution of intelligent tinkering. – Aldo Leopold

In part because the value of biodiversity and the resulting ecosystem services are poorly understood by a lot of people, nature's "cogs and wheels" are going missing at an alarming rate – on the order of 100 to 1000 times the background rate, estimated from fossil records to be from one to ten species/year (Pimm, et al., 1995 and others). Some estimates of current rates are much higher. There have been five mass extinctions in the past 500 million years, the most recent about 65 million years ago (Raup and Sepkoski, 1982). We appear to be in the sixth, with the major difference being that for this one, the cause appears to be not a major physical catastrophe such as severe volcanism or a meteor strike, but a single species: us. The Millennium Ecosystem Assessment (2005) reports that there has been a substantial and largely irreversible loss in the earth's biodiversity, with some 10-30% of mammal, bird and amphibian species currently threatened with extinction, and 15 of 24 ecosystem services being degraded. Fortunately, it comes at a time when the earth probably contains more species than ever before (Rhode and Muller, 2005), and there's some redundancy built into the system. We can lose some species – some – before things start to really unravel.

The loss of biological diversity is second only to nuclear warfare in its threat to human and other life on this planet. – U.S. Environmental Protection Agency

The causes of these losses are many and varied, and can be encompassed in the term HIPPO:

Habitat loss. Habitat loss, alteration and fragmentation directly affect the species that rely on the habitat that is being changed. Habitat loss is particularly serious in southern Ontario where urbanization, agriculture and road density are greatest.

Within southern Ontario, some of the province's rarest habitats are also found (e.g., alvars and tall grass prairies). In the north, resource extraction (i.e. forestry and mining), hydro-electric power development and associated roads and bridges can impact biodiversity through habitat changes, fragmentation and/or degradation of local water bodies. In addition, recreational activities (e.g., overuse of campsites, use of all-terrain vehicles, boating and rock-climbing) can destroy local vegetation, pollute waterways and/or disturb wildlife (OBS, 2005).

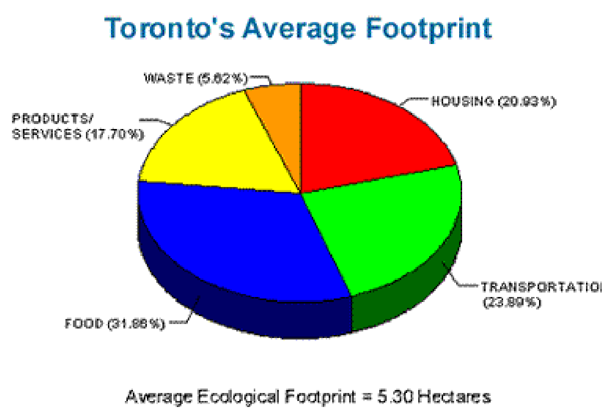
Invasive species. Invasive species are harmful non-native species whose introduction or spread threatens the environment, the economy and/or society, including human health. Invasive species originate from other continents, adjacent countries or from other ecosystems within Canada. Free from predation and competition that would normally limit their distribution and abundance in their natural habitats, many of these invasive species reproduce prolifically, infest and damage, displace or destroy native species an/or ecosystems (e.g., emerald ash borer), agricultural crops (e.g., plum pox virus), wetlands (e.g., purple loosestrife) and lakes and rivers (e.g., zebra mussel), inflicting significant ecological and economic damage. The zebra mussel, for example, disrupts ecosystem composition and structure, clogs water intake pipes, and affects public beaches (by cutting bathers' feet). It is but one of 160 invasive species that have been introduced into the Great Lakes (e.g., through ballast water release) (OBS, 2005).

Some impacts are very subtle. Garlic mustard, an insignificant-looking weed, can slow the growth of sugar maples and other hardwood trees by as much as 90% by releasing chemicals that kill off a soil fungus that the trees need to grow (CBC, 2006).


