Pathway to Canada Target 1
En route vers l'objectif 1 du Canada

Identifying Areas Important for Biodiversity and Ecosystem Services in Canada

A Pathway to Canada Target 1 Expert Task Team paper

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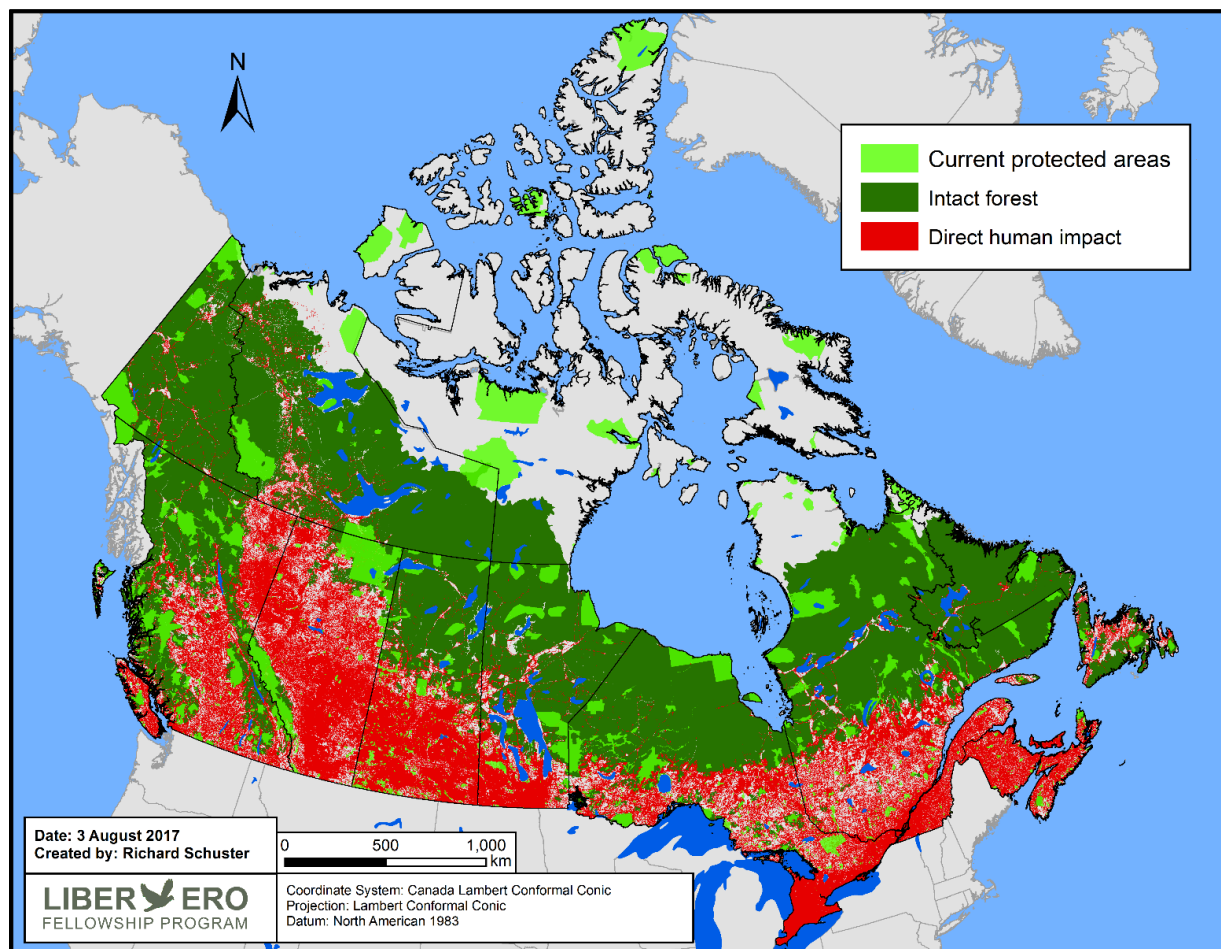Anish Neupane, Angele Vickers and Sandra McMillan

Figure 1 Distribution of current protected areas in relation to intact forest landscapes and areas of direct human impact.

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1 Executive Summary

Establishing and effectively managing protected areas is key to conserving biodiversity and ecosystem services. However, maximizing these two mandates depends first on designing protected areas in locations that are important for biodiversity, and ecosystem services. This discussion paper 1) summarizes and assesses the existing global and Canada-specific scientific information and best science based practices in identifying areas important for biodiversity and ecosystem services, and 2) provides Canada-specific options for approaches to this process that could be implemented as part of Canada's Pathway to Target 1. In doing so, it explicitly considers biodiversity first and ecosystem services second, in order to effectively safeguard the biodiversity and ecosystems that contribute to human wellbeing. It also recognizes, but does not address the potential overlap and complementarity between these two goals and Indigenous traditional knowledge.

Consistent with the Convention on Biological Diversity, Canada has committed to increasing the percentage of its land and inland waters protected from the current 10.6% (2015) to at least 17% by the year 2020. However, while Canada has an official biodiversity strategy, it does not currently have an official method to identify areas important for conserving either biodiversity or ecosystem services. Although protected areas strategies, developed by federal, provincial and territorial governments, set forth ecological elements used to prioritize areas for protection, current actions are not comprehensive enough and Canada continues to be faced with an increasing loss of biodiversity. Since the primary goal of Canada Target 1 is to protect biodiversity, it is not only essential that the area covered by the network of protected areas be increased, but also that protection focus on places that are most important for the persistence of biodiversity. Such an approach will need to address biodiversity at all levels and across many scales. In order to be implemented across the country and within different political and jurisdictional contexts, the approach will also need to be flexible enough to accommodate varying human impacts and data availabilities, and must have delineated boundaries in order to be manageable at a site-scale.

A successful protected areas strategy must conserve biodiversity across multiple levels (genes, species, ecosystems, and ecological processes). At the species level, species at risk of extinction are identified and evaluated globally by the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, and nationally by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). However, current range maps are often too coarse and have too high uncertainty for national or regional planning. At the ecosystem level, there is no current global standard, and although the IUCN has developed a Red List of Ecosystems framework, it has not yet been applied to Canada. Additionally, a National Ecological Framework for Canada exists and was updated in 2014, but only at the broad level of ecozones, not the finer level of ecoregions, which have not been updated since 1996. For ecological processes and functions, little data for Canada are available or have been systematically collected (exceptions include wildfires). For landscape diversity (including geodiversity), a variety of remotely-sensed spatial datasets exist, including land facet and elevational diversity from AdaptWest, climate velocity, and soils data from the SoilGrids project.

Notably, a new global standard for identifying sites that contribute significantly to the global persistence of biodiversity was released by the IUCN in 2016. The Key Biodiversity Areas (KBA) approach consolidated existing standards and is being applied to all elements of biodiversity (genes, species, and ecosystems) and all taxa. KBAs have been identified in most countries of the world and the new standard aims to help further this effort. KBAs are identified with respect to threatened biodiversity (species and ecosystem types), geographically restricted biodiversity (species, assemblages, and ecosystems), ecological integrity (wholly intact ecological communities), biological processes, and irreplaceability (through quantitative analysis). While the KBA approach has significant data requirements, a substantial amount of data required for KBA assessment already exist in Conservation Data Centers, COSEWIC and Species At Risk Act (SARA) records, and government databases; further data exist but are not currently accessible. The global KBA approach could also be adapted to national or subnational scales to identify areas significant for biodiversity at the national, or provincial/territorial levels. A number of key biodiversity areas in Canada already identified under other systems (Important Bird and Biodiversity Areas, Alliance for Zero Extinction Sites) are currently considered global KBAs.

To better understand current and preferred future approaches to identifying areas important for biodiversity, our Expert Task Team sent a brief survey to all departments of parks or protected areas in each of the provincial/territorial governments in early 2017. Findings from the survey include:

- Most jurisdictions favour a "biodiversity first" approach;
- A common framework across Canada is desirable, but must be flexible enough to adapt to regional context and data availability;
- A common data standard could also be valuable, although if too stringent or data-intensive it could limit the identification of sites;
- A variety of approaches to identifying areas important for biodiversity are favoured across the jurisdictions surveyed, with systematic conservation planning often mentioned; and,
- Equal numbers of jurisdictions had no knowledge, basic knowledge, or were familiar with the global Key Biodiversity Areas Standard.

Given the current state of the identification of areas important for biodiversity in Canada, the status of national and global standards for identifying such areas, and input from provincial/territorial governments, the following three broad options for identifying areas important for biodiversity in Canada are suggested:

1. **Each Province or Territory creates an individual standard for identifying areas important for biodiversity;**
2. **Create a custom national standard for identifying areas important for biodiversity; or**
3. **Adopt and adapt the IUCN global standard for identifying Key Biodiversity Areas.**

In addition, a number of short-term actions could help support each of these broader options, irrespective of the final option(s) chosen. These are:

Suggested Actions

- Work with NatureServe to continue developing the Red List of Ecosystems of the Americas to complete the assessment of all upland and wetland ecosystems (see section 3.3.4).

- Update the ecoregion layer of Canada's National Ecological Framework to ensure that it aligns with the 2014 update to the ecozone layer (see section 3.3.5).

- Update how the Canadian Environmental Sustainability Indicators (CESI) program reports on protected areas in Canada to include reporting by ecoregion not just ecozones (see section 3.9.1).

- Create a permanent, centralized, free, and publicly accessible catalog of biodiversity data collected by all levels of government, as well as Indigenous Traditional Knowledge holders where appropriate, contractors and private companies e.g., during environmental assessments. Where possible, also make the raw, georeferenced biodiversity data itself publicly accessible either through a free and permanent government repository or a platform like the Global Biodiversity Information Facility (see section 3.2.5).

- Harmonize data to internationally recognized standards wherever possible to minimize duplication and ensure consistency and comparability (see section 4.5).

A secondary goal of protected areas is conserving ecosystem services – the benefits people derive from natural and semi-natural ecosystems. This includes but is not limited to moderating effects from heat, wind, and stormwaters; air quality regulation; carbon sequestration; and supporting recreation, leisure, cultural and spiritual benefits, and emotional wellbeing. Current approaches to identifying areas important for ecosystem services include empirical and process-based models, participatory methods that involve relevant stakeholders, and expert opinion. Irrespective of which method is used, important ecosystem service areas are most commonly identified using hotspot analysis – pinpointing areas where a high number of services are supplied or delivered to people compared to other locations.

While biodiversity and functioning ecosystems underlie the provision of all ecosystem services, the spatial overlap between biodiversity and ecosystem services can vary greatly. One reason for this is that the delivery of ecosystem services requires and depends on human beneficiaries and often the "flow" of benefits across large distances. Since these processes can happen in different geographic locations and at different times, it can be challenging to create conservation plans that protect both biodiversity and ecosystem services. Overall, scientific studies have shown that prioritizing for biodiversity often also encompasses areas important for ecosystem services, although the opposite is not always true.

In Canada, quantifying and valuing ecosystem services is increasingly informing land management and conservation decisions. Currently, the majority of this work focuses on value transfer approaches, where the ecosystem service of economic value of different land use/land cover types are estimated using local data or data from a different region. However, some new modelling techniques (e.g., off-site benefits of Ontario protected areas) and participatory approaches (e.g., ecosystem service hotspots in the Peace

River watershed of British Columbia) are starting to be used. While ecosystem services are currently not a primary consideration for most protected area planning in Canada, some provincial/territorial and municipal jurisdictions are expanding their planning frameworks to include ecosystem services more explicitly.

Consideration of ecosystem services for conservation planning is at a much more preliminary stage than for biodiversity and there are more questions about how it can be effectively incorporated into the selection of areas for protection. Thus, four broad options are suggested for identifying areas important for ecosystem services:

1. **Analyze the ecosystem services provided by current Canadian protected areas;**
2. **Assess ecosystem services in an urban context across Canada;**
3. **Create or select a common ecosystem services framework for protection prioritization; and,**
4. **Support local-level ecosystem service evaluations across Canada.**

Irrespective of the specific ecosystem service option or strategy chosen, the following two actions will facilitate the consideration of ecosystem services in protected areas strategies:

Suggested Actions

- Move forward in considering and improving ecosystem service estimates regardless of the challenges identified (see section 4.4).

- Investigate and use the expertise and tools (e.g. Co$ting Nature, MARXAN) to identify priority conservation areas based on ecosystem services (and biodiversity) provision (see section 4.4).

Finally, two broad factors should be taken into account when considering a national standard for identifying areas important for biodiversity and ecosystem services. First, since climate change will have varying impacts across Canada, it will impact the distribution of biodiversity and ecosystem services. It will be important to evaluate connectivity across the Canadian protected areas network in order to facilitate species movement and gene flow, and identify and conserve refugia where climate change impacts are forecast to be low. One key suggested action with respect to climate change is:

Suggested Action

- Explore future climatic conditions of proposed parks and protected areas to determine if targets and goals are achievable in the long term (see section 6.1.26.1).

Being mindful of the varied geography, biodiversity, and patterns of human settlement across Canada and how this will impact conservation planning or implementation will also be crucial. One potentially useful framework is that of 'The 3 Canadas for Biodiversity Conservation'. This framework considers biodiversity, a gradient of intactness versus human modification, and the health of ecological processes to define 3 regions: 1) the crowded, fertile, developed south; 2) the open landscape of middle Canada; and 3) the wild north. Strategies for identifying areas important for biodiversity and ecosystem services will need to be flexible to take into account different goals, threats, and risks in each of these regions.

2 Introduction

2.1 Context

A Strategic Plan for Biodiversity was adopted in 2010 at the Conference of the Parties for the Convention on Biological Diversity (CBD). Canada, the European Community, and another 195 member states are Parties to the CBD. The plan includes 20 biodiversity targets, known as the Aichi Targets, to be achieved by 2020 in order to reverse the global decline of biodiversity. Aichi Target 11 focuses on the conservation of biological diversity through protected areas and other measures. Aichi Target 11 states:

> *"By 2020, at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape."*

Parties were urged to develop their own national targets in support of the strategic plan using Aichi targets as a guide. In 2015, Canada adopted the "2020 Biodiversity Goals and Targets for Canada", a set of 19 targets covering issues such as species at risk, sustainable forestry, connecting Canadians to nature, and others. The first of these 19 targets (henceforth called Canada Target 1), which is aligned with the numeric component of Aichi Target 11, states:

> *"By 2020, at least 17% of terrestrial areas and inland waters, and 10% of coastal and marine areas of Canada, are conserved through networks of protected areas and other effective area-based measures."*

While Canada Target 1 does not include the qualitative elements of Aichi Target 11 ("...especially areas of importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape.") jurisdictions are encouraged to consider these elements in the formulation of strategies. . Given the differences in conservation, management and governance issues in terrestrial versus marine regions, and the differences in the quantitative targets, the Government of Canada has developed separate processes for terrestrial areas and inland waters versus coastal and marine areas.

On April 11, 2016, for the terrestrial areas and inland waters component, federal, provincial, and territorial (FPT) Deputy Ministers responsible for parks agreed to establish a national steering committee through the Canadian Parks Council (CPC) to develop a pathway that will outline how jurisdictions could contribute to Canada Target 1. This National Steering Committee, as a major component of its Pathway to Canada Target 1, established a set of Expert Task Teams to provide information and analysis on each qualitative element to assist in the development of guidance for achieving Canada Target 1. The Expert Task Teams, which represent each of the qualitative elements, are:

1. Defining protected areas and other effective area based conservation measures
2. Equitable management from a local community perspective
3. Ecological representation
4. Management effectiveness

5. Areas important for biodiversity and ecological services
6. Connecting conservation areas and integrating into landscapes

The purpose of Expert Task Teams is to produce a discussion paper that researches, assesses and summarizes existing information related to each element and its application to the establishment and management of protected areas networks for the conservation of biodiversity. More specifically, the National Steering Committee has tasked Expert Task Teams to undertake the following with respect to each of the qualitative elements: 1. Research, assess, and summarize existing guidance (paying attention to divergent views where appropriate), 2. Identify options with an analysis of pros and cons related to criteria, best practices, and indicators for measuring progress, and 3. Identify potential issues for consideration in applying the qualitative element to Canada Target 1.

2.2   Connections between biodiversity and ecosystem services

Around the world, the growing number and intensity of human pressures on the environment have had profound detrimental impacts on biodiversity, ranging from changing migration routes and species interactions to population declines and outright extinctions (Ceballos et al., 2015). Since biodiversity, ecosystem function, and the benefits that people receive from nature and naturals systems (i.e., ecosystem services) are connected, conservation planners are increasingly thinking about how protected areas can provide mutually beneficial and positive outcomes for both biodiversity and human well-being. Identifying and prioritizing areas for protection, connection, and/or restoration is a key part of efficient conservation planning. In a recent survey, the majority of Canadian provincial, territorial and federal government terrestrial protected areas organizations identified the conservation of biodiversity as one of their top two conservation objectives. It is the primary objective for 10/15 organizations (67%) and the secondary objective for another 3/15 (20%). Despite the importance that these organizations place on biodiversity conservation, only 3/15 reported that their protected areas network or system was substantially complete (Government of Canada, 2016).

2.3   Biodiversity and protected areas

"Protected areas contribute to the conservation of biodiversity, although they must be complemented by sound stewardship across the entire country"

Canadian Biodiversity Strategy, 1995

The importance of protected areas in safeguarding biodiversity is widely accepted; however these conservation benefits are only realized if protected areas are placed in locations that are important for biodiversity. Historically, protected areas have often been established in locations that are considered less desirable for human use either because they are difficult to access or because they have little value for agriculture. Protected areas have also been placed in locations where the threat to biodiversity is low (Joppa and Pfaff, 2009). The Convention on Biological Diversity text reflects a growing desire to remedy this by calling for more deliberate placement of protected areas through the directive that they to be established in locations of "importance for biodiversity and ecosystem services" (Convention on Biological Diversity, 2011).

3   Identifying areas important for biodiversity

In a world with better biodiversity data, scientists, managers, and conservation planners would know the locations, distributions and numbers of all species. However, those making current conservation decisions must do so with available and often incomplete data. This is made more difficult as Canada does not have a central repository of biodiversity data and thus existent data may not be known or accessible. In addition, Canada has not adopted a single, nationwide definition of what constitutes an area important for biodiversity. This means that each government conservation organization across the country (federal, provincial and territorial) has been left to develop its own approach to evaluating biodiversity and areas requiring protection (see section 3.8.2). Before delving into current and alternative approaches, it is important to understand the components of biodiversity that must be considered to have a complete strategy for identifying important areas that, if safeguarded, will aid in the long-term persistence of biodiversity.

Broadly, important areas for biodiversity can be identified by examining biological features, particularly those that may be under threat, such as species or ecosystems, or by examining features that may act as a proxy or surrogate for biodiversity, such as geology, soil, climate, ecoregions, vegetation types, or human impact. As biodiversity is a multifaceted concept, a rigorous standard for identifying biodiversity must examine all components.

3.1   What is Biodiversity

The definition of biodiversity, as embraced by Canada and the Convention on Biological Diversity, defines it to be "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"(Secretariat of the Convention on Biological Diversity, 2005).

Biodiversity can be divided into three main components: structure, composition and function (Figure 2) (Franklin et al., 1981). Composition includes the elements of biodiversity that, for many, are the first to come to mind when thinking of this topic: species, ecosystems and genes. Structure is the

Figure 2 Compositional, structural, and functional components of biodiversity state, each encompassing multiple levels of organisation. Source: redrawn by Werner et al. (2016) from Noss (1990).

way that all of these compositional elements fit together. This happens at different scales, ranging from

the very small structure of genes to the very large structures of habitats and whole landscapes. Function is the way that these compositional and structural elements interact. These functional processes also take place at varying scales ranging from tiny genetic processes, to the interactions between species or large natural disturbances. Historically, biodiversity conservation has focused most heavily on compositional diversity with less emphasis on the structural or functional aspects (Franklin, 1988). The three components of biodiversity are interdependent with the higher levels of organization both incorporating and constraining the behaviour of the lower levels (Allen and Starr, 1982; Noss, 1990; O'Neill, 1986). The implication of this is that biodiversity must be understood and accounted for at multiple levels and scales.

As one of the topics of this paper is identifying the areas important for biodiversity the main focus is on its compositional aspects; however, both structural and functional aspects of biodiversity are also covered. In order to present both the theory behind the elements of biodiversity as well as the connection to determining areas of importance, the authors of this paper have broken biodiversity down into four categories: species diversity (Section 3.2), ecosystem diversity (Section 3.3), ecological processes and functions (section 3.4), and landscape diversity (Section 3.5).

3.2 Species diversity

Species are the most easily recognized unit of biodiversity and because of this, focal species are often used to capture the public's interest and hearts to build support for conservation initiatives (Groves and Game, 2016). In protected areas, conservation planning strategies typically focus on assuring ecosystem representation so as to capture maximum diversity across a variety of scales, and species-level evaluation, rather than ecosystem or landscape-level evaluation, is often performed as a fine-filter approach focusing on threatened and endangered species. While threatened and endangered species are important and legally must be considered in protected area planning, there are other aspects of species-level conservation that also must be taken into account for comprehensive conservation planning. This includes endemic as well as common species, surrogate species and species with high ecoregional significance.

3.2.1 Threatened and endangered species

3.2.1.1 IUCN Red List of Threatened Species
 The International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, often referred to simply as "the Red List", is the international standard for the identification of species at risk and is the world's most comprehensive source of information on the global status of species.

The process of evaluating species entails the use of a set of standardized scientific criteria to assess the extinction risk of species and includes high standards of scientific documentation and expert review. Criteria include population trends, size and structure as well as geographic range. Once reviewed, species are placed into one of eight Red List Categories of which Critically Endangered, Endangered or Vulnerable are collectively considered threatened (Figure 3). To date, nearly 80,000 species have been assessed. The Red List includes amphibians, birds, mammals, fish, plants, invertebrates, lichens and fungi (International Union for the Conservation of Nature (IUCN), 2015).

One area of concern is that the Red List has largely focused on well-known species, reflecting reflection of the state of scientific knowledge for most species (Gaston and May 1992; Mace 2004). Baillie et al., (2004) suggested that less than 2% of known species have been assessed. However, as knowledge and understanding of species increases, so too does the Red List (Rodrigues et al., 2006).
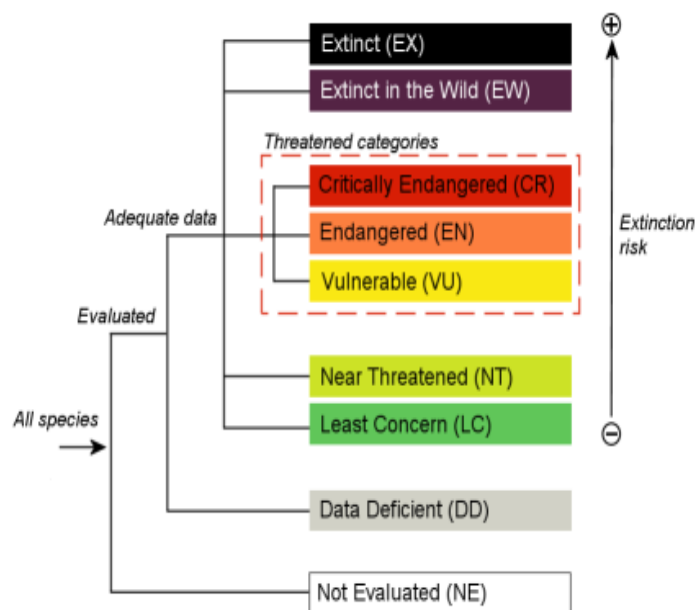
Figure 3. Categories of threatened species within according to IUCN classification. Source: IUCN, 2017

3.2.1.2   *Committee on the Status of Endangered Wildlife in Canada (COSEWIC)*

One of the more significant results of the IUCN Red List of Threatened species is that it has inspired many national and regional lists (Rodrigues et al., 2006), including in Canada where the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is responsible for the scientific assessment of wildlife species at risk (Government of Canada, 2002). There are 12 taxonomic groups from which species are assessed by COSEWIC: terrestrial mammals, marine mammals, birds, reptiles, amphibians, marine fishes, freshwater fishes, arthropods, molluscs, vascular plants, mosses, and lichens (Mooers et al., 2007). Species meeting specific eligibility criteria, are evaluated according to a set of standardized scientific criteria, based on the revised IUCN Red List Criteria and Categories to assess extinction risk (COSEWIC, 2015a). Species are assessed as endangered (EN), threatened (TH), not at risk (NAR), data deficient (DD), or special concern (SC) (COSEWIC, 2015b). Figure 4 shows the number of species at risk predicted to be present at any given location in Canada, based on species range maps. The mapping resolution for this representation was chosen at 1km. The species at risk (SAR) range dataset only contains species that are either an Environment and Climate Change Canada (ECCC) responsibility or a joint Parks Canada – ECCC responsibility, and that were Species at Risk Act (SARA) Schedule 1 listed as of March 28th 2013. The only exception is that this dataset also contains range data on the Banff Spring Snail (Physella johnsoni) which is the sole responsibility of Parks Canada. The source of range maps is a combination of feature classes from an older ECCC geospatial dataset combined with new feature classes originating from COSEWIC assessments or recovery strategies depending on their availability. Some of the maps were not available online and were digitized using a rubber sheeting technique using digital copies of the reports. Some maps also came from NatureServe (when the previous two sources were unavailable).

Like the IUCN Red List of Threatened Species, COSEWIC reports represent a large compilation of data and information on species at risk. New locations of species have been found as a result of the COSEWIC

work, habitat models have been developed, threats and population trends assessed, and all available information compiled. These data can be used by conservation organizations in protected areas and biodiversity conservation planning. COSEWIC listed species have been suggested for use in identifying areas important for biodiversity (Warman et al., 2004) as protection of terrestrial endangered species habitat is the most effective way to recover species at risk (Kerr and Deguise, 2004). However, despite the gathering and amassing of these large datasets and information, terrestrial COSEWIC listed species have been poorly represented in the protected areas network in Canada (Deguise and Kerr, 2006). COSEWIC listed marine species are also being suggested for consideration in the identification of marine protected areas (Day et al., 2000; Venter et al., 2006).
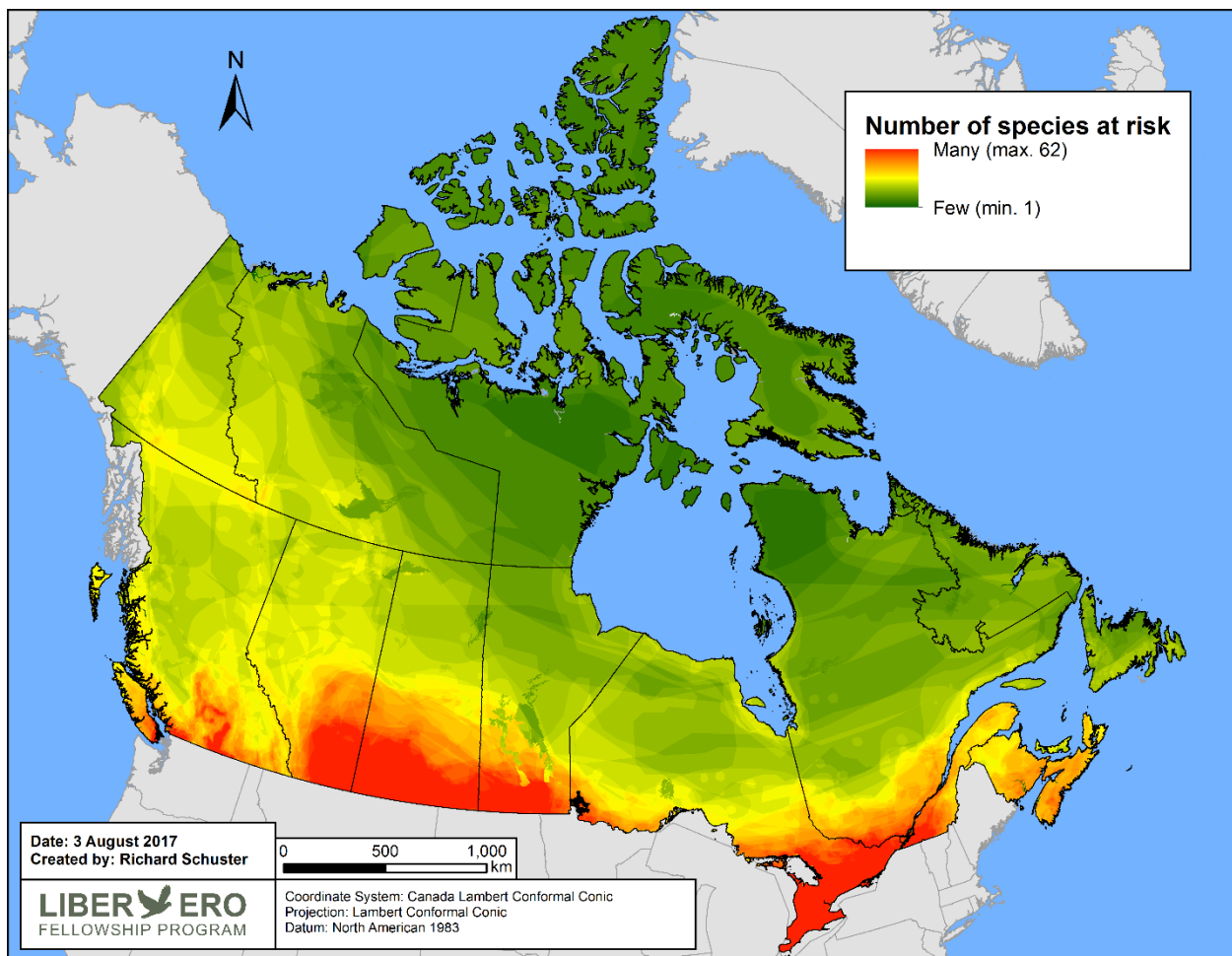
Figure 4. The number of species at risk predicted to be present at any given location in Canada, based on species range maps. Data source: ECCC and Scott Findlay (University of Ottawa), date received: 12 December 2016

3.2.1.3   Critical Habitat

Critical habitat, under the Species at Risk Act (SARA), is the habitat that is required for the survival or recovery of species listed as extirpated, endangered, or threatened. Critical habitat or a schedule of studies must also be identified in a species recovery strategy or action plan, which is reviewed by

partners, stakeholders and jurisdictions as well as the public. Some effort has been made to help ensure that the critical habitat identification process is applied consistently across Canada with good documentation to ensure transparent decision making (Government of Canada, 2014b). However, the 2013 Fall Report of the Commissioner of the Environment and Sustainable Development (Office of the Auditor General of Canada, 2013) found that critical habitat had not been identified in 43 percent of recovery strategies for EN and TH species.

Textbox 2 - Freshwater Ecologically Significant Species: a potential approach for identifying important freshwater species

The Oceans Action Plan, applied in Canadian marine systems, defines specific criteria for identifying Ecologically Significant Species (ESS) that require enhanced management (Fisheries and Oceans Canada, 2005). In this case "sensitive" indicates that if the species was removed or severely depleted, the effect on the ecosystem would be much greater than an equal disturbance on most other species (Fisheries and Oceans Canada 2006). A 2014 study in Lake Ontario determined that the ESS concept could be applied in large freshwater systems (Glass, Mandrak, and Koops 2014) but would require additional sampling to characterize community composition, detect rare species, and describe the geographic distribution of species. However, several weaknesses may apply. First, since assessing ESS also relies on expert opinion, it may prove limiting in poorly studied areas. Second, the ESS criteria tend to focus on the identification of charismatic and valuable species. Third, a lack of data and shifting abundances among species mean that ESS criteria do not apply well to lower trophic levels and community properties (Glass, Mandrak, and Koops 2014).

3.2.2 Endemic species

An endemic species is a native species restricted to a particular geographic region owing to factors such as isolation or in response to particular soil or climatic conditions (Convention on Biological Diversity). At a global level, a species can be considered common or not threatened, while being at risk in a particular location or country. These species may be of conservation concern locally, however not at a global scale. For example, a species may occur in healthy populations in some parts of world but be threatened locally in others. Locally threatened populations may be of conservation concern to a country for many reasons such as the possibility that they indicate a larger ecosystem problem, are a keystone species or have high human value locally. Species that are both threatened and endemic, found only in a particular country or location, are of great global concern. In other words, species that are endemic to Canada may be of great importance, not only to Canadians, but also to the whole world. Of the 37 globally at risk mammals, 13 of them are endemic to Canada; three of which are threatened (Table 1, (Rainer, R. et al., 2017). Endemic species are important from a conservation planning perspective since, if they are not safeguarded in their current restricted location, biodiversity will be permanently diminished.

