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Abstract:

We analyzed the existing set of Canadian protected areas for their ability to both represent the range of Canadian Ecoregions and ensure effective conservation of biodiversity. The analysis shows that Canada's protected areas do not adequately represent the range of Canadian Ecosystems and that Canadian protected areas are generally too small to make effective conservation cores. 83% of protected areas in Canada are less than 100 Km^2. A range of approaches to conservation has been proposed to resolve these issues, under the banner of moving from "islands to networks" of protected areas. The "islands to networks" idea appears in the scientific literature, in national policy documents and even in the program of work for protected areas under the Convention on Biological Diversity. Island to networks models have been expressed as 1) managing parks within a larger matrix of consumptive land uses that are complimentary to the conservation goals of the protected areas; 2) physical linkages between protected areas that allow movement of individuals and genes and 3) comprehensive conservation planning where conservation priorities are considered first in the planning process. We conclude that islands to networks approaches are inadequate for large parts of Canada, because the exiting protected areas network is composed of core units that are too small to be effective. Approaches to conservation using "islands to network" approaches will have to very different for each specific Ecoregion.

Introduction:

At the Parks for Tomorrow Conference in 1968, it was noted that ecological considerations were not part of the establishment of national parks in Canada; rather, the focus was on public enjoyment of parks (Cowan, 1968). There was call for an establishment of a well-planned system of national parks devoted to understanding and management of nature, incorporating ecological perspectives. Since the first Parks for Tomorrow Conference in 1968, there have been dramatic changes in the amount of lands dedicated to parks and protected areas. Globally, 12% of the earth's surface is nominally protected under one of the 6 management categories specified by the International Union for the Conservation of Nature. In Canada there are over 1 million hectares or 11% of the country lands nominally protected, a 3.5 fold increase. National Parks in Canada have expanded from the 19 present during the Parks for Tomorrow Conference to 42 National Parks. The picture is less compelling in the marine world, with Canada setting aside only

0.5% of its oceans as protected areas (32,783 Km^2 total area). Of this a large percentage is still open to commercial harvest.

Since 1968, there is has been a revolution in the science of ecology and the application of ecology to protected areas design and management. In 1967 MacAuthor and Wilson published their seminal book on island biogeography. The idea that the number of species on an island is a function of the size and isolation of the island has been transferred as a cornerstone of protected area thinking. In 1968, the term conservation biology was not yet in use. The body of theoretical and practical information that constituted conservation biology has developed exponentially since the 1980s. Now most protected area agencies employ conservation biologists.

The term biodiversity was also not in common use in 1968, but in 2008 protected areas are critical components to preserving biodiversity. Indeed the internationally accepted definition of protected areas speaks specifically to biodiversity conservation:

An area of land and/or sea especially dedicated to the protection and maintenance of <u>biological diversity</u>, and of natural and associated cultural resources, and managed through legal or other effective means. (IUCN)

The developing ecological sciences have been, and are being, applied to protected area design and management so that protected areas can play a role in biodiversity conservation. The title of this paper, "Island to Networks" speaks to a range of approaches that attempt to make protected areas more effective at conserving biodiversity. The paper examines the development of the protected area system in Canada and its potential ability to conserve Canada's biodiversity by itself, and in conjunction with a range of approaches that fall under the banner of "islands to networks".

Methods

For this paper we assembled the best available set of Canadian protected areas. Because there is no complete list of protected areas in Canada, we combined datasets from the Protected Areas of Canada, (CCAD, 2006) dataset and the NCAD (2000) point data set. The Protected Areas data set provides polygons of all protected areas in Canada that are 1000 hectares or more in size. The NCAD is a point data set of all protected areas in Canada, with attached attribute data including area. The NCAD set was converted to polygons by buffering the points to created circular polygons equal in area to the size of the protected areas in hectares. All geographic information systems analysis for this project was conducted using ESRI (1999-2006) ArcInfo software. The two datasets were joined together creating a data set of 3498 protected areas and any overlapping areas were queried and discrepancies resolved. Where they represented one protected area, the best available polygon was chosen to represent the protected area, usually from the CCAD data set.

To calculate the potential for network connections between protected areas, each protected boundary was buffered using distances of 5, 10 and 25 kilometres. For each of the buffered distances, polygons that overlapped were dissolved together to create new potential protected areas. The area of protected lands within these new potential areas was then calculated as a potential new effective protected area with a new combined area.