Sannse, Wikipedia

Pollution. Pollution is emitted in many different forms, including atmospheric pollution (e.g., sulphur and nitrogen oxides), soil and water pollution (e.g., nitrates and phosphates), pesticides, particulate matter, and heavy metals. There are thousands of pollutants circulating through the Earth's ecosystems, and many of these materials have significant, large-scale impacts, such as acid rain on boreal and deciduous forests and associated aquatic ecosystems. Pollution can also disrupt ecological processes. At the individual and population level, manufactured chemicals and pollutants contribute to a variety of health issues in people and wildlife, including cancer, birth defects, behavioural changes and chronic illness. Synthetic chemicals that block, mimic or interfere with natural hormone production have been blamed for causing abnormalities in reproduction, growth and development, particularly in fish, amphibians and aquatic invertebrates. Some chemicals deplete the ozone layer, which allows increased ultraviolet (UV) radiation to reach the Earth. For example, UV rays, higher now than even 10 or 20 years ago, can be especially damaging on ecosystems in the early spring when vegetation is young and fish and frogs lay their eggs in shallow water. Human health (e.g., skin cancer) and some food crops are also vulnerable to the effects of a depleted ozone layer. There is also a growing concern about excessive light at night and its impacts on biodiversity (e.g., migrating birds, amphibians and plant dormancy) (OBS, 2005).

Population growth. Human population growth escalates all the other causes because more people require more space and more resources. There are now about 6 billion people on Earth, more than twice as many as in 1950. While the rate of increase is slowing, it still adds more than 90 million people each year, and won't level out (barring significant calamities or pandemics) until there are between 8 and 11 billion (AZA, 2006). The problem here is *carrying capacity.* Habitats, even healthy ones, can support just so many of anything, including people, indefinitely. Beyond that level, things degrade for all the reasons that you see here. Yet some planners project a population increase of 3.7 million people in the Golden Horseshoe by 2031 without really coming to grips with whether the landscape can support it (Anon., 2005). How many is too many?



Well, that depends on the resource demand that is put on the Earth, and that varies radically from the developed to the developing world (by a factor of up to 20 times) (RP, 2006). One way of looking at demand is the *ecological footprint,* or how much land is required to support one person at varying levels of resource demand and waste production. Using this concept, created by Bill Rees, a professor at UBC, you can determine that the footprint of an average Canadian is 6.5 -7.7 ha, and the average Torontonian 5.3 ha (according to survey results) (City of Toronto, 2006). This represents an area more than 200 times as big as the actual city, and as much productive land as is found in Belgium or Denmark. In comparison, the world average is 2.8 ha. Most telling, the available productive land and sea for each person on the earth are 2.1 ha, and less if we set aside land for biodiversity preservation. So we're already exceeding global carrying capacity, even with current economic inequities. In Canada we're lucky to have 9.6 ha/person in available capacity, which buffers us from some of the problems occurring in other areas (RP, 2006).

Over-consumption. Over-consumption, or unsustainable use, is the harvest of individuals at a rate higher than can be sustained by the natural reproductive capacity of the population being harvested. In Ontario, for example, wild American Ginseng has been over-harvested from its natural rich woodland habitat to the point of being endangered. In addition, unsustainable use can impact the genetic integrity of a species through improper harvesting, and in other instances jeopardize a species' ability to maintain its traditional role(s) in ecosystem composition, structure and function. Unregulated, unsustainable and/or illegal harvest of some species remains a concern. Regulation of resource harvest through education and effective enforcement, along with a commitment to conservation among fishing, hunting and trapping communities, has contributed to the sustainable harvest of many game and commercial fisheries and game wildlife species (OBS, 2005).

Cumulative impacts and Climate Change (the "C" in HIPPOC). The OBS adds an additional letter. The cumulative impacts of pollution, habitat modification, the unprecedented (intentional and accidental) global redistribution of species and over-harvesting place many ecosystems at risk. These cumulative impacts affect ecosystems in different ways, at different times and at different scales. They cause alteration, reduction and/or loss of ecosystem function, populations and species, degradation, loss and fragmentation of habitat. They also damage human health – in inner cities, for example, asthma is the leading cause of hospitalization of children.

Climate change represents yet another huge threat to biodiversity, further adding to the cumulative effects of unsustainable behaviour. For example, people have added carbon dioxide, nitrous oxide, methane and other greenhouse gases to the atmosphere by extracting and burning fossil fuels such as coal, oil and natural gas. In addition, the drainage of wetlands and the conversion of forests and grasslands to other uses such as urban development also have contributed to the increase in greenhouse gases as carbon stored in these ecosystems is released by decomposition. Atmospheric carbon dioxide has increased 30 per cent since pre-industrial times, and these additional greenhouse gas molecules have trapped heat and accelerated the rate of global warming and climate change.