Table 1. Number of Canadian endemic animals and plants classified as Vulnerable to Possibly extinct/eliminated, from 13 species groups, plus endemic mosses, lichens, and other invertebrates that are of global conservation concern. (Source: adapted from: Rainer, R. et al. 2017)

	Vulnerable to possibly extinct/ eliminated
Vertebrates	19
Mammals	3
Birds	0
Reptiles and Turtles	0
Amphibians	0
Freshwater Fishes	16
Invertebrates	46
Freshwater Mussels	0
Crayfishes	0
Butterflies and Skippers	4
Tiger Beetles	0
Dragonflies and Damselflies	0
Other Invertebrates	42
Vascular Plants	57
Ferns and Relatives	1
Conifers	0
Flowering Plants	56
Mosses	3
Lichens	3
Total	128

3.2.3 Surrogate species approach

Surrogate species are used by conservation biologists as indicators for other less well-documented species that occur in the same geographical area. Surrogates can be a single species or a suite of species that are thought to best represent some quality of interest. An umbrella or focal species is one whose needs for survival are thought to encompass those of many other species in its environs (Noss, 1990). Often, rather than focusing on a single species, a suite of species or an entire taxon is used (i.e. birds or mammals) (Ryti R.T., 1992). The concept that a single or several species can act as an indicator for the needs of a suite of other species or as an indicator as to where other species may be concentrated is debated and conservation efforts often tend to focus on large and charismatic species (Kerr J.T., 1996). Biodiversity indicator species are another type of surrogate that is used to identify areas of high biodiversity (Ricketts et al., 1999). This means that instead of determining the full species composition of an area, inferences are made according to the presence of certain key, well-documented species

(Beccaloni and Gaston, 1994). This approach to identifying areas important for biodiversity is seen to be most appropriate at a larger scale for identifying large regions with high diversity (Ryti R.T., 1992). For any surrogate species approach the selection of species is very important, depending heavily on the goal and the location of the conservationist(Ozaki et al., 2006; Roth, 2008).

3.2.4   Genetic Diversity – diversity within species

Genetic diversity helps ensure the health and long-term survival of a species in changing environments. Shifting environmental conditions caused by natural disturbances, natural disasters, direct anthropogenic stress, or climate change are commonly occurring and higher genetic diversity within a population increases the likelihood that some individuals are adapted to survive the changes (Bouzat, 2010). Maintaining or enhancing evolutionary potential of a population requires maintaining large populations that are well connected to allow gene flow. Larger populations are more likely to have greater genetic variation than smaller populations (Frankham, 1996). But it is also necessary to maintain connection within and between populations to maintain the genetic diversity. This means that individuals or genetic material (e.g. pollen, seeds) must able to move within or between populations.

Losses in genetic diversity can lead to a decrease in fitness traits related to species' growth, survival and fecundity (Gall, 1987). This can manifest in many ways including decreased sperm quality (Asa et al., 2007; Hedrick and Fredrickson, 2010), decreased offspring production (Hedrick and Fredrickson, 2010; Regmi et al., 2016), increased susceptibility to parasites and disease (Coltman et al., 1999) as well as increased juvenile mortality (Ralls K., et al. 1988).

The relationship between a population bottleneck, which is generally an event that greatly reduces the size of a population, and the loss of genetic diversity is well documented (Wright, 1931); (Nei et al., 1975); (Chakraborty and Nei, 1976); Leberg 1992) and in a fragmented landscape, where populations of a species become isolated from one another and when genetic transfer between populations is decreased or non-existent, genetic bottlenecks, genetic drift (non-selective changes in the genetic makeup of a population that decreases the genetic diversity), inbreeding and inbreeding depression (decrease in biological fitness) often result (Andersen et al., 2004; Farias et al., 2015; Heller et al., 2010; Johnson et al., 2004; Jump and Peñuelas, 2006; Martínez-Cruz et al., 2007). The smaller the isolated population and the longer that it remains small and genetically isolated, the more genetic variation will be lost (Leberg, 1992).

Southern Canada is characterized by a heavy human footprint, a highly fragmented landscape, and the highest concentration of species at risk in the country (see section 6.2). The distribution of protected areas in this temperate portion of the country is characterized as being numerous but small (Government of Canada, 2016). Thus, many species in southern Canada may be facing genetic bottlenecks and at risk of genetic drift, inbreeding and inbreeding depression. Numerous studies have highlighted the importance of maintaining connectivity to provide for dispersal and gene flow among populations (Crooks and Sanjayan, 2006). The Convention of Biological Diversity has also recognized the value of linkages between protected areas which will enable species to move and genes to flow thus reducing the risks of genetic bottlenecks (Ervin et al., 2010).Ensuring that, where possible, protected areas are large enough to sustain large, genetically diverse populations of species and that protected

areas of all sizes are well connected in order to allow genetic flow will be essential to the persistence of Canadian biodiversity.

3.2.5   Data availability and gaps for species diversity

The IUCN has put together range maps for species (threatened and not-threatened) of amphibians, birds, mammals and reptiles globally. These are often used in global analysis, but their relatively coarse scale and related uncertainty make them less useful for conservation planning on national and regional levels.

Often more relevant for Canada are the COSEWIC species-at-risk range maps, a dataset produced by Environment and Climate Change Canada and Scott Findlay's group at the University of Ottawa. In contrast to the IUCN range maps, the COSEWIC maps are produced one by one and although COSWIC maps differ in quality, the attention paid to each increases accuracy. Figure 4 shows the number of species-at-risk throughout Canada, based on available COSEWIC range maps. One limitation of range maps is that they are often coarse scale and don't accurately represent the true distribution of species. An alternative dataset in some cases specific to Canada is NatureServe's element occurrence dataset for species at risk in which only confirmed selected occurrences (not absences) of a species are reported. As a result, all identified locations of a species in this dataset are true occurrences and not potentially over-predicted occurrences from range maps. A drawback of this dataset is that it is highly biased towards easily accessible locations (e.g., roads) and does not differentiate between true absence and not surveyed. As such, this dataset can only be used to infer the true distribution of a species in rare cases where the entirety of the range has been well surveyed.

An ideal dataset for estimating species distributions would be a mix of the types described above, based on systematic sampling throughout Canada to create a representative dataset that could be used in sophisticated species distribution modelling to estimate true occurrence or, even further, patterns of species distribution.

As it is not currently feasible to conduct the above data collection and analyses for an exhaustive list of species, it would be best to start with surrogate species that are, for example, indicative of a region or habitat type or easily detectable species where data gathering is relatively cheap. No such approach exists as of yet for Canadian species, given the logistical difficulties and cost of country-wide systematic surveys and the inaccessibility of much of the geography. A rule of thumb for Canada in terms of data availability: the further north one looks, the less data there are publicly available. This makes it difficult to reliably estimate species occurrences.

One way to improve the availability of species data is to encourage that baseline data (e.g., occurrence, abundance, spatial location) collected as part of environmental impact assessments across Canada be made publicly accessible in a free, permanent, searchable database. This could be especially useful for areas with limited access by the general public and researchers, i.e., remote areas. With some exceptions, sharing such information is becoming an international best practice among researchers around the world, including Canada's three federal research granting agencies (Government of Canada),

the European Commission (European Commission (17 Jul 2012)), top peer-reviewed scientific journals (Center for Open Science; McNutt, 2014; Miguel et al., 2014; Nature), and charitable foundations (Wellcome, 2017).

> **Suggested Action**
> Create a permanent, centralized, free and publically accessible catalog of biodiversity data collected by all levels of government, as well as contractors, and private companies during e.g. environmental assessments. Where possible, also make the raw, georeferenced biodiversity data itself publically accessible either through a free and permanent government repository or a platform like the Global Biodiversity Information Facility (http://www.gbif.org/).

3.3   Ecosystem diversity

An ecosystem can be defined as a dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit (Convention of Biological Diversity). Classifying ecosystems has been defined as the process of delineating and classifying ecologically distinctive areas of the Earth's surface. Each area can be viewed as a discrete system which has resulted from the mesh and interplay of the geologic, landform, soil, vegetative, climatic, wildlife, water, and human factors which may be present. The holistic approach to land classification can be applied incrementally on a scale-related basis from site-specific ecosystems to very broad ecosystems" (Wiken, 1986).

While there is no globally agreed upon classification for ecosystems, most definitions include four main elements, organized at varying spatial, temporal and thematic scales (Keith et al., 2013):

1. A biotic complex or an assemblage of species;
2. An associated abiotic environment or complex;
3. Interactions within and between these complexes; and
4. A physical space in which these operate.

3.3.1   Characterizing ecosystems

The many methodologies that are used to identify and distinguish ecosystems mostly fall into four broad categories of approaches (Rankin et al., 2011): physiognomic units (section 3.3.1.1), drainage basins (section 3.3.1.2), biogeoclimatic zones (section 3.3.1.3), and ecoregionalization (section 3.3.1.4).

3.3.1.1   Physiognomic units

This approach classifies discontinuous areas based on vegetation life form, structure, and composition (i.e., tundra, tall grasslands, wetlands) (Rankin et al., 2011). The Canadian National Vegetation Classification (CNVC) is a partnership between international, federal, provincial, and territorial governmental and non-governmental agencies aiming to provide a standardized, hierarchical taxonomic nomenclature for Canadian vegetation units, describing vegetation conditions at different levels of organization from global to local (Canadian National Vegetation Classification, 2013). Although CNCV is in the early stages of development and will require more effort to complete, it could form the basis for a physiognomic approach to characterizing ecosystems in Canada.

3.3.1.2   Drainage Basins (watersheds)

A drainage basin is an area of land that drains surface and ground waters into a body of water like a river or stream, separated by elevations in the landscape known as drainage divides. Drainage basins are often used as the unit to delineate and manage inland aquatic and wetland systems (Government of New Brunswick, 2009; Government of Prince Edward Island). Canada has 25 major drainage basins, and 167 sub-drainage basins (WWF, 2017); each has unique characteristics such as total area, shape, arrangement of slopes, and elevation change (Government of Canada, 2014a). One unique consideration for this category of ecosystem is the necessity of understanding how activities upstream affect downstream ecosystems (Lindberg et al., 2011; Schlosser and Karr, 1981). The finest level of drainage data available from the National Hydrological Network of Canada is that of Catchments. There is a total of 1200 Catchments present throughout Canada (Figure 5). 297 of 1200 catchments (25%) currently have less than 1% direct human impact. These are almost exclusively located in the North of the country. In contrast, 780 of 1200 catchments (65%) are at least 5% impacted; 464 of 1200 catchments (38%) are at least 50% impacted.
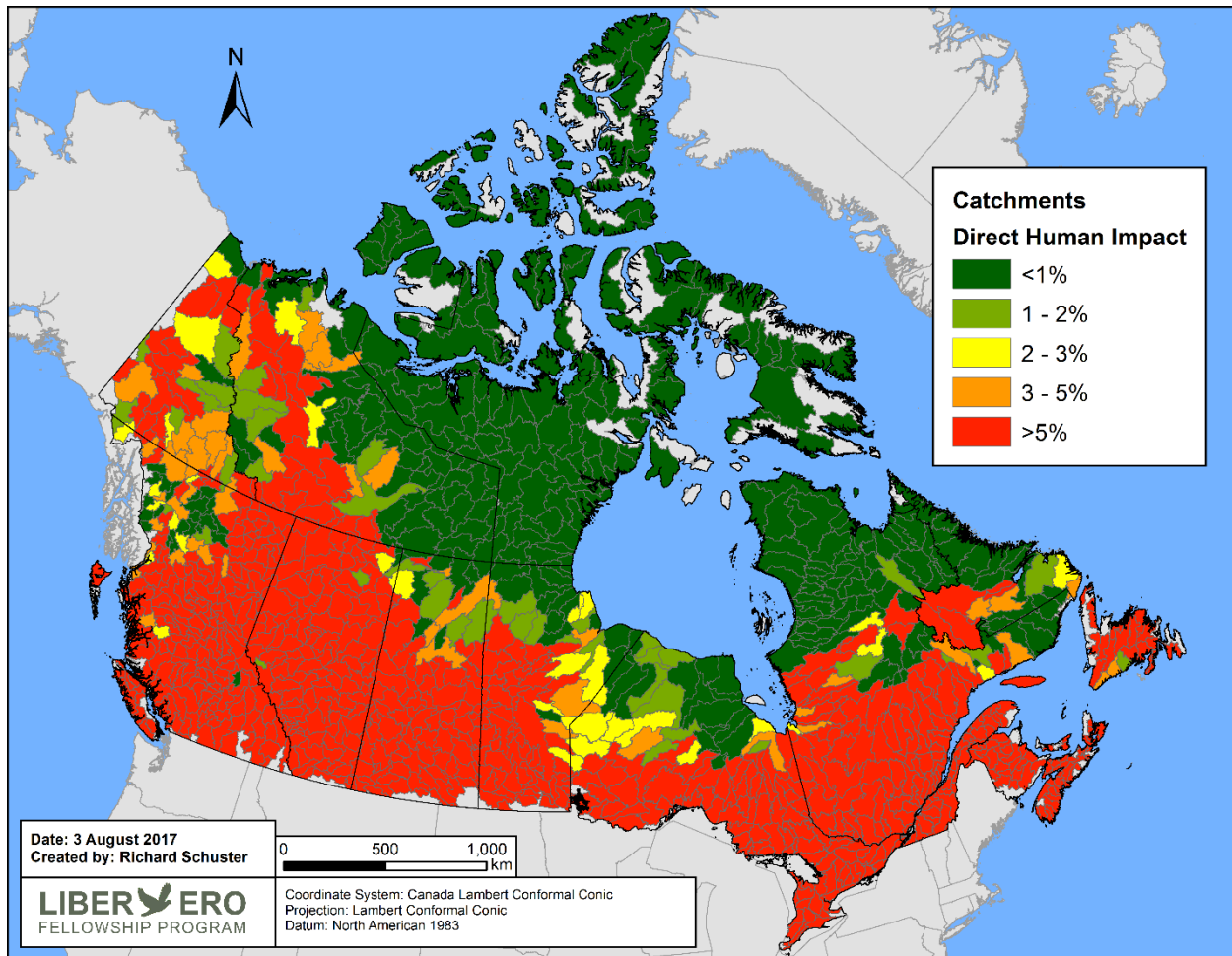
Figure 5. Direct human impact in areal percent of each catchment area across Canada. Data sources: Direct human impact (Canada Access 2010, Global Forest Watch Canada, http://www.globalforestwatch.ca/node/198, date accessed: 22 April 2017); Catchments, National Hydrological Network, ftp://ftp.geogratis.gc.ca/pub/nrcan_rncan/vector/geobase_nhn_rhn/index/, date accessed: 14 December 2016)

3.3.1.3 Biogeoclimatic zones

The biogeoclimatic approach organizes ecosystems at three levels: local, regional and chronological. At a regional level, areas sharing uniform climate are inferred through topography, soil and vegetation and are referred to as biogeoclimatic units. A similar classification process is carried out at the local level wherein segments of the landscape are classified as site units, again according to their topography, soils and vegetation. The chronological classification, also called successional classification, describes plant communities that have been modified by disturbances, but which, given enough time, may revert to a mature plant community at climax (Biogeoclimatic Ecosystem Classification Program, 2017). This category of approach is often used in forestry (Ministry of Forests, British Columbia, 2017)

3.3.1.4 Ecoregionalization

This approach classifies contiguous units that are nested at various scales and for which the boundaries are defined by biotic and abiotic characteristics (Rankin et al., 2011). A National Ecological Framework

for Canada was released in 1996 (CCEA, 1996) with the goal of advancing a more holistic approach to conservation and allowing ecosystems at various hierarchical levels to be described, monitored and reported on. As such, ecozones, ecoprovinces, ecoregions and ecodistricts were mapped Canada-wide. Attributes used to distinguish between areas within levels of the framework include those associated with climate, physical landscape characteristics, land cover and population. Figure 6 shows the current distribution of the 194 ecoregions of Canada. The map also shows the direct human impact in areal percent of each terrestrial ecoregion across Canada to give a sense of the current anthropogenic impact on each ecoregion. 63 of 194 ecoregions (32%) are less than 1% impacted. These are exclusively located in the North of the country. In contrast, 107 of 194 ecoregions (55%) are at least 5% impacted; 47 of 194 ecoregions (24%) are at least 50% impacted. Complementary to this figure, Figure 14 in the appendix shows the current state of protection per ecoregion across Canada. When Canada's terrestrial protected areas are viewed within the National Ecological Framework for Canada, 74 of 194 ecoregions (38%) are at least 10% protected; 42 of 194 ecoregions (22%) are at least 17% protected.
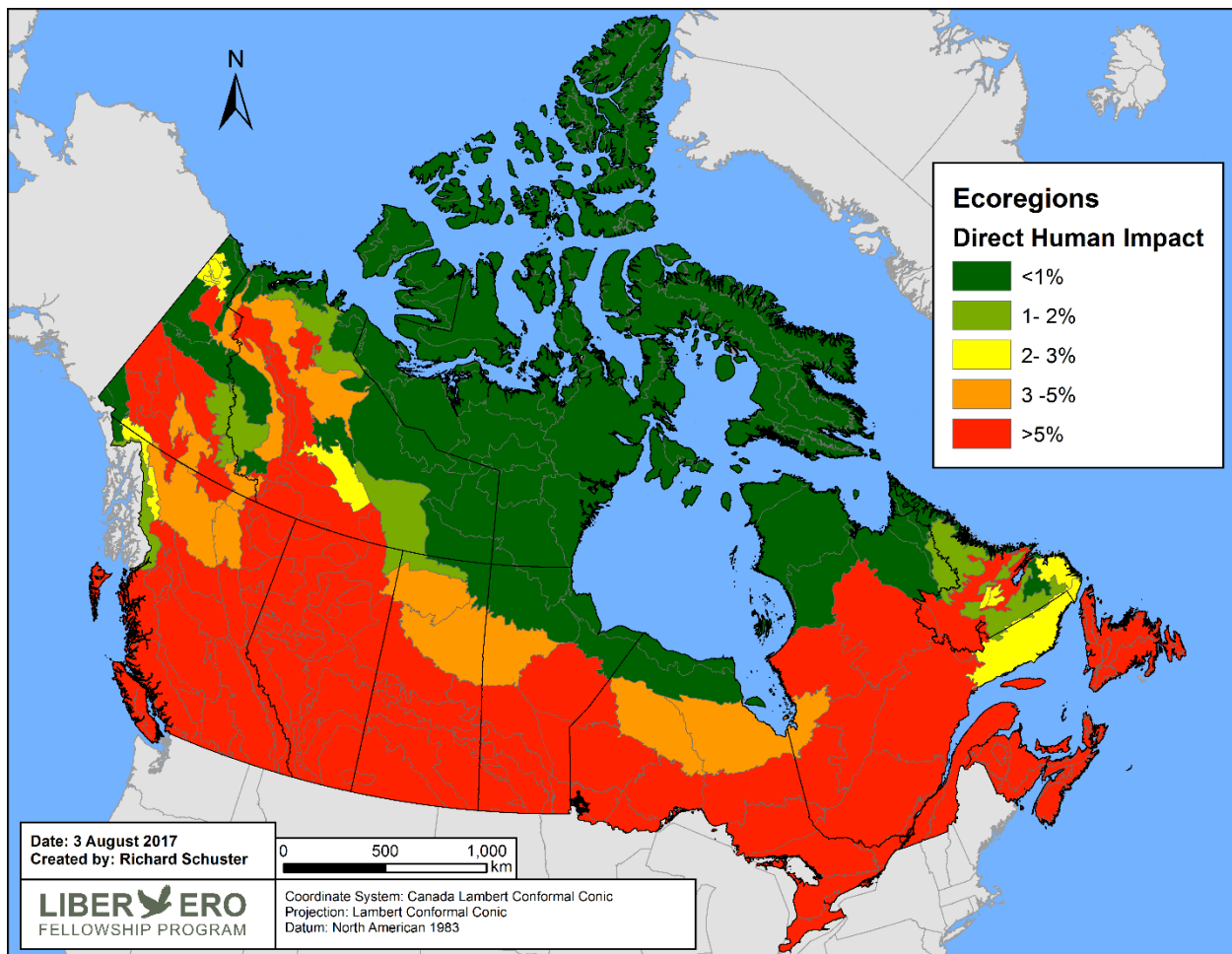
Figure 6. Direct human impact in areal percent of each terrestrial ecoregion across Canada. Data sources: Direct human impact (Canada Access 2010, Global Forest Watch Canada, http://www.globalforestwatch.ca/node/198, date accessed: 22 April 2017); Ecoregions (Ecoregions of Canada 1996, National Ecological Framework for Canada, http://sis.agr.gc.ca/cansis/nsdb/ecostrat/region/ecoregion_shp.zip, date accessed: 18 May 2017)

Textbox 3 - Ecosystem classifications are not mutually exclusive: an example from Nova Scotia

Complementary ecosystem classification systems are used in several provinces including Nova Scotia:

° *A biogeoclimatic Ecological Land Classification* is used for ecosystem based forest management. The classification uses 9 ecoregions and 40 ecodistricts for the province (Neily et al., 2005).

° *An ecoregion classification* comprising of 80 Natural Landscapes is based mainly on landform and climate. Natural Landscapes are used to design and assess representivity of ecosystems for protected areas (Cameron and Williams, 2011).

Why are several Ecosystem Classification Systems used?

Ecosystem classification systems used in forest management are designed to aid forest managers in applying ecosystem based management to help ensure sustainability and maintain biodiversity. These systems are designed to focus on forest ecosystems and to help identify ecosystems where similar forest practices can be applied. Thus, they can be weak on non-forest classification and tend to amalgamate units. Classification systems used in biodiversity conservation are designed to help identify different ecosystem types so that all elements of biodiversity are considered and thus tend to identify differences rather than amalgamate units. Classification systems for biodiversity also focus on all ecosystems types, forest and non-forest alike.

3.3.2   Ecological communities and hierarchy

An ecological community is a group of two of more species that occur together at the same place and time, frequently appearing in a regular repeating pattern across a landscape. The structure and composition of ecological communities are dependent on environmental factors such as soil, topography, climate and water availability. Identifying and classifying ecological communities is important because they represent unique assemblages of species that interact with one another as well as their environment and often depend on each other for survival. As ecosystems are nested, with large ecosystems being made up of many smaller ecosystems, the patterns and processes at one scale affect the patterns and processes at other scales (Klijn, F., and H.A. Udo de Haes, 1994). It is therefore helpful to classify ecosystems hierarchically, allowing different levels of hierarchy to be examined, depending on the goal. Fine-scale ecosystem classification and mapping can be used for conservation planning at provincial or ecoregional levels, while coarse-scale classification may be more appropriate for regional or national levels.

3.3.3   Intact landscapes and ecological integrity

The degradation, conversion and destruction of natural ecosystems is the primary cause of biodiversity loss worldwide (Pereira et al., 2010). Today, just 13 countries contain 90% of the world's total intact forest landscape (Potapov et al., 2008) -- together, Canada, Russia, and Brazil make up over 63% of this total (Potapov et al., 2008).

Human land use and its impacts on natural ecosystems are very unevenly distributed in Canada and while human activity and modern land use have greatly affected the most biodiversity-rich forests to the south, the Atlas of Canada's Intact Forest Landscapes (Global Forest Watch Canada, 2016; Peter Lee et al., 2010), shows that nearly one half of Canada's total land area is still composed of intact forest landscapes. These intact forest landscapes are unevenly distributed across the country and are mostly found in northern Canada as well as at higher elevations in western Canada (Figure 13 and Section 6.2).

Between 2000 and 2013, large intact forest landscapes in Canada decreased by 4.8% (216,199 km2) – nearly two-thirds of this decrease occurring in Quebec, Alberta and Ontario (Smith et al., 2016). Of this reduced area, 92% is known to intersect with species at risk and over 14% of the decreased area coincides with the presence of at least six species at risk. Intact forest landscapes are important, not only for the conservation of species and biodiversity in general, but also for their role in uptake and storage of carbon (Thies et al., 2011). As of 2013, 17.5% of Canada's intact forest landscapes were covered by protected areas (including permanent and interim protected areas) (Smith et al., 2016).

While forest ecosystems may receive much of the attention when discussing intactness, other land types must also be considered. Peatlands for instance are estimated to represent approximately 12% of Canada's land area and are impacted by human activities such as hydroelectric development and commercial extraction. They are also expected to be severely affected by climate change due to permafrost thaw with the corresponding release of methane expected to have significant negative climate impacts (Canada and Environment Canada, 2010). Another important example is grasslands, losses of which have exceeded those of any other biome in North America and, although losses have slowed, declines continue in some areas. Prairie grasslands have declined by about 70% while tallgrass prairie and tallgrass savannah have declined more than 90% (Canada and Environment Canada, 2010).

The growing recognition of the importance of intact landscapes has given rise to much research on this topic and the advent of many methods for evaluating it; biodiversity intactness indices and wilderness areas are two of these approaches.

3.3.3.1   Biodiversity impact indices
In 2012, Vačkář et al. undertook a review of multispecies indices for monitoring human impacts on biodiversity. They reviewed eight biodiversity indices: Living Planet Index, Species Trend Indices, Red List Index, Marine Trophic Index, Natural Capital Index, Mean Species Abundance, Biodiversity Intactness Index, and, Index of Biotic Integrity.

Of all these indices, the Biodiversity Intactness Index appears to be the only index with a sufficiently high resolution for identifying areas important for biodiversity in Canada. It also meets the Convention on Biological Diversity criteria for policy relevance (Scholes and Biggs, 2005). The Biodiversity Intactness Index is an indicator of the overall state of biodiversity in a given area, synthesizing land use, ecosystem extent, species richness and population abundance data. As may be expected, data limitations have hampered efforts to date with the result that the Biodiversity Intactness Index has so far only been estimated, from expert opinion, for seven southern African countries (Newbold et al., 2016). However, in a slightly modified implementation approach, primary data were recently used on sampled local

species abundance including a wide range of animal (vertebrates and invertebrates), plant and fungal taxa (Newbold et al., 2016). These updated statistical models incorporate more extensive pressures as well as land use and they produced fine-scale (~1 km2) global estimates of how land-use pressures have affected the numbers of species and individuals found in samples from local terrestrial ecological assemblages. While the global dataset that (Newbold et al., 2016) created does not work very well for Canada, their framework and underlying PREDICTS data (Hudson et al., 2014) could be useful in the Canadian context.

There are several challenges for impact or intactness indices such as they require comparing current biological measures (e.g. species richness) against historical measures. Often historical data is not available especially for the less studied groups of species. A number of approaches have been proposed, for example (Scholes and Biggs, 2005) suggest using large protected areas as references. Another challenge is that current occurrences and populations about most species are unknown. Therefore, many authors suggest use of data for known species, usually vertebrates and vascular plants. Although these short comings limit the usefulness of indices of impact or intactness, they can provide a broad outline of trends and highlight areas for conservation priority. No one, single indicator can integrate all aspects of biodiversity and therefore these indices are best used in conjunction with other conservation planning tools.

3.3.3.2 Wilderness and/or roadless areas

One approach put forward to identify intact landscapes, or wilderness areas, is to first get a sense of the sum total of ecological footprints of the human population. The human footprint introduced by (Sanderson et al., 2002) expresses that sum with four types of data as proxies for human influence: population density, land transformation, accessibility, and electrical power infrastructure These data were mapped at a resolution of 1 km2 and are globally available. In addition to mapping the human footprint, Sanderson et al. (2002) also mapped the least influenced, or "wildest," areas in each biome. In 2016, Venter et al. (2016a), mapped the change in global human footprint over the last 16 years using recently available data on infrastructure, land cover and human access into natural areas to construct a globally standardized measure of the cumulative human footprint on the terrestrial environment at 1 km2 resolution from 1993 to 2009. Based on this work by Venter et al. (2016a), Watson et al. (2016) specifically looked at wilderness areas, which they defined as largely biologically and ecologically intact natural landscapes generally, although not always entirely, free of human disturbance. One of their findings was that over the last two decades' extensive losses of wilderness have occurred. Examples of global datasets that can be used to investigate human footprint/wilderness areas are i) (Venter et al., 2016b), which represents the maps introduced above, and ii) (Ibisch et al., 2016), which produced a global map of roadless areas and an assessment of their status, quality, and extent of coverage by protected areas. A Canada specific dataset of higher resolution and arguably more relevance to Canada was produced by Global Forest Watch Canada (GFW, 2014)s, http://www.globalforestwatch.ca/node/198). This dataset provides an overall picture of the extent of human access in Canada and is based on National Road Network data with manual digitization (i.e. mapping) of anthropogenic disturbances using 30-m resolution Landsat imagery (shown in red on Figure

1). Finer scale data also exist for some provinces. For example the Alberta Biodiversity Monitoring Institute has mapped human footprint at a scale of 1:15,000 m.

Data Resolution and Mapping

Forest and Water

Low Resolution Image Forest and Water

High Resolution Image Forest and Water

Resolution of data that is used in mapping roadless areas, wilderness areas, biodiversity indices or other ecological values is important. This is demonstrated in the images above. The left-hand low resolution image of forest and water would indicate 25% of the study area is water. The right hand high resolution image above would indicate that 36% of the study area is water. Clearly the high resolution image would be more accurate. Analyses using higher resolution data can lead to more accurate land cover classifications and pattern analyses, which could greatly improve the detection and quantification of land cover change for conservation, habitat prediction models, species and ecosystems distribution predictions (Boyle et al., 2014).

When undertaking analysis at large scales such as globally, continentally or even nationally, concessions have to be made. Data resolution will vary between regions of the study area and in order to maintain consistency, analysts will use the resolution of the coarsest data. The trade-off for consistency is loss of data resolution for many areas within a study region. However, consistency across a study area is necessary when comparing one area to another.   As a result, global data sets tend to be very coarse and less useful when planning or analyzing at finer scales.

3.3.4   Red list of Ecosystems

A common theme in this paper is the importance of addressing multiple levels and scales of biodiversity. The IUCN Red List of Ecosystems is another tool towards this end with its application intended to be complementary to that of the IUCN Red List of Threatened Species. This ecosystem-based Red List highlights threatened biodiversity at a broader scale than the species Red List as its goal is to support conservation in resource use and management decisions by identifying whole ecosystem types most at risk of loss across their range (Bland et al., 2015; Keith et al., 2013, 2015). For this red list, ecosystem types are defined as units of assessment that represent complexes of organisms and their associated

physical environment within an area (Keith et al., 2013). Therefore, each ecosystem type is defined according to its characteristic biotic and abiotic complexes, interactions and a site location (Keith et al., 2015). The Red List of Ecosystems includes eight assessment categories, three of which (Critically Endangered, Endangered and Vulnerable) are considered to be threatened ecosystems (Figure 7).
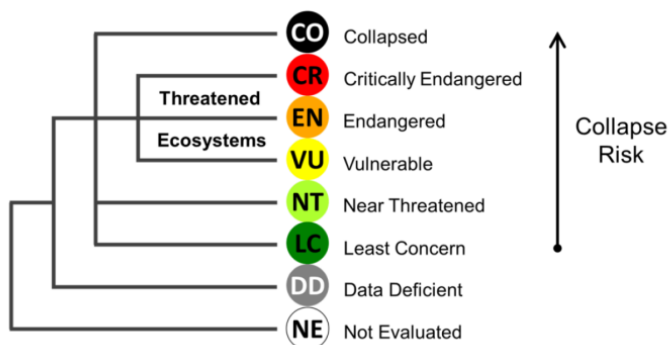
The selection premise for most Canadian provincial and territorial networks of protected areas is based on ecosystem representation [for more information on this, please see the Expert Task Team paper on Representation] and the Red List of Ecosystems is a tool that is nested within this broader representation approach to help prioritize conservation actions toward ecosystems most likely to disappear without intervention.

Within this context, ecosystem type is considered to have Collapsed when "it is virtually certain that its defining biotic or abiotic features are lost from all occurrences, and the characteristic native biota are no longer sustained. Collapse may occur when most of the diagnostic components of the characteristic native biota are lost from the system, or when functional components (biota that perform key roles in ecosystem organisation) are greatly reduced in abundance and lose the ability to recruit" (Bland et al., 2015). (Comer et al., 2016) state that ecosystem collapse is analogous to local extirpation of a given species, but whereas species can go extinct, ecosystems transform into novel forms of composition, structure and function that have no natural analog. An prime example of ecosystem collapse (IUCN, 2016a) is the Aral Sea in Central Asia. This sea was the 4th largest continental water body whose native biota consisted of 20 species of freshwater fish and more than 150 species of invertebrates. Shoreline reed beds provided habitat for water birds including migratory species. Water extraction for agriculture after 1960 led to shrinkage and salinization so that by 2005 only 28 aquatic species were found and reed beds had disappeared. The Aral Sea had transformed into saline lakes and desert plains.