Road density was calculated from National Topographic Database, NTDB (2004) edition, specifically the "road" and "limited used roads" layers as defined by the NTDB. These two layers were joined together. The final analysis conducted was the calculation of the road density for Canada at the one kilometre level. The density calculation was conducted by first creating a one kilometre square hexagonal grid for Canada. The grid was creating using Jenness (2006) repeating shape extension for ArcInfo. We then calculated the length of roads within each of the one kilometre hexagon using Hawth's Tools (2002-2006).. The resulting densities were then calculating by converting these road lengths into kilometres and dividing by the size of the hexagons. Seven density classes were then established.

Biodiversity Conservation – Designing Protected Area Systems

There is global recognition that our planet is undergoing human-caused extinction crises, with estimates of the current extinction rates being 2-3 orders of magnitude higher than found in the fossil record (Cardinale et al., 2006). The international community, both through the global Convention on Biological Diversity and academic literature, suggest that protected areas will be the key places where remnants of the natural world, and it associated biodiversity, will be conserved (Terborgh, 1974). There appears to be academic agreement that well-designed and managed protected areas can preserve biodiversity as well as perform various other ecosystem functions that are beneficial to humankind (Langhammer et al., 2007; Bruner et al., 2001).

At the IVth World Parks Congress in 1992, the importance of establishing protected areas was reiterated in the recommendation to protect at least 10% of each global biome by 2000 (IUCN, 1993). The IVth World Parks Congress was followed by the development of a program of work on protected areas under the auspicious of the Convention on Biological Diversity. The Program was ratified at the 8th Conference of the Parties. It commits 88 countries, including Canada to a wide range of time bound targets for protected area establishment and management.

Despite the fact world has notionally 12% of its landmass in protected area systems; there is a range of problems with linking these protected areas to the conservation of biodiversity. First and foremost is the problem that a large percentage of these areas are not effectively managed, and in fact many are "paper parks", existing on official government documents but lacking any management controls. This paper does not deal in depth with the issue of paper parks, except to note that the global protected area estate is, in fact, effectively far lower than 12%. Second, protected areas were overwhelmingly established in areas that were not valuable for other human needs, especially agriculture or commercial forestry. Thus protected have most often been established in low productivity, high altitude or dry environments. Most countries protected area systems do not fully represent all biological regions, ecosystems, biodiversity hotspots, endemic species, values and ecological services (Barber et al., 2004). Clearly protected area systems have not been designed to maximize biodiversity protection.

The Representativity of the Canadian Protected Areas System

A comprehensive State of Protected Areas in Canada report was compiled by Environment Canada in 2005. We have updated the data base complied for that study in attempt to provide the most current database on protected areas in Canada. However the conclusions in the paper are entirely consistent with the 2005 Report. In Canada, 10% of the landmass is set aside in protected areas and 0.5% of its oceans in marine protected areas (CPSAR, 2006). The administration of the protected area lands is split evenly between the federal government (49.2% of lands in Canada's terrestrial protected areas and the provinces and territories (49.3%).

There has never been a comprehensive national strategy for ensuring Canadian protected area systems represent the full range of ecosystems in Canada. Within Canada, there are national and protected area systems, but the combined result of park establishment is that the adequacy of representative protection if highly variable. A table of the coverage is given below.

Table 1. The number and % Area of Protected Areas for each of the 15 Canadian Ecozones

Ecozone	Area (Km^2)	Number of Parks	Total Area of parks (Km^2)	% Protected
Arctic Cordillera	258400.00	8	68884	26.7
Atlantic Maritime	205900.00	376	18835	9.1
Boreal Cordillera	456700.00	56	71328	15.6
Boreal Plains	725400.00	466	67478	9.3
Boreal Shield	1881000.00	764	250576	13.3
Hudson Plains	368400.00	31	78057	21.2
Mixedwood Plains	117700.00	578	1849	1.6
Montane Cordillera	484200.00	412	81492	16.8
Northern Arctic	1550000.00	23	122957	7.9
Pacific Maritime	206500.00	245	27245	13.2
Prairies	464700.00	434	17340	3.7
Southern Arctic	831600.00	18	140064	16.8
Taiga Cordillera	260900.00	8	32678	12.5
Taiga Plains	639600.00	38	37036	5.8
Taiga Shield	1356000.00	41	84698	6.2

As can be seen from Table 1, the extent of protected areas in Canada varies considerably between different ecological regions of the country. Two thirds of the total area protected in Canada is located within a small number of large reserves and the extent of land protected varies dramatically by Ecozone. The Arctic Cordillera (26.7%), Hudson Plain (21.2%), and Montane Cordillera (16.8%) Ecozones are the top three in terms of percentage of protected area. These are areas of low productivity and relatively low biodiversity.