Biodiversity is involved in three major ways:

- It is directly impacted by climate change. In Ontario, certain populations of Caribou and Polar Bears, among others, are declining in number and health due largely to climate change. Sadly, many species with poor dispersal capabilities, as well as many habitat specialists, will simply not survive its effects.
- Healthy, biodiverse systems help to reduce carbon emissions and blunt the effects of climate change. Healthy wetlands, for example, continue

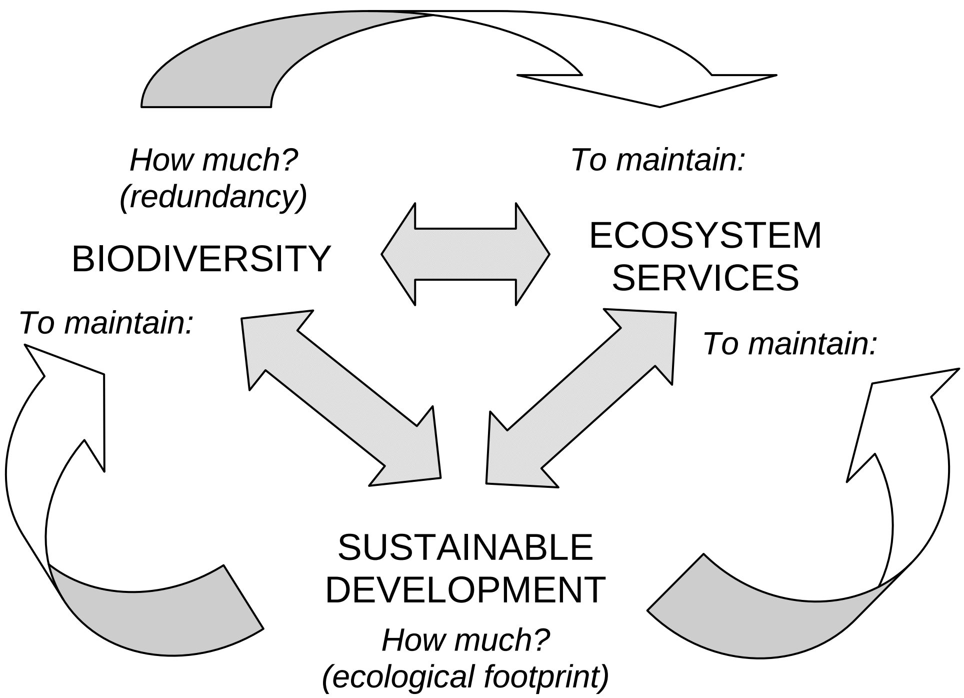
to absorb more carbon than they release, storing it in slowly-decaying bottom muck or peat, while forests condition the air, reducing the Indeed, large-scale ecosystems, such as the boreal forest, play key roles in regulating the earth's climate. average temperature of their interiors through the evaporative process of transpiration.

- When adapting to climate change, we will need to consider the needs of all living things and the systems they create. Many species may need to migrate, so we need to think about natural migration corridors, preserves for them to migrate to, and additional assistance, if necessary, in getting them there.

Scientists, and now some of the world’s leading industrialized nations, are calling for strong and immediate action to limit global temperature increases to 2^0C over the pre-industrial average. Impacts to biodiversity and other social, political and economic systems will be significant even below this level, but going above it may be catastrophic. Since an increase of about 0.8^0C has already occurred, that leaves a buffer of only 1.2^0C. This challenge in part requires institutional responses at all levels, but it is also up to us as individuals. And the good thing is that climate change and biodiversity are so intimately connected that almost anything you do to positively affect one affects the other as well -- a two-for-one deal! Please see below for ways in which you can help (UNEP, 2008).