Figure 7. Categories of the IUCN Red List of Ecosystems Categories. Source: Bland et al. 2015

This process requires that each ecosystem type be classified, described, and mapped, followed by a series of measures that aim to determine trends in distribution (e.g., percent loss from land conversion), environmental degradation (e.g., altered hydrology, insect pests, or natural wildfire dynamics), and disruption of biological processes (e.g., fragmentation or invasive species effects). Trends are addressed by scoring types as they have changed over recent centuries as well as over the past 50 years, and how they are likely to change over the upcoming 50 years. Risks due to climate change are addressed mainly under measures of environmental degradation over the upcoming 50 years.

A preliminary assessment of upland and wetland ecosystems is currently in late stages for the United States and transboundary ecosystems with Canada, Mexico and the Caribbean (personal communication with Patrick Comer, NatureServe) and several publications along with data layers are planned for release

later this year or next year (2017-2018). The study area of this project encompasses 10.3 M km^2, which is equivalent to 8% of the global terrestrial area (excluding Antarctica) and, to date, 350 ecosystem types, which historically covered over 90% of the study area's land surface, have been assessed for red listing.

The Red List of Ecosystems may aid in addressing both the Aichi Target 11 aim of identifying areas important for biodiversity through the identification of ecosystems at risk requiring urgent action for protection, as well as Target 5, which focuses on drastically decreasing the rate of loss of all natural habitats.

> **Suggested Action**
> Work with NatureServe to continue the development of the Red List of Ecosystems of the Americas in order to complete the assessment of all upland and wetland ecosystems.
>
> (See Appendix - section 8.1 for details on potential first steps for creating a Canadian Red List of Ecosystems)

3.3.5 Data availability and gaps for ecosystem diversity

General ecosystem diversity data availability was covered inline in section 3.3 above, thus the focus in this section is on data gaps and potential solutions.

The National Ecological Framework for Canada was significantly updated in 2014 (see section 3.3.1.4). Unfortunately, this update only included the ecozone map and, as no updates were carried out on the ecoregion map (Appendix Figure 14), the hierarchical relationship is now broken. Figure 14 shows how the ecoregional classification can be used to quantify the percentage of an ecoregion currently under protection. Another example of data that is useful when mapped at the ecoregional level is that of direct human impact (Figure 6) as it indicates which areas are most heavily threatened by human activities.

> **Suggested Action**
> Update the ecoregion layer of Canada's National Ecological Framework to ensure that it lines up with the latest update to the ecozone layer

A second ecologically relevant way to represent biodiversity at a national scale is to use drainage basins (watersheds) (see section 3.3.1.2) The finest level in the drainage basins hierarchy currently available in Canada are catchment areas, of which there are roughly 1100 of in Canada. These catchments can be used at an even finer scale than ecoregions for biodiversity, intactness or wilderness assessments. One example of this is shown in Figure 5, where the direct human impact in areas percent for each of the 1100 catchments in Canada is shown. This type of map can be used to identify areas with little to no human impact.

The Wildlife Conservation Society Canada is leading efforts underway in Canada to identify intact landscapes and ecological integrity at a country wide scale. These efforts represent a pilot for the newly created global Key Biodiversity Areas standard (for Criterion C on Ecological Integrity) (IUCN, 2016b) (see section 3.6). The group working on this has surveyed and tested multiple biodiversity intactness indices,

some of which were mentioned earlier (see section 3.3.3). Unfortunately, none of the published metrics have met the high standard that would allow this kind of index to be implemented in Canada, which is why the development of a biodiversity intactness index, specific to Canada, would be very useful.

3.4   Ecological processes and functions

In order to conserve biodiversity for the long term, it is necessary not only to conserve the composition (species, ecosystems, etc.) and the structure (populations, landscapes, etc.), but also the functional aspects of biodiversity. These include all ecological processes and interactions. In order to simplify this concept, (Bennett et al., 2009) classified ecological processes into seven categories: climatic variables, space/time variability in primary productivity, hydrological processes, formation of biophysical habitats, interactions between organisms, movement of organisms and natural disturbance regimes (see details in Textbox 1).

Many biological processes are relevant at a local scale; however, others can have global implications. Carbon storage is an example of a globally important process that benefits greatly from Canada's contribution to global carbon sinks. When discussing Canadian carbon storage, Canada's large intact forests are often referenced; however, other landscapes also play significant contributory roles to carbon storage. For example, peatlands in Alberta, Saskatchewan and Manitoba alone are estimated to store approximately 2.1% of the world's terrestrial carbon (Turetsky et al., 2002) and including the rest of the country, specifically Ontario, Canada has the second largest peatland occurrence in the world. Figure 8 shows the distribution of carbon, in this case organic carbon in the soil up to 150cm depth, across Canada, highlighting the vast carbon stores present in Canada.
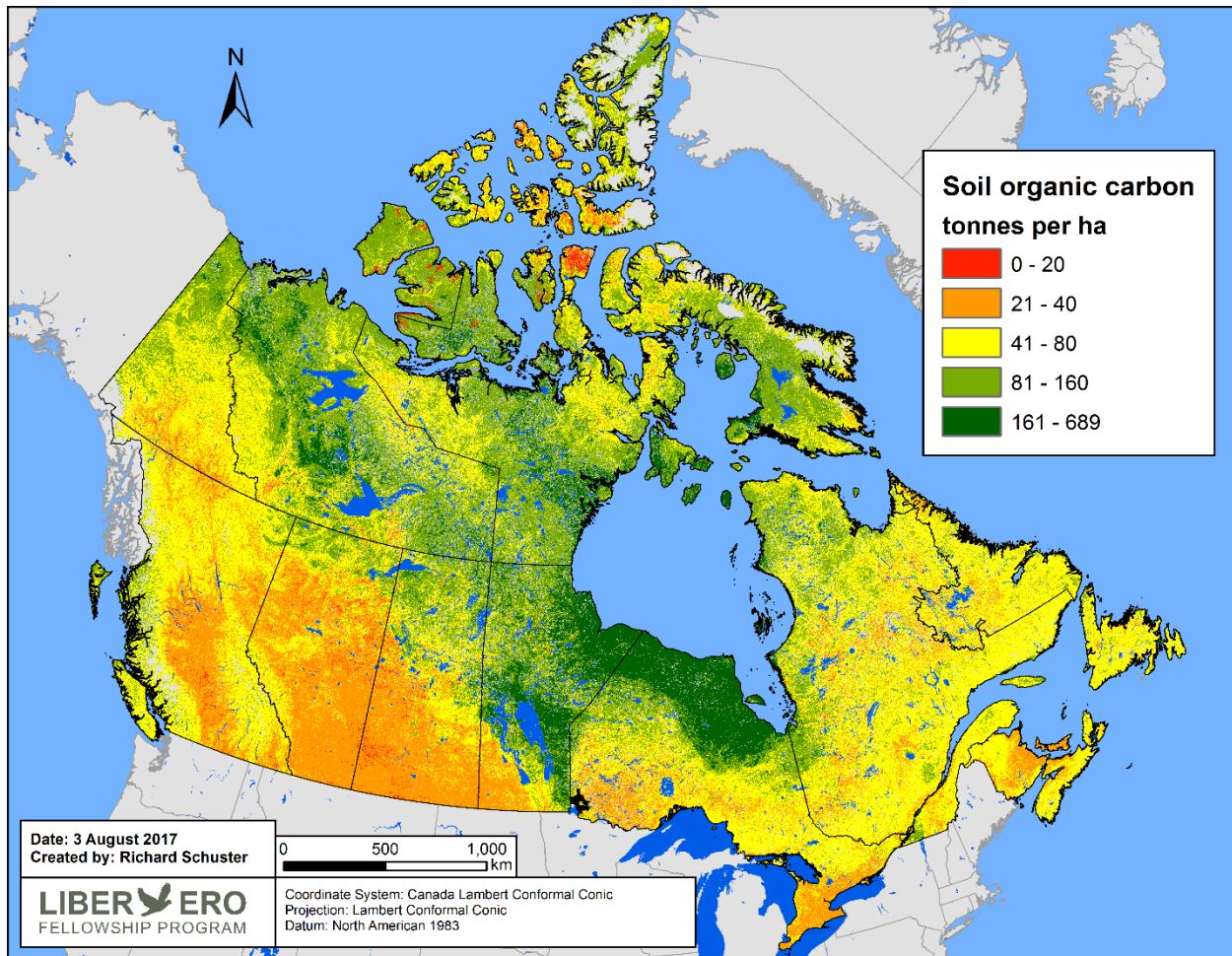
Figure 8. Soil organic carbon. Data source: Soil Grids, https://www.soilgrids.org, date accessed: 8 February 2017.

Textbox 1. Seven categories of ecological processes and functions ((Bennett et al., 2009)

- Climatic variables
  These variables include temperature and precipitation, both of which influence where species are found based on their climatic tolerance and the availability of necessary resources.
- Space/time variability in primary productivity
  The natural resources that organisms require can vary in availability according to both location and time of year. For example, due to climate change, the ice in northern Hudson Bay now breaks up several weeks earlier in the spring than it did historically. This decrease in ice is tightly linked to food availability in these waters causing food abundance to also peak earlier. This causes problems for species such as Thick-billed Murres. These birds must now lay their eggs earlier in the year; however the gap in timing between when chicks hatch and when food is at its peak availability continues to grow (Gaston et al., 2009).
- Hydrological processes
  In the Athabasca River in Jasper National Park, Alberta, many plant communities in the floodplain wetlands are adapted to seasonal flooding. Both natural and man-made changes to the water flow in these areas will drastically change the types and number of plant species (Bayley and Guimond, 2008).

- Formation of biophysical habitats
  Numerous small-scale processes influence micro-habitats. In a forest environment, this could include the composition of leaf litter and water infiltration, while in an aquatic habitat, substrate and structural features like rocks and logs influence the habitat diversity.
- Interactions between organisms
  Organisms both compete with each other and rely on each other for survival. These interactions are both constant and fluctuating. For example, due to change in ice break up, Polar bears have a much shorter spring season for hunting seal pups and they are required to fast longer during the summer (Derocher et al., 2004; Rode et al., 2015). As a consequence, Polar bears are eating more seabird eggs (including those of Thick-billed Murres, see example above) because once the ice melts and they can no longer hunt seals they seek alternative forage such as bird eggs. Polar bear consumption of seabird eggs is expected to continue increasing in the future (Dey et al., 2017; Iverson et al., 2014).
- Movement of organisms
  Organisms move at many scales and for many reasons, this can be as drastic as a seasonal migration or as simple as an animal moving a plant seed from one part of a habitat to another.
- Natural disturbance regimes
  Many ecosystems rely on natural disturbances including floods, fires and droughts. These natural processes are often disrupted for human safety and benefit, thereby affecting the biodiversity of the disrupted ecosystems. In many parts of the country, especially BC, wildfire prevention or suppression measures have a long history. These measures often prevent undergrowth fires from burning off dead vegetation on the forest floor. As a consequence, fuel loads increased over decades and forest fires that in the past would have only burned in the understory are now using these additional fuels to lead to more severe fires that reach the crowns, with often devastating effects for both wildlife and people, as witnessed in the fire seasons of 2016 and 2017, which saw mass-evacuations of towns and cities.

3.4.1   Data availability and gaps for ecological processes and functions

Data on ecological processes and functions is not readily available. One ecological process for which fairly good data exist in Canada is wildfires. The Canadian Wildland Fire Information System provides the National Fire Database (http://cwfis.cfs.nrcan.gc.ca/datamart), a database that houses information on wildfires across the country, in some cases reaching back to the early nineteen hundred. Figure 9 shows the maximum fire sized ever recorded per ecoregion across Canada. 39 of the 194 ecoregions (20%) have had fires >7500km^2 in size over the last roughly 100 years. Other processes and functions are far from being exhaustively covered for Canada. Although not systematic, we have good knowledge about the location of some highly productive habitats, and we also know movements/migrations of key organisms, e.g., birds and caribou and important stop over sites.
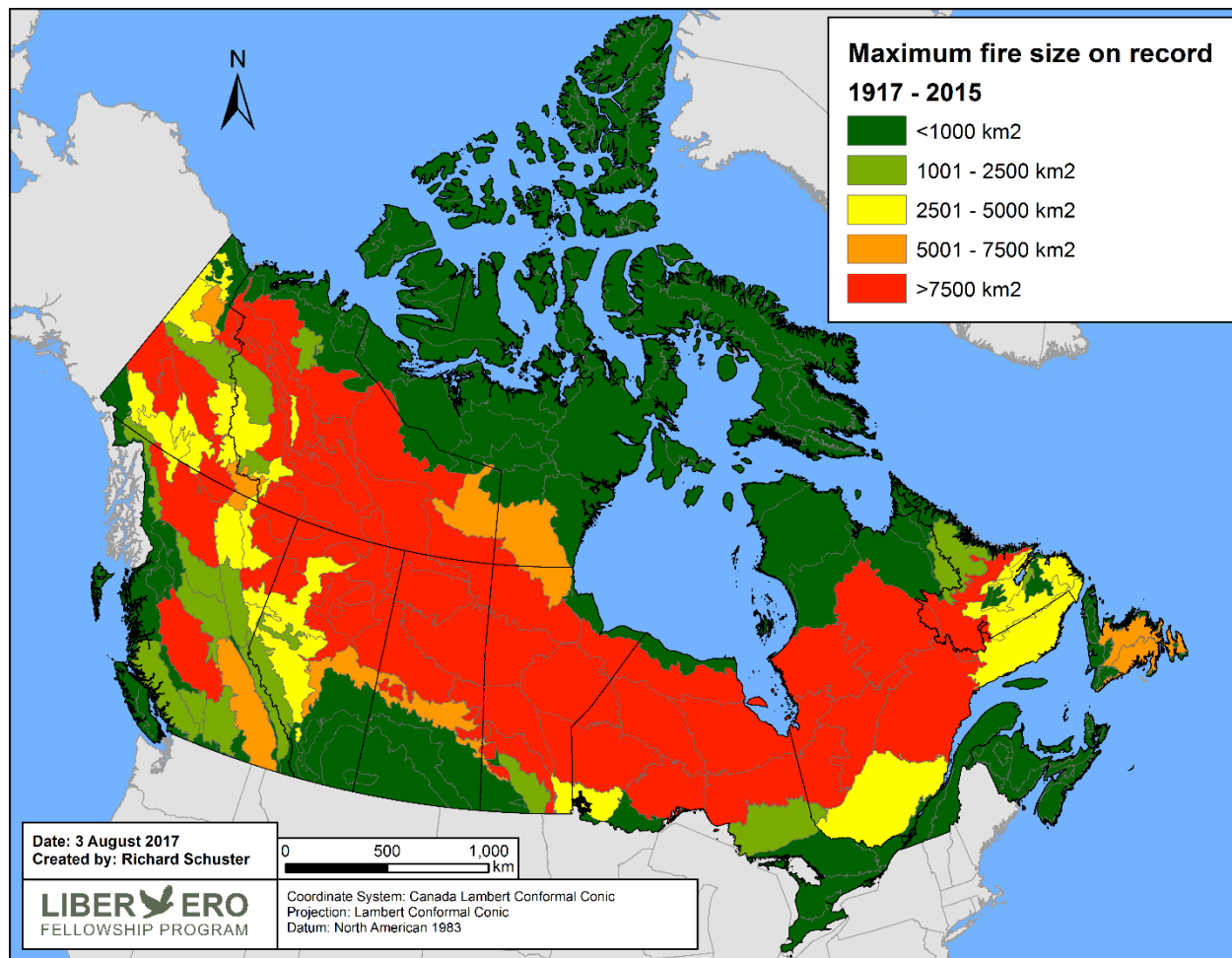
Figure 9. The maximum fire size per terrestrial ecoregion, as recorded in the Canadian National Fire Database is show. The data spans from 1917 to 2015. Data sources: Canadian Forest Service. 2016. Canadian National Fire Database – Agency Fire Data. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. http://cwfis.cfs.nrcan.gc.ca/ha/nfdb, date accessed: 7 December 2016; Ecoregions (Ecoregions of Canada 1996, National Ecological Framework for Canada, http://sis.agr.gc.ca/cansis/nsdb/ecostrat/region/ecoregion_shp.zip, date accessed: 18 May 2017)

3.5 Landscape diversity

Conservation at a landscape level is based on the idea that the distribution of flora and fauna is strongly influenced by the abiotic properties of the landscape (climate, elevation, geography, soil type, etc.) (Hunter et al., 1988). It follows that, for many species, environmental variation drives species variation and so conserving the diversity of the landscapes in a region will conserve the underlying biodiversity. This is done under the assumption that by accounting for these abiotic features there is a high likelihood that the majority of the species living in a region will be accounted for (Groves et al., 2002). This approach of conserving representative samples of broadly defined environments in order to conserve biotic diversity is often called Conserving Nature's Stage or geodiversity and is informed by enduring

features or lands facets. This is seen as a bigger picture approach that does not require extensive species-specific data and is thought to serve as a surrogate.

3.5.1 Conserving nature's stage (geodiversity or enduring features)

A recent special issue in the journal Conservation Biology (June 2015) presented nine papers and an editorial on conserving nature's stage/geodiversity. The conclusion from this review was that additional studies are needed to answer the question of whether abiotic surrogates such as enduring features can efficiently represent biodiversity. In a compendium of eight case studies that used geodiversity in conservation planning (Anderson et al., 2015), it was found that adding geodiversity targets to a traditional conservation plan (i.e., a plan designed to represent vegetation types and species) usually does not increase the total area prioritized or decrease the achievement of other targets. Under these circumstances, using geodiversity surrogates is a low-cost type of bet hedging that results in networks more robust to climate changes but that are compatible and complementary to existing plans. Geodiversity can also be incorporated into the work of agencies with legal, political, and cultural mandates to focus on the conservation of particular species (Comer et al., 2015). It has been suggested that a landscape can be classified into 1 of 4 classes of vulnerability to climate change (resistant, resilient, susceptible, and sensitive), depending on the landscape's current geodiversity, ecological intactness, and connectivity. For each class of vulnerability particular activities can be assigned to manage disturbance, restoration, and connectivity (Comer et al., 2015). In a recent effort to map environmental diversity across North America Caroll et al. (Carroll et al., 2017) produced a series of products that are useful for an approach that takes geodiversity into account. The three products that we think could be most useful for Canada Target 1 efforts are current climate diversity (Appendix, Figure 15), ecotypic diversity (Appendix, Figure 17) and land facet diversity (Appendix, Figure 16).

The first global map of land facets (geodiversity types) was created in 2015, along with frequency distributions of the sizes of individual facets and an estimate of the amount of each of the 672 land facet types that are protected in each of eight biogeographic realms (Sanderson et al., 2015). Future conservation efforts should focus on the least protected types (low elevation mollisols and vertisols) that are also the most productive for agriculture. A Canada specific approach that incorporates principles from Conserving Nature's Stage is the Rapid Assessment of Circum-Arctic Ecosystem Resilience (RACER) tool developed by WWF (Christie and Sommerkorn, 2012), which is currently restricted to the arctic, but WWF has recently started efforts to make this tool more broadly applicable for Canada.

3.5.2 Data availability and gaps for landscape diversity

One of the most widely used and easily available types of data on landscape diversity, particularly for conserving nature's stage, stems from remote sensing efforts. In a 2017 paper (Carroll et al., 2017) provided a number of data layers useful for Canada on the environmental diversity of North America. These freely available datasets include land facet diversity, elevational diversity and others. The authors of this paper are part of a group called AdaptWest (https://adaptwest.databasin.org/), a Climate Adaptation Conservation Planning Database for Western North America, which also provides data on climate velocity. Other useful sources for landscape diversity (analysis) are the SoilGrids project

(https://www.soilgrids.org) as well as the normalized difference vegetation index (NDVI) or the enhanced vegetation index (EVI), both freely available from several sources online (e.g. EarthExplorer from the USGS: https://earthexplorer.usgs.gov/).

3.6 Key Biodiversity Areas - A more holistic approach to biodiversity

In 2016, the new standard for identifying sites that contribute significantly to the global persistence of biodiversity was released by the International Union for Conservation of Nature: A Global Standard for the Identification of Key Biodiversity Areas (IUCN, 2016b). While the concept of key biodiversity areas (KBA) existed previously, there was a need to consolidate existing standards for various taxa or thematic subsets of biodiversity, such as Important Bird and Biodiversity Areas (IBAs) and Alliance for Zero Extinction sites. The new Key Biodiversity Areas standard is being applied to all elements of biodiversity (genes, species and ecosystems) as well as all taxa. In Canada, previously identified IBAs and AZE sites become global or regional Key Biodiversity Areas and will be reviewed on an 8-12 years cycle.

The global identification of Key Biodiversity Areas is being managed by the KBA Partnership (http://www.keybiodiversityareas.org/kba-partners), comprised of eleven of the world's leading nature conservation organizations. The Key Biodiversity Area Partnership, formed in 2016, will mobilize the expertise, experience and resources of the partner organizations to:

- identify, map and document thousands of Key Biodiversity Areas worldwide;
- promote targeted conservation action in Key Biodiversity Areas; and
- inform and influence public policy and private sector decision-making.

3.6.1 Background

At the World Conservation Congress in Bangkok, Thailand in 2004, the World Commission on Protected Areas (WCPA) and The Species Survival Commission (SSC) was requested to work in partnership with IUCN members "to convene a worldwide consultative process to agree [on] a methodology to enable countries to identify Key Biodiversity Areas, drawing on data from the IUCN Red List of Threatened Species and other datasets, building on existing approaches and paying particular attention to the need to:

(i) enlarge the number of taxonomic groups used for site-based priority-setting approaches;

(ii) have quantitative, transparent and objective criteria to identify Key Biodiversity Areas; and

(iii) report on progress towards achieving this objective at the 4th IUCN World Conservation Congress" (IUCN, 2005).

In response, the WCPA-SSC Joint Task Force on Biodiversity and Protected Areas was created. This task force examined the existing taxonomic-specific approaches of identifying important areas for biodiversity (such as Important Birds Areas, Important Plant Areas, Prime Butterfly Areas, Alliance for Zero Extinction, etc.) as well as other elements of biodiversity not considered by existing approaches, in

order to formulate a multi-taxon, global set of criteria for identifying important areas for biodiversity known as Key Biodiversity Areas. This revised set of Key Biodiversity Area criteria underwent an extensive global consultation process that included stakeholder engagement, technical papers, framing workshops, regional consultations, end users consultations, technical working groups (on topics such as criteria and delineation, rules and procedure, thresholds, and marine) and finally two online consultations.

3.6.2 Defining Key Biodiversity Areas

Key Biodiversity Areas are sites contributing significantly to the global persistence of biodiversity, usually identified by national constituencies using globally-standard criteria (IUCN, 2016b).While these areas must have delineated boundaries, they are not necessarily protected areas, as Key Biodiversity Area status is a designation and not a management prescription.

The Key Biodiversity Areas standard builds on several initiatives that have seen international success, notably IBAs. Identified through quantitative criteria to recognize conservation targets, they have been in use by BirdLife International since the 1980s (Osieck and Mörzer Bruyns, 1981). The identification of IBAs has been carried out in 48 countries, with regional initiatives for Europe (Heath et al., 2000), the Middle East (Evans, 1994), and Africa (Fishpool et al., 2001) and the success of this initiative has led to several projects that expanded upon the IBA approach. These include important plant areas in Europe (Anderson, 2002) and Algeria (Yahi et al., 2012), prime butterfly areas in Europe (Van Swaay and Warren, 2003), and important mammal areas in the United States (Linzey, 2002). The Key Biodiversity Areas standard builds on these single taxon approaches and other thematic subsets of biodiversity[1] to create a global set of criteria identifying areas important for biodiversity that consider all taxon and all elements of biodiversity. Many, if not most, of the biodiversity elements discussed earlier in this report are incorporated into the Key Biodiversity Area approach, including the Red List of Species, the Red List of Ecosystems, ecological process (species aggregations), endemism and ecological intactness.

This new standard consists of five major criteria, multiple sub-criteria and the associated global thresholds required to trigger each (IUCN, 2016b). The criteria for the identification of key biodiversity areas include:
- Threatened Biodiversity
    1. Threatened species
    2. Threatened ecosystem types
- Geographically restricted biodiversity
    1. Individually geographically restricted species
    2. Co-occurring geographically restricted species
    3. Geographically restricted assemblages
    4. Geographically restricted ecosystem types
- Ecological integrity
- Biological processes

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[1] E.g., places where species evaluated to be Endangered or Critically Endangered under IUCN-World Conservation Union criteria are restricted to single remaining sites (Alliance for Zero Extinction) or ecologically or biologically significant marine areas (EBAs).

1. Demographic aggregations
2. Ecological refugia
3. Recruitment sources
- Irreplaceability through quantitative analysis

Similar to the IUCN Red List criteria, triggering any one threshold, under any one criterion or sub-criterion, is sufficient for a site to be recognized as a Key Biodiversity Area (IUCN, 2016b).

Overall, the Key Biodiversity Areas standard is a tool that provides decision-makers with a quantitative, scientific understanding of which sites are important for biodiversity as well as the reasons why these sites are of particular importance.

3.6.3 Strengths and limitations of Key Biodiversity Areas

Once an area is identified as a global Key Biodiversity Area it carries the weight of having met an internationally-recognized standard. One of the strengths of this particular standard is that it is made up of quantitative criteria that can be applied consistently and repeatedly across various taxa (IUCN, 2016b) and is independently peer-reviewed by the KBA partnership. The use of quantitative criteria means that the process of identifying Key Biodiversity Areas is objective and repeatable, suggesting that the process can be done multiple times with the same results or done in different regions with consistent outcomes. This gives planners the confidence that the areas identified are truly important for biodiversity. A further strength of the Key Biodiversity Areas approach is that it is applicable across not only regions but also taxonomic groups and all levels of biodiversity. The global Key Biodiversity Areas standard makes use of the IUCN Red List of Species and the Red List of Ecosystems which have been wildly applied (IUCN, 2016b) and Key Biodiversity Areas have been identified in multiple biogeographic regions around the world including tropical Andes, Turkey, Indochina, East Africa, Caribbean, Japan and Madagascar (Eken et al., 2016; Foster et al., 2012).

Another advantage of this approach is that the KBA partnership provides for an online data management system, the (World Database of Key Biodiversity Areas). This is a standardized open database that can be accessed by all users of the data at no cost to Canada.

The Key Biodiversity Areas approach requires data and significant coordination in identification. However, in Canada most data do exist in Conservation Centers, in COSEWIC and SARA records, and government databases to allow for most criteria to be applied fairly comprehensively, relative rapidly and without significant incremental cost.

Global conservation initiatives such as biodiversity hotspots (Myers et al., 2000), endemic bird areas (Stattersfield et al., 1998) and endemic plants areas (Davis et al., 1994, 1995b, 1995a) have been effective in identifying regions for targeting conservation efforts. These initiatives, however, have not been very successful at site-specific implementation (Brooks et al., 2006). Global Key Biodiversity Areas, on the other hand, are designed to be a national or regional level bottom up approach involving local stakeholders (Eken et al., 2004).

Although Key Biodiversity Areas are not usually derived from systematic conservation planning, they can provide invaluable inputs into such processes as well as priority setting.

3.6.4   Adapting the global standard for the national perspective

The IUCN Key Biodiversity Areas standard is used to identify sites of global importance. Such sites will always be important from a Canadian perspective. However, there will also be a need to identify sites that are important for Canada, but that do not meet the thresholds of global significance.

As such, it is important to note that the global Key Biodiversity Area standard can be adapted to national and subnational scales similar to how the IBA program partnership adapted criteria identifying globally significant IBAs to identify regional (continental) and national IBAs. In other words, it is possible to adapt the criteria thresholds to make the standard relevant for identifying not only areas of global significance, but also areas of national or provincial/territorial significance. The precedent of drawing on a global standard in order to develop national criteria/threshold was previously set in Canada with COSEWIC's adaptation of global IUCN Red List criteria to guide the status assessment of wildlife species in Canada. These criteria have been in place since November 2001 (COSEWIC, 2015b).

3.6.5   Current status of Key Biodiversity Areas in Canada

As the Key Biodiversity Areas standard is a multi-taxon approach to identifying globally important areas for biodiversity, it subsumes previously identified single taxon important areas. This means that in Canada, Important Bird and Biodiversity Areas (325 globally Important Bird Area sites (BirdLife International, 2017) and Alliance for Zero Extinction sites (two sites (Alliance for Zero Extinction, 2017) are considered to be global Key Biodiversity Areas. These sites will be included as Key Biodiversity Areas until they are due to be reevaluated; at which point they will be reassessed under the full Key Biodiversity Areas standard (Stephen Woodley, personal communication, 2017).

While the majority of currently identified sites that qualify as global Key Biodiversity Areas in Canada are based on avian data, a forthcoming report looking at freshwater Key Biodiversity Areas in Canada, identifies and delineates 13 new Key Biodiversity Areas that cover 0.18% of the country's area and support 15 globally threatened species (Critically Endangered, Endangered or Vulnerable) as well as six geographically restricted species. Three species of fish and two mollusk species are also identified as Alliance for Zero Extinction species. Of these 13 areas identified, three have boundaries corresponding to previously delineated protected areas of terrestrial key biodiversity areas and 10 are newly delineated Key Biodiversity Areas (Tognelli et al., 2017).

An examination of the overlap between sites designated as important bird and biodiversity areas (Key Biodiversity Area subset) in Canada and designated protected areas reveals that nearly 70% of these sites have little or no overlap with a protected area (less than 20% by area), while only just over 8% are entirely overlapped by a protected area (
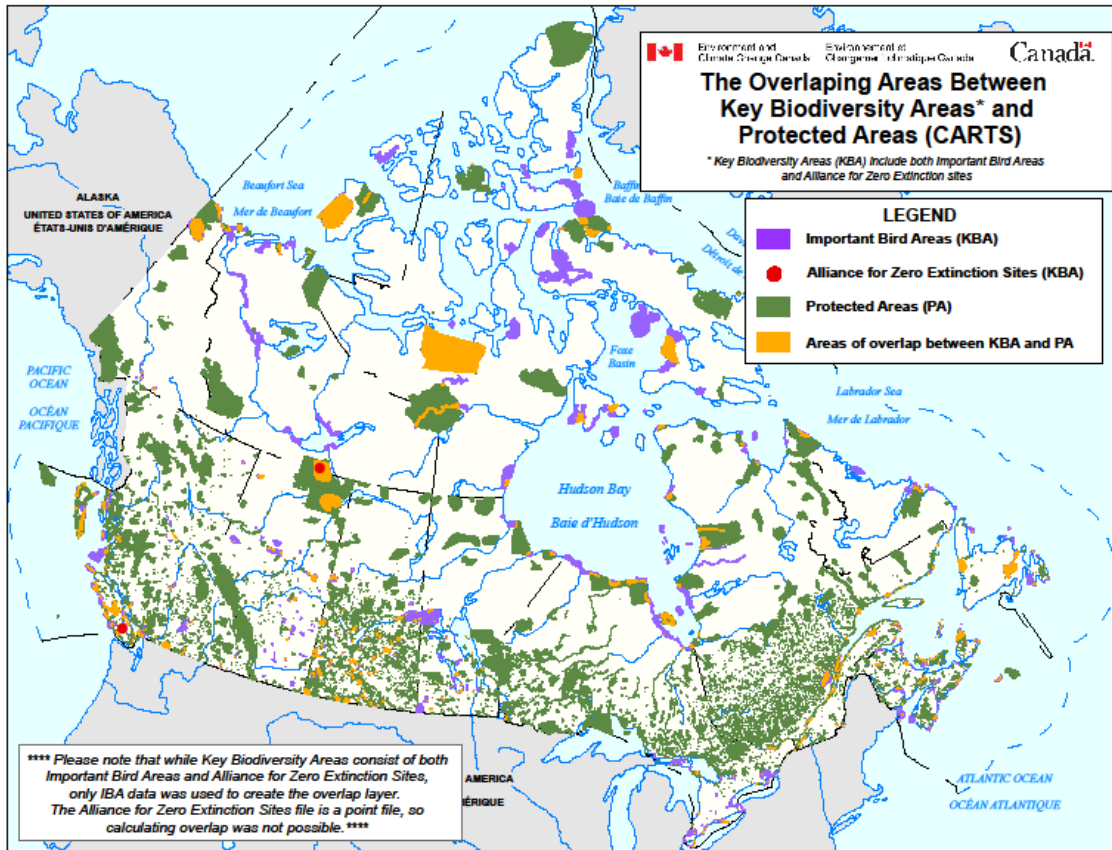
Figure 10 and Figure 11).