The areas of highest productivity and highest biodiversity value in Canada have some of the lowest coverage of protected areas. This well illustrated by the low coverage in the Prairies Ecozone (3.7%), the Mixedwood Plains Ecoregion of southern Ontario and Quebec (1.6%).

In looking at Ecoregion representation, the next level in the hierarchy of ecological classification, 40% of the 217 Ecoregions are unrepresented by protected areas (CPASR, 2006). So clearly there is inadequate representation of protected areas in Canada, whatever scale of analysis is used.

The ability of Canada's existing protected areas to protect endangered species has been examined by several authors (Kerr and Chilar, 2004; Warman et al 2004; Deguise and Kerr, 2006). In most of Canada's Ecozones, existing reserves include no more endangered species than what one would predict by chance (Deguise and Kerr 2006). The benefits of reserves in the most threatened regions of Canada are limited by their small size. Further, endangered species in Canada are concentrated in areas of high human use, which inhibits reserve establishment (Deguise and Kerr, 2006).

We did not do any independent analysis of the status of marine coverage for this paper. However the 2005 Status of Protected Areas in Canada shows Canada has set aside only 0.5% of its oceans in marine protected areas. The area and % is so low that we did not do any further analysis of coverage by marine Ecozone. Globally, Canada ranks 70th in the percentage of its oceans that are protected.

So from a representatively perspective, Canada has not been successful in representing the full range of its ecological diversity in protected areas. Further protected areas poorly represent some of Canada's most biologically diverse ecosystems.

Protected area size and biodiversity

In addition to representivity, the size and configuration of individual protected areas becomes the next critical consideration. With the application of island biogeography theory to the mainland, it was predicted that parks isolated by altered habitat would hold fewer species; and that smaller parks would hold fewer species than larger parks (Diamond, 1975). The application of biogeography theory to protected areas was explored by Newmark (1987), who found that out of 14 North American Park reserves, all except the very largest were too small to maintain the mammal assemblage that was there at park establishment. He attributed this species relaxation to habitat loss and active elimination of fauna on surrounding lands, which reduced the potential for colonization from surrounding areas and increased the probability of extinction due to low population size; essentially, the parks were functioning as islands. The application of island biogeography theory to mainland systems has received considerable debate (summarized in Doak and Mills, 1994), but remains a useful model for protected areas. For example, western North American parks have experienced extinction rates that are inversely related to park size (Newmark, 1995). Gurd et al. (2001) examined reserves within the Alleghenian-Illinoian mammal province of eastern North America, and empirically estimated the minimum area requirement of terrestrial mammals such that reserves should not lose species because of insularization. They then compared this estimate to the actual size of 2355 reserves and reserve assemblages within the mammal province. The estimated minimum area requirement to protect the complete mammal fauna was estimated to be 5037 Km^2 (95% CI: 2700–13,296 Km^2). This kind of area estimate is consistent with many other estimates for population viability published in the conservation biology literature. For this paper, we have used 3000 Km^2 as a threshold minimum park size for an effective protected area. This is consistent with the lower confidence from Gurd et. al., as well as many other papers on population viability for mammals (Leroux et al. 2007).

The proposition that smaller, more isolated parks will hold fewer total species had important implications for the design of parks as it related to protection of biodiversity; the question was whether to create a single large or several small reserves of the same area (the SLOSS debate; Burkey, 1989). It has been suggested that creating several small parks can serve an important role in protecting endemic species with low area requirements and therefore a series of several small reserves could protect a broader range of species than a single large reserve of the same area (Simberloff and Abele, 1976). However, a further problem with small parks in patchy environments is that they tend to support small populations, which are very sensitive to extinction from demographic stochasticity (Burkey, 1989). Small population sizes can also lead to genetic malfunction due to a loss in heterozygosity, inbreeding and genetic drift, all of which can contribute to genetic stochastic extinction (Sinclair et al., 2006). It is generally accepted that larger protected areas are better at protecting species due to these large effects of demographic stochastisity rather than several small reserves (Burkey, 1989).

Although island biogeography provided valuable insight into protected areas, it was important to maintain that parks are part of the greater landscape, with which they exchange energy, mineral nutrients, and species. This removed the focus from the total number of species a park can protect to a focus on protecting species that are most sensitive to extinction (Diamond, 1975). Noss (1983) asserted that the main goal of conservation is the “perpetuation of indigenous ecosystem structure, function, and integrity”. The focus on numbers of species tends to obscure the fundamental point that saving complete ecosystems is what is at stake (Lovejoy and Oren 1981). Thus, there was a change in the focus from within park boundary conditions onto the larger regional landscape because ecological phenomena operate at large temporal scales. Isolated protected areas were deemed an inappropriate design for long-term conservation (Noss, 2002). The new focus for integrating conservation strategy turned to the regional landscape (Noss 1983, Henderson et al., 1985).