Countering the threats to biodiversity

The global, institutional response to HIPPOC has been the framing and promotion of *sustainable development,* defined by the OBS as *development that meets the needs of the present without compromising the ability of future generations to meet their own needs.* But what does that mean, in a practical sense? How do we measure "lack of compromise"? One way is to link biodiversity to sustainable development through the concept of *sustainable use: the use of components of biodiversity in a way and at a rate that does not lead to their long-term decline, thereby maintaining the potential for future generations to meet their needs and aspirations* (OBS, 2005). And the connection between biodiversity and the needs of future generations goes through natural capital and its ecosystem services. We don't want to lose species because it will eventually degrade our natural capital, and any reduction in ecosystem services, apart from being *unsustainable*, is a sure sign that biodiversity is eroding. These relationships are represented here:



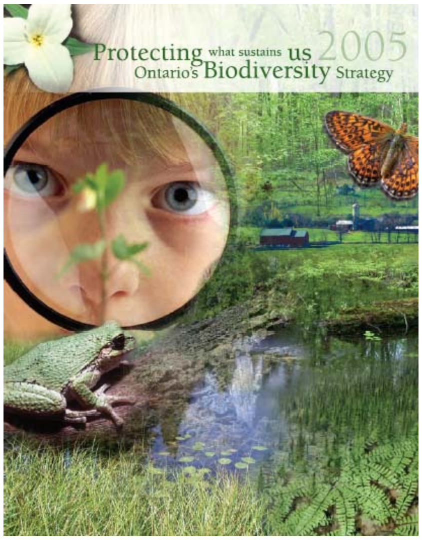
The key is *redundancy.* The loss of a single species is not "the end of the world as we know it," but cumulatively it may be. Many experimental studies have found that only 20-50% of species are needed to maintain most ecosystem processes and services (Purvis and Hector, 2000). However, they do function and respond to impacts such as invasion better when there are more species. Are the other species also "insurance" against environmental change, particularly since major changes due to climate may be in the works? So how many are enough? We just don't know. The precautionary principle states, when in doubt do *no* harm. In this case, stopping all species loss where possible is probably the best rule of thumb.

Putting the brakes on habits that generate up to 100 species lost/day around the world is a big task. Slaying the HIPPO will take decades if not generations. But it won't happen at all if we all don't start doing a better job of conserving biodiversity at all levels.

Ontario's Biodiversity Strategy: "Protecting What Sustains Us"

This strategy was developed with the help and input of many Ontario individuals and organizations in the hope of reversing the trend towards the loss of biodiversity in Ontario. It correlates with the *Canadian Biodiversity* Strategy and the UN *Convention on Biological Diversity.* It briefly looks at Ontario's biodiversity, where the province needs to be in relation to biodiversity, and current threats and opportunities before describing 37 action items designed to be carried out in a coordinated effort by all Ontarians. These actions are grouped under the following strategic directions, as described in the OBS:

Engage Ontarians – Our success will depend on the values that guide how Ontarians behave. We must build a broad public understanding of and a commitment to biodiversity, and develop a variety of ways in which people can participate in maintaining our natural heritage as a legacy for future generations.



Promote Stewardship – Private landowners, farmers and non-farmers alike, have a key role to play in the stewardship of the biological resources of this province, particularly in southern Ontario. Private resource-based companies operating on Crown land in northern Ontario also have a key role in the sustainable use and conservation of biodiversity.

Work Together – No one agency or organization retains the scientific expertise, the legal authority, or the financial resources to care for all of Ontario's biodiversity. Partnership is an important tool in the protection and sustainable use of biological assets. This strategic direction overlaps all the others. If this strategy is to be successfully implemented, a broad coalition including private landowners, academic institutions, non-government organizations (NGOs), industrial sectors, urban and rural communities, Aboriginal communities, all levels of government and individual Ontarians must work together.

Integrate Biodiversity Conservation into Land Use Planning – We need to plan growth carefully in southern Ontario. There is an urgent need to recognize in our planning rules and processes the importance of green spaces and conserving biodiversity.

Prevention – Reducing threats now will be more effective and less expensive than trying to recover what we have lost. There are many threats to biodiversity and action must be taken on a number of fronts. Where there is a threatened imminent loss of biodiversity, we should act, even if our knowledge is not complete. An area can be considered for development at a later date; however once an area has been developed, future options to protect the area's biodiversity may be limited or eliminated.

Improve Understanding – We must make use of expanding scientific knowledge and new mapping and other technologies that make information analysis and sharing faster and more effective. But knowledge is not always about the "new". Traditional knowledge from Aboriginal cultures and rural communities should be valued and integrated into decision-making.