For potential steps on how to implement the identification of Key Biodiversity Areas in Canada, see Appendix section 8.2.
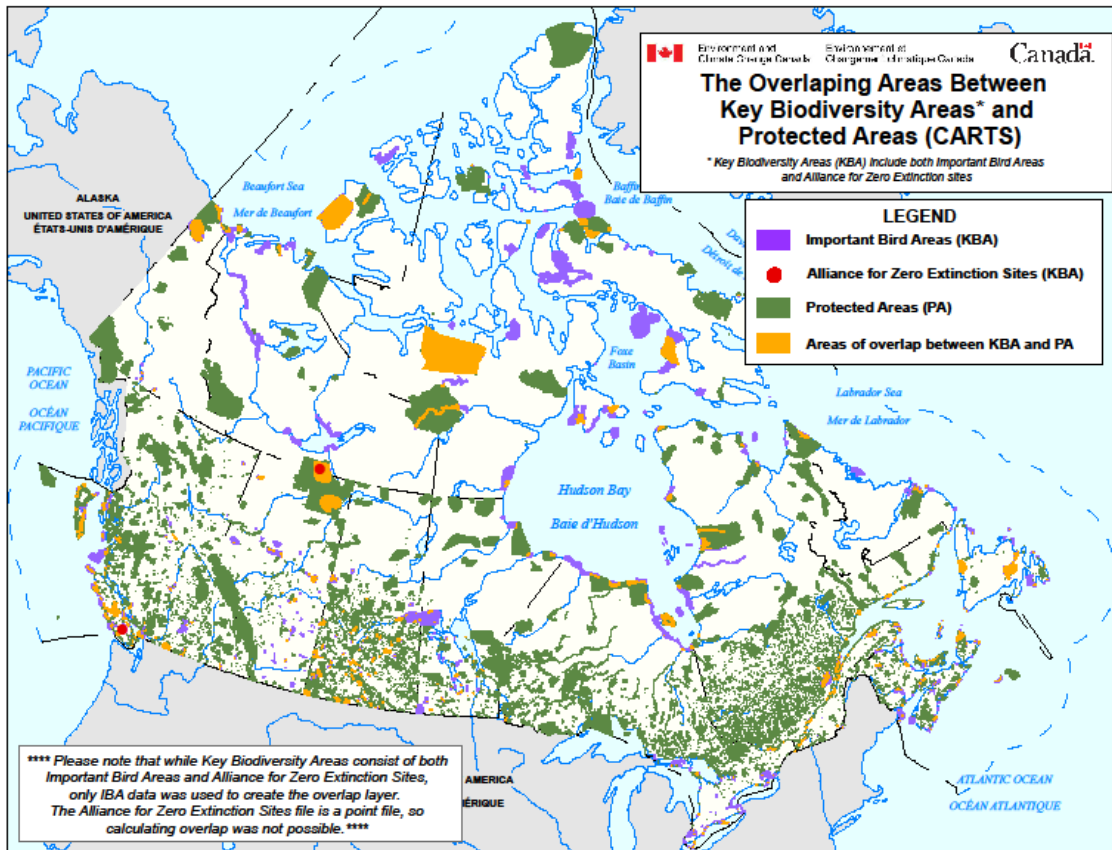
Figure 10. The Overlap of Key Biodiversity Areas (Important Bird Areas) and Canadian protected areas (federal, provincial and territorial). Alliance for Zero Extinction Sites, though also Key Biodiversity Areas, are indicated separately. Map created by Environment and Climate Change Canada, 2017.
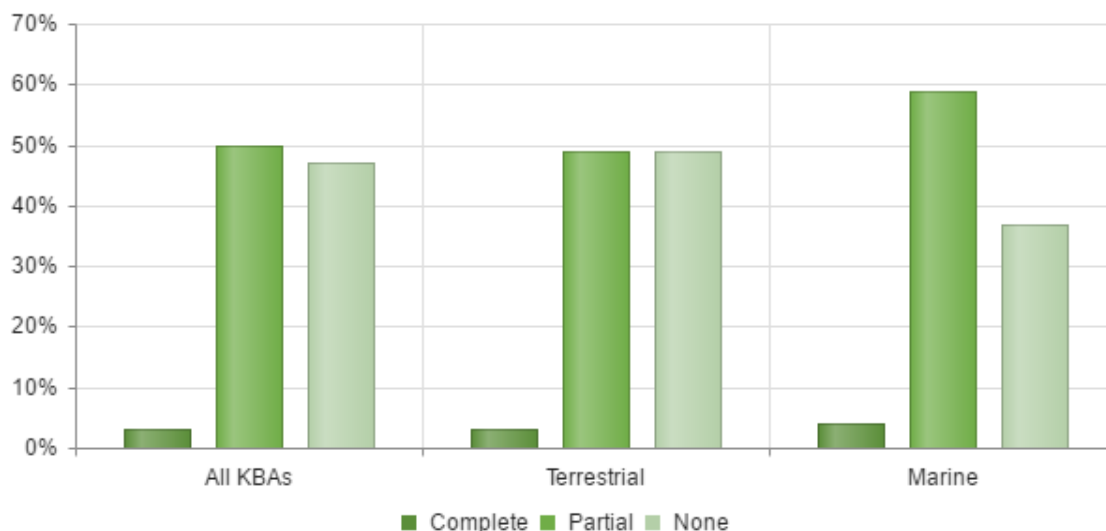
Figure 11 Protected Area coverage of all KBAs in Canada (N=326), IBAs (N=325) and AZEs (N= 2). Complete (>98% coverage) = dark green, Partial = bright green; No coverage (<2%) = light green Source: https://www.ibat-alliance.org/ibat-conservation/nbsap/display/kba

3.7   Nature Conservancy Canada's conservation assessment

 Nature Conservancy Canada (NCC), the largest land trust in the country, is currently developing a conservation assessment for southern Canada which is intended to help identify important areas Canada-wide within the Canadian national ecological framework (personal communication from Michael Bradstreet, supporting data and publications on this assessment are due to be released in 2018). In order to inform the conservation work being done by NCC and its partners, 79 ecoregions were assessed in southern Canada. This area of the country was targeted due to the high level of threat to biodiversity as well as the relatively high data availability for both biodiversity and threats to biodiversity. This data driven process focused on three assessment categories (Table 2), biodiversity, threat and conservation response, each of which included set criteria and measures. Eight biodiversity criteria, encompassing 21 measures (range map species, natural cover, important bird areas, distinctiveness, endemic richness, etc.), were examined. Threat factors included were those deemed likely to exert negative influence on biodiversity. These were grouped into 6 criteria encompassing 10 measures (human footprint, habitat risk index, watershed stress, etc.). Conservation response was developed to show "on the ground" conservation response (current actions, not plans and goals) with representation including landform features in protected areas (enduring features and elevation).

Table 2 Assessment categories and criteria for the Nature Conservancy Canada approach for their conservation assessment for southern Canada.

	Biodiversity	**Threat**	**Conservation response**
Criteria	Species at risk	Human footprint	Representation
	species richness	watershed stress	protected areas
	intactness	risk index	
	congregatory species	lack of connectivity	
	habitat diversity	climate change	
	unique and distinctive species	land cover change	
	endemic species		
	globally rare species		

This assessment categorized the 79 ecoregions assessed into four "tiers" (Figure 12) according to their total biodiversity and threat scores. The highest priority areas, or "Tier 1" ecoregions were those deemed to have high or very high biodiversity and threat scores, while "Tier 2" ecoregions were those with a high or very high total biodiversity score, but a lower threat score.

Nationally Outstanding Ecoregions in Southern Canada

Tier 1: Ecoregion with high or very high total biodiversity and threat scores

Tier 2: Ecoregion with high or very high total biodiversity score

Other Ecoregions

Tier 3: Ecoregion with low total biodiversity and low total threat scores

Tier 4: Ecoregion with low total biodiversity and high or very high threat scores

Boreal Plains Ecozone
139 Mid-Boreal Uplands
145 Western Alberta Upland
148 Mid-Boreal Lowland
149 Boreal Transition
155 Interlake Plain

Boreal Shield Ecozone
91 Lake of the Woods
92 Rainy River
93 Thunder Bay-Quetico
94 Lake Nipigon
96 Abitibi Plains
97 Lac Temiscamingue Lowland
98 Algonquin-Lake Nipissing
99 Southern Laurentians
101 Central Laurentians
107 Northern Peninsula
108 Long Range Mountains
109 Southwestern Newfoundland
112 Central Newfoundland
113 Northeastern Newfoundland
114 Maritime Barrens
115 Avalon Forest
116 South Avalon-Burin Oceanic Barrens

Pacific Maritime Ecozone
173 St.Elias Mountains
184 Mount Logan
185 Northern Coastal Mountains
187 Nass Basin
188 Queen Charlotte Ranges
189 Queen Charlotte Lowland
190 Nass Ranges
191 Coastal Gap
192 Pacific Ranges
193 Western Vancouver Island
194 Eastern Vancouver Island
195 Georgia-Puget Basin
196 Lower Mainland
197 Cascade Ranges

Montane Cordillera and Semi-Arid Plateaux Ecozones
198 Skeena Mountains
199 Omineca Mountains
200 Central Canadian Rocky Mountains
201 Bulkley Ranges
202 Fraser Plateau
203 Fraser Basin
204 Chilcotin Ranges
205 Columbia Mountains and Highlands
206 Western Continental Ranges
207 Eastern Continental Ranges
208 Interior Transition Ranges
209 Thompson-Okanagan Plateau
210 Okanogan Range
211 Okanogan Highland
212 Selkirk-Bitterroot Foothills
213 Southern Rocky Mountain Trench
214 Northern Continental Divide

Prairies Ecozone
156 Aspen Parkland
157 Moist Mixed Grassland
158 Fescue Grassland
159 Mixed Grassland
160 Cypress Upland
162 Lake Manitoba Plain
163 Southwest Manitoba Uplands

Mixedwood Plains Ecozone
132 St-Laurent Lowlands
133 Frontenac Axis
134 Manitoulin-Lake Simcoe
135 Lake Erie Lowland

Atlantic Maritime and Atlantic Highlands Ecozones
117 Appalachians
118 Northern New Brunswick Highlands
119 New Brunswick Highlands
120 Saint John River Valley
121 Southern New Brunswick Uplands
122 Maritime Lowlands
123 Fundy Coast
124 Southwest Nova Scotia Uplands
125 Atlantic Coast
126 Annapolis-Minas Lowlands
127 South-central Nova Scotia Uplands
128 Nova Scotia Highlands
129 Cape Breton Highlands
130 Prince Edward Island
131 Iles-de-la-Madeleine

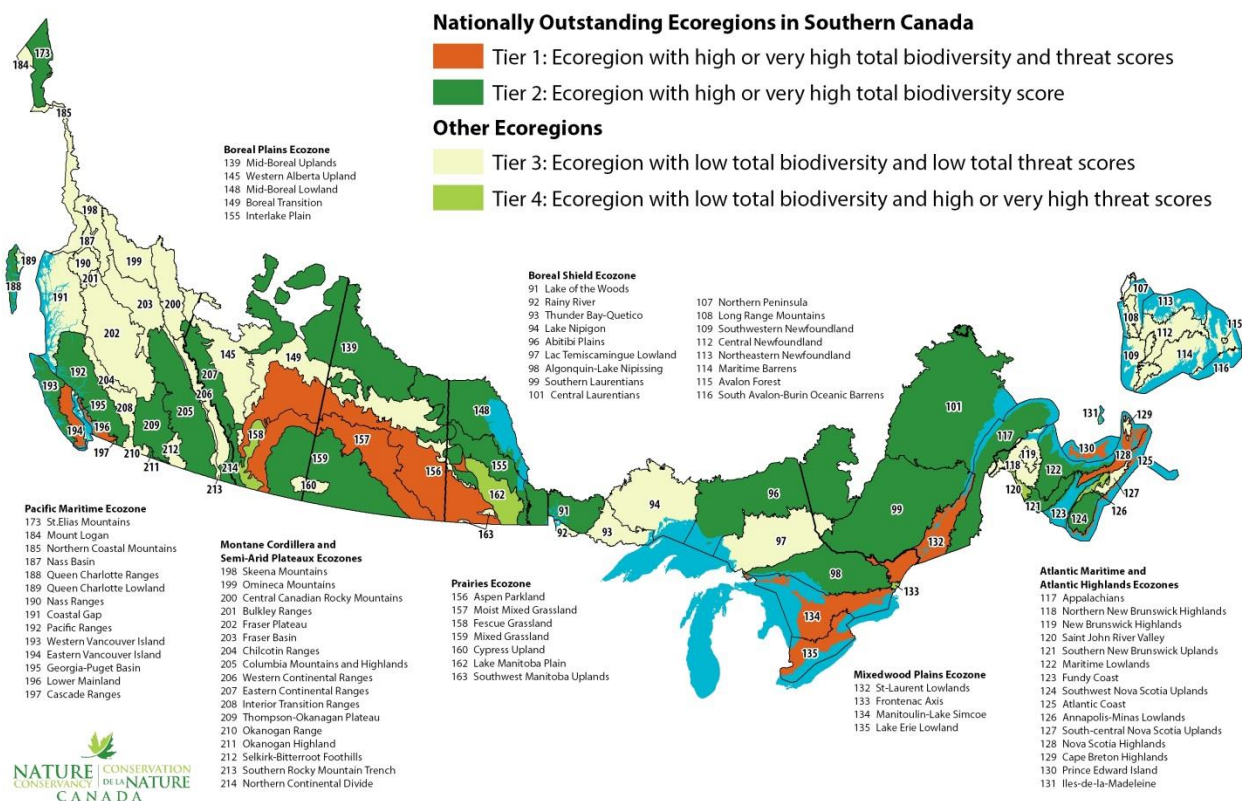NATURE CONSERVANCY | CONSERVATION DE LA NATURE — CANADA

Figure 12 Classification of 79 ecoregions by biodiversity and threat according to the Nature Conservancy of Canada's conservation assessment for southern Canada.

Many of the biodiversity criteria and measures in the NCC conservation assessment for southern Canada are very similar to those of the Key Biodiverstiy Areas criteria and sub-criteria, differences include the inclusion of species richness and climate change in the NCC approach. This approach to identifying important areas for biodiversity is an interesting one for Canada and bears continued examination as it develops and more information becomes available.

3.8   The identification of areas important for biodiversity in Canadian jurisdictions

3.8.1   Provincial and territorial approaches

In the early days of Canadian conservation, protected areas were established to safeguard beautiful scenery or threatened species. Elk Park, now known as Elk Island National Park, was established in 1906 to protect Canada's dwindling elk population. Last Mountain Lake Migratory Bird Sanctuary was officially established in 1917 to protect an important area for waterfowl. Since that time, the selection premise for conservation areas has shifted in focus to the creation of representative networks of protected areas. Within this framework, individual protected areas are still established for a variety of reasons including to protect species at risk, conserve sites of particular cultural value or to help connect

Canadians with nature. While the goal of expanding protected areas within the context of the Biodiversity Goals and Targets for Canada is to conserve biodiversity, no government jurisdiction (federal, provincial of territorial) currently has a comprehensive approach for identifying areas that are important to biodiversity.

Protected areas strategies, which often indicate the ecological elements that are considered to be important for protection, are created to provide a framework for the selection of sites for protection and defines the role, direction and scope of a protected area organization. At the end of 2015, 12 of the 16 government protected areas organizations (provincial, territorial and federal) had protected area strategies in place. While the selection of areas that may be ecologically important for protection can be approached in many ways, the majority of these Canadian government jurisdictions identifying potential parks and protected areas use a strategy based on ecological representation. This is often approached through the categorization and selection of biological features using coarse and fine filters. The coarse filter approach works on the principle that by conserving representative, large-scale features, many small scale features will be captured within these. This approach is often used to compensate for a lack of more detailed biological data; however, coarse filter approaches will not necessarily capture certain biological features. These can include threatened or endangered species, endemic species or restricted range species and a biotic, fine filter approach is therefore a necessary complement to the coarse filter approach in order to identify the existence or absence of these biological features. While ecological representation is a widely accepted conservation strategy, it should not in any way be construed as constituting a complete conservation planning strategy. It is important to keep in mind that ecological representation itself is not the objective as it is a coarse-filter surrogate for biodiversity (Canadian Parks and Wilderness Society-Yukon Chapter, 2005).

Government jurisdictions (federal, provincial and territorial) also publish biodiversity strategies, which expand on the necessity to protect biodiversity as well as the commitments and actions that are planned to be carried out within each jurisdiction. While these documents often highlight specific species or ecosystems that may be deemed of particular importance for biodiversity within a specific jurisdiction, the do not present how these biodiversity elements were selected over all others nor any cohesive, repeatable approach for identifying areas important for biodiversity. Even though the link between biodiversity and protected areas is well established (see section 2.3), biodiversity strategies do not focus greatly on protected areas, nor do they link up with protected areas strategies. A summary of the biodiversity strategies available for provincial and territorial jurisdictions is presented in Table 3.

Table 3. Published biodiversity strategies for each province and territory in Canada.

Province/ territory[2]	Biodiversity Strategy (year published)	Includes strategy for identifying areas important for biodiversity
Alberta	No specific biodiversity strategy	No
British Columbia	No specific biodiversity strategy - Special Elements of Biodiversity in British Columbia (2007) - Key elements of biodiversity in British Columbia: Some examples from the terrestrial and freshwater aquatic realms (2007)	Preliminary structure for how to identify important biodiversity. No area delineation presented.
Manitoba	Tomorrow Now: Manitoba's Green Plan (2012)	No
New Brunswick	Biodiversity Strategy (2009)	No
Newfoundland and Labrador	No specific biodiversity strategy [3]	No
Northwest Territories	Northwest Territories Biodiversity Action Plan: - Report one: Major Initiatives on Biodiversity - Report two: Gap and overlap analysis and recommendations for future actions	No
Nova Scotia	- Biodiversity: The Foundation for Environmental, Social and Economic Prosperity in Nova Scotia	No
Nunavut	No specific biodiversity strategy [3]	No
Ontario	- Ontario's biodiversity strategy - Biodiversity implementation plan	
Prince Edward Island	No specific biodiversity strategy [3]	No
Quebec	Orientations gouvernementales en matière de diversité biologique (2013)	No

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[2] Information provided is only for provincial and territorial governments. This was done both due to time limitations as well as the importance of these jurisdictions for developing and implementing biodiversity policy in Canada. It must be acknowledged however that there are many non-governmental organizations that are also contributing to the protection of biodiversity.

[3] See Ministerial briefing book (2015), Federal, provincial and territorial environment profiles as reference

Province/ territory[2]	Biodiversity Strategy (year published)	Includes strategy for identifying areas important for biodiversity
Saskatchewan	Caring for Natural Environments: A Biodiversity Action Plan for Saskatchewan's Future (2004 to 2009)	No
Yukon	No specific biodiversity strategy [3]	No

3.8.1.1 Identifying important biodiversity in British Columbia – functional importance

While no documentation showing a set of criteria for determining how to define an important area for biodiversity was found for any of the above provinces of territories. Several publications out of British Columbia did examine a set of criteria for defining important biodiversity. If complemented by guidelines on how to delineate the areas important for this biodiversity, this could be interpreted as the start of a strategy for identifying important areas for biodiversity.

In preparation for the development of a provincial biodiversity action plan for British Columbia, several reports were prepared that examine important biodiversity in this province. While the Biodiversity Action Plan was never completed (Office of the Auditor General of British Columbia, 2013), these background status reports still provide interesting insight on potential definitions of important biodiversity. One of these reports, Key elements of biodiversity in British Columbia: Some examples from the terrestrial and freshwater aquatic realms (Holt and Hatfield, 2007), provides a framework of how key elements of biodiversity might be defined and identified. Within this context "key elements" are defined as "those elements that are particularly important from a functional perspective". While the authors focus mainly on species, they do define key elements at three organizational scales - species, habitats and processes.

Key species
The authors postulate that species having a high degree of functional importance and subject to a high degree of threat that may impact their functional role should be prioritized for conservation. The species that are identified as being "key" according to these two criteria will vary according to factors such as ecosystem, community context, position within the food chain, etc.
These species are prioritized for conservation based on their population status or level of threat and their community interactions, relative to their biomass. Thus, species that are currently vulnerable or under threat and whose removal from an ecosystem would have a large, cascading impact within that ecosystem should be considered key species and prioritized for conservation. These may include:

· Organisms controlling potential dominants
· Resource providers
· Mutualists
· Ecosystem engineers
· Etc.

Key ecosystems

In this context, a key ecosystem is one that has a higher functional importance than other ecosystems and which is either common, but subject to threat or naturally rare. Other characteristics of a key ecosystem may include:

· Interfacing with multiple communities
· Having high biodiversity (resulting in a higher cascading effect if lost)
· Being naturally uncommon or relatively small
· Being under threat or vulnerable

Key processes

Key processes are the most difficult to identify as any changes to processes will have far reaching effects within an ecosystem. The authors identify two potential criteria by which processes that may be under threat may be considered as key processes:

· Those that maintain ecosystems at multiple spatial and temporal scales. Fire is a prime example of this.
· Those involving mutualism such as when a particular community or species is reliant on a particular process like nitrogen fixation in a nitrogen limited community.

The authors applied the above criteria for identifying key species, ecosystems and processes through a variety of approaches and inputs that included literature reviews, a review of the Bio Gaps database, interviews with local experts and data from the key functional relationships database. They also expressed that the identification of key elements of biodiversity will need to be placed into a broader, systematic framework within a Biodiversity Action Plan.

The authors point out within the paper that while the literature supports the high value of assessing functional importance, no examples of this being well integrated into a management planning process were found. This is attributed to a lack of scientific data to properly identify these key elements and the limitations put forward for this approach include:

· Species that may not be functionally important may also require prioritized protection, including threatened species, endemic species, etc.
· The complexity of the concept of functional importance makes it difficult to monitor
· There is likely no way to systematically determine THE key elements of biodiversity as this would vary by ecosystem, spatial scale, etc.

Overall, the authors state that: "we suggest the concept of key functional elements may have limited immediate utility since it is difficult to apply. However, the concepts are likely to be an important component of a successful conservation strategy and should be retained within the framework and used where information exists, or as new information is developed."

While this approach looks at prioritizing biodiversity at multiple scales, it does not provide guidance on delineating areas that are important for these key elements. For this approach to be successfully applied in Canada, the limitations of this strategy, including examining what potentially important biodiversity may be excluded by using criteria focused on functional importance will need to be further evaluated

and the process through which important areas for these key biodiversity elements would be delineated would also need to be examined.

Textbox 6 - Ecologically and Biologically Significant Areas (EBSA) and freshwater

Fisheries and Oceans Canada's Ecologically and Biologically Significant Areas (EBSAs) are recognized nationally and internationally as a potential tool for aquatic resource conservation, management and planning. The identification and creation of EBSAs under the Canada's Ocean's Act is well-established in marine areas of Canada and is based upon three criteria (uniqueness, aggregation and fitness consequences) and two qualifiers (resilience and naturalness), which are evaluated in the context of ecological functions and structural features. A 2014 report from the Department of Fisheries and Oceans concluded that EBSA criteria could be applied to large lake systems in Canada such as the Great Lakes and the Oceans Action Plan definition of ecological "significance" could be applied to freshwater ecosystems and species. The caveat added, however , states that considerations of scale would be very important for freshwater ecosystems and that data-poor areas, such as parts of northern Canada, would require further research in order to determine at what scale the criteria should be applied (DFO, 2014). No assessment of the application potential of EBSAs has yet been carried out in fluvial freshwater fish habitat.

3.8.2   Provincial and territorial survey

In March 2017, a short survey was sent to contacts working in the departments of parks or protected areas in each of the provincial/territorial governments. This short survey asked for basic information regarding the identification of areas important for biodiversity and ecosystem services in each province/territory. Responses to the survey were received from 10 of the 13 jurisdictions. A summary of the answers to several questions follows.

1. When asked what the balance should be between biodiversity and ecosystem services when identifying important areas, seven jurisdictions responded:

- Six jurisdictions indicated that a "biodiversity first" approach needed to be taken. One mentioned that ecosystem services would co-benefit from this approach, but would not be the primary goal. One jurisdiction stated that while both are important and both can be co-benefits for the other, when it comes to the selection of protected areas, conserving areas with high biodiversity should take precedence. Another indicated that maintaining ecosystem services depends on healthy and functioning ecosystems.
- One jurisdiction felt that biodiversity and ecosystem services are mutually compatible and therefore did not need to be balanced against one another.

2. When asked if a common framework for identifying important areas for biodiversity is desirable and possible, out of the 10 jurisdictions that answered this question:[4]

- Two jurisdictions felt that a basic, common approach could be useful, but they also recommended not limiting jurisdictions that already have existing approaches. One of these jurisdictions suggested that a common minimum standard could be set for all jurisdictions, but cautioned that this could undermine ambitious projects.
- Six jurisdictions responded that a common framework is desirable. Two of these stated that this framework would need to be sufficiently flexible to allow jurisdictions to adapt it to the regional context as well as needing to be scalable and available for data-poor jurisdictions to use. One jurisdiction stated that a more unified approach even within their own jurisdiction would improve efficiency and effectiveness of conservation efforts, while another jurisdiction stated that each jurisdiction currently "does their own thing" and having a framework with a common set of criteria and indicators that can be applied regionally as well as rolled up nationally would be ideal. One jurisdiction also indicated that a unifying framework that links to National and International reporting systems was desirable.

As a follow up, nine jurisdictions responded to the question of whether or not a data standard was also desirable and/or possible:
- One jurisdiction felt that a data standard would not work as certain jurisdictions may be more data poor than others and a standard would cause difficulty for them.
- One jurisdiction felt that this would be difficult and likely expensive
- Seven jurisdictions indicated that a common data standard would be valuable. One jurisdiction cautioned that too high a standard could be limiting in identifying or reporting sites. One jurisdiction mentioned that a standard needed to be created before privately managed working lands could be integrated in conservation networks. Another jurisdiction suggested that there would need to be some flexibility to manage local variation.

3. When asked if they had any approaches to recommend, six jurisdictions provided the following answers:
- One recommended a gap analysis balanced with the identification of key biodiversity areas.
- One recommended a systematic conservation planning approach with the goal of a representative network at an ecoregional scale.
- One recommended looking to existing standards such as Important Bird areas, RAMSAR wetlands and other similar programs.
- One indicated that systematic conservation planning should be carried out, but noted that a lack of data is often an issue for carrying out a true systematic conservation planning process.

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[4] It is important to note that the questionnaire was, for the most part, answered by people focused on protected areas. Thus, when a jurisdiction states that it has an approach for identifying areas important for biodiversity, it is referring to the process established within that jurisdiction to identify areas important for biodiversity based on a subset of biodiversity elements (generally threatened species) for the purpose of establishing protected areas. Therefore, while still very important to consider, the answers provided reflect the processes carried out within or related to parks and protected areas and not a general approach for identifying areas important for biodiversity.

- One jurisdiction indicated that key biodiversity areas should be identified along with identifying their condition, the measures in place to protect them, the gaps in their conservation and that long term objectives should be set for their management and monitoring.
- One jurisdiction indicated that a systematic conservation planning approach should be followed, which would include biodiversity hotspots, representative ecosystems, coarse/fine filter approaches, etc. as allowed by the available data.

4. Of the nine jurisdictions that answered the question asking if they were familiar with the global Key Biodiversity Areas Standard (IUCN 2016):

- Three jurisdictions responded that they were either unaware of the standards existence or that they had no familiarity with it.
- Three jurisdictions responded that they had superficial or very basic knowledge of the standard. One of these identified that a consistent approach was desirable, but was cautious regarding a "one size fits all" approach stating that it would need to allow for flexibility and professional judgement. Another jurisdiction stated that it appeared promising and another expressed a concern regarding the fact that there is a cap on the number of sites that can be created per ecoregion under the ecological integrity criteria (Criterion C, see section 3.6).
- Three jurisdictions were familiar with the standard and saw value in its application in Canada. One jurisdiction saw the global standard as a starting point for the country and suggested that tools be created to help jurisdictions adapt the standard to a finer, regional scale. It was also noted that the global standard would need to be adapted to the national scale first as the lack of appropriate information across the country would be an issue which would need to be addressed through further refinement of the criteria thresholds. The second jurisdiction saw the Standard as a key approach to biodiversity conservation and stated that protecting these areas would be integral to effectively protecting biodiversity. They also stated that current approaches focus on protecting areas that can potentially support biodiversity, such as enduring features, but that these are only valuable if there are source areas for species to come from. The third jurisdiction saw Key Biodiversity Areas as being potentially useful in recognizing biodiversity elements, but cautioned that the standard is intended to help inform management decisions and while this would inform conservation priorities, it should not be the sole basis for identifying new protected areas.

3.9 An indicator for areas important for biodiversity

"An indicator is a measurement or value which gives you an idea of what something is like"

"Collins English Dictionary" 2017

Indicators are used to assess the degree to which a specified target has been attained. They should help answer the question: "How are we doing at attaining our goal?". Selecting the proper indicator requires asking the proper questions, such as what do we want to assess and why? A simple, real world example of an indicator is the check engine light in a car. This light indicates the status of your engine; if it lights up, you know that you need to find out what is wrong and take action. An indicator for identifying areas important for biodiversity should provide a clear indication of the state of progress towards a stated goal and highlight when there may be an issue to be addressed.

3.9.1   Selecting an indicator

According to the Biodiversity Indicators Partnership (Brooks and Bubb, 2014) a successful indicator must possess certain key attributes. These include being:

- Scientifically valid (known relationship between indicator and purpose, reliable and verifiable data, etc.);
- based on available data allowing it to be produced regularly over time;
- easily understood; and
- championed by an institution that will take responsibility for its continued production and communication.

With respect to areas important for biodiversity, the main question that must be asked is whether or not, or to what degree, areas important for biodiversity are being protected.

Main indicator:

> Proportion of important areas for biodiversity that are within protected areas

The Canadian Environmental Sustainability Indicators program (CESI) currently reports the extent of protected areas in Canada by ecozone, by province/territory and nationally by biome. There is currently no reporting metric to evaluate the extent to which established protected areas overlap with areas identified as important for biodiversity. This is due in part to the lack of a national standard for identifying areas important for biodiversity.

Suggested Action

   Update how CESI reports on protected areas in Canada to include reporting by ecoregion.

Considerations:

- In order for this to be calculated and monitored, there will need to be an agreed upon definition as to what constitutes an "area important for biodiversity".
- This indicator can be extended to also report on areas important for biodiversity covered by Other Effective Areas-Based Conservation Measures (OECM) (i.e. the number of areas important for biodiversity that are covered by an OECM), once these have been formally defined in Canada.
- Canada currently reports on terrestrial and inland freshwater jointly. Consideration should be given to moving towards reporting on these two separately.

3.9.2   Current global indicators for areas important for biodiversity

In 2010, the existing global indicator for "increasing coverage and effectiveness of protected areas" was the Protected Areas coverage of Important Bird Areas and Areas for Zero Extinction (Tyrrell T. et al., 2011). Since that time, the global indicator put forward by the Biodiversity Indicators Partnership has been updated and is now accepted to be the coverage of Key Biodiversity Areas by Protected Areas.

A current example of this is a biodiversity indicators dashboard (Han et al., 2014)), developed by NatureServe with the goal of enabling users to track biodiversity and conservation indicators. Within this dashboard four specific biodiversity indicators are examined:

- Pressure on biodiversity (deforestation rate)
- State of species (the IUCN Red List Index)
- Conservation response (Key Biodiversity Areas)
- Benefits to human populations (freshwater provision)

The conservation response indicator examined is calculated as the mean percentage determined by the area of Key Biodiversity Areas covered by protected areas divided by the total Key Biodiversity Area. Note also that the fourth indicator, benefits to humans, is an example of an indicator for ecosystem services (see section 4.6).

This dashboard initiative is currently only incorporating global data to analyze global indicators; however, the aim of this project is to eventually expand this to incorporate national and site-scale data in order to track progress towards Aichi Targets.

It is important to note that while the protected areas coverage of Key Biodiversity Areas is a valid conservation response indicator, it is not necessarily sufficient if examined alone. For example, whether or not these areas are well managed would also be important to assess.

3.10 Options for identifying areas important for biodiversity in Canada

In response to a provincial and territorial survey (see section 3.8.2) the majority of respondents indicated that a common framework for identifying areas important for biodiversity in Canada as well as a common data standard are desirable. There are many ways in which identifying areas important for biodiversity in Canada could be approached; three broad options are included in Table 4.

Table 4. Options for identifying areas important for biodiversity in Canada including pros and cons.