Park Size and the Collection of Canadian Protected Areas

The Canadian collection of protected areas numbers 3489 units, as identified by this study. The size class distribution for this set of protected areas is given below in Table 2.

Table 2. Number of Protected Areas In Canada by Area Size Class (Km^2)

Size Class Km^2	**Number of Protected Areas**
0-100	2908
100-1000	430
1000 - 10000	136
10000 -20000	18
20000 - 30000	3
30000 - 40000	2
>40000	1

It is clear from table 2 that the size distribution of Canadian protected areas is highly skewed to the small size class of less that 100 Km^2, which make up 83% of all protected areas. There are very few large protected areas over 3000 Km^2 (the minimum size effective size figure we assume in this paper) and the large areas tend to be in the north.

Islands to Networks of Protected Areas

The preceding analysis demonstrates two problems with the Canadian collection of protected areas. First the existing set of protected areas does not represent the range of Canadian ecosystems, at either the Ecoregion or Ecozone level. Second, the size distribution of the existing collection of protected areas is skewed toward small-protected areas in most Ecozones. Because of these problems, there has been a push to expand the "effective" size of Canadian protected areas. This has taken the form of three approaches, which overlap to an certain extend:

1. Biosphere Reserve and greater ecosystem approaches
2. Nodes and Corridors approaches
3. Large scale bioregional panning or "conservation first" approaches.

These three approaches are often lumped under and "islands to networks" terminology. The concept of connecting island-type reserves into an ecological network has taken protected area design in a new direction. It is now a mainstream part of the conservation biology literature, but its translation into actual protected area systems in Canada has not been well embraced.

Biosphere And Greater Ecosystem Approaches

That protected areas needed to be larger than their boundaries is found in the general notion of ecosystem management. An excellent general review of the idea, especially for the United States, was given by Grumbine (1994). Ecosystem management in protected areas was discussed as early as 1932, with the Ecological Society of America's Committee for the Study of Plant and Animal Communities. Committee members recognized that a comprehensive system of sanctuaries in the United States must protect ecosystems as well as particular species, represent a wide range of ecosystem types, manage for ecological fluctuations (i.e., natural disturbances), and employ a core reserve and buffer approach (Shellford, 1932).

Agee and Johnson (1988) published an edited book on the ecosystem management in protected areas. The modern approach to ecosystem management was pioneered in Yellowstone National Park and the Greater Yellowstone Ecosystem has been the subject of much literature and debate. In Canadian National Parks, the concept evolved from the extensive use of biophysical land use inventories in the 1970's. Fundy National Park assessed the condition of its “greater ecosystem” in 1993 (Woodley). By the late 1990, most national parks in Canada had some sort of greater ecosystem arrangement in place.

These ideas found in “greater ecosystem” approaches were also the foundations for the establishment of biosphere reserves, which included the idea of a protected core and a complimentary surrounding buffer zone. Biosphere Reserves date from 1968 and are a designation by the United Nations Educational, Scientific and Cultural Organization. Canada has 15 biosphere reserves in 8 provinces with a total area of 102,237 sq km. Globally, there are 529 designated areas (in 105 countries) in the World Network of Biosphere Reserves.

Greater Ecosystem approaches have been employed across a range of protected area in Canada. Some have been formal programs with core funding such as Model Forests. Most other are informal groups of willing landowners and interested parties. Most are not formally binding. The actual changes to land management that resulting from greater ecosystem approaches are difficult to quantify, as are any conservation gains.

One of the few formal examples of a greater ecosystems approach is found in the Muskwa-Keehika, designated by the The Muskwa-Kechika Management Area Act in 1998. Located in northeastern British Columbia, the 6.4 million hectare Muskwa-Kechika is a legally protected core surrounded by a legally regulated conservation zone. The protected core is 25% of the areas, managed under the B.C. provincial park system. Resource development is permitted in 75% of the area, done in a way that is sensitive to wildlife and environmental values. The legislation provides for an appointed board be to advise government on management of the area and that a special trust fund be created to support conservation and planning initiatives within the Muskwa-Kechika. The Muskwa-Kechika Advisory Board is a volunteer board appointed by the Premier of British

Columbia. Board members represent a variety of perspectives including First Nations, conservation, local Land use decisions in the buffer zone are done by a consensus team of First Nations, local land and resource planning groups.