The full text and more information on the OBS can be found at http://www.mnr.gov.on.ca/en/Business/Biodiversity/2ColumnSubPage/STEL02_166816.html.

What can individuals do?

We need informed action by all Ontarians to halt biodiversity loss. There are things we all can do to help:

<u>Learn more</u>. Knowledge is power. The more we know about the causes, consequences and (most particularly) mitigation of biodiversity loss, the more power we will have if we choose to act, and the more efficient and focused those actions will be. This primer's a start, as is the OBS. The sources and citations provided here should get us going as well. Some particularly good we blinks are provided under *Resources.*

<u>Tell others</u>. As we learn more about biodiversity, we need to let others know as well that biodiversity conservation is a cause worth pursuing. We can discuss it among groups we belong to, even if (and perhaps particularly if) they are not environmentally oriented – sustainability transcends such borders. We can write letters or emails to editors and others of influence.

<u>Help monitor Ontario's biodiversity</u>. *Citizen Science*, the monitoring and assessment of species and ecosystems by individuals and groups using standard protocols (for example, FrogWatch), is growing across the province. It's a good way to involve people who already have an interest and perhaps knowledge related to some aspect of nature. Learn more and make a difference! A great

place to start is
http://dev.stewardshipcanada.ca/communities/citizenScience/home/csnIndex.asp

Reduce our Ecological Footprints. We all do things every day which directly, or more often indirectly, affect biodiversity by putting pressure on our natural systems. Reduce or mitigate such pressure by, for example:

- Being aware of *Species at Risk* and not doing anything to reduce their populations or habitat. See http://www.mnr.gov.on.ca/en/Business/Species/index.html.
- Being knowledgeable of *Invasive Species*, and acting to limit their spread. See http://www.invadingspecies.com/.
- Avoiding use of low-lying rural roads during and immediately after a rainstorm – frogs may be on the move.
- Creating habitat for wild things on their property – planting butterfly or wildflower gardens with native plants and trees, maintaining brush piles, letting, if possible, some grass grow uncut, participating in a local habitat restoration project.
- The LandOwner Resource Centre Website has free pdf downloadable extension notes for landowners covering a variety of topics: http://www.lrconline.com/Extension_Notes_English/index.html
- More specific, wildlife-related tips, including reduction of international trade in endangered species can be found at http://www.biodiversity911.org/wildlife_trade/pdfs/trade_actions.pdf.
- Avoiding pesticides, herbicides and chemical fertilizers.
- Buying locally grown food whenever possible.
- Reducing energy use in homes and vehicles.
- World Wildlife Fund has an excellent compendium of actions related to wildlife trade, landscaping and soils, forests, fisheries, toxics and climate change at http://www.biodiversity911.org/TakingAction/TakingAction.html.

Contribute to the OBS Actions. Work is ongoing on many of the Action Items. If you belong to organizations that might or should be involved, contact that group and offer to help if they are, or encourage involvement if they're not. The following organizations are currently represented on the OBS Council, which leads and coordinates the implementation of the OBS:

Ag Care
Building Industry & Land Development Association
Bird Studies Canada
Canadian Environmental Law Association
Chiefs of Ontario
Conservation Ontario
Ducks Unlimited
Environmental Defence Canada
Federation of Ontario Cottagers' Associations
Nature Conservancy Canada
Ontario Nature
Ontario Forest Industries Ass'n
Ontario Forestry Association
Ontario Federation of Anglers and Hunters
Ontario Federation of Agriculture
Ontario Mining Association

Ontario Ministry of Natural Resources
Ontario Power Generation
Ontario Stone, Sand & Gravel Assoc.
Union of Ontario Indians
Wildlife Habitat Canada

Influence politicians. Let politicians at all levels know that biodiversity conservation and resource sustainability are critical issues that the government needs to do more about.

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ANNOTATED RESOURCES

Aurora Online with William Rees. Athabasca University. http://www.urban-renaissance.org/urbanren/BillRees.pdf Development and background of the ecological footprint concept; additional links.

Biodiversity and Climate Change. United Nations Environment Programme. www.cbd.int/doc/bioday/2007/ibd-2007-booklet-01-en.pdf A good, general introduction to the topic from a global perspective.

Biodiversity and Conservation. Chicago Field Museum. http://www.fieldmuseum.org/biodiversity/ Introduction to the basics of biodiversity.