Options	Details	Pros	Cons
Option 1 Each Province or Territory creates an individual standard for identifying areas important for biodiversity	· Each province and territory is encouraged to explicitly and publicly lay out their approach for identifying important areas for biodiversity. · This would need to be distinct from either the protected areas strategy or the biodiversity strategy and would need to provide a repeatable process with criteria and thresholds for identifying important areas. · To support this process, a working group of experts is assembled that will: - Provide support for jurisdictions that may not currently be aware of the latest research on important areas for biodiversity. - Provide support for jurisdictions to continue improving standard for identifying areas important for biodiversity one it is created.	· This option would allow each government jurisdiction to customize their strategy according to the biodiversity situation (i.e. priority of species at risk, presence of intact landscapes, etc.) in their jurisdiction.	· Without a common, established framework to guide this development, the products produced will vary drastically and may be applied with limited success. · National reporting on areas important for biodiversity will be difficult due to the varied criteria for each jurisdiction. · Biodiversity does not stop at jurisdictional borders (nor do ES), differing criteria and priorities may make collaborations between jurisdictions difficult. · Not all jurisdictions have an up to date biodiversity strategy or a protected areas strategy; this makes it seem unlikely that each provincial or territorial jurisdiction will be able to follow through with the development of a standard for identifying areas important for biodiversity before 2020. · Given the expressed desire from jurisdictions for a common framework (see section 3.8.2), it is possible that one may still be desired a later date causing this option to be more expensive and time consuming in the long-run.

| Option 2 Create a custom national strategy for identifying areas important for biodiversity | · Assemble a team that would determine what criteria for biodiversity would be important to consider in Canada (threatened biodiversity, restricted range biodiversity, rare biodiversity, etc.), ensuring that all elements of biodiversity are accounted for (genes, species, ecosystems, processes).
· Assemble all criteria into a complete standard for identifying areas important for biodiversity and determine suitable thresholds for each (i.e. if greater than 10 breeding pairs of a threatened species are found a specified area, this area is deemed important).
· Define how important areas are to be delineated.
· This process could potentially be modelled after the Nature Conservancy of Canada's conservation assessment for southern Canada (forthcoming). | · This would ensure that elements of the standard are suitable for the Canadian context.
· A national approach would simplify national reporting. | · Extensive expert and public consultations will be required
· Each criteria and associated threshold will require extensive testing to ensure that it is suitable for capturing important biodiversity.
· The approach may not meet international standards and may make reporting internationally difficult
· This process will be extremely time-consuming and it is unlikely that it would be in place by the year 2020.
· Once a national standard is created, it would still need to be adopted by provincial and territorial governments, which would then need to adapt it to their jurisdiction (see option 1 above)
· If there was a desire to model a national strategy after the Nature Conservancy of Canada's conservation assessment for southern Canada (forthcoming), further research into how this could be applied more broadly across all of Canada, particularly in northern Canada, would be required. |

| Option 3 Adopt and adapt the IUCN global standard for identifying Key Biodiversity Areas | · This would be based on the global standard released by the IUCN in 2016
· This global standard is designed to be adapted at national and sub-national levels through the modification of the criteria thresholds.
· This would be a complementary approach, meant to add value to current Canadian approaches, not to replace them. | · The global strategy is designed to be adapted to the national and sub-national context through the modification of criteria thresholds.
· Consolidates previously tested Important Bird Areas and other single taxon approaches in to a multi-taxon standard with tested criteria
· Incorporates all elements of biodiversity
· The KBA Partnership, the body managing the global identification of Key Biodiversity Areas, supports the identification of global Key Biodiversity Areas.
· Of three Canadian jurisdictions that were familiar with the global Key Biodiversity Areas strategy, all three saw value in adopting it in Canada (see section 3.8.2)
· As a global strategy with tested criteria and global thresholds that already exist, this will be one of the least costly options.
· As work on key biodiversity areas is currently underway in Canada, it is likely that the identification of global and possibly national key biodiversity areas could be completed by 2020.
· A Key Biodiversity Areas database and data storage has already been created globally. | · Of the nine Canadian jurisdictions that responded to the survey question on Key Biodiversity Areas (see section 3.8.2), six of them had either never heard of, or knew very little of, the global strategy; therefore increasing awareness would be essential.
· Adapting the standard to the Canadian context will require testing and establishing national and sub-national thresholds for the global criteria.
· Additional approaches to account for climate change would be required as this is not part of the Key Biodiversity Area standard. |

4 Identifying areas important for ecosystem services

4.1 What are ecosystem services?

Ecological or ecosystem services (ES) are the benefits that people derive from natural and semi-natural ecosystems (Millennium Ecosystem Assessment, 2005). These benefits include the production of materials critical for life (e.g., *provisioning services*: food, air, water, timber, fiber), processes that maintain favourable environmental conditions for people and their activities (e.g., *regulating services*: mitigation of extreme events, carbon storage, improvement of water quality, maintenance of pollinator populations), and more intangible contributions to quality of life (e.g., *cultural services*: recreational, educational, and spiritual opportunities) (Millennium Ecosystem Assessment, 2005).

As ES are of critical importance to people, their wellbeing, and economies, they are increasingly being included in land use planning, natural resource management, and conservation decision-making (Harrison et al., 2014). It is important to note, however, that the ES concept only captures some of the ways that people depend on the functioning of healthy ecosystems; it was created primarily to increase the awareness of decision-makers and society of the critical contributions that ecosystems make to human well-being (Daily et al., 1997). ES as currently defined do not fully capture all that is important about ecosystems or how they should be managed and do not replace other ecosystem-focused analyses. In most cases consideration of ES should be applied in combination with other biophysical and ecological approaches (Value of Nature to Canadians Study Taskforce, 2017).

ES are fundamentally interactions between ecosystems and people; both components must be present for an ES to be realized (Mitchell et al., 2015). This is a consequence of the definition of ES, that they are benefits provided to people. For example, the ability of a wetland to capture floodwater and improve water quality does not result in an ecosystem service unless there are people downstream that can benefit from these functions. The assessment of ES therefore requires measurement of the capacity of ecosystems to produce ES, as well as the actual ES benefits realized by people (de Groot et al., 2010), as social groups have different values around and access to ES (Diaz et al., 2011). It is therefore common in ES assessments to quantify both ES supply (i.e., the potential capacity of an ecosystem to produce an ES) as well as ES demand or flow (i.e., the realization of a benefit from an ecosystem by people) (Bagstad et al., 2013a)(Villamagna et al., 2013). For example, Bagstad et al. (Bagstad et al., 2014) quantified locations where flood regulation and sediment regulation are produced, where the beneficiaries of these ES are located, and the spatial connections that connect the two across the Puget Sound of Washington state. Critically, the social-ecological nature of ES means that accurately quantifying them and identifying areas important for ES typically requires biophysical, ecological, and socioeconomic data (Jones et al., 2016). In other words, the multiple dimensions of the value of ES to people requires a range of analytical approaches, data and information as well combined in a multi/interdisciplinary way (Pascual et al., 2017). Similarly, the supply, demand, and flow framework is not always suitable for conceptualizing ES, especially many cultural ES or how Indigenous Peoples characterize their experiences and relationships with nature (Díaz et al., 2015); (Chan et al., 2016).

ES are increasingly being incorporated into conservation planning because they are thought to better represent the costs and benefits of alternative land planning options to people (Daily and Matson, 2008; Naidoo et al., 2008) . The assumption is that this will lead to more successful conservation that will preserve both species and human livelihoods (Kareiva et al., 2007). There are two main rationales for this shift. First, many argue that explicitly incorporating human benefits and values into conservation planning, as opposed to a biodiversity-only focus, will lead to decisions that can protect biodiversity and minimize impacts to nearby communities or even improve their condition (Tallis et al., 2008). Second, it is widely assumed that areas with high biodiversity will also provide more, or higher levels of ES (Balvanera et al., 2006, 2014)(Balvanera et al., 2014) and that win-win locations for both biodiversity and ES will be common. While biodiversity does underpin many ES and species loss affects a large number of ES (Cardinale et al., 2012), the exact relationship between biodiversity and ES provision varies greatly depending on the ES in question and the social-ecological context in which that ES is realized. Determining these links between ES and biodiversity is a current area of intense research (Chazdon et al. 2009; Harrison et al 2014; Balvanera et al 2014; de Groot et al 2014).

4.2   Ecosystem services in urban, rural and wilderness areas

ES are highly relevant in urban, rural and wilderness areas. As predominantly built environments, the ecosystem components in urban areas that provide many ES must often be planned for and incorporated through urban design. Of particular relevance in light of climate change are the moderating effects from heat, wind, and stormwaters provided by urban forests and tree canopy in parks and along streets and in private yards. Biodiverse selections in urban vegetation choices encourage resilience against the loss of this canopy through natural controls of species-specific pests and diseases. Urban forests provide many additional ES such as oxygen production and air quality regulation, carbon sequestration, creating habitat for songbirds, and supporting recreation, leisure, cognitive health and emotional well-being. For example, the *Canadian Nature Survey* found that more than half of Canadian adults participated in nature-related education activities such as visiting a public garden less than 20 kilometers from their homes (Canada et al., 2014). Likewise, the 2013 *Households and the Environment Survey* found that 25% of Canadian households have birdfeeders and birdhouses in their yards (Government of Canada, 2015).

Many vital ES are also produced in rural areas surrounding towns and cities. The degree of human intervention required to produce or maintain these ES varies. Some have direct consequences in adjacent urban areas, such as the role of wetlands in flood mitigation and the role of both wetlands and forested areas in protecting water quality. Wetlands provide a wide array of ES in each of the four broad categories identified through the UN Millennium Ecosystem Assessment process. The 2006 Ramsar technical report on wetland value charted the relative extent of each ecosystem service provided by different classes of both inland and coastal wetlands (Groot et al., 2006). The report found for example that inland wetlands provide the following ES: provisioning (e.g. food, water, fiber, biochemical products, and genetic materials); regulating (e.g., climate, hydrology, pollution control and detoxification, erosion control, and natural hazards regulation); cultural (e.g., spiritual and inspirational,

recreational, aesthetic, and educational); and supporting (e.g., biodiversity, soil formation, nutrient cycling, and pollination).

Some other rural ES include farm crops and wild-harvested foods that are consumed by people locally, regionally, and further afield. Increasingly the rural landscapes provide a form of leisure and education through agritourism, attracting people from across regions. Ecosystem services are essential for the functioning of rural landscapes as well, for example, by providing and filtering groundwater and providing wildlife habitat for many species including, importantly, pollinators.

Although difficult to estimate conclusively, the United Nations (UN) Food and Agriculture Organization (FAO) cited the global value of pollination *only* for food crops as €(2009)153 billion (C$(2009)243 billion) (Bank of Canada). This does not account for pollination of non-food-bearing trees and other plants that are important to other economic sectors. Nor does it account for the role of pollinators in biodiversity and ecosystem functions, including the persistence of natural vegetation. And it does not account for the other ES provided by pollinator species (e.g., insect control). A review of expert literature by the FAO reported in 2013 that "Eighty-six percent of all flowering plant species require an animal pollinator to reproduce (Ollerton et al., 2011). About one-third of food production depends on animal pollinators, and 75 percent of all fruits and vegetables increase production when visited by animals (Klein et al., 2007)."[5]

Pollination by domestic honey bees alone is valued at well over C$2 billion per year in Canada (Agriculture and Agri-Food Canada, 2015), and more than US$15 billion per year in the United States. The annual value of pollination by all pollinators (wild and domestic) combined in the US is estimated at more than US$24 billion (The White House, 2014). The continued decline of pollinators will have direct costs for the agricultural, food, cosmetic, pharmaceutical, and other sectors that rely on pollinated plants for production, with a wider range of impacts on society, for example human health.

 A full suite of ES are also associated variously with more remote, undeveloped, or lightly populated landscapes across Canada. Some of these ES are locally generated and their human 'recipients' (beneficiaries) may also be local, but beneficiaries may also be at greater distances. For example, forests in Canada are vital for carbon sequestration and influence larger-scale climate patterns. They are also essential habitats for migratory species, and important sources of genetic materials and biochemical products, places associated with cultural identity and knowledge.

It is clear then, that ES are important to urban, rural, or wilderness settings. The idea of "ecosystem services" presupposes the presence of human beneficiaries of those services, but is not defined by immediate proximity of people to unspoiled landscapes because the ecosystem processes and functions that generate ES occur at many different scales and can "travel" great distances to reach beneficiaries, and of course people can travel great distances to benefit from some ES.

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[5] FAO 2014: 4. "Animals" in this quote refers to many types of insects, birds, bats, and other mammals.

4.3   Key challenges in mapping and quantifying ecosystem services

Determining key areas for ES depends on being able to identify and map locations where ES are supplied by ecosystems as well as where the benefits of these ES are realized and by whom (Burkhard et al., 2012). The interdisciplinary nature of ES and the need to consider both ecological and social data also makes identifying key areas for ES challenging. Previous ES mapping projects have identified the following key obstacles:

° ***Determining which ES to assess.*** The list of potential ES to assess for any given location or region will be long and most likely it will not be possible to evaluate every ES (Primmer and Furman, 2012). Important ES will also likely vary across socioeconomic and cultural beneficiary groups (Diaz et al., 2011). Priority ES for the assessment will need to be identified in a systematic, transparent, and defensible manner. These range from expert-based approaches where key ES are identified and selected by experts, to participatory approaches where key stakeholders and groups are consulted to determine the which ES should be included in the assessment (Preston et al., 2017).

° ***Selecting the specific methods, indicators, and spatial scale to quantify and map ES***. Directly measuring ES is often not feasible except for provisioning ES like crop production, timber, or water where clear market pricing signals already exist. Instead, proxies or indicators for ES provision are often used. For some ES biophysical and ecological data will be most appropriate, while for other ES social and economic data is required. Selecting the best indicators and data for each key ES is almost always a balance between availability, accuracy, reliability, and cost.

° ***Choosing the method to identify areas of importance for ES.*** While a large number of studies have quantified and mapped ES spatially, only a limited number have attempted to identify key locations for ES provision. Added complexity is introduced due to the fact that the location where an ES is supplied (e.g., sediment absorption by upstream aquatic ecosystems) might not necessarily be where the ES benefit to people is realized (e.g., water reservoirs near human settlements).

4.4   Current methods for identifying areas important for ecosystem services

The first step in identifying areas important for multiple ecosystem services is quantifying and mapping ES provision. Because ES are the result of complex social-ecological interactions, there are a wide variety of methods to do this, and there is no standardized way to quantify all ES. Often, different methods are used for each ES, depending on the ES in question, data availability, and project purpose. These different methods can be roughly broken down into three types: empirical/process-based modeling approaches, participatory approaches, and expert-based approaches.

Empirical and Process-Based Model Approaches. Data available via field measurements, remote sensing (de Araujo Barbosa et al., 2015; Ayanu et al., 2012)(de Araujo Barbosa et al., 2015), social surveys, or censuses can be used to directly quantify ES or proxies for ES. This can include both measures of ES supply (e.g., crop production, biomass, water quality) and ES demand (e.g., population density, food consumption, water extraction), although the latter is less common (Wolff et al., 2015). Most

commonly, simple methods are employed, such as using land use/land cover (LULC) categories (e.g., forest type, wetland, agricultural, etc.) as proxies for ES supply (Schägner et al., 2013). Data from biophysical assessments are also used, although these usually can only identify the types and locations of ecosystems that generate ES, and not how those ES flow to beneficiaries (Haines-Young et al., 2012). Empirical methods are used most often to map regulating ES, followed to a lesser extent by provisioning and cultural ES (Martínez-Harms and Balvanera, 2012).

In some cases where scientific understanding allows, empirical data can be combined into process-based models to quantify ES across a study area. The best known modeling framework for this is the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) set of models developed by the Natural Capital Project at the University of Stanford (Tallis and Polasky, 2009). The InVEST set of models can quantify 17 different terrestrial, freshwater, and marine ES incorporating both ES supply and demand. InVEST has been used to model ES around the world, notably in the Willamette Basin of Oregon (Nelson et al., 2009) to model changes in water quality, soil conservation, storm peak management, and carbon sequestration across future LULC scenarios.

An alternative model, the ARIES framework (Artificial Intelligence for Ecosystem Services) uses advanced statistical methods to model and map ES flows. Bagstad et al. (Bagstad et al., 2013b) provides a comprehensive comparison of 17 of these types of ES decision-making tools. Notably, only one of these tools – Co$ting Nature – is designed specifically to identify priority conservation areas based on biodiversity and ES. However, it does not allow mapping of individual ES or their tradeoffs.

ES proxy data and modeling methods can also be combined to map ES or the supply and demand components of ES. Nedkov & Burkhard (Nedkov and Burkhard, 2012) combined widely-used process-based hydrologic models to estimate the ability of different land cover types to regulate flood waters with secondary data on elevation and land use to quantify ES demand. Combined methods were also used to map ES in the Central Coast Region of California by Chan et al. (Chan et al., 2006). Here, six ES (carbon storage, flood control, forage production, pollination, recreation, and water provision) and biodiversity were modeled using a variety of primary and secondary data. The authors then used MARXAN (Ball et al., 2009), a spatial optimization algorithm that generates conservation networks to meet multiple targets, to explore how conservation goals for biodiversity aligned with ES provision. A study in South Africa (Egoh et al., 2011) used similar methods and MARXAN to map five ES to identify key areas to protect ES.

One prevalent method to utilize empirical data to quantify ES provision is the benefits- or value-transfer method. Quantification of ES benefits, either in monetary or sociocultural values is subject to much debate from both methodological and conceptual perspectives. Practically speaking, valuation requires collection and analysis of primary data and this can be a resource-intensive exercise. One approach that is often used to overcome this is the value transfer method. Here, monetary or sociocultural values for ES are estimated for specific land use/land cover (LULC) categories in one region, and then these values are transferred for use by another region based on the same LULC classification (Maes et al., 2012a)(Plummer, 2009). The assumption is that specific LULC categories (e.g., forests, wetlands, etc.) in both areas provide similar ES that are valued and used in comparable ways by people. However, this

transfer is only valid where the two regions share a similar physical landscape, where the social and cultural values of the beneficiaries are similar, and the sampling and quantification of ES in the primary region is large and unbiased (Brown et al., 2016). In most cases, value-transfer methods result in a variety of errors since these assumptions are often unlikely to be met (Plummer, 2009; Tognelli et al., 2017)(Tognelli et al., 2017).

Suggested Action
Investigate and utilize the expertise and tools (e.g. Co$ting Nature, MARXAN) to identify priority conservation areas based on ecosystem services (and biodiversity) provision.

Overall, seven key challenges in quantifying and mapping ES using empirical data have been identified:

1) data scarcity and uncertainty, especially for primary data (Egoh et al., 2007; Maes et al., 2012a; Troy and Wilson, 2006) across different regions or at national scales;
2) the fact that proxy data (e.g., LULC, soils, vegetation, and nutrient related indicators) are most commonly available but also have the highest potential to inaccurately quantify ES (Crossman et al., 2013; Eigenbrod et al., 2010; Maes et al., 2012a);
3) spatial scale mismatches between the available data and the processes at which ES operate (Burkhard et al., 2013);
4) significant shifts in ES provision as the spatial scale of available data changes that are not equal across different ES (Grêt-Regamey et al., 2014)(Anderson et al., 2009; Grêt-Regamey et al., 2014);
5) ES models are difficult to validate using primary or secondary data and therefore are often unvalidated (Schägner et al., 2013);
6) the methods for mapping different ES are diverse, making it difficult to develop consistent and realistic methods that can be applied at national levels for broader conservation decision-making (Crossman et al., 2012);
7) identifying beneficiaries, their location and use of ES (Egoh et al., 2007).

Despite these challenges, we can still continue to improve our knowledge base and data sets, as well as mapping accuracy.

Suggested Action
Move forward in considering and improving ES estimates regardless of the challenges identified.

Participatory Approaches. Participatory approaches utilize the personal experiences of relevant stakeholders and the public to identify areas important for ES provision. Most commonly this is done through Public Participatory Geographical Information System or Participatory Geographical Information System (PPGIS/PGIS) methods (Brown and Fagerholm, 2015). Here, the experts or the public are asked to map locations that correspond to the places in the landscape where they perceive ES are provided (Brown et al., 2012), either on physical paper maps, or using online of computer-based mapping software. Examples where these methods have been used include mapping of the range of cultural ES in eastern Germany (Plieninger et al., 2013), quantify key ES areas and their threats in southeastern

Australia (Raymond et al., 2009), and cultural and provisioning ES in the Peace River watershed of British Columbia (Darvill and Lindo, 2015).

This type of approach is especially useful for identifying provisioning and cultural ES (Brown et al., 2012), while regulating services can often be difficult for most lay public to quantify (Brown and Fagerholm, 2015). PPGIS/PGIS can also allow the type of ES provided in a given study region to emerge from the research process (Brown and Fagerholm, 2015). It is also argued that participatory exercises like these are more likely to result in decisions that meet both social and ecological needs (Chazdon et al., 2009). Challenges of using PPGIS/PGIS methods include: (i) distinguishing between areas that supply high levels of ES but have little human demand, from those where ES supply might be more modest but demand is higher; and (ii) spatially differentiating between those areas that supply an ES and those pathways that allow ES to flow to beneficiaries. To address this first point, García-Neto et al. (García-Nieto et al., 2013) used semi-structured interviewing and GIS to map ES supply, but face-to-face questionnaires to assess ES demand in the Sierra Nevada of Spain.

In some cases ES values from participatory approaches have been mapped to larger areas based on landscape features (Brown and Fagerholm, 2015), basically a value-transfer approach. The SolVES (Social Values for Ecosystem Services) model specifically allows users to assess, map, and quantify the perceived social value of ES across a region using data from public surveys (Sherrouse et al., 2011). A broader, global-scale analysis of these relationships found that sociocultural values of ES (i.e., place-based landscape values such as esthetic/scenic, economic, recreation, spiritual, historic, cultural, and wilderness values) are most often correlated with forests and water bodies, while agricultural lands often have low provision of these place-based sociocultural values (Brown, 2013).

Expert-based Approaches. These types of approaches use expert-knowledge to either map areas important for ES or assign ES values to different LULC categories. One common method is the "matrix model" where the capacity of each LULC category in a given study area to supply a variety of ES is quantified using expert knowledge (Burkhard et al., 2012). While this method is fast, accessible and adaptable, there are also questions about the scientific rigour of this approach, its legitimacy, and transparency (Jacobs et al., 2015). However, including uncertainty in the matrix model, carefully choosing the expert pool, incorporating expert opinions iteratively until results converge, and validating the matrix results, have all been proposed to create a stronger matrix approach (Jacobs et al., 2015). Many of these suggestions were incorporated in a study of ES in the Swiss Alps (Grêt-Regamey et al., 2013). This study employed an iterative process, where ES are first mapped using empirical data and process-based models, and then expert knowledge is used to update and improve these maps, identify areas with implausible ES values, and reduce uncertainty. The expert knowledge is then used to improve the original ES models.

Methods for Identifying Key ES Areas. Most approaches for identifying key areas for ES have been limited to cold and hotspot analysis: pinpointing those locations where a high or low number of ES are supplied or realized compared to the average across other locations in the study area. Results of these studies have varied, with many studies finding key ES hotspots (Qiu and Turner, 2013) that are well differentiated from coldspots (Li et al., 2017), while other studies have seen little overlap in hotspots

between different ES (Egoh et al., 2008). One source of this inconsistency could be the statistical methods used to identify cold/hotspots. A study of different ES cold/hotspot methods in national forests of Colorado and Wyoming (Bagstad et al., 2017) found wide divergence in the number of cold/hotspots identified and their spatial location. Currently, there is very little advice or knowledge around the appropriate methods for identifying key areas for multiple ES.

A combination of approaches may best capture mapping requirements. Expert-based approaches can be combined with participatory mapping techniques to map key areas for ES. Palomo et al. (Palomo et al., 2013) used expert workshops to map ES hotspots in and around two national parks in Spain. This approach allowed them to pinpoint both key areas for ES supply and where beneficiaries are located. More sophisticated methods to prioritize areas for protecting ES have also been proposed. Luck et al. (Luck et al., 2012) identified ecosystem features that supply ES, threats to this supply, the capacity of the ES to meet demand, potential actions to ensure a future supply of ES, the availability of alternate ways of providing the ES (e.g., technological options), and the costs of these actions. This system holds great potential to improve how areas identified to conserve ES but has not yet been put into practice.

4.5   Current approaches for identifying areas important for ecosystem services in Canada

In Canada, ES quantification and valuation is becoming increasingly widespread for land management and conservation decisions (Value of Nature to Canadians Study Taskforce, 2017). Most of this has focused on value-transfer – using ES or economic values of different LULC types from other areas to estimate ES values for a different region (Molnar and Kubiszewski, 2012), when other local data either does not exist or is not available. Examples include ES evaluations in the Lake Winnipeg Watershed (Voora and Venema, 2008), Great Lakes Basin (Krantzberg and de Boer, 2006), Rouge National Park (Wilson, 2012), southern Ontario (Tory and Bagstad, 2009), the Peace River Watershed (Wilson, 2014), and the Columbia River Basin (Cotter and Sihota, 2011). The main issue with these types of studies is the lack of Canada or region-specific data on the ES potentials of different ecosystems and how Canadians value these ES. However, they still provide important information about the ES values of these regions that can better inform decision-making (Value of Nature to Canadians Study Taskforce, 2017).

Some exceptions to the common value-transfer studies exist however. A study of the off-site benefits of protected areas in Ontario used the ARIES framework to quantify ES flows from parks to beneficiaries and compared this to value-transfer. Results from ARIES for carbon sequestration, recreation, surface water supply, and sediment regulation identified hotspots of ES provision, sinks that prevent ES from reaching beneficiaries, and key locations for ES flows. While value-transfer was simple and relatively fast, the ARIES results offered a much more comprehensive analysis of the ES provided to different beneficiary groups. A participatory approach was used to identify ES hotspots in the Peace River Watershed of British Columbia (Darvill and Lindo, 2015). Here, PPGIS was used to allow local stakeholders to identify key ES locations and how they different between seven stakeholder groups. Key areas for both provisioning and cultural ES were identified and mapped across the study area, identifying hotspots of ES congruent across diverse groups of participants.

Approaches to identifying key areas of ES is a rapidly growing field of study. Concurrent with those efforts, government agencies and conservation organizations in Canada have begun to assess ES in their regions of interest. While ES are currently not an upfront consideration in the planning of protected areas in most Canadian jurisdictions, some ES (such as recreation and other cultural services) are captured through usual planning efforts/selection of protected areas. Some Canadian jurisdictions, including municipalities, however, are expanding their planning frameworks to consider ecosystem services more explicitly in the following ways: setting objectives related to natural capital and its associated ecosystem services; setting targets for specific ecosystem services; providing guidance on the integration of the value of nature; and developing ecosystem services data sets and maps (Table 5).

Suggested Action
Harmonize data to internationally recognized standards wherever possible to minimize duplication and ensure consistency and comparability.

Inclusion of the conservation of ecosystem services could be achieved either through the incorporation of ecosystem services in selection of protected areas, or it could be considered as a "value add" once a protected area has been designated for other objectives depending on the resources and direction the jurisdiction chooses to take.

Table 5. Approaches used and progress to date regarding ecosystem services in protected areas management for Canadian provinces and territories (based on survey results)

Province/Territory	Parks/Protected Areas Approach on Ecosystem Services
British Columbia	· No formal approach
Alberta	· No formal approach · A general ecosystem services policy framework under development; not specific to parks/protected areas
Saskatchewan	· Provincial objectives focus on managing various forms of natural capital and related ecosystem services and monitors and reports on various indicators and performance measures related to these
Manitoba	· No formal approach
Ontario	· Have developed ecosystem services datasets and mapped offsite benefits · Has developed guidance documents on integrating value of nature
Quebec	· No formal approach
New Brunswick	· Includes targets for select ecosystem services

Nova Scotia	· No formal approach
Newfoundland	· No formal approach
Prince Edward Island	· Ecosystem services currently informs the conservation of wetlands
Northwest Territories	· No formal approach
Yukon	· No formal approach
Nunavut	· No formal approach but cultural values are explicitly mentioned

4.6 Indicator for identifying areas important for ecosystem services

Unlike for areas important for biodiversity, there is currently no global indicator proposed for evaluating the extent to which areas important for ES are being protected (UNEP-WCMC and IUCN, 2016). This is likely due to the fact that ES are numerous and do not necessarily overlap spatially. This creates the need that indicators be considered separately for each ES to be evaluated, taking into account the service beneficiary. The recently published Ecosystem Services Toolkit, a project endorsed by federal, provincial and territorial governments of Canada (Value of Nature to Canadians Study Taskforce, 2017), provides an extensive, if not exhaustive, list of indicators that may be considered depending on the context for which an indicator is required. Table 6 below contains a single example for each category of ES to show what these indicators may look like. In order to evaluate how well a specific ES is being protected in Canada, a specific ES of interest would need to be selected and then mapped for protected areas in Canada.

Table 6. Examples of specific indicators for each category of ES. Indicators presented area for both ecosystems and human beneficiaries. Content is a subset of the indicators presented in the Ecosystem Services Toolkit (Value of Nature to Canadians Study Taskforce, 2017).

ES category	ES example	Indicators for natural capital, ecological functions and ES	Human benefit indicators
Provisioning service	Fresh water for human consumption and use	· Total amount of water (m^3/ha) · Maximum sustainable water extraction · (m^3/ha/year) · Presence of water reservoirs · Untreated spring and groundwater (million m^3) and percentage share of water supply · Amount of water extracted per year per area	· Number of people with access to clean water or who do not have access to clean water · Cost ($) to clean water where ecosystem is degraded (e.g., all infrastructure, labour, inputs that could have been avoided, plus maintenance costs)

		· Total renewable freshwater supply by surface waters	
Regulating service	Air-quality regulation	· Leaf-area index · NOx-fixation, among others · Amount of aerosols or chemicals "extracted" (effect on air quality) · Flux in atmospheric gases · Atmospheric cleansing (tropospheric oxidizing) · Deposition velocity of air pollutants on leaves (m/year) · Critical loads · Total amount of pollutants removed via dry deposition on leaves (ton/ha/year)	· Correlating air-quality/particulate data with incidence of respiratory illness (medical records) · Number of people who are exposed to "good air" (below emissions limits) and vice versa at their residence, at their place of work or where they engage in daily activity
Cultural service	Cultural identity and heritage	· Number/area of culturally important landscape features of species · Number of people using forests (or other ecosystems) for cultural heritage identity	· Extent of access to places of traditional/cultural significance · Level of satisfaction (expressed) with access to these places or condition of these places · Continuation of nature-based activities linked to cultural identity at local/societal scale (in this case frequency and extent may not be as important as "just doing it" – even once a year, e.g., Y/N and how many activities, % relevant population involved)
Supporting and habitat service	Primary production	· Amount of food available to herbivores · Algal primary productivity (t/ha/year) · Total NPP · % occurrence of problems limiting crop and livestock productivity	· Costs associated with restoration of green areas

5 Linkages between biodiversity and ecosystem services

The ecosystem services concept was first proposed as a way to argue for biodiversity conservation because of its positive impact on human wellbeing. Since all ecosystem services are ultimately produced by the natural capital and natural processes that ecosystems encompass, the hope was that biodiversity and ecosystem services would be positively correlated. However, the relationships between biodiversity and ecosystem services are complicated and non-linear (Mace et al., 2012). For example, biodiversity can be: (i) a regulator of ecosystem processes that contribute to healthy ecosystems and ecosystem services (e.g., soil dynamics are often controlled by soil biota); (ii) a final ecosystem service that provides a direct benefit to people (e.g., wild medicines or the genetic diversity of crop species); and (iii) an ecosystem good itself that is valued by society (e.g., wildlife and scenic places that have sociocultural value; Mace et al., 2012). Thus, depending on the ecosystem service, its relationship with biodiversity, and the biophysical and socioecological conditions in question, biodiversity and ecosystem service provision can have positive, negative, or neutral relationships (Reyers et al., 2012). Additionally, the ecosystem services paradigm can also ignore species with little obvious utilitarian value and ecosystem functions that don't directly benefit people (Ingram et al., 2012). This makes it especially challenging to identify areas that are important for both biodiversity and ecosystem services.