Nodes and Corridors Approaches

The idea of an ecological network, with core conservation areas (nodes) connected with corridors, is well described by Noss et al. (1999). Core areas are generally strictly protected regions where natural biotic and abiotic processes proceed undisturbed, or they can be areas of focused ecosystem restoration. The main function of the core areas is to protect the needs of species that are sensitive to human activities. The connection of various cores via corridors aims to enhances dispersal of biological elements and genetic exchange. It also perpetuates natural space-time disturbance and recovery patterns (Noss and Harris, 1986). Parks or refuges connected by corridors maintain higher species diversity by allowing reciprocal immigration, lowering extinction rates, and minimizing the effects of catastrophes upon populations (Simberloff et al., 1992). Today, the objective of connecting parks with corridors is seen as vital to maintaining not only parks, but also ecological functions, across broader landscapes. Corridors are seen as a way to ensure large effective park sizes so that area-demanding species, such as grizzly bears and wolves can persist in viable populations.

Nodes and corridor approaches also often incorporate buffer areas surrounding the nodes or core. Buffer zones typically encompass multiple uses of appropriate type, scale, and intensity for each core. Management of buffer zones should be consistent with preservation of the node or core. The concept of protected area networks drew from some aspects of biosphere reserves (Barber et al., 2004). The network concept attempted to resolve the traditional conflict between "hands-on" conservation/management and "hands-off" preservation. The system of core – buffer- corridors can potentially allow for the long-term survival of wide-ranging species, facilitate gene flow among populations, and help perpetuate the ecological processes that operate at large spatial and temporal scales (Noss and Harris, 1986).

Networks of protected areas have not been validated in practice because most are still in the development stage (Bennett and Wit 2001). Some researchers suggest they are an oversimplification of complex and still evolving ecological concepts and a cautionary approach should be taken in their development (Boitani et al 2007). Nodes and corridors aim to overcome fragmentation of regional landscapes, which is recognized as a major threat to biodiversity (Singleton et al, 2002). Fragmentation tends to decrease genetic exchange between groups (Singleton et al, 2002) and result stochastic extinction of small populations (Henderson et al, 1985). Restoring connective habitat in a fragmented landscape might mitigate the problem of island-like nature reserves by allowing for the flow of species, individuals, genes, energy and habitat patches such that adequate populations can be maintained (Noss, 1987).

Nodes and corridors is a generalized theory, which certainly does not apply to all species or even to all species at all times. For example, corridors are species-specific and the use of surrogacy has often been used although species-co-occurrences and the power of surrogacy of individual species. Optimal management for one species might be the opposite for another. Some networks, such as Natura 2000 sites, use already existing protected areas as core areas in their networks, although there is little evidence that these areas are actually representing ideal core areas for biodiversity (Boitani et al 2007).

Despite some criticisms, the establishment of ecological networks (cores, corridors and buffer areas) has received international attention as a way forward for protection of biological diversity and as a means to deal with threats such as climate change (IUCN, World Commission on Protected Areas Strategic Plan 2005-2012; Barber et al, 2004). Article 8 of the Convention on Biological Diversity (CBD) recognizes *in situ* conservation as the primary approach to biodiversity conservation and calls for the establishment of a system of protected areas, maintaining that they are the central element to conserve biodiversity (Glowka et al., 1994). The CBD also calls for sustainable development in areas surrounding the protected area, at the same time ensuring that it does not undermine the core conservation (Glowka et al, 1994).

Ecological networks can be applied at a variety of scales. Initiatives can range from the local level, such as municipal projects, to supra-continental scale. International examples include the Pan European Ecological Network, which includes core areas, corridors, buffers and restoration areas spanning 52 countries in Europe and northern Asia and the Mesoamerican Biological Corridor, which consists of core areas, corridors and buffer zones and spans from Southern Mexico to Panama (Bennett, 2003). Europe has placed a particularly large focus on ecological networks as a means to preserve biodiversity, with 42 Ecological Network initiatives active across Europe, 7 of them occurring at the national level (Boitani et al., 2007).

Conservation First Planning

"Conservation first" planning builds on the preceding approaches of greater ecosystem, and nodes and corridors approaches. This approach is different in two key ways. Conservation first planning aims to work at a very large spatial scale, in the order of many millions of hectares. The spatial scale is meant to encompass the dynamics of large ecosystems, which are necessary to protect viable populations of area-demanding species and key ecological processes such as fire. This kind of approach works best in lands that are relatively lightly developed. Most importantly conservation first planning aims to do as the name implies, ensure conservation planning is done prior to allocating lands for industrial or development purposes.