Canadian Biodiversity Information Network. Environment Canada. http://www.cbin.ec.gc.ca/index.cfm?lang=e Clearing house node with links to Canadian Biodiversity Strategy and international /UN documentation.

The Canadian Biodiversity Website. Redpath Museum, McGill University. http://www.canadianbiodiversity.mcgill.ca/english/index.htm An excellent, well-written, Canadian-based introduction to biodiversity, including theory, ecozones, species and issues. One of the best sites to start with.

Ecological Footprint Quiz. Earth Day Network. http://www.myfootprint.org/ Calculate your own footprint.

Ecological Footprints of Nations. 2005 update. Redefining Progress. http://www.rprogress.org/publications/2006/Footprint%20of%20Nations%202005.pdf A good introduction to the concept of ecological footprints and how it is applied to assessing levels of impact. Contains an excellent table comparing footprints by nation.

Insight. Nature, 405: 208-241. Four review articles that summarize the state of biodiversity science as of 2000 (three cited in this primer). Well sourced and dense in places, but can be tackled by the lay reader.

Millennium Ecosystem Assessment. United Nations. http://www.millenniumassessment.org/en/Article.aspx?id=58 Landmark study conducted by 1,300 experts from 95 countries. Very extensive. Key findings are in this article. Basic finding: "the ongoing degradation of ecosystem services is a road block to the Millennium Development Goals agreed to by the world leaders at the United Nations in 2000." See also http://www.greenfacts.org/biodiversity/index.htm for a user-friendly approach to the MEA by GreenFacts, in particular climate change and ecosystems: http://www.greenfacts.org/studies/climate_change/l_3/climate_change_9.htm#0.

Smithsonian Online Resources, including *Biodiversity in the Classroom.* Smithsonian National Zoological Park. http://nationalzoo.si.edu/Education/OnlineResources/default.cfm Programs, fact sheets and web cams focusing on biodiversity and the variety of species in their collection.

The Known and Potential Effects of Climate Change on Biodiversity in Ontario's Terrestrial Ecosystems. Case studies and recommendations for adaptation. Ontario Ministry of Natural Resources. Climate Change Research Report CCRR-09. 47 pp. http://www.mnr.gov.on.ca/196749.pdf A fairly detailed assessment of climate change impacts on Ontario's terrestrial biodiversity, including case studies of the Deer Tick, Moose, Eastern Bluebird, Polar Bear, Red Squirrel and Black-capped Chickadee.

The Value of Natural Capital in Settled Areas of Canada. Ducks Unlimited and the Nature Conservancy of Canada. 36 pp. http://www.ducks.ca/aboutduc/news/archives/pdf/ncapital.pdf Four case studies (one from Ontario) that illustrate the concept of Natural Capital and its valuation methods, and conservatively estimate its economic value.

APPENDIX A: Ecosystem Services

Ecosystem Services are the benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain other services. Many of the services listed here are highly interlinked (primary production, photosynthesis, nutrient cycling, and water cycling, for example, all involve different aspects of the same biological processes).

Provisioning Services. These are the products obtained from ecosystems, including:

- *Food*. This includes the vast range of food products derived from plants, animals, and microbes.
- *Fibre*. Materials such as wood, jute, cotton, hemp, silk, and wool.
  Fuel. Wood, dung, and other biological materials serve as sources of energy.
- *Genetic resources*. This includes the genes and genetic information used for animal and plant breeding and *biotechnology*.
- *Biochemicals, natural medicines, and pharmaceuticals*. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.
- *Ornamental resources*. Animal and plant products, such as skins, shells and flowers are used as ornaments and whole plants are used for landscaping and ornaments.
- *Freshwater*. People obtain freshwater from ecosystems and thus the supply of freshwater can be considered a provisioning service. Freshwater in rivers is also a source of energy. Because water is required for other life to exist, however, it could also be considered a supporting service.

Regulating Services. These are the benefits obtained from the regulation of *ecosystem processes*, including:

- *Air quality regulation*. Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality;
- *Climate regulation*. Ecosystems influence climate both locally and globally. For example, at a local scale, changes in *land cover* can affect both temperature and precipitation. At the *global scale*, ecosystems play an important role in climate by either sequestering or emitting *greenhouse gases*.
- *Water regulation*. The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in *land cover*, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.