5.1 Links between ecosystem services and biodiversity

A number of broad-scale literature reviews around the links between ecosystem services and biodiversity have been performed over the past ten years. (Balvanera et al., 2006) investigated 446 measures of the relationships between biodiversity and 18 ecosystem functions related to ecosystem services. While they found positive impacts of biodiversity on most of these functions, how these functions relate to ecosystem service provision was less clear. Similarly, (Cardinale et al., 2012) reviewed over 1,700 papers and found that biodiversity is either directly or strongly correlated with many provisioning and regulating services. However, for some services these relationships are less clear, and for others the evidence suggests relationships are the opposite of what was expected. For example, wood production, the stability of fisheries yields, and fodder yield are all positively related to biodiversity, while for carbon storage and pollination the results are mixed. One of most detailed analyses of the relationships between biodiversity and ecosystem service provision is that of (Harrison et al., 2014). Here, the authors found that the vast majority of relationships between ecosystem attributes (e.g., community area, habitat area, functional richness, functional diversity, stand age, species abundance, species richness) and 11 ecosystem services were positive. Negative relationships were uncommon; except for water provision where increases in biodiversity often led to increased ecosystem water consumption and reduced water yield for people.

Ricketts et al., (2016) analyzed over 500 papers, including studies that examined spatial correlations, management comparisons, and functional experiments involving biodiversity and four ecosystem services – carbon storage, crop pollination, pest control and water purification. They found that while there is often a positive relationship spatially between biodiversity and ecosystem function (supply), this relationship weakens when ecosystem services (demand for benefits) are considered. For management

comparisons, the diversity of species that are key for service provision better predict ecosystem service provision than overall biodiversity. Importantly, the balance of evidence varies widely among services, with 37% of the relationships positive for pest control, but 60-71% positive for carbon storage, pollination, and water purification.

Overall, while there exist many positive effects of biodiversity on services, a number of uncertainties limit current understanding (Balvanera et al., 2014). These include: (i) mismatches between the ecosystem function measured and final service; (ii) mismatches between study conditions and actual management conditions; (iii) insufficiently comprehensive studies (Sandifer et al., 2015) and monitoring of outcomes (Goldman et al., 2008); (iv) simultaneous effects of different components of biodiversity; (v) confounding environmental factors; (vi) trade-offs between positive and negative effects of richness on the ecosystem functions that underpin service supply; and (vii) context-dependent patterns vary depending on spatial resolution and extent of the study (Anderson et al., 2009).

5.2   Spatial overlap between areas important for biodiversity and ecosystem services

Numerous studies have examined the spatial overlap between biodiversity and ecosystem services and the results appear mixed. For example, Naidoo et al., 2008 used a global scale to assess four ecosystem services –carbon sequestration, carbon storage, grassland production and water provision- to show that regions selected to maximize biodiversity provide no more ecosystem services than regions chosen randomly.   The authors conclude that the spatial relationships between services and biodiversity vary widely, but that some important areas of overlap (e.g., "win-win" areas) can be identified that are critical to conserve. Contrasting results come from a global study identifying priority watersheds for conservation: watersheds high in biodiversity (based on Conservation International hotspots, Global 200 priority ecoregions, and Birdlife International endemic bird areas), were generally positively correlated with ecosystem service provision, especially for water provisioning and flood mitigation (Luck et al., 2009). Win-win watersheds were also identified, with those in Southeast Asia, Africa, and South America most likely to be priorities for both biodiversity and ecosystem services.

Chan et al. (Chan et al., 2006) examined the relationships between priority areas for biodiversity conservation, carbon storage, flood control, forage production, outdoor recreation, crop pollination, and water provision in the Central Coast ecoregion of California. They found weak positive and negative relationships, although all negative correlations occurred with two ecosystem services – crop pollination and forage production. Similarly, weak positive relationships between biodiversity and ecosystem services were observed across South Africa (Egoh et al., 2009). In particular, hotspots of species richness were associated with water flow regulation and soil accumulation while priority areas for biodiversity had high overlap with water flow regulation, surface water supply, and carbon storage. Positive relationships between biodiversity and nine ecosystem services (food, raw materials, freshwater, air quality regulation, climate regulation, water flow regulation, erosion prevention, soil fertility, and recreation/tourism) have also been observed across Europe at broad spatial scales (e.g., 10 km resolution; (Maes et al., 2012b) and in Madagascar between the biodiversity and hydrological importance of Key Biodiversity Areas (Rogers et al., 2010).

In contrast, other studies have shown strong concordance between biodiversity and ecosystem services. (Nelson et al., 2009) used the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) tool to model how different scenarios of land use/land cover change in the Willamette Valley of Oregon would affect biodiversity and ecosystem services. That study examined the spatial correlation between biodiversity and four ecosystem services (water quality, soil conservation, storm peak management, carbon sequestration, commodity production) and found that scenarios that improved ecosystem services provision also conserved biodiversity, suggesting that the two could be managed together. Similarly, a study in China of the Bayangdian watershed looked at the spatial overlap of biodiversity, soil retention, water yield, carbon sequestration, N/P retention, and pollination (Bai et al., 2011). Overall, relationships between biodiversity and ecosystem services were strong, with biodiversity positively correlated with all services except N/P retention and pollination. The results of this study also suggested that there were two distinct clusters of services and biodiversity that covaried spatially and could potentially be managed separately. One cluster included biodiversity, water yield, carbon sequestration, and soil retention, while the other incorporated N/P retention and pollination.

5.3   Conservation planning for biodiversity and ecosystem services

While many positive spatial relationships between biodiversity and ecosystem services have been recorded, testing of systematic plans to conserve both have generally shown that the targeted conservation of biodiversity can also encompass ecosystem services, but that the opposite is not always true. For example, at a global scale, prioritizing conservation for ecosystem services resulted in only a small fraction (22-35%) of species being represented as compared to prioritizing solely for species (Naidoo et al., 2008). At a more regional scale, Chan et al. (Chan et al., 2006) found that conservation plans targeting just ecosystem services resulted in only 44% of biodiversity targets being met compared to a plan targeting just biodiversity. Conversely, conserving areas important for biodiversity in Europe through the Natura 2000 initiative has also protected areas more likely to supply regulating and cultural services (Maes et al., 2012b). Similarly, in the Little Karoo region of South Africa, targeting biodiversity meant that at least 30% of those areas important for three services (carbon storage, water recharge, and fodder) were also conserved (Egoh et al., 2010). However, any further gains in ecosystem services could only be realized if biodiversity targets were relaxed, although even a small relaxation (8% less biodiversity conserved) meant 40-70% increases in ecosystem services.

In sparsely populated regions where ecosystem service benefits to people are reduced or scattered (see section 4.2), there may be even less overlap between ecosystem services and biodiversity. A recent study in Central Labrador showed that wetland conservation plans focused solely on biodiversity underrepresented 10 services (moose hunting, salmon fishing, duck hunting, trout fishing, berry picking, aesthetic value, cultural sites, flood control, carbon storage, iconic species) by ~60% while plans that only incorporated services underrepresented biodiversity by 34% (Cimon-Morin et al., 2016). However, if both were considered in tandem, all biodiversity and ecosystem service targets could be met with just a 6% increase in the area of the conservation network. A similar study of the U.S. state of Minnesota found a similar overlap between priority areas for ecosystem services and biodiversity, such that targeting one of these objectives meant that between 47-70% of the maximum of the other objective was conserved (Polasky et al., 2012).

Spatial relationships between biodiversity and ecosystem services vary widely across different services and measures of biodiversity. Thus, which aspect of biodiversity or which ecosystem service is prioritized in a conservation plan can have significant effects on how well that plan conserves biodiversity or services. For example, at the global scale, the measure of biodiversity used to prioritize areas for conservation greatly influenced how well different ecosystem services were also conserved. Naidoo et al. (Naidoo et al., 2008) compared biodiversity hotspots, high-biodiversity wilderness areas, (HBWA) or Global 200 ecoregions as priority areas for conservation, and showed that HBWA did best for carbon sequestration and storage compared to the other two schemes, but worst for grassland production and water provision Similarly, at the watershed scale in China, targeting carbon sequestration, soil retention and water yield hotspots had relatively high overlap with biodiversity hotspots (37-43%) while N/P retention and pollination had almost no overlap (0.1-0.3%) (Bai et al., 2011). Chan et al. (Chan et al., 2006) used their knowledge of the positive and negative correlations between biodiversity and services to create a "Strategic" conservation network that focused only on positively correlated targets, including carbon storage, flood control, recreation, water provision, and biodiversity. This strategy was much better at conserving biodiversity than an ecosystem service-only approach. Related research suggests that the best conservation plans may be ones that explicitly incorporate these positive and negative relationships between biodiversity and services. Analyzing conservation plans in the central interior of British Columbia, Chan et al (2011) showed that explicitly incorporating synergies and tradeoffs between biodiversity conservation and ecosystem service provision (e.g., biodiversity conservation benefits carbon and angling while it reduces the opportunity to produce timber) can produce a more cost effective reserve network, one that minimizes the impact to forest harvesting.

5.4   Considerations for further action

One novel way to address the fact that biodiversity and ecosystem services don't always overlap spatially is to explicitly address this in conservation plans. Xu et al. (2017) propose different categories to address this lack of spatial congruence – areas focused on conserving biodiversity (Nature Reserves) and others on ecosystem service provision (Ecosystem Service Protected Areas). Nature Reserves would be traditional protected areas where human activities are restricted, while in the Ecosystem Service Protected Areas human activities that are essential for or do not compromise ecosystem service provision would be encouraged or allowed. The assumption is that the creation of these two types of parks would simultaneously help conserve biodiversity and improve local and national support for conservation and protected areas.

5.5   Options for identifying ecosystem services in the context of Canada's biodiversity target 1

Depending on the goals, identifying areas important for ES may be conducted separate or in conjunction with prioritization for biodiversity. For example, i) areas could be identified as important for biodiversity and then prioritized according to national, regional, and/or local provision of ES, or ii) areas could be identified as important for ES using a process separate from biodiversity. With either approach, after identifying which ES are of interest, the next step is to identify the physical areas that provide ES supply (i.e., physical place(s) on the landscape where ES are created) and delivery (i.e., where the benefit of ES are received by people). This may include quantifying and mapping individual ES, as well as suites of ES, to identify where protection will yield the greatest return. However, it also important to focus attention on alternative management actions, e.g., evaluating tradeoffs between ES and/or different policy options, different scenarios of spatial allocation of protected areas (Martinez-Harms et al., 2015). Within the context of Canada's biodiversity target 1, this paper examines the application of ES for prioritizing protection of areas important for biodiversity.

Table 7 - Options for identifying areas important for ecosystem services in Canada (within the context of Pathway to Target 1), including pros and cons

Option	Description	Pros	Cons
Analysis of ES provided by Canadian protected areas	For each ES of interest, evaluate the degree to which it is currently represented in (provided by) Canadian protected areas. (Note: desired ES informed by a protected area's management plan/intent)	· Could aid future prioritization of protection for areas important for biodiversity. · Provides a good picture of the current state of ES in protected areas in Canada	· May be time consuming if the underlying data to do the assessment is not readily available or has to be assembled. · Assessment would not in itself provide information for prioritizing protection for areas important for biodiversity.
Assess ES in urban context	Starting with select, urban areas, assess ES provided by natural landscapes within or in proximity to those areas.	· Would show the connection between the environment and human beneficiaries · Scalable - this process could initially be started in several cities and expanded as time, appetite and resources allow. · Allows for partnerships with local government authorities who are engaged in biodiversity conservation and protection within their jurisdictions. · Applies well to developed, southern Canada (see section 6.2) where, combined with the identification of areas important for biodiversity, could be used to help prioritize conservation and protection.	· May be time consuming if the underlying data to do the assessment is not readily available or has to be assembled. · Would need to develop a process to select priority ES. · Omits rural or wilderness landscapes (see section 6.2). · Does not apply well in middle and northern Canada

Common ES framework for protection prioritization	Use a common framework (i.e. Ecosystem Services Toolkit[6]) to evaluate ES for potential protected areas. This evaluation could be an encouraged complement for jurisdictions to prioritize the selection of areas important for biodiversity	· Consistent with current understanding of the need to consider both ES and biodiversity in conservation and protection planning.	· May be time consuming if the underlying data to do the assessment are not readily available or have to be assembled. · The evaluation of ES in the decision making of which area important for biodiversity to protect may lead to the prioritization of an important area for biodiversity with high ES value over the protection of an area with even higher value for biodiversity, but low ES value. · Could fail to incorporate regional/local context in ES evaluations, which can be critical in properly evaluating ES.
Support local level ES evaluations	Encourage small-scale, local organizations to aid communities and municipal governments to identify ES.	· This option would set evaluation and data standards, but would then allow the public to lead the process of evaluating ES. · The locally relevant process could be used in the developed southern Canada (see section 6.2) to help justify the protection of local areas important for biodiversity. · Builds off existing initiatives such as the Municipal Natural Assets Initiative[7] · This could be done through financial incentives or business startup support.	· May underrepresent ES that have beneficiaries across wider geographic space · May be time consuming if the underlying data to do the assessment is not readily available or has to be assembled. · May involve considerable collaboration with public and local organizations, which could be time consuming and costly

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[6] (Preston et al., 2017)
[7] (Valeriote et al., 2016)

6   Broader considerations for implementation

6.1   Addressing climate change

The impacts of climate change are a major threat to biodiversity and the provision of ecosystem services and the rate at which climate change has been increasing is now unprecedented (Stocker et al., 2013). According to the Intergovernmental Panel on Climate Change (IPCC), the international body responsible for assessing the science related to climate change:

"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen." (Pachauri et al., 2015).

This accelerated rate of change emphasizes the need for timely and definitive action. A recent study commissioned by the Canadian Council on Ecological Areas (CCEA) (Lemieux, 2010) points out that incremental adaptation to climate change within Canada's protected areas agencies is occurring to some extent, but there remains an important gap between the perceived importance of the issue and the capacity (funding, staff expertise, etc.) of protected areas agencies and organizations to respond (Canada and Environment Canada, 2015). Habitat protection is one of the most frequently cited climate change adaptation measures for biodiversity conservation (Hannah et al., 2007; Heller and Zavaleta, 2009; Hodgson et al., 2009) and protected areas can contribute to species' resilience to climate change by limiting the added pressures of human disturbance (Nixon, A., C. Shank, and D. Farr, 2015).

It is important to recognize that climate change impacts will not be uniformly distributed across Canada. While there can be no 'one size fits all' solution, there are tools that can be commonly used while being adapted for local concerns such as land use change or habitat fragmentation through the provision of connectivity and refugia.

6.1.1   Connectivity

Connectivity is an important consideration when identifying important areas for biodiversity. A well connected network prevents isolation of species and ecosystems, allows for the movement of animals that need large home ranges (like many large mammals), provides access to a variety of habitats essential for accommodating a range of life stages and cycles as well as helping to maintain ecological processes like water flow. In the face of climate change, connectivity allows for species and ecosystems to naturally adapt by shifting their distribution. It can also improve the chances that a species or ecosystem will bounce back from a disturbance by increasing its ecological integrity and resilience.

Connectivity can be structural (physical) or functional (behavioral) and can have dimensions that are longitudinal (such as pathways along the length of a stream), lateral (like a river connecting to a floodplain), vertical (like the recharging of subterranean groundwater) or temporal (like the change in the distribution of a species through time). The most common focus of connectivity is the development of corridors between conservation areas to accommodate animal movement. In the freshwater

environment, connectivity is not only critical for the migration of fish, but also for the movement of sediment, nutrients and water itself.

The protection of large, intact terrestrial and aquatic ecosystems will provide refuges for wildlife, including species at risk. Connectivity between protected areas facilitates species movement and gene flow, and this resilience will be particularly important in mitigating the effects of climate change (Canadian Protected Areas - Status Report 2006-2011).

One way to enhance connectivity is to use it as an input in the selection and design of new protected areas (Dawson et al., 2011); (Schneider et al., 2011) by either establishing larger protected areas oriented along major climate gradients or having smaller protected areas as stepping stones between other sites in the system (Hunter et al., 2010). In doing so, the movement required to accommodate climate change can take place within the protected area system itself (Schneider, 2014).

It is important to note however, that the best connectivity for one species may not be the best solution for another species; or that by creating a corridor between two areas; invasive species or diseases may also find an easier pathway to propagate. [For more information on connectivity, please see landscape and connectivity ETT paper]. Examining additional factors beyond climate change will also need to be considered in the development of connectivity planning.

6.1.2   Climate refugia

Climate refugia are most commonly defined as an area-based location with properties of climate change attenuation relative to surrounding regions. Climate refugia do not prevent climate changes but rather exhibit attenuation for reasons such as topography, vegetation, etc. and reduces species exposure to climate change.

Climate refugia are based on climate velocities (and variability) captured within a geographic region (Coristine et al., 2016). Climate refugia have a counter-part which involves geographic regions with amplified climate changes (Cools et al., 2016). Regions with amplified climate change could greatly increase extinction risk for biodiversity and the potential for a loss of ecosystem services. Some countries/regions are currently examining climate change considerations in area-based management, policies for conservation and protected areas. In Australia, there was identification of eight implications from analysis of climate change impacts on biodiversity conservation and their National Reserve System (protected areas) including assessing comprehensiveness, representativeness and adequacy of protected areas within the reserve system (Dunlop and Brown, 2008). The implications of not considering climate change within protected area planning could be detrimental to the goals of conservation. Species dispersal and colonization rates fall far below necessary movement to retain suitable climates (Devictor et al., 2012), leading to population loss and declines in distributional breadth (Coristine and Kerr, 2015). As species lose suitable climate space, extinction risk increases - with the expectation that one in five species could be threatened by climate change-related extinction by 2100 (Urban, 2015). Retroactive management for such extinction risk would be prohibitive in terms of cost

and time (Stern, 2007). Low amounts of protected areas and lack of connectivity could further hinder efforts to allay future climate change-related extinction.

Schneider (2014) points out that refugia:

> "can be applied at different scales and for different purposes. In one type of application, the objective is to maximize the overall stability of the protected area system by selecting sites that are least likely to change as the climate warms. This can be achieved by comparing the current locations of ecosystems with their projected locations in the future and assigning priority to regions of overlap (Carvalho et al., 2011); (Stralberg and Bayne, 2013). This approach should be applied in conjunction with a physical landscape representation approach, to avoid gaps in representation (Tingley et al., 2013). Regional-scale physical landscapes would be delineated as a first step, and then the refugia approach would be used to select the most stable sites within each landscape".

While climate change isn't the only factor to consider with respect to biodiversity and ecosystem services conservation, it is important that the impacts of climate change on biodiversity be examined in tandem with the suite of threats facing any particular conservation scenario such as human land use and actions as it will have an impact on the success of conservation targets and as such should be a consideration going forward.

> **Suggested Action**
> Explore future climatic conditions of proposed parks and protected areas to determine if targets and goals are achievable in the long term.

6.2   The "Three Canadas" for biodiversity conservation

Canada, like many countries with varied geography, biodiversity, and patterns of human settlement, does not have uniform conditions for conservation. As such, a one-size-fits-all approach is unlikely to be effective for conservation planning or implementation.

The idea of three different conditions spread across the country has been suggested: '*The Three Canadas for Biodiversity Conservation*' (Locke, 2017). Each condition, and region, is a combination of biodiversity (e.g., richness, species-at-risk), degree of intactness vs. human modification of the landscape, and health of ecological processes. Therefore, the goals and approaches for conservation in each of the three regions will necessarily also be different. Success will involve collaborating across national and provincial jurisdictions, and with Indigenous peoples, private landowners, and communities. Figure 13 shows a rough idea how the 3 Canada's could be delineated. It is important to note that the depiction on the map does not represent hard boundaries between the different regions, but rather the rough approximation of each of the categories in Canada. The three regions are: 1) heavily settled/agricultural areas, mostly in the south of Canada, 2) areas of resource extraction and other direct human impacts, and 3) pristine/wilderness areas that form the rest of the country.

6.2.1 The crowded, fertile, and developed south

This region includes the majority of Canada's human population, major metropolitan centers, productive farmlands, with high levels of biodiversity and species-at-risk. Here, effective conservation strategies can focus on i) protecting and restoring species-at-risk, habitat, and ecological functions and processes, and ii) encouraging human recreation in, and connection to, nature. This may include assisted migration; innovative habitat conservation and zoning; habitat restoration; incentives for municipal planners, private landowners, and developers, with the goals of no species extinctions (short-term) and restoring native species to viable populations (long-term). Although the size of conservation areas might not be large, habitat and species protection in this region is exceptionally important for biodiversity. Ecosystem services of particular relevance in especially urban areas are the moderating effects from heat, wind, and storm waters provided by urban forests and tree canopy in parks and along streets and in private yards.

6.2.2 The open landscape of middle Canada

This region can be characterized by 'working landscapes', e.g., ranching (not cultivation-based farming), hunting, industrial development (e.g., mining, logging, oil and gas), as well as existing parks and protected areas. Here, effective conservation strategies can focus on i) protected areas that are ecological representative and ecologically important (e.g., old growth forests), ii) connecting existing protected areas, and iii) restoring and maintaining ecological functions and processes (e.g., reducing habitat fragmentation). Many of these places provide important ecosystem services benefiting the health and well-being of people living in metropolitan areas; conservation here has far-reaching effects.

6.2.3 The wild north

This area is largely characterized by intact wilderness and roadless areas, ecological function and processes, and low human population density. Indigenous people are a major part of the population with strong connection and practice to traditional lifestyles. Here, effective conservation strategies can focus on i) large, interconnected protected areas, iii) incentivizing territorial governments, and iii) protecting existing ecological functions and processes. The result could be a few nodes of intense industrial development, with globally leading best-practices, enveloped in a largely wild matrix with innovative Indigenous Protected Areas. Protecting and connecting large areas can contribute in meaningful ways towards both the quantity and quality aspects of Pathway to Target 1.
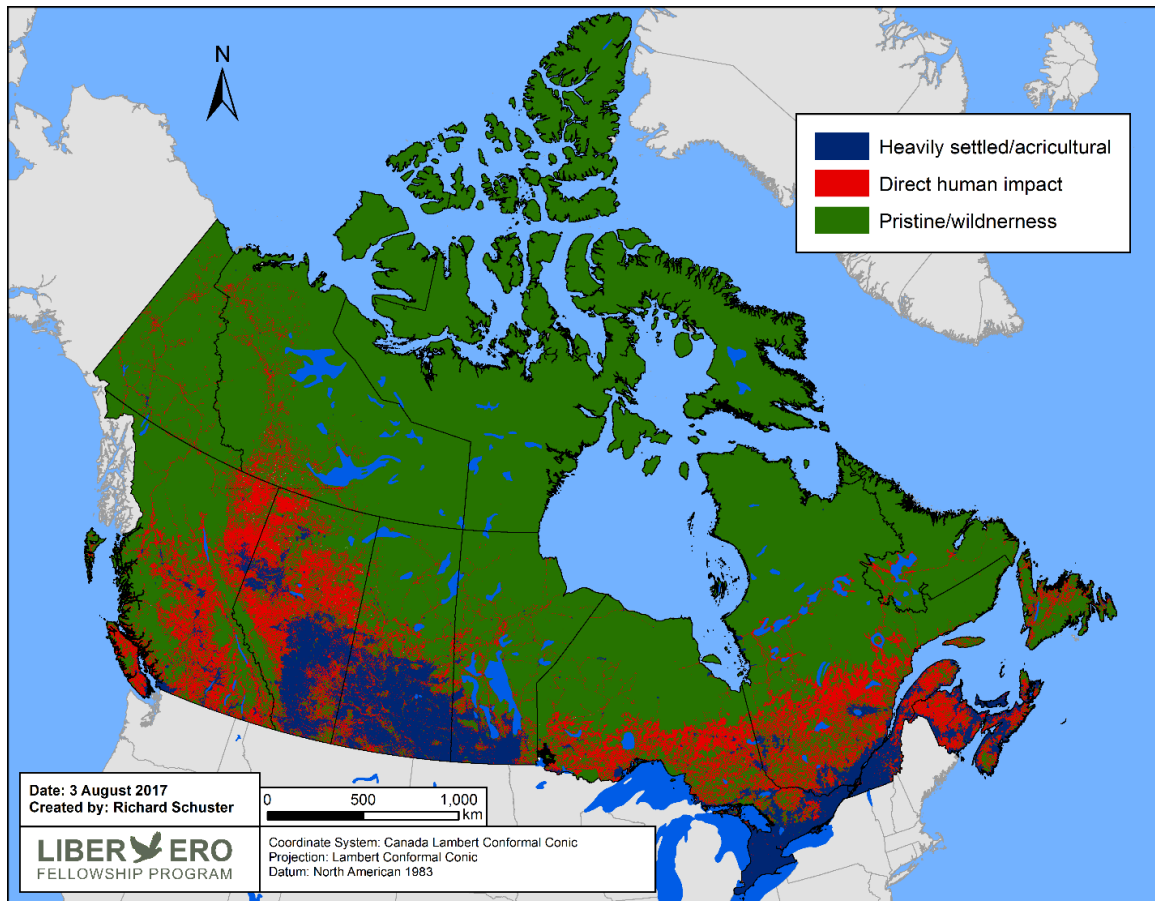
Figure 13. Shown is the rough idea of 3 Canadas. It is important to note that the depiction on the map does not represent hard boundaries between the different regions, but rather the rough approximation of each of the categories in Canada. Data sources Heavily settled/agriculture (Gridded population of the World v.4, European Space Agency Land cover 2015), Direct human impact (Canada Access 2010, Global Forest Watch Canada, http://www.globalforestwatch.ca/node/198, date accessed: 22 April 2017); Pristine/wilderness (locations that where neither of the previous two categories were assigned pristine/wilderness status).

7 Bibliography

Agriculture and Agri-Food Canada (2015). The Importance of Bee Health to Sustainable Food Production in Canada URL: https://sencanada.ca/Content/SEN/Committee/412/agfo/rep/rep09may15-e.pdf.

Allen, T.F., and Starr, T.B. (1982). Hierarchy perspectives for ecological complexity. URL: https://philpapers.org/rec/ALLHPF-2.

Alliance for Zero Extinction, sites in Canada, http://www.zeroextinction.org/search_results_country.cfm, Accessed: 2017-06-12

Andersen, L.W., Fog, K., and Damgaard, C. (2004). Habitat fragmentation causes bottlenecks and inbreeding in the European tree frog (Hyla arborea). Proc Biol Sci *271*, 1293–1302 URL: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1691722/.

Anderson, S. (2002). Identifying important plant areas (Plantlife International London) URL: http://hirc.botanic.hr/hbod/IPA/Identifying-IPAs-in-Europe.pdf.

Anderson, B.J., Armsworth, P.R., Eigenbrod, F., Thomas, C.D., Gillings, S., Heinemeyer, A., Roy, D.B., and Gaston, K.J. (2009). Spatial covariance between biodiversity and other ecosystem service priorities. Journal of Applied Ecology *46*, 888–896.

Anderson, M.G., Comer, P.J., Beier, P., Lawler, J.J., Schloss, C.A., Buttrick, S., Albano, C.M., and Faith, D.P. (2015). Case studies of conservation plans that incorporate geodiversity. Conservation Biology *29*, 680–691 URL: http://onlinelibrary.wiley.com/doi/10.1111/cobi.12503/abstract.

de Araujo Barbosa, C.C., Atkinson, P.M., and Dearing, J.A. (2015). Remote sensing of ecosystem services: A systematic review. Ecological Indicators *52*, 430–443.

Asa, C., Miller, P., Agnew, M., Rebolledo, J. a. R., Lindsey, S.L., Callahan, M., and Bauman, K. (2007). Relationship of inbreeding with sperm quality and reproductive success in Mexican gray wolves. Animal Conservation *10*, 326–331 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1469-1795.2007.00116.x/abstract.

Ayanu, Y.Z., Conrad, C., Nauss, T., Wegmann, M., and Koellner, T. (2012). Quantifying and Mapping Ecosystem Services Supplies and Demands: A Review of Remote Sensing Applications. Environ. Sci. Technol. *46*, 8529–8541 URL: http://dx.doi.org/10.1021/es300157u.

Bagstad, K.J., Johnson, G.W., Voigt, B., and Villa, F. (2013a). Spatial dynamics of ecosystem service flows: a comprehensive approach to quantifying actual services. Ecosystem Services *4*, 117–125.

Bagstad, K.J., Semmens, D.J., Waage, S., and Winthrop, R. (2013b). A comparative assessment of decision-support tools for ecosystem services quantification and valuation. Ecosystem Services *5*, 27–39.

Bagstad, K.J., Villa, F., Batker, D., Harrison-Cox, J., Voigt, B., and Johnson, G.W. (2014). From theoretical to actual ecosystem services: mapping beneficiaries and spatial flows in ecosystem service assessments. Ecology and Society *19*, art64.

Bagstad, K.J., Semmens, D.J., Ancona, Z.H., and Sherrouse, B.C. (2017). Evaluating alternative methods for biophysical and cultural ecosystem services hotspot mapping in natural resource planning. Landscape Ecol *32*, 77–97 URL: https://link-springer-com.ezproxy.library.ubc.ca/article/10.1007/s10980-016-0430-6.

Bai, Y., Zhuang, C., Ouyang, Z., Zheng, H., and Jiang, B. (2011). Spatial characteristics between biodiversity and ecosystem services in a human-dominated watershed. Ecological Complexity *8*, 177–183.

Baillie, J., Hilton-Taylor, C., and Stuart, S.N. (2004). IUCN red list of threatened species: a global species assessment.

Ball, I.R., Possingham, H.P., and Watts, M. (2009). Marxan and relatives: Software for spatial conservation prioritisation. In Spatial Conservation Prioritisation: Quantitative Methods and Computational Tools, A. Moilanen, K.A. Wilson, and H.P. Possingham, eds. (Oxford, UK: Oxford University Press), p.

Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.-S., Nakashizuka, T., Raffaelli, D., and Schmid, B. (2006). Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecology Letters *9*, 1146–1156.

Balvanera, P., Siddique, I., Dee, L., Paquette, A., Isbell, F., Gonzalez, A., Byrnes, J., O'Connor, M.I., Hungate, B.A., and Griffin, J.N. (2014). Linking Biodiversity and Ecosystem Services: Current Uncertainties and the Necessary Next Steps. BioScience.

Bank of Canada Exchange Rates URL: http://www.bankofcanada.ca/rates/exchange/.

Bayley, S.E., and Guimond, J.K. (2008). Effects of river connectivity on marsh vegetation community structure and species richness in montane floodplain wetlands in Jasper National Park, Alberta, Canada. Ecoscience *15*, 377–388 URL: http://www.bioone.org/doi/abs/10.2980/15-3-3084.

Beccaloni, G.W., and Gaston, K.J. (1994). Predicting the species richness of neotropical forest butterflies: Ithomiinae (Lepidoptera: Nymphalidae) as indicators URL: http://ac.els-cdn.com/000632079400023J/1-s2.0-000632079400023J-main.pdf?_tid=4aac9f6e-60e3-11e7-a36f-00000aacb35e&acdnat=1499191678_1dd2fd7f8c12890858fc22c725f58bda.

Bennett, A.F., Haslem, A., Cheal, D.C., Clarke, M.F., Jones, R.N., Koehn, J.D., Lake, P.S., Lumsden, L.F., Lunt, I.D., Mackey, B.G., et al. (2009). Ecological processes: A key element in strategies for nature conservation. Ecological Management & Restoration *10*, 192–199 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1442-8903.2009.00489.x/abstract.

Biogeoclimatic Ecosystem Classification Program (2017). How BEC works URL: https://www.for.gov.bc.ca/HRE/becweb/system/how/index.html.

BirdLife International (2017). Country profile: Canada. URL: http://datazone.birdlife.org/country/canada/ibas.

Bland, L.M., Keith, D.A., Miller, R.M., Murray, N.J., and Rodríguez, J.P. (2015). Guidelines for the application of IUCN Red List of ecosystems categories and criteria. URL: https://portals.iucn.org/library/sites/library/files/documents/2016-010.pdf.

Bouzat, J.L. (2010). Conservation genetics of population bottlenecks: the role of chance, selection, and history. Conservation Genetics *11*, 463–478 URL: http://link.springer.com/10.1007/s10592-010-0049-0.

Boyle, S.A., Kennedy, C.M., Torres, J., Colman, K., Pérez-Estigarribia, P.E., and de la Sancha, N.U. (2014). High-Resolution Satellite Imagery Is an Important yet Underutilized Resource in Conservation Biology. PLoS ONE *9*, e86908 URL: http://dx.plos.org/10.1371/journal.pone.0086908.

Brooks, T.M., Mittermeier, R.A., Fonseca, G.A.B. da, Gerlach, J., Hoffmann, M., Lamoreux, J.F., Mittermeier, C.G., Pilgrim, J.D., and Rodrigues, A.S.L. (2006). Global Biodiversity Conservation Priorities. Science *313*, 58–61 URL: http://science.sciencemag.org/content/313/5783/58.

Brooks and Bubb (2014). Key Knowledge for Successful Biodiversity Indicators URL: https://www.bipindicators.net/system/resources/files/000/000/410/original/901.pdf?1482313832.