In North America, there are several ongoing efforts to do conservation first planning. One prominent example is the Yellowstone-Yukon Conservation Initiative, which has 12 Priority Conservation Areas that are linked through corridors and buffers. The Yellowstone to Yukon Conservation Initiative belongs to a new global family of farsighted, broad-based biodiversity strategies that have arisen in response to the lessons of conservation biology. The Yellowstone to Yukon Initiative aims to maintain and restore large-scale ecosystem process and patterns. The planning area is vast, stitching together 1800 contiguous miles of the Rocky, Columbia and Mackenzie Mountains, all the way from Yellowstone to Yukon. The mission is to build and maintain a life-sustaining system of core protected areas and connecting wildlife movement corridors, both of which will be further insulated from the impacts of industrial development by transition zones. Existing national, state and provincial parks and wilderness areas will anchor the system, while the creation of new protected areas and the conservation and restoration of critical segments of ecosystems will provide the cores, corridors and transition zones needed to complete it.

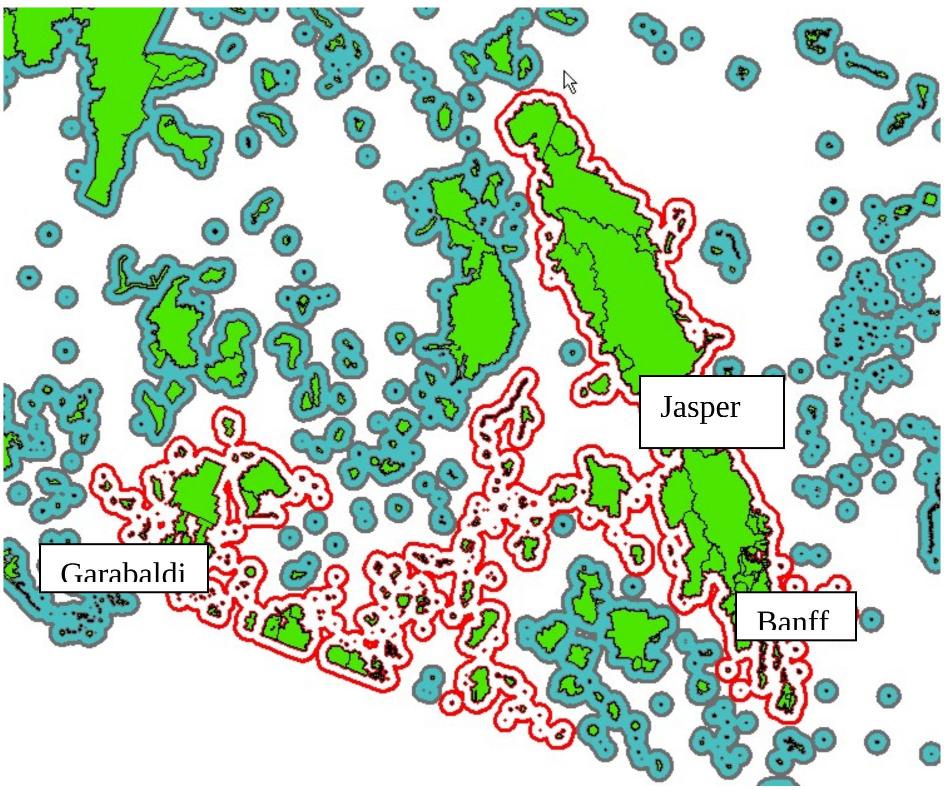
On the marine side, the Baja California to Bering Sea Marine Conservation Initiative is tri-national effort between Canada, USA and Mexico to foster a network of marine protected areas in the Northeast Pacific to safeguard marine biodiversity (http://www.mcbi.org/what/b2bcd.htm). The vision is to link a set of 28 Priority Conservation Areas spanning the coast of the three countries through marine migratory corridors. Establishment of Marine Protected Areas is still in its infancy, but is urgently needed for marine conservation.

One of the best examples of conservation first planning in Canada is the Deh Cho land use plan (Dehcho Land Use Planning Committee, 2006). The Plan was developed using the best available data from both conservation biology and traditional knowledge perspectives. The plan aims to make land use decisions that integrate ecological, social, cultural and economic values. The Plan contains five zone types 1) Conservation Zones (38.1%) with significant ecological and cultural values, 2) The Protected Areas Strategy Zone for Candidate Protected Areas (12.0%); 3) Special Management Zones (24.4%) are areas where there is significant potential for both conservation and resource development together; 4) General Use Zones (25.5%) permit all land uses; and 5) Special Infrastructure Corridors, primarily for a proposed pipeline. The plan is innovative in putting conservation first in land use planning and ensuring close to 50% of the entire landscape is protected for conservation values.