- *Erosion regulation*. Vegetative cover plays an important role in soil retention and the prevention of landslides.
- *Water purification and waste treatment*. Ecosystems can be a source of impurities (e.g., in fresh water) but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and assimilate and detoxify compounds through soil and sub-soil processes.
- *Disease regulation*. Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.
- *Pest regulation*. Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
- *Pollination*. Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- *Natural hazard regulation*. The presence of coastal ecosystems such as *mangroves* and coral reefs can reduce the damage caused by hurricanes or large waves.

Cultural Services. These are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

- *Cultural diversity*. The diversity of ecosystems is one factor influencing the diversity of cultures.
- *Spiritual and religious values*. Many religions attach spiritual and religious values to ecosystems or their components.
- *Knowledge systems (traditional and formal)*. Ecosystems influence the types of knowledge systems developed by different cultures.
- *Educational values*. Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.
- *Inspiration*. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- *Aesthetic values*. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations.
- *Social relations*. Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.
- *Sense of place*. Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.
- *Cultural heritage values*. Many societies place high value on the maintenance of either historically important *landscapes* ("cultural landscapes") or culturally significant species.

- *Recreation and ecotourism*. People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Supporting Services. Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, like erosion regulation, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people.)

- *Soil Formation*. Because many provisioning services depend on soil fertility, the rate of soil formation influences human *well-being* in many ways.
- *Photosynthesis*. Photosynthesis produces oxygen necessary for most living organisms.
- *Primary Production*. The assimilation or accumulation of energy and *nutrients* by organisms.
- *Nutrient cycling*. Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems.
- *Water cycling*. Water cycles through ecosystems and is essential for living organisms.

Source & © : Millennium Ecosystem Assessment Synthesis Report (2005), Chapter 2, p.40

Appendix B: Glossary

Note: All definitions (OBS, 2005) unless otherwise indicated.

alien species – plants, animals and micro-organisms that have been accidentally or deliberately introduced into areas beyond their normal range. Synonyms may include introduced, non-native and exotic.

biodiversity or biological diversity – the variability among living organisms from all sources including, *inter alia*, 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.

ecological footprint – the Ecological Footprint is a measure of the "load" imposed by a given population on nature. It represents the land area necessary to sustain current levels of resource consumption and waste discharged by that population (Wackernagel and Rees, 1996).

ecosystem – a dynamic complex of plants, animals and microorganisms and their non-living environment interacting as a functional unit. The term ecosystem can describe small scale units, such as a drop of water, as well as large scale units, such as the biosphere.

ecosystem services – services that humans derive from ecological functions such as photosynthesis, oxygen production, water purification and so on.

endangered species – species that are threatened with immediate extinction or extirpation if the factors threatening them continue to operate. Included are species whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction.

keystone species – a species that has a disproportionate effect on its environment relative to its abundance. Such an organism plays a role in its ecosystem that is analogous to the role of a keystone in an arch. While the keystone feels the least pressure of any of the stones in an arch, the arch still collapses without it. Similarly, an ecosystem may experience a dramatic shift if a keystone species is removed, even though that species was a small part of the ecosystem by measures of biomass or productivity. (Wikipedia, 2006)

natural capital – natural resources, environmental and ecosystem resources, and land that yield goods and services over time that are essential to the sustained health of our environment and the economy (Olewiler, 2004).

precautionary approach – in order to protect the environment, the precautionary approach shall be widely applied by States [i.e. jurisdictions] according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation (1992 UNEP *Rio Declaration on Environment and Development*).

Species at Risk – any wild plant or animal threatened by, or vulnerable to extirpation in Ontario or extinction. Species at Risk are assigned a designation (i.e. Special Concern, Threatened, Endangered or Extirpated) to represent the degree of imperilment. Note: Six species (i.e. Macoun's Shining Moss, Blackfin Cisco, Blue Pike, Deepwater Cisco, Passenger Pigeon, Eastern Elk), formerly found in Ontario, are extinct (i.e. no longer exist anywhere).

sustainable development – development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

sustainable use – the use of components of biodiversity in a way and at a rate that does not lead to their long-term decline thereby maintaining the potential for future generations to meet their needs and aspirations. Sustainable use in this strategy refers to consumptive uses of biological resources.