Brown, G. (2013). The relationship between social values for ecosystem services and global land cover: an empirical analysis. Ecosystem Services *5*, e58–e68.

Brown, G., and Fagerholm, N. (2015). Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation. Ecosystem Services *13*, 119–133 URL: http://www.sciencedirect.com/science/article/pii/S2212041614001235.

Brown, G., Montag, J.M., and Lyon, K. (2012). Public Participation GIS: A Method for Identifying Ecosystem Services. Society & Natural Resources *25*, 633–651 URL: http://www-tandfonline-com.ezproxy.library.ubc.ca/doi/abs/10.1080/08941920.2011.621511.

Brown, G., Pullar, D., and Hausner, V.H. (2016). An empirical evaluation of spatial value transfer methods for identifying cultural ecosystem services. Ecological Indicators *69*, 1–11 URL: http://www.sciencedirect.com/science/article/pii/S1470160X16301571.

Burkhard, B., Kroll, F., Nedkov, S., and Müller, F. (2012). Mapping ecosystem service supply, demand and budgets. Ecological Indicators *21*, 17–29 URL: http://www.sciencedirect.com/science/article/pii/S1470160X11001907.

Burkhard, B., Crossman, N., Nedkov, S., Petz, K., and Alkemade, R. (2013). Mapping and modelling ecosystem services for science, policy and practice. Ecosystem Services *4*, 1–3 URL: http://www.sciencedirect.com/science/article/pii/S2212041613000259.

Canada, and Environment Canada (2010). Canadian biodiversity: ecosystem status and trends 2010. URL: http://site.ebrary.com/id/10443500.

Canada, and Environment Canada (2015). Canadian protected areas status report 2006-2011. URL: http://epe.lac-bac.gc.ca/100/201/301/weekly_acquisition_lists/2016/w16-04-F-E.html/collections/collection_2016/eccc/En81-9-2011-eng.pdf.

Canada, Environment Canada, and Canadian Councils of Resource Ministers (2014). 2012 Canadian nature survey: awareness, participation, and expenditures in nature-based recreation, conservation, and subsistence activities. URL: http://epe.lac-bac.gc.ca/100/201/301/weekly_checklist/2014/internet/w14-25-U-E.html/collections/collection_2014/ec/En4-243-2014-eng.pdf.

Canadian National Vegetation Classification, 2013 Canadian National Vegetation Classification (CNVC) URL: http://cnvc-cnvc.ca/index.cfm.

Canadian Parks and Wilderness Society-Yukon Chapter (2005). Towards a Yukon Conservation Strategy URL: http://cpaws.org/uploads/pubs/report-yukon-conservation-2005.pdf.

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A., Mace, G.M., Tilman, D., Wardle, D.A., et al. (2012). Biodiversity loss and its impact on humanity. Nature *486*, 59–67 URL: http://www.nature.com.ezproxy.library.ubc.ca/nature/journal/v486/n7401/full/nature11148.html.

Carroll, C., Roberts, D.R., Michalak, J.L., Lawler, J.J., Nielsen, S.E., Stralberg, D., Hamann, A., Mcrae, B.H., and Wang, T. (2017). Scale-dependent complementarity of climatic velocity and environmental diversity for identifying priority areas for conservation under climate change. Glob Change Biol n/a-n/a URL: http://onlinelibrary.wiley.com/doi/10.1111/gcb.13679/abstract.

Carvalho, S.B., Brito, J.C., Crespo, E.G., Watts, M.E., and Possingham, H.P. (2011). Conservation planning under climate change: Toward accounting for uncertainty in predicted species distributions to increase confidence in conservation investments in space and time. Biological Conservation *144*, 2020–2030 URL: http://linkinghub.elsevier.com/retrieve/pii/S0006320711001649.

CCEA (1996). Ecozones Introduction URL: http://www.ccea.org/fr/ecozones-introduction/.

Ceballos, G., Ehrlich, P.R., Barnosky, A.D., García, A., Pringle, R.M., and Palmer, T.M. (2015). Accelerated modern human–induced species losses: Entering the sixth mass extinction. Science Advances *1*, e1400253 URL: http://advances.sciencemag.org/content/1/5/e1400253.

Center for Open Science The Transparency and Openness Promotion Guidelines URL: https://cos.io/our-services/top-guidelines/#summary.

Chakraborty, R., and Nei, M. (1976). Hidden genetic varaiability within electromophs in finite populations. URL: http://igem.temple.edu/labs/nei/downloads/publications/1976%20Publications/1976-chakrabory-nei.pdf.

Chan, K.M.A., Shaw, M.R., Cameron, D.R., Underwood, E.C., and Daily, G.C. (2006). Conservation planning for ecosystem services. Plos Biology *4*, 2138–2152.

Chan, K.M.A., Hoshizaki, L., and Klinkenberg, B. (2011). Ecosystem Services in Conservation Planning: Targeted Benefits vs. Co-Benefits or Costs? PLOS ONE *6*, e24378 URL: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0024378.

Chan, K.M.A., Balvanera, P., Benessaiah, K., and chapman, M. (2016). Why protect nature? Rethinking values and the environment URL: http://www.pnas.org/content/113/6/1462.full.pdf.

Chazdon, R.L., Harvey, C.A., Komar, O., Griffith, D.M., Ferguson, B.G., Martinez-Ramos, M., Morales, H., Nigh, R., Soto-Pinto, L., van Breugel, M., et al. (2009). Beyond Reserves: A Research Agenda for Conserving Biodiversity in Human-modified Tropical Landscapes. Biotropica *41*, 142–153.

Christie, P., and Sommerkorn, M. (2012). RACER: Rapid assessment of circum-Arctic ecosystem resilience. Ottawa, Canada: WWF Global Arctic Programme.

Cimon-Morin, J., Darveau, M., and Poulin, M. (2016). Site complementarity between biodiversity and ecosystem services in conservation planning of sparsely-populated regions. Environmental Conservation *43*, 56–68 URL: https://www.cambridge.org/core/journals/environmental-conservation/article/site-complementarity-between-biodiversity-and-ecosystem-services-in-conservation-planning-of-sparsely-populated-regions/F7775F0132A6710A566F7645F0508267.

Coltman, D.W., Pilkington, J.G., Smith, J.A., and Pemberton, J.M. (1999). Parasite-Mediated Selection against Inbred Soay Sheep in a Free-Living, Island Population. Evolution *53*, 1259–1267 URL: http://www.jstor.org/stable/2640828.

Columbia, B. Applying Ecosystem Classification in British Columbia. URL: http://elibrary.sd71.bc.ca/subject_resources/science/Biogeo_folder/biogeo_bro19.pdf.

Comer, P., J., Hak, J.C., and Ecology Department Staff of NatureServe (2016). Red List of Ecosystems - Status and Trends in Terrestrial Ecosystems of the USA (IUCN WCC 2016 Poster).

Comer, P.J., Pressey, R.L., Hunter, M.L., Schloss, C.A., Buttrick, S.C., Heller, N.E., Tirpak, J.M., Faith, D.P., Cross, M.S., and Shaffer, M.L. (2015). Incorporating geodiversity into conservation decisions. Conservation Biology *29*, 692–701 URL: http://onlinelibrary.wiley.com/doi/10.1111/cobi.12508/abstract.

Convention of Biological Diversity Article 2. Use of Terms URL: https://www.cbd.int/convention/articles/default.shtml?a=cbd-02.

Convention on Biological Diversity (2011). Conference of the Parties Decision X/2: Strategic plan for biodiversity 2011-2020. URL: https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-02-en.pdf.

Convention on Biological Diversity Definitions - Indicative definitions taken from the Report of the ad hoc technical expert group on forest biological diversity URL: https://www.cbd.int/forest/definitions.shtml.

Cools, J., Innocenti, D., and O'Brien, S. (2016). Lessons from flood early warning systems. Environmental Science & Policy *58*, 117–122 URL: http://www.sciencedirect.com/science/article/pii/S1462901116300065.

Coristine, L.E., and Kerr, J.T. (2015). Temperature-related geographical shifts among passerines: contrasting processes along poleward and equatorward range margins. Ecol Evol *5*, 5162–5176 URL: http://onlinelibrary.wiley.com/doi/10.1002/ece3.1683/abstract.

Coristine, L.E., Soroye, P., Soares, R.N., Robillard, C., and Kerr, J.T. (2016). Dispersal Limitation, Climate Change, and Practical Tools for Butterfly Conservation in Intensively Used Landscapes. Natural Areas Journal *36*, 440–452 URL: http://www.bioone.org/doi/abs/10.3375/043.036.0410.

COSEWIC, E.C. (2015a). Committee on the Status of Endangered Wildlife in Canada (COSEWIC) - Brief History URL: http://www.cosewic.gc.ca/default.asp?lang=en&n=325FB535-1.

COSEWIC, E.C. (2015b). Committee on the Status of Endangered Wildlife in Canada (COSEWIC) - Wildlife species assessment URL: http://www.cosewic.gc.ca/default.asp?lang=en&n=ED199D3B-1.

Cotter, A., and Sihota, S. (2011). Valuing Ecosystem Goods and Services in the Columbia River Basin (Adaptation to Climate Change Team, Simon Fraser University).

Crooks, K.R., and Sanjayan, M. (2006). Connectivity conservation: maintaining connections for nature. CONSERVATION BIOLOGY SERIES-CAMBRIDGE- *14*, 1 URL: http://www.langtoninfo.com/web_content/9780521673815_excerpt.pdf.

Crossman, N.D., Burkhard, B., and Nedkov, S. (2012). Quantifying and mapping ecosystem services. International Journal of Biodiversity Science, Ecosystem Services & Management *8*, 1–4 URL: http://dx.doi.org/10.1080/21513732.2012.695229.

Crossman, N.D., Burkhard, B., Nedkov, S., Willemen, L., Petz, K., Palomo, I., Drakou, E.G., Martín-Lopez, B., McPhearson, T., Boyanova, K., et al. (2013). A blueprint for mapping and modelling ecosystem services. Ecosystem Services *4*, 4–14 URL: http://www.sciencedirect.com/science/article/pii/S2212041613000041.

Daily, G.C., and Matson, P.A. (2008). Ecosystem services: From theory to implementation. Proceedings of the National Academy of Sciences *105*, 9455–9456.

Daily, G.C., Matson, P.A., and Vitousek, P.M. (1997). Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems URL: http://leml.asu.edu/jingle/Web_Pages/BIO320_Website/Lectures/8-Biodiversity_Conservation/misc/Daily_1997_issue2.pdf.

Darvill, R., and Lindo, Z. (2015). Quantifying and mapping ecosystem service use across stakeholder groups: Implications for conservation with priorities for cultural values. Ecosystem Services *13*, 153–161 URL: http://www.sciencedirect.com/science/article/pii/S221204161400120X.

Davis, S.D., Heywood, V.H., and Hamilton, A.C. (1994). Centres of plant diversity. NATURAL HISTORY *111*, 01–1 URL: http://www.nativefishlab.net/library/textpdf/18340.pdf.

Davis, S.D., Heywood, V.H., and Hamilton, A.C. (1995b). Centres of Plant Diversity. A Guide and Strategy for their Conservation. Volume 2. Asia, Australasia and the Pacific. (The World Wildlife Fund (WWF) and IUCN - The World Conservation Union. IUCN Publications Unit, Cambridge (U.K.).), p.

Davis, S.D., Heywood, V.H., and Hamilton, A.C. (1995a). Centres of Plant Diversity. A Guide and Strategy for their Conservation. Volume 3. The Americas. (The World Wildlife Fund (WWF) and IUCN - The World Conservation Union. IUCN Publications Unit, Cambridge (U.K.).), p.

Dawson, T.P., Jackson, S.T., House, J.I., Prentice, I.C., and Mace, G.M. (2011). Beyond predictions: biodiversity conservation in a changing climate. Science *332*, 53–58 URL: http://science.sciencemag.org/content/332/6025/53.short.

Day, J.C., Roff, J.C., and Laughren, J. (2000). Planning for representative marine protected areas: a framework for Canada's oceans (World Wildlife Fund Canada Toronto) URL: http://charlie-gibbs.org/charlie/NEA_Website/Publication/Submissions/OSPAR2001/WWF_BDC00_MPAs_Annex.pdf.

Deguise, I.E., and Kerr, J.T. (2006). Protected Areas and Prospects for Endangered Species Conservation in Canada: Endangered Species in Random Reserve Networks. Conservation Biology *20*, 48–55 URL: http://doi.wiley.com/10.1111/j.1523-1739.2005.00274.x.

Derocher, A.E., Lunn, N.J., and Stirling, I. (2004). Polar Bears in a Warming Climate. Integr Comp Biol *44*, 163–176 URL: https://academic.oup.com/icb/article/44/2/163/674253/Polar-Bears-in-a-Warming-Climate1.

Devictor, V., van Swaay, C., Brereton, T., Brotons, L., Chamberlain, D., Heliölä, J., Herrando, S., Julliard, R., Kuussaari, M., Lindström, Å., et al. (2012). Differences in the climatic debts of birds and butterflies at a continental scale. Nature Clim. Change *2*, 121–124 URL: http://www.nature.com/nclimate/journal/v2/n2/abs/nclimate1347.html.

Dey, C.J., Richardson, E., McGeachy, D., Iverson, S.A., Gilchrist, H.G., and Semeniuk, C.A.D. (2017). Increasing nest predation will be insufficient to maintain polar bear body condition in the face of sea ice loss. Glob Change Biol *23*, 1821–1831 URL: http://onlinelibrary.wiley.com/doi/10.1111/gcb.13499/abstract.

Diaz, S., Quetier, F., Caceres, D.M., Trainor, S.F., Perez-Harguindeguy, N., Bret-Harte, M.S., Finegan, B., Pena-Claros, M., and Poorter, L. (2011). Linking functional diversity and social actor strategies in a framework for interdisciplinary analysis of nature's benefits to society. Proceedings of the National Academy of Sciences *108*, 895–902.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., et al. (2015). The IPBES Conceptual Framework—connecting nature and people. Current Opinion in Environmental Sustainability *14*, 1–16 URL: http://www.sciencedirect.com/science/article/pii/S187734351400116X.

Dunlop, M., and Brown, P. (2008). Implications of climate change for Australia's National Reserve System: a preliminary assessment. URL: http://www.climatechange.gov.au/impacts/publications/pubs/nrs-report.pdf.

Egoh, B., Rouget, M., Reyers, B., Knight, A.T., Cowling, R.M., van Jaarsveld, A.S., and Welz, A. (2007). Integrating ecosystem services into conservation assessments: A review. Ecological Economics *63*, 714–721 URL: http://www.sciencedirect.com/science/article/pii/S0921800907002662.

Egoh, B., Reyers, B., Rouget, M., Richardson, D.M., Le Maitre, D.C., and van Jaarsveld, A.S. (2008). Mapping ecosystem services for planning and management. Agriculture, Ecosystems & Environment *127*, 135–140 URL: http://www.sciencedirect.com/science/article/pii/S0167880908001217.

Egoh, B.N., Reyers, B., Rouget, M., Bode, M., and Richardson, D.M. (2009). Spatial congruence between biodiversity and ecosystem services in South Africa. Biological Conservation *142*, 553–562.

Egoh, B.N., Reyers, B., Carwardine, J., Bode, M., O'Farrell, P.J., Wilson, K.A., Possingham, H.P., Rouget, M., de Lange, W., Richardson, D.M., et al. (2010). Safeguarding biodiversity and ecosystem services in the Little Karoo, South Africa. Conservation Biology *24*, 1021–1030.

Egoh, B.N., Reyers, B., Rouget, M., and Richardson, D.M. (2011). Identifying priority areas for ecosystem service management in South African grasslands. Journal of Environmental Management *92*, 1642–1650.

Eigenbrod, F., Armsworth, P.R., Anderson, B.J., Heinemeyer, A., Gillings, S., Roy, D.B., Thomas, C.D., and Gaston, K.J. (2010). The impact of proxy-based methods on mapping the distribution of ecosystem services. Journal of Applied Ecology *47*, 377–385.

Eken, G., Bennun, L., Brooks, T.M., Darwall, W., Fishpool, L.D.C., Foster, M., Knox, D., Langhammer, P., Matiku, P., Radford, E., et al. (2004). Key Biodiversity Areas as Site Conservation Targets. BioScience *54*, 1110–1118 URL: http://www.bioone.org/doi/abs/10.1641/0006-3568(2004)054%5B1110:KBAASC%5D2.0.CO;2.

Eken, G., Isfendiyaroğlu, S., Yeniyurt, C., Erkol, I.L., Karataş, A., and Ataol, M. (2016). Identifying key biodiversity areas in Turkey: a multi-taxon approach. International Journal of

Biodiversity Science, Ecosystem Services & Management *12*, 181–190 URL: http://dx.doi.org/10.1080/21513732.2016.1182949.

Ervin, J., Mulongoy, K.J., Lawrence, K., Game, E., Sheppard, D., Bridgewater, P., Bennett, G., Gidda, S.B., and Bos., P. (2010). Making protected areas relevant: a guide to integrating protected areas into wider landscapes, seascapes, and sectoral plans and strategies. URL: http://www.cbd.int/doc/publications/cbd-ts-44-en.pdf.

European Commission (17 Jul 2012) Commission recommendation on access to and preservation of scientific information URL: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/open-science-open-access.

Evans, M.I. (1994). Important bird areas in the Middle East (Birdlife international).

Farias, I.P., Santos, W.G., Gordo, M., and Hrbek, T. (2015). Effects of Forest Fragmentation on Genetic Diversity of the Critically Endangered Primate, the Pied Tamarin (Saguinus bicolor): Implications for Conservation. J Hered *106*, 512–521 URL: https://academic.oup.com/jhered/article/106/S1/512/2961838/Effects-of-Forest-Fragmentation-on-Genetic.

Fishpool, L.D., Evans, M.I., and others (2001). Important Bird Areas in Africa and associated islands: Priority sites for conservation (BirdLife International Cambridge, UK) URL: https://www.researchgate.net/profile/Falk_Huettmann/publication/312398316_Important_Bird_Areas_in_Africa_and_Associated_Islands_Priority_Sites_for_Conservation_by_L_D_C_Fishpool_and_M_I_Evans_2001_book_review/links/58d8ce7f92851c44d4ad4000/Important-Bird-Areas-in-Africa-and-Associated-Islands-Priority-Sites-for-Conservation-by-L-D-C-Fishpool-and-M-I-Evans-2001-book-review.pdf.

Foster, M.N., Brooks, T.M., Cuttelod, A., Silva, N.D., Fishpool, L.D.C., Radford, E.A., and Woodley, S. (2012). The identification of sites of biodiversity conservation significance: progress with the application of a global standard. Journal of Threatened Taxa *4*, 2733–2744 URL: http://threatenedtaxa.org/index.php/JoTT/article/view/779.

Frankham, R. (1996). Relationship of genetic variation to population size in wildlife. Conservation Biology *10*, 1500–1508 URL: http://onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.1996.10061500.x/full.

Franklin, J.F. (1988). Structural and functional diversity in temperate forests. URL: https://books.google.com/books?hl=en&lr=&id=MkUrAAAAYAAJ&oi=fnd&pg=PA166&ots=AAYyxDRcnp&sig=5ZvKrdnhEV9LzCOvG-vjBu4aGvM.

Franklin, J.F., Denison, W., McKee, A., Maser, C., Sedell, J., Swanson, F., Juday, G., and others (1981). Ecological characteristics of old-growth Douglas-fir forests. URL: http://www.treesearch.fs.fed.us/pubs/5546.

Gall, G.A.. (1987). Inbreeding. In Population Genetics and Fishery Management (Seattle: Washington Sea Grant Program.).

García-Nieto, A.P., García-Llorente, M., Iniesta-Arandia, I., and Martín-López, B. (2013). Mapping forest ecosystem services: From providing units to beneficiaries. Ecosystem Services *4*, 126–138 URL: http://www.sciencedirect.com/science/article/pii/S2212041613000193.

GFW (2014). Canada Access 2010 | Global Forest Watch Canada URL: http://www.globalforestwatch.ca/node/198.

Global Forest Watch Canada (2016). Canada's Intact Forest Landscapes 2013 Dataset URL: http://globalforestwatch.ca/node/252.

Goldman, R.L., Tallis, H., Kareiva, P.M., and Daily, G.C. (2008). Field evidence that ecosystem service projects support biodiversity and diversify options. Proceedings of the National Academy of Sciences *105*, 9445–9448.

Government of Canada Tri-Agency Open Access Policy on Publications URL: http://www.science.gc.ca/eic/site/063.nsf/eng/h_F6765465.html?OpenDocument.

Government of Canada, A. and A.-F.C. of (2014a). Understanding Watersheds URL: http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/water/watershed-protection/understanding-watersheds/?id=1371490974517.

Government of Canada, E. and C.C.C. (2016). Canadian Protected Areas Status Report 2012-2015 URL: http://greenlanedev2.ncr.ec.gc.ca/ap-pa/default.asp?lang=En&n=C711CAB1-1.

Government of Canada, E.C. (2014b). Species at Risk Public Registry - Critical Habitat Identification Toolbox URL: https://www.registrelep-sararegistry.gc.ca/default.asp?lang=En&n=AA794D41-1.

Government of Canada, P.W. and G.S.C. (2002). A guide to the Species at Risk Act (SARA) : information for federal land managers URL: http://publications.gc.ca/site/eng/463205/publication.html.

Government of Canada, S.C. (2015). Canadians and Nature: Birds, 2013 - Enviro Fact Sheet URL: http://www.statcan.gc.ca/pub/16-508-x/16-508-x2015001-eng.htm.

Government of New Brunswick (2009). Biodiversity Strategy: Conserving biodiversity and usign biological resources in a sustainable manner. URL: http://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/ForestsCrownLands/Biodiversity.pdf.

Government of Prince Edward Island A Guide to Watershed Planning on Prince Edward Island.

Grêt-Regamey, A., Brunner, S., Altwegg, J., Christen, M., and Bebi, P. (2013). Integrating Expert Knowledge into Mapping Ecosystem Services Trade-offs for Sustainable Forest Management. Ecology and Society *18* URL: https://www.ecologyandsociety.org/vol18/iss3/art34/.

Grêt-Regamey, A., Weibel, B., Bagstad, K.J., Ferrari, M., Geneletti, D., Klug, H., Schirpke, U., and Tappeiner, U. (2014). On the Effects of Scale for Ecosystem Services Mapping. PLOS ONE *9*, e112601 URL: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0112601.

Groot, D. de, Ramsar Convention Secretariat, and Secretariat of the Convention on Biological Diversity (2006). Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services (Gland, Switzerland; Montreal, Quebec, Canada: Ramsar Convention Secretariat ; Secretariat of the Convention on Biological Diversity) URL: http://www.ramsar.org/pdf/lib/lib_rtr03.pdf.

de Groot, R.S., Alkemade, R., Braat, L., Hein, L., and Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity *7*, 260–272.

Groves, C.R., and Game, E.T. (2016). Conservation Planning: informed decisions for a healthier planet (Roberts and Company Publishers).

Groves, C.R., Jensen, D.B., Valutis, L.L., Redford, K.H., Shaffer, M.L., Scott, J.M., Baumgartner, J.V., Higgins, J.V., Beck, M.W., and Anderson, M.G. (2002). Planning for Biodiversity Conservation: Putting Conservation Science into Practice. BioScience *52*, 499–512 URL: http://www.bioone.org/doi/full/10.1641/0006-3568%282002%29052%5B0499%3APFBCPC%5D2.0.CO%3B2.

Haines-Young, R., Potschin, M., and Kienast, F. (2012). Indicators of ecosystem service potential at European scales: Mapping marginal changes and trade-offs. Ecological Indicators *21*, 39–53 URL: http://www.sciencedirect.com/science/article/pii/S1470160X11002767.

Han, X., Smyth, R.L., Young, B.E., Brooks, T.M., S?nchez de Lozada, A., Bubb, P., Butchart, S.H.M., Larsen, F.W., Hamilton, H., Hansen, M.C., et al. (2014). A Biodiversity Indicators Dashboard: Addressing Challenges to Monitoring Progress towards the Aichi Biodiversity Targets Using Disaggregated Global Data. PLoS ONE *9*, e112046 URL: http://dx.plos.org/10.1371/journal.pone.0112046.

Hannah, L., Midgley, G., Andelman, S., Araújo, M., Hughes, G., Martinez-Meyer, E., Pearson, R., and Williams, P. (2007). Protected area needs in a changing climate. Frontiers in Ecology and the Environment *5*, 131–138 URL: http://onlinelibrary.wiley.com/doi/10.1890/1540-9295(2007)5[131:PANIAC]2.0.CO;2/abstract.

Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Llorente, M., Geamănă, N., et al. (2014). Linkages between biodiversity attributes and ecosystem services: A systematic review. Ecosystem Services *9*, 191–203 URL: http://www.sciencedirect.com/science/article/pii/S2212041614000576.

Heath, M.F., Evans, M.I., Hoccom, D.G., Payne, A.J., Peet, N.B., and others (2000). Important Bird Areas in Europe: priority sites for conservation. URL: http://agris.fao.org/agris-search/search.do?recordID=XF2015033536.

Hedrick, P.W., and Fredrickson, R. (2010). Genetic rescue guidelines with examples from Mexican wolves and Florida panthers. Conservation Genetics *11*, 615–626 URL: http://link.springer.com/10.1007/s10592-009-9999-5.

Heller, N.E., and Zavaleta, E.S. (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. Biological Conservation *142*, 14–32 URL: http://www.sciencedirect.com/science/article/pii/S000632070800387X.

Heller, R., Okello, J.B.A., and Siegismund, H. (2010). Can small wildlife conservancies maintain genetically stable populations of large mammals? Evidence for increased genetic drift in geographically restricted populations of Cape buffalo in East Africa. Molecular Ecology *19*, 1324–1334 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-294X.2010.04589.x/abstract.

Hodgson, J.A., Thomas, C.D., Wintle, B.A., and Moilanen, A. (2009). Climate change, connectivity and conservation decision making: back to basics. Journal of Applied Ecology *46*, 964–969 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2009.01695.x/abstract.

Holt, R., and Hatfield, T. (2007). Key Elements of Biodiversity in British Columbia: some examples from the terrestrial and freshwater aquatic realm. URL: http://biodiversitybc.org/assets/Default/BBC%20Key%20Elements%20Examples.pdf.

Hudson, L.N., Newbold, T., Contu, S., Hill, S.L.L., Lysenko, I., De Palma, A., Phillips, H.R.P., Senior, R.A., Bennett, D.J., Booth, H., et al. (2014). The PREDICTS database: a global database of how local terrestrial biodiversity responds to human impacts. Ecol Evol *4*, 4701–4735 URL: http://onlinelibrary.wiley.com/doi/10.1002/ece3.1303/abstract.

Hunter, M., Dinerstein, E., Hoekstra, J., and Lindenmayer, D. (2010). A Call to Action for Conserving Biological Diversity in the Face of Climate Change. Conservation Biology *24* URL: http://www.readcube.com/articles/10.1111/j.1523-1739.2010.01569.x.

Hunter, M.L., Jacobson, G.L., and Webb, T. (1988). Paleoecology and the coarse-filter approach to maintaining biological diversity. Conservation Biology *2*, 375–385 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.1988.tb00202.x/full.

Ibisch, P.L., Hoffmann, M.T., Kreft, S., Pe'er, G., Kati, V., Biber-Freudenberger, L., DellaSala, D.A., Vale, M.M., Hobson, P.R., and Selva, N. (2016). A global map of roadless areas and their conservation status. Science *354*, 1423–1427 URL: http://science.sciencemag.org/content/354/6318/1423.

Ingram, J.C., Redford, K.H., and Watson, J.E. (2012). Applying ecosystem services approaches for biodiversity conservation: benefits and challenges. S.A.P.I.EN.S Surveys and Perspectives Integrating Environment and Society.

International Union for the Conservation of Nature (IUCN) (2015). The IUCN red list of threatened species.

IUCN (2005). Resolutions and Recommendations.

IUCN (2016a). An Introduction to the IUCN Red List of Ecosystems: The Categories and Criteria for Assessing Risks to Ecosystems. URL: https://portals.iucn.org/library/sites/library/files/documents/2016-035.pdf.

IUCN (2016b). A Global Standard for the Identification of Key Biodiversity Areas, Version 1.0. URL: https://portals.iucn.org/union/sites/union/files/doc/a_global_standard_for_the_identification_of_key_biodiversity_areas_final_web.pdf.

Iverson, S.A., Gilchrist, H.G., Smith, P.A., Gaston, A.J., and Forbes, M.R. (2014). Longer ice-free seasons increase the risk of nest depredation by polar bears for colonial breeding birds in the Canadian Arctic. Proceedings of the Royal Society B: Biological Sciences *281*, 20133128–20133128 URL: http://rspb.royalsocietypublishing.org/cgi/doi/10.1098/rspb.2013.3128.

Jacobs, S., Burkhard, B., Van Daele, T., Staes, J., and Schneiders, A. (2015). 'The Matrix Reloaded': A review of expert knowledge use for mapping ecosystem services. Ecological Modelling *295*, 21–30 URL: http://www.sciencedirect.com/science/article/pii/S0304380014004141.

Johnson, J.A., Bellinger, M.R., Toepfer, J.E., and Dunn, P. (2004). Temporal changes in allele frequencies and low effective population size in greater prairie-chickens. Molecular Ecology *13*, 2617–2630 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-294X.2004.02264.x/abstract.

Jones, L., Norton, L., Austin, Z., Browne, A.L., Donovan, D., Emmett, B.A., Grabowski, Z.J., Howard, D.C., Jones, J.P.G., Kenter, J.O., et al. (2016). Stocks and flows of natural and human-derived capital in ecosystem services. Land Use Policy *52*, 151–162 URL: http://www.sciencedirect.com/science/article/pii/S026483771500410X.

Joppa, L.N., and Pfaff, A. (2009). High and Far: Biases in the Location of Protected Areas. PLoS ONE *4*, e8273 URL: http://dx.plos.org/10.1371/journal.pone.0008273.

Jump, A.S., and Peñuelas, J. (2006). Genetic effects of chronic habitat fragmentation in a wind-pollinated tree. Proceedings of the National Academy of Sciences *103*, 8096–8100 URL: http://www.pnas.org/content/103/21/8096.short.

Kareiva, P., Watts, S., McDonald, R., and Boucher, T. (2007). Domesticated Nature: Shaping Landscapes and Ecosystems for Human Welfare. Science *316*, 1866–1869 URL: http://www.jstor.org.ezproxy.library.ubc.ca/stable/20036578.

Keith, D.A., Rodríguez, J.P., Rodríguez-Clark, K.M., Nicholson, E., Aapala, K., Alonso, A., Asmussen, M., Bachman, S., Basset, A., Barrow, E.G., et al. (2013). Scientific Foundations for an IUCN Red List of Ecosystems. PLOS ONE *8*, e62111 URL: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0062111.

Keith, D.A., Rodríguez, J.P., Brooks, T.M., Burgman, M.A., Barrow, E.G., Bland, L., Comer, P.J., Franklin, J., Link, J., McCarthy, M.A., et al. (2015). The IUCN Red List of Ecosystems:

Motivations, Challenges, and Applications. Conservation Letters *8*, 214–226 URL: http://onlinelibrary.wiley.com/doi/10.1111/conl.12167/abstract.

Kerr, J.T., and Deguise, I. (2004). Habitat loss and the limits to endangered species recovery. Ecology Letters *7*, 1163–1169 URL: http://doi.wiley.com/10.1111/j.1461-0248.2004.00676.x.

Kerr J.T. (1996). Species Richness, Endemism, and the Choice of Areas for Conservation URL: http://aix1.uottawa.ca/~jkerr/Kerr%201997%20ConsBiol.pdf.

Klein, A.-M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., and Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. Proc Biol Sci *274*, 303–313 URL: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1702377/.

Klijn, F., and H.A. Udo de Haes (1994). A hierarchical approach to ecosystems and its implications for ecological land classification URL: https://link.springer.com/content/pdf/10.1007%2FBF00124376.pdf.

Krantzberg, G., and de Boer, C. (2006). A Valuation of Ecological Services in the Great Lakes Basin Ecosystem to Sustain Healthy Communities and a Dynamic Economy (Dofasco Centre for Engineering and Public Policy, McMaster University).

Leberg, P.L. (1992). Effects of Population Bottlenecks on Genetic Diversity as Measured by Allozyme Electrophoresis. Evolution *46*, 477–494 URL: http://www.jstor.org/stable/2409866.

Lemieux, C.J. (2010). Protected areas and climate change in Canada: challenges and opportunities for adaptation (Gatineau, Qué: Canadian Council on Ecological Areas).