Future Opportunities Canadian Protected Areas

For this paper we examined potential opportunities for “islands to networks” approaches using corridors for each of the Ecozones of Canada. In conservation circles, it is often stated that we must move from “islands” of protected areas to “networks” of protected areas, using linking corridors. To test this idea for Canada, we established an idealized set of corridors that would connect the existing set of protected areas (see methods). We buffered all of the existing protected areas polygons by 5 and 10 km buffers. This would make the maximum potential corridors length 10 km and 20 km respectively. So any existing protect areas falling within these distances were added together to form a new protected area core. We wanted to see if corridors would make the connected cores into an effective protected area size that would result in long-term conservation. This analysis assumes the best possible scenarios for the potential corridors, specifically that all the corridors were functional for all species and that the corridors allowed the connected protected areas to actually function as contiguous habitat. An illustration of this approach is shown in Figure 1. The map in Figure 1 shows a GIS output of potential 10 Km buffers in the area of the great divide, including the block of Banff, Jasper, Kootenay and Yoho National Parks. In this case there is potentially connectivity from the mountain block of National Parks westward to Glacier National Park and a series of provincial protected areas (largest is Garabaldi Provincial park) in British Columbia.

Figure 1 – An example of connecting existing protected areas by using potential corridors of 10 km in length. The protected areas are in green (largest is the block of Banff, Jasper, Kootenay and Yoho) and the buffer to determine potential corridors are in blue. The red line outlines the are connected by a 10 km buffer.



Where the buffers connected with a buffer from another protected areas, we then added the protected areas together into a new larger core protected areas. The assumption here is that the buffers represented potential (and also functional) corridors. By adding the potentially connected protected areas together, we get a new set of protected area sizes. This new potential set is shown in table 3 below:

Table 3: The number of potential Canadian protected areas and their size classes if either 10 Km or 20 km corridors connected all existing protected areas.

Size Class Km^2	Existing Number of Protected Areas	Number of Effective Protected Areas with 10 Km Corridors	Number of Effective Protected Areas with 20 Km Corridors
0-100	2908	1315	470
100-1000	430	258	169
1000-10000	136	107	98
10000-20000	18	21	21
20000-30000	3	5	7
30000-40000	2	4	2

Table 3 illustrates that potentially connecting the existing collection of protected areas does not change the sized class distribution in a way that will make for effective conservation. Most of the aggregation in protected areas that results from corridors is amoung the small size class parks. Aggregation of small-protected areas is simply not enough to make then into an effective size class that would be sufficient for conservation. In the size classes that will ensure effective conservation (again we are using over 3000 Km^2), the total number of parks goes from 24, to 31 with 10 Km corridors and 35 with 20 Km corridors. While this is a conservation gain, it is not a dramatic gain in a Canadian protected area collection of 3489 units.

If it were possible to wave a magic wand and connect all Canadian protected areas by 10 km or even 20 km corridors, the resulting conservation gains would not be dramatic. This is further illustrated by Table 4, which presents the gain in average effective protected area size, by Ecozone, if the existing Canadian protected area collection were connected by corridors of 10 Km or 20 Km. Again this table shows a aggregation of small-size class protected areas, but the resulting new effective sizes are still far to small for effective conservation (less that 3000 km^2). For example, the average size of the protected areas in the Mixedwood Plains ecosystem of southern Ontario and Quebec would only increase from 3.2 Km^2 for to 12.0 Km^2 for 10 km corridors and 59.6 Km^2 for 20 km corridors. None of these figures comes close to the kind of effective protected area sizes that are required to conserve whole functioning ecosystems with viable populations of all native species.

Table 4. The Gain in Average Effective Protected Size, by Ecozone, if the Existing Canadian Protected Area Collection was Connected by Corridors of 10 Km and 20 Km

Ecozone	Average Protected Area Size (km^2)	Average Protected Area Size (km^2) with 10 km corridors	Average Protected Area Size (km^2) with 20 Km corridors
Mixedwood Plains	3.2	12.0	59.6
Prairies	40.0	64.5	145.7
Atlantic Maritime	50.1	95.6	400.7
Boreal Plains	144.8	260.5	576.7
Pacific Maritime	111.2	306.1	717.0
Montane Cordillera	197.8	426.7	1086.6
Taiga Plains	974.6	1089.3	1234.5
Boreal Shield	328.0	657.7	1340.0
Boreal Cordillera	1273.7	1981.3	2853.1
Taiga Shield	2065.8	2289.1	3257.6
Hudson Plains	2518.0	3902.9	6004.4
Northern Arctic	5346.0	6147.9	6147.9
Taiga Cordillera	4084.8	8169.5	8169.5
Southern Arctic	7781.3	7781.3	9337.6
Arctic Cordillera	8610.5	13776.8	13776.8

Table 4 shows the resulting effective protected area size after connecting the existing protected collection with corridors of 10km or 20 km. If we use the cutoff value of 3000 km^2, nine of fifteen Canadian Ecoregions do not have an average effective protected size to guarantee long-term conservation. Some of these ecosystems are located in the southern, more developed areas of Canada, as would be expected. However the Boreal Ecozones, including the Boreal Plains, the Boreal Shield and the Boreal Cordillera also fall with in this group The Ecozones that have the best set of large effective protected areas are in the fare north with in the lowest productivity environments.

Conclusions

Protected areas are one of the cornerstones of national conservation plans to prevent biodiversity loss. Canada holds a significant amount of the planet's remaining undeveloped land (Sanderson et al., 2002) and thus has the opportunity for significant protected areas. However it appears that the existing set of Canadian protected areas cannot guarantee long-term conservation of its biodiversity. In general existing protected area collection is not area representative of Canada's Ecozones. The existing protected area collection is also generally far too small to ensure effective conservation.

The analysis for this paper was done by Ecozone and the results vary considerably between Ecozones. In general the southern Ecozones have the lowest representivity (% of Ecozone protected) and the smallest effective protected area size. For Canada in total, only six of fifteen Ecozones have adequate average protected area sizes, as determined by benchmarks from the ecological literature. Only the far northern Ecozones have both high levels of representivity and large effective protected area sizes.

The need for effective size targets for protected areas is documented in the scientific literature. However this scientific understanding has not been expressed in effective protected area design. The reason for this is that protected area establishment is a very difficult and lengthy land-use decision. Arguably, setting aside protected areas in Canada is the most difficult land use decision to make in the Canadian contact. For example, most National Parks take decades to establish. Also the prospect of setting up very large protected areas over 3000 Km^2 in size leads to a wider range of land use conflicts, thus making the establishment of large areas even more difficult. That said, new National Parks established in recent times have met size criteria for effective conservation and the smaller southern parks are legacies of earlier times where the needs for large protected areas was not understood.

There have been calls to make effective areas larger by moving from “islands to networks”. There are three, overlapping types of approaches to doing this, greater ecosystem, nodes and corridors, and conservation first planning and they are described in this paper. Clearly there are opportunities for conservation in using these approaches. However all approached depend on establishing large enough effective protected area sizes.

Our analysis of using corridors to connect the existing set of Canadian protected areas clearly shows this will not result in effective conservation. The existing set of Canadian protected areas is comprised of small core areas, so merely connecting them together with corridors will not be the answer. The new resulting protected area set will still be well below the required size for effective conservation. This is especially true in the most developed parts of Canada. This does not mean that corridors are a bad idea; it only illustrates that corridors will not be an effective tool for most of the existing Canadian situation.

All this analysis points to solutions that must be regionally based. In southern Canada, the best hope for long-term effective conservation is to redevelop large core protected areas. This will have to be a long-term approach and involve dramatic efforts at ecosystem restoration. Given current land use, it might seem impossible to establish a 3000 Km protected area in the Mixedwood Plain Ecoregion. However we have seen dramatic land use changes in formally highly developed landscapes, as the reversion of large areas of eastern Canadian agriculture to forests in the 20th century. A current opportunity in the Mixedwood plains might be changes in the growing of tobacco on sandy soils. Because of a dramatic decrease in demand for tobacco, there may be an opportunity to purchase such lands for ecosystem restoration. This is just one example used to illustrate the possibility to establishing large protected areas cores in southern Ecoregions. Clearly a successful conservation future will require rethinking old approaches to protected area planning.

In large parts of Canada there still remain opportunities to apply our understanding from conservation biology to design and create protected areas that are designed for long-term success. Here there is the opportunity for large landscape planning, using formalized greater ecosystem approaches and conservation first approaches. We already have well developed models to use as guides for these approaches, including the Yellowstone to Yukon initiative, the Muskua-Keechaka legislation, the Deh Cho land use plan.

From a global perspective, Canada has one of the best opportunities to conserve biodiversity through effective protected areas. Contrary to most thinking of global patterns of biodiversity, we also have a global responsibility. The work of Cardillo et al., 2006, shows that Northern Canada and Eastern Canadian forests are areas of high latent extinction risk; regions where there of high potential for future loss of mammalian species. As such, there is large potential to ensure ecologically functioning and viable populations in these regions, and the rest of Canada, into the future through establishment of protected area networks. A network of scientifically sound protected areas in Canada can provide the most effective and efficient means to protect biodiversity.

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