Li, Y., Zhang, L., Yan, J., Wang, P., Hu, N., Cheng, W., and Fu, B. (2017). Mapping the hotspots and coldspots of ecosystem services in conservation priority setting. J. Geogr. Sci. *27*, 681–696 URL: https://link.springer.com/article/10.1007/s11442-017-1400-x.

Lindberg, T.T., Bernhardt, E.S., Bier, R., Helton, A.M., Merola, R.B., Vengosh, A., and Giulio, R.T.D. (2011). Cumulative impacts of mountaintop mining on an Appalachian watershed. PNAS *108*, 20929–20934 URL: http://www.pnas.org/content/108/52/20929.

Linzey, A.V. (2002). Important Mammal Areas: A US pilot project. Page A80 in Society for Conservation Biology. In 16th Annual Meeting: Programme and Abstracts. Canterbury (United Kingdom): Durrell Institute of Conservation and Ecology, p.

Locke, H. (2017). Personal submission to Parks Canada Minister's Roundtable.

Luck, G.W., Chan, K.M.A., and Fay, J.P. (2009). Protecting ecosystem services and biodiversity in the world's watersheds. Conservation Letters *2*, 179–188.

Luck, G.W., Chan, K.M., and Klein, C. (2012). Identifying spatial priorities for protecting ecosystem services. F1000Research 1–17.

Mace, G.M., Norris, K., and Fitter, A.H. (2012). Biodiversity and ecosystem services: a multilayered relationship. Trends In Ecology & Evolution *27*, 19–26.

Maes, J., Egoh, B., Willemen, L., Liquete, C., Vihervaara, P., Schägner, J.P., Grizzetti, B., Drakou, E.G., Notte, A.L., Zulian, G., et al. (2012a). Mapping ecosystem services for policy support and decision making in the European Union. Ecosystem Services *1*, 31–39 URL: http://www.sciencedirect.com/science/article/pii/S2212041612000058.

Maes, J., Paracchini, M.L., Zulian, G., Dunbar, M.B., and Alkemade, R. (2012b). Synergies and trade-offs between ecosystem service supply, biodiversity, and habitat conservation status in Europe. Biological Conservation *155*, 1–12.

Martínez-Cruz, B., Godoy, J.A., and Negro, J.J. (2007). Population fragmentation leads to spatial and temporal genetic structure in the endangered Spanish imperial eagle. Molecular Ecology *16*, 477–486 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-294X.2007.03147.x/abstract.

Martinez-Harms, M.J., Bryan, B.A., Balvanera, P., Law, E.A., Rhodes, J.R., Possingham, H.P., and Wilson, K.A. (2015). Making decisions for managing ecosystem services. Biological Conservation *184*, 229–238 URL: http://www.sciencedirect.com/science/article/pii/S0006320715000452.

McNutt, M. (2014). Reproducibility. Science *343*, 229–229 URL: http://science.sciencemag.org/content/343/6168/229.short.

Miguel, E., Camerer, C., Casey, K., Cohen, J., Esterling, K.M., Gerber, A., Glennerster, R., Green, D.P., Humphreys, M., Imbens, G., et al. (2014). Promoting transparency in social science research. Science *343*, 30–31 URL: http://science.sciencemag.org/content/343/6166/30.short.

Millennium Ecosystem Assessment (2005). Ecosystems and human well-being (Washington, DC: Island Press).

Mitchell, M.G.E., Suarez-Castro, A.F., Martinez-Harms, M., Maron, M., McAlpine, C., Gaston, K.J., Johansen, K., and Rhodes, J.R. (2015). Reframing landscape fragmentation's effects on ecosystem services. Trends in Ecology & Evolution *30*, 190–198 URL: http://www.sciencedirect.com/science/article/pii/S0169534715000233.

Molnar, J.L., and Kubiszewski, I. (2012). Managing natural wealth: Research and implementation of ecosystem services in the United States and Canada. Ecosystem Services *2*, 45–55 URL: http://www.sciencedirect.com/science/article/pii/S2212041612000319.

Mooers, A. ø., Prugh, L. r., Festa-Bianchet, M., and Hutchings, J. a. (2007). Biases in Legal Listing under Canadian Endangered Species Legislation. Conservation Biology *21*, 572–575 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2007.00689.x/abstract.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Da Fonseca, G.A., and Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature *403*, 853–858 URL: http://www.nature.com/nature/journal/v403/n6772/abs/403853a0.html.

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R.E., Lehner, B., Malcolm, T.R., and Ricketts, T.H. (2008). Global mapping of ecosystem services and conservation priorities. Proceedings of the National Academy of Sciences of the United States of America *105*, 9495–9500.

Nature Availability of data, material and methods URL: http://www.nature.com/authors/policies/availability.html?foxtrotcallback=true.

Nedkov, S., and Burkhard, B. (2012). Flood regulating ecosystem services—Mapping supply and demand, in the Etropole municipality, Bulgaria. Ecological Indicators *21*, 67–79 URL: http://www.sciencedirect.com/science/article/pii/S1470160X11001932.

Nei, M., Maruyama, T., and Chakraborty, R. (1975). The Bottleneck Effect and Genetic Variability in Populations. Evolution *29*, 1–10 URL: http://www.jstor.org/stable/2407137.

Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D.R., Chan, K.M.A., Daily, G.C., Goldstein, J., Kareiva, P.M., et al. (2009). Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Frontiers in Ecology and the Environment *7*, 4–11.

Newbold, T., Hudson, L.N., Arnell, A.P., Contu, S., Palma, A.D., Ferrier, S., Hill, S.L.L., Hoskins, A.J., Lysenko, I., Phillips, H.R.P., et al. (2016). Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. Science *353*, 288–291 URL: http://science.sciencemag.org/content/353/6296/288.

Nixon, A., Shanks, C., and Farr, D. (2015). Understanding and Responding to the Effects of Climate Change on Alberta's Biodiversity URL: http://biodiversityandclimate.abmi.ca/wp-content/uploads/flipbook/files/inc/8f4db5399d.pdf.

Noss, R.F. (1990). Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology *4*, 355–364 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.1990.tb00309.x/full.

Office of the Auditor General of British Columbia (2013). An audit of Biodiversity in B.C assessing the effectiveness of key tools. URL: https://www.bcauditor.com/sites/default/files/publications/2013/report_10/report/OAGBC-Audit%20of%20Biodiversity%20in%20B.C%20assessing%20the%20effectiveness%20of%20key%20tools.pdf.

Office of the Auditor General of Canada (2013). Fall Report of the Commissioner of the Environment and Sustainable Development URL: http://www.oag-bvg.gc.ca/internet/English/parl_cesd_201311_e_38658.html.

Ollerton, J., Winfree, R., and Tarrant, S. (2011). How many flowering plants are pollinated by animals? Oikos *120*, 321–326 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0706.2010.18644.x/abstract.

O'Neill, R.V. (1986). A hierarchical concept of ecosystems (Princeton University Press) URL: https://books.google.com/books?hl=en&lr=&id=Bj1cx_UeLK4C&oi=fnd&pg=PP9&dq=a+hierarchical+concept+of+ecosystems&ots=-9tBS2j6SN&sig=iqB75BbVMHTReuEJabj-rxTOpo4.

Osieck, E.R., and Mörzer Bruyns, M.F. (1981). Important bird areas in the European community (International Council for Bird Preservation, Cambridge, UK).

Ozaki, K., Isono, M., Kawahara, T., Iida, S., Kudo, T., and Fukuyama, K. (2006). A Mechanistic Approach to Evaluation of Umbrella Species as Conservation Surrogates. Conservation Biology *20*, 1507–1515 URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2006.00444.x/abstract.

Pachauri, R.K., Mayer, L., and Intergovernmental Panel on Climate Change (2015). Climate change 2014: synthesis report (Geneva, Switzerland: Intergovernmental Panel on Climate Change).

Palomo, I., Martín-López, B., Potschin, M., Haines-Young, R., and Montes, C. (2013). National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows. Ecosystem Services *4*, 104–116 URL: http://www.sciencedirect.com/science/article/pii/S2212041612000277.

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R.T., Başak Dessane, E., Islar, M., Kelemen, E., et al. (2017). Valuing nature's contributions to people: the IPBES approach. Current Opinion in Environmental Sustainability *26*, 7–16 URL: http://www.sciencedirect.com/science/article/pii/S1877343517300040.

Pereira, H.M., Leadley, P.W., Proença, V., Alkemade, R., Scharlemann, J.P.W., Fernandez-Manjarrés, J.F., Araújo, M.B., Balvanera, P., Biggs, R., Cheung, W.W.L., et al. (2010). Scenarios for Global Biodiversity in the 21st Century. Science *330*, 1496–1501 URL: http://science.sciencemag.org/content/330/6010/1496.

Peter Lee, Matthew Hanneman, Jeannette Gysbers, Ryan Cheng, and Wynet Smith (2010). Atlas of Canada's Intact Forest Landscapes. Atlas of Canada's Intact Forest Landscapes By: Peter Lee Matthew Hanneman Jeannette Gysbers Ryan Cheng Wynet Smith ISBN: ___ ©Global Forest Watch Canada, 2010 *16*, 2411–2425 URL: http://onlinelibrary.wiley.com/doi/10.1890/1051-0761(2006)016%5B2411:DAMCFA%5D2.0.CO;2/full.

Plieninger, T., Dijks, S., Oteros-Rozas, E., and Bieling, C. (2013). Assessing, mapping, and quantifying cultural ecosystem services at community level. Land Use Policy *33*, 118–129 URL: http://www.sciencedirect.com/science/article/pii/S026483771200258X.

Plummer, M.L. (2009). Assessing Benefit Transfer for the Valuation of Ecosystem Services. Frontiers in Ecology and the Environment *7*, 38–45 URL: http://www.jstor.org.ezproxy.library.ubc.ca/stable/25595036.

Polasky, S., Johnson, K., Keeler, B., Kovacs, K., Nelson, E., Pennington, D., Plantinga, A.J., and Withey, J. (2012). Are investments to promote biodiversity conservation and ecosystem services aligned? Oxf Rev Econ Policy *28*, 139–163 URL: https://academic.oup.com/oxrep/article/28/1/139/374175/Are-investments-to-promote-biodiversity.

Potapov, P., Yaroshenko, A., Turubanova, S., Dubinin, M., Laestadius, L., Thies, C., Aksenov, D., Egorov, A., Yesipova, Y., Glushkov, I., et al. (2008). Mapping the World's Intact Forest Landscapes by Remote Sensing. Ecology and Society *13* URL: https://www.ecologyandsociety.org/vol13/iss2/art51/main.html.

Preston, S.M., Canada, and Environment and Climate Change Canada (2017). Completing and using ecosystem service assessment for decision-making: an interdisciplinary toolkit for managers and analysts. URL: http://publications.gc.ca/collections/collection_2017/eccc/En4-295-2016-eng.pdf.

Primmer, E., and Furman, E. (2012). Operationalising ecosystem service approaches for governance: Do measuring, mapping and valuing integrate sector-specific knowledge systems? Ecosystem Services *1*, 85–92 URL: http://www.sciencedirect.com/science/article/pii/S2212041612000137.

Qiu, J., and Turner, M.G. (2013). Spatial interactions among ecosystem services in an urbanizing agricultural watershed. PNAS *110*, 12149–12154 URL: http://www.pnas.org/content/110/29/12149.

Rainer, R., Bennett, B., Blaney, S., Enns, A., Henr, and y, P., Lofroth, E. & Mackenzie, J. (2017). On Guard for Them: Species of Global Conservation Concern in Canada URL: http://www.natureserve.org/mwg-internal/de5fs23hu73ds/progress?id=vC1NqYN0yuiBCVjGru_CO74tREUPBhIRgShnW8AmgqI,&dl.

Ralls K., Ballou J. D., and Temlpeton A (1988). Estimates of Lethal Equivalents and the Cost of Inbreeding in Mammals URL: http://www.montana.edu/mwg-internal/de5fs23hu73ds/progress?id=YkA9FYE4JpzJ-2NcssQnQi3M6FlJWWUWFA1eQsSN5mQ,&dl.

Rankin, R., Austin, M, and Rice, J (2011). Ecological classification system for the ecosystem status and trends report (Ottawa: Canadian Councils of Resource Ministers) URL: http://epe.lac-bac.gc.ca/100/201/301/weekly_checklist/2012/internet/w12-10-U-E.html/collections/collection_2012/ec/En14-43-1-2012-eng.pdf.

Raymond, C.M., Bryan, B.A., MacDonald, D.H., Cast, A., Strathearn, S., Grandgirard, A., and Kalivas, T. (2009). Mapping community values for natural capital and ecosystem services. Ecological Economics *68*, 1301–1315 URL: http://www.sciencedirect.com/science/article/pii/S0921800908005326.

Regmi, B., Douglas, M.R., Anthonysamy, W.J.B., Douglas, M.E., and Leberg, P.L. (2016). Salinity and hydrological barriers have little influence on genetic structure of the mosquitofish in a coastal landscape shaped by climate change. Hydrobiologia *777*, 209–223 URL: http://link.springer.com/10.1007/s10750-016-2786-7.

Reyers, B., Polasky, S., Tallis, H., Mooney, H.A., and Larigauderie, A. (2012). Finding common ground for biodiversity and ecosystem services. BioScience *62*, 503–507.

Rode, K.D., Wilson, R.R., Regehr, E.V., St. Martin, M., Douglas, D.C., and Olson, J. (2015). Increased Land Use by Chukchi Sea Polar Bears in Relation to Changing Sea Ice Conditions. PLOS ONE *10*, e0142213 URL: http://dx.plos.org/10.1371/journal.pone.0142213.

Rodrigues, A., Pilgrim, J., Lamoreux, J., Hoffmann, M., and Brooks, T. (2006). The value of the IUCN Red List for conservation. Trends in Ecology & Evolution *21*, 71–76 URL: http://linkinghub.elsevier.com/retrieve/pii/S0169534705003320.

Rogers, H.M., Glew, L., Honzak, M., and Hudson, M.D. (2010). Prioritizing key biodiversity areas in Madagascar by including data on human pressure and ecosystem services. Landscape And Urban Planning *96*, 48–56.

Roth, R.J. (2008). "Fixing" the Forest: The Spatiality of Conservation Conflict in Thailand. Annals of the Association of American Geographers *98*, 373–391 URL: http://dx.doi.org/10.1080/00045600801925557.

Ryti R.T. (1992). Effect of the focal taxon on the selection of nature reserves URL: http://planet.botany.uwc.ac.za/NISL/Conservation%20Biology/Chapter1_bak/articles/Ryti_1992.pdf.

Sanderson, E.W., Jaiteh, M., Levy, M.A., Redford, K.H., Wannebo, A.V., and Woolmer, G. (2002). The Human Footprint and the Last of the Wild. BioScience *52*, 891–904 URL: http://www.bioone.org/doi/abs/10.1641/0006-3568(2002)052[0891:THFATL]2.0.CO%3B2.

Sanderson, E.W., Segan, D.B., and Watson, J.E.M. (2015). Global status of and prospects for protection of terrestrial geophysical diversity. Conservation Biology *29*, 649–656 URL: http://onlinelibrary.wiley.com/doi/10.1111/cobi.12502/abstract.

Sandifer, P.A., Sutton-Grier, A.E., and Ward, B.P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. Ecosystem Services *12*, 1–15 URL: http://www.sciencedirect.com/science/article/pii/S2212041614001648.

Schägner, J.P., Brander, L., Maes, J., and Hartje, V. (2013). Mapping ecosystem services' values: Current practice and future prospects. Ecosystem Services *4*, 33–46 URL: http://www.sciencedirect.com/science/article/pii/S2212041613000120.

Schlosser, I.J., and Karr, J.R. (1981). WATER QUALITY IN AGRICULTURAL WATERSHEDS: IMPACT OF RIPARIAN VEGETATION DURING BASE FLOW. Journal of

the American Water Resources Association *17*, 233–240 URL: http://doi.wiley.com/10.1111/j.1752-1688.1981.tb03927.x.

Schneider, R.R., Hauer, G., Farr, D., Adamowicz, W.L., and Boutin, S. (2011). Achieving Conservation when Opportunity Costs Are High: Optimizing Reserve Design in Alberta's Oil Sands Region. PLoS ONE *6*, e23254 URL: http://dx.plos.org/10.1371/journal.pone.0023254.

Schneider R. (2014). Conserving Alberta's biodiversity under a changing climate: A review and analysis of adaptation measures URL: http://biodiversityandclimate.abmi.ca/wp-content/uploads/2015/02/Schneider_2014_AdaptingBiodiversityManagementtoClimateChange.pdf.

Scholes, R.J., and Biggs, R. (2005). A biodiversity intactness index. Nature *434*, 45–49 URL: https://www.nature.com/nature/journal/v434/n7029/abs/nature03289.html.

Secretariat of the Convention on Biological Diversity (2005). Handbook of the Convention on Biological Diversity: including its Cartagena Protocol on Biosafety.

Sherrouse, B.C., Clement, J.M., and Semmens, D.J. (2011). A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. Applied Geography *31*, 748–760 URL: http://www.sciencedirect.com/science/article/pii/S0143622810000858.

Smith, W., Cheng, R., and Lee, P. (2016). Canada's Intact Forest Landscapes Updated to 2013 (Ottawa, ON: Global Forest Watch Canada) URL: http://globalforestwatch.ca/sites/gfwc/files/publications/GFWC%20IFL%20bulletin%202016%20July%20Final_0.pdf.

Stattersfield, A.J., Crosby, M.J., Long, A.J., and Wege, D.C. (1998). Global directory of endemic bird areas. BirdLife International, Cambridge, United Kingdom.

Stern, N.H. (2007). The economics of climate change: the Stern review (cambridge University press).

Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, B., and Midgley, B.M. (2013). IPCC, 2013: climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change (Cambridge University Press).

Stralberg, D., and Bayne, E.M. (2013). Modeling avifaunal responses to climate change across Alberta's Natural Regions. Alberta Biodiversity Monitoring Institute, Edmonton, AB.

Tallis, H., and Polasky, S. (2009). Mapping and Valuing Ecosystem Services as an Approach for Conservation and Natural-Resource Management. Annals of the New York Academy of Sciences *1162*, 265–283 URL: http://onlinelibrary.wiley.com.ezproxy.library.ubc.ca/doi/10.1111/j.1749-6632.2009.04152.x/abstract.

Tallis, H., Kareiva, P.M., Marvier, M., and Chang, A. (2008). An ecosystem services framework to support both practical conservation and economic development. Proceedings of the National Academy of Sciences of the United States of America *105*, 9457–9464.

Thies, C., Rosoman, G., Cotter, J., and Meaden, S. (2011). Intact forest landscapes. Why It Is Crucial to Protect Them from Industrial Exploitation. Greenpeace Research Laboratories Techn Note, Bd *5* URL:
http://www.greenpeace.org/international/Global/international/publications/forests/2011/IntactFor estLandscapes.pdf.

Tingley, M.W., Estes, L.D., and Wilcove, D.S. (2013). Ecosystems: Climate change must not blow conservation off course : Nature : Nature Research URL:
https://www.nature.com/nature/journal/v500/n7462/full/500271a.html.

Tognelli, M.F., Máiz-Tomé, L., Kraus, D., Lepitzki, D., Mackie, G., Morris, T., Carney, J., Alfonso, N., Tonn, B., Cox, N.A., et al. (2017). Freshwater Key Biodiversity Areas in Canada. Informing species conservation and development planning in freshwater ecosystems.

Tory, A., and Bagstad, K. (2009). Estimating Ecosystem Services in Southern Ontario (Spatial Informatics Group).

Troy, A., and Wilson, M.A. (2006). Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer. Ecological Economics *60*, 435–449 URL:
http://www.sciencedirect.com/science/article/pii/S0921800906002357.

Turetsky, M., Wieder, K., Halsey, L., and Vitt, D. (2002). Current disturbance and the diminishing peatland carbon sink. Geophys. Res. Lett. *29*, 21–1 URL:
http://onlinelibrary.wiley.com/doi/10.1029/2001GL014000/abstract.

Tyrrell T. et al. (2011). Biodiversity indicators and the 2010 biodiversity target outputs, experiences and lessons learnt from the 2010 biodiversity indicators partnership (New York, NY: UNEP).

UNEP-WCMC and IUCN (2016). Protected Planet Report 2016 - How protected areas contribute to achieving global targets for biodiversity URL:
https://wdpa.s3.amazonaws.com/Protected_Planet_Reports/2445%20Global%20Protected%20Pl anet%202016_WEB.pdf.

Urban, M.C. (2015). Accelerating extinction risk from climate change. Science *348*, 571–573 URL: http://science.sciencemag.org/content/348/6234/571.

Vačkář, D., ten Brink, B., Loh, J., Baillie, J.E.M., and Reyers, B. (2012). Review of multispecies indices for monitoring human impacts on biodiversity. Ecological Indicators *17*, 58–67 URL:
http://www.sciencedirect.com/science/article/pii/S1470160X11001051.

Valeriote, J., Machado, E., and Brooke, R. (2016). The Municipal Natural Assets Initiative. URL: http://tinyurl.com/hbmffc9.

Value of Nature to Canadians Study Taskforce (2017). Completing and Using Ecosystem Service Assessment for Decision-Making: An Interdisciplinary Toolkit for Managers and Analysts (Ottawa, ON: Federal, Provincial, and Territorial Governments of Canada).

Van Swaay, C., and Warren, M. (2003). Prime Butterfly Areas in Europe. Priority Sites for Conservation URL: http://www.bc-europe.eu/upload/PBA_summary.pdf.

Venter, O., Brodeur, N.N., Nemiroff, L., Belland, B., Dolinsek, I.J., and Grant, J.W.A. (2006). Threats to Endangered Species in Canada. BioScience *56*, 903–910 URL: https://academic.oup.com/bioscience/article/56/11/903/272301/Threats-to-Endangered-Species-in-Canada.

Venter, O., Sanderson, E.W., Magrach, A., Allan, J.R., Beher, J., Jones, K.R., Possingham, H.P., Laurance, W.F., Wood, P., Fekete, B.M., et al. (2016a). Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. Nature Communications *7*, 12558 URL: http://www.nature.com/ncomms/2016/160823/ncomms12558/full/ncomms12558.html.

Venter, O., Sanderson, E.W., Magrach, A., Allan, J.R., Beher, J., Jones, K.R., Possingham, H.P., Laurance, W.F., Wood, P., Fekete, B.M., et al. (2016b). Global terrestrial Human Footprint maps for 1993 and 2009. Scientific Data *3*, 160067 URL: http://www.nature.com/articles/sdata201667.

Villamagna, A.M., Angermeier, P.L., and Bennett, E.M. (2013). Capacity, pressure, demand, and flow: A conceptual framework for analyzing ecosystem service provision and delivery. Ecological Complexity *15*, 114–121 URL: http://www.sciencedirect.com/science/article/pii/S1476945X1300055X.

Voora, V., and Venema, H.D. (2008). An Ecosystem Services Assessment of the Lake Winnipeg Watershed (International Institute for Sustainable Development).

Warman, L.D., Forsyth, D.M., Sinclair, A.R.E., Freemark, K., Moore, H.D., Barrett, T.W., Pressey, R.L., and White, D. (2004). Species distributions, surrogacy, and important conservation regions in Canada: Surrogacy and biodiversity conservation. Ecology Letters *7*, 374–379 URL: http://doi.wiley.com/10.1111/j.1461-0248.2004.00590.x.

Watson, J.E.M., Shanahan, D.F., Di Marco, M., Allan, J., Laurance, W.F., Sanderson, E.W., Mackey, B., and Venter, O. (2016). Catastrophic Declines in Wilderness Areas Undermine Global Environment Targets. Current Biology *26*, 2929–2934 URL: http://www.sciencedirect.com/science/article/pii/S0960982216309939.

Wellcome (2017). Policy on data, software and materials management and sharing | Wellcome URL: https://wellcome.ac.uk/funding/managing-grant/policy-data-software-materials-management-and-sharing.

whitehouse.gov (2014). Fact Sheet: The Economic Challenge Posed by Declining Pollinator Populations URL: https://obamawhitehouse.archives.gov/the-press-office/2014/06/20/fact-sheet-economic-challenge-posed-declining-pollinator-populations.

Wiken, Ed.B. (compiler) (1986). Terrestrial Ecozones of Canada. Ecological Land Classification Series No. 19.

Wilson, S. (2012). Canada's Wealth of Natural Capital: Rouge National Park (David Suzuki Foundation).

Wilson, S. (2014). The Peace Dividend: Assessing the Economic Value of Ecosystems in B.C.'s Peace River Watershed (Natural Capital Research & Consulting).

Wolff, S., Schulp, C.J.E., and Verburg, P.H. (2015). Mapping ecosystem services demand: A review of current research and future perspectives. Ecological Indicators *55*, 159–171 URL: http://www.sciencedirect.com/science/article/pii/S1470160X15001405.

World Database of Key Biodiversity Areas What are KBAs & how are they identified? URL: http://www.keybiodiversityareas.org/what-are-kbas.

Wright, S. (1931). Evolution in Mendelian populations. Genetics *16*, 97–159 URL: http://www.genetics.org/content/genetics/16/2/97.full.pdf.

WWF (2017). Watershed Reports : A national assessment of Canada's freshwater.

Xu, W., Xiao, Y., Zhang, J., Yang, W., Zhang, L., Hull, V., Wang, Z., Zheng, H., Liu, J., Polasky, S., et al. (2017). Strengthening protected areas for biodiversity and ecosystem services in China. PNAS *114*, 1601–1606 URL: http://www.pnas.org/content/114/7/1601.

Yahi, N., Vela, E., Benhouhou, S., Belair, G.D., and Gharzouli, R. (2012). Identifying Important Plants Areas (Key Biodiversity Areas for Plants) in northern Algeria. Journal of Threatened Taxa *4*, 2753–2765 URL: http://threatenedtaxa.org/index.php/JoTT/article/view/781.

8 Appendix

8.1 Potential first steps for creating a Canadian Red List of Ecosystems

Work in partnership with NatureServe, who are currently working on a Red List of Ecosystems in the Americas and have already assessed all United States/Canadian transboundary upland and wetland ecosystems, to organize and carry out Red List assessments of Canadian ecosystems.

An analysis for Canada would likely be most efficiently divided up in several ways, each with distinct emphases:

- Establish distinct approaches according to temperate, boreal, and arctic areas of Canada. Analysis (expertise and data used/required) would likely proceed differently in each of these areas. For example, the Arctic would be best addressed as a circumpolar effort. The Boreal would also benefit from this approach, but could feasibly be addressed from a North American perspective. The temperate zone is strongly transboundary with the USA, and shares much land use history and data/expertise requirements.
- Divide the developed, southern, temperate zone of the country (see section 6.2) into three sections East to West (possibly East coast to Great Lakes, Great Lakes to Rockies (prairies), Rockies to West Coast)
- Analysis for southern, temperate Canada will likely emphasize land use history, and require highest resolution data from diverse sources, with much shared with adjacent areas of the United States.
- As the focus moves northward, into Boreal and up into the Arctic, land usage becomes less applicable and climate change measures will be more relevant. Under the IUCN red list criteria, climate change falls under current/next 50 year projected environmental degradation (e.g., change to natural disturbance regimes, species composition turnover, peatland degradation and thawing permafrost) or forecasted change in extent (loss of coastal ecosystem's extent due to rising sea levels).

Step 1 - Hold planning webinar(s) for Canadian partners. NatureServe could provide an overview of the red-listing analysis and facilitate discussion of needed expertise and data by ecosystem realm.

- Red list analysis steps include a) defining ecosystems to be assessed, b) mapping ecosystem distributions, c) documenting key ecosystem processes that are vulnerable to degradation, d) identifying measures to assess degradation, e) implementing red list measures to document trends in distribution and degradation by ecosystem type.
- Identify options for desired final products of red list assessments.
- Identify needs and requirements for data management to meet needs of an integrated assessment process and dissemination across jurisdictions.
- Consider options for sequencing and regional organization of assessments for each realm: terrestrial (upland and wetland) vs. freshwater (lakes and streams), vs. coastal marine, vs. subterranean (dry caves and aquatic caves).

Step 2 - Hold a planning workshop in each of the three sections of the temperate zone (divided east to west). These workshops would require bringing together key players such as the provincial natural resource agencies, conservation data centers, and federal protected areas agencies. Workshops would look at:

- Identify who needs to be involved in the overall process
- Review what has already been accomplished for red listing ecosystems by the project in the United States (for cross-boundary ecosystems)
- Review what expertise is available to advance the project and determine what is missing in order to move forward
- Review what data is are available to advance the project and determine what is missing in order to move forward
- Establish next steps for work planning and start thinking about how the final product will be communicated and made available

Step 3 - Organizing expert input and data preparation will be among the most labour intensive steps of the entire process. Most data will need to prepared for processing by the GIS scripts created to do the actual data analysis. It may be most efficient to pilot the analysis in one section of Canada.

- Experts will be required to finalize the classification and description of ecosystem types as units of analysis.
- Their expertise will be needed to determine the appropriate measures for assessments, and thus, what data will be most essential for the analysis.
- Once all the data is identified, collected, and pre-processed for a section of Canada, each step of the red listing analysis can be completed.
- Pilot assessment products by ecosystem type, region, and national area.

Step 4 - Implement subsequent assessments for Canadian ecosystems; by realm and region.

- Disseminate final products by ecosystem type, region, and national area.

8.2   Potential steps for identifying Key Biodiversity Areas in Canada

As the Global Standard for the identification of Key Biodiversity Areas was released only very recently, one of the most important actions that would need to be taken in order to implement the standard in Canada will be continued outreach to promote awareness and training. Those responsible for conservation planning in all jurisdictions would need to be made aware of the standard and have opportunities to ask questions regarding its potential applications. The Canadian Council on Ecological Areas is already planning to begin this process with a workshop on Key Biodiversity Areas in the fall of 2017 in coordination with the IUCN Taskforce on Protected Areas and Biodiversity and members of the KBA partnership.

The Key Biodiversity Areas standard is a global standard that identifies sites that contribute significantly to the global persistence of biodiversity. However, for the purposes of Canadian domestic use, the standard can be adapted to identify sites that are significant at a national (i.e. National Key Biodiversity Areas) or provincial/territorial scale by adjusting the thresholds for various criteria. The initial steps (not necessarily sequential) for identifying KBAs would include:

Step 1 – identify a process for national coordination, in keeping with terms of reference for national coordinating bodies issued by the Partnership, tailored to Canada.

Step 2 - Identify global Key Biodiversity Areas in Canada. This will likely require the effort of relatively small groups of experts drawn from Conservation Date Centres, NGOs, consulting agencies, universities and Government Departments. This, it is estimated, would take approximately 9 months to complete identification. This would involve the evaluation of:

i) The currently identified Important Bird Areas and Areas for Zero Extinction to determine if they should remain global Key Biodiversity Areas and
ii) the IUCN Red-Listed species that occur in Canada to determine whether any sites within their distributions in Canada qualify as global Key Biodiversity Areas.
iii) A separate process with different datasets to elucidate criterion C areas (ongoing, led by Wildlife Conservation Society Canada) (Ray et al. 2017) presentation at ICCB

Step 3 - Submit Canadian identified global Key Biodiversity Areas to the KBA partnership for review, ratification and inclusion in the Key Biodiversity Areas Database.

Step 4 -Develop Canadian Key Biodiversity Area thresholds. This would entail an analysis of the current global criteria thresholds to determine how they would need to be adjusted to be more suitable for the national context.

Step 5 -Begin the identification of national Key Biodiversity Areas incrementally.

      i.   Evaluate the Important Bird Areas and Areas for Zero Extinction that did not qualify as being global Key Biodiversity Areas to determine if they qualify as national Key Biodiversity Areas.

      ii.   Evaluate the other taxa, starting with an assessment of threatened (COSEWIC-listed) biodiversity (criterion A) and geographically restricted biodiversity (criterion B), followed by biological processes (criterion D) This would be followed by the delineation of the identified key areas. (note: criterion C areas will be global)

Step 6 - Submit Canadian identified national Key Biodiversity Areas to the KBA partnership for ratification and inclusion in the Key Biodiversity Areas Database.

Step 7 - Provide provinces and territories with support and assistance in order to develop thresholds for the Key Biodiversity criteria that would be appropriate for each jurisdiction.

Step 8 – Determine which sites, if any, meet the Aichi Target 11 requirements for reporting.

Feedback Summary:

The feedback received from the individuals who reviewed this document was extremely helpful in improving not only the quality, but also the clarity of the information provided. While the vast majority of the comments were addressed and incorporated into the paper, some were not. In some cases this was due to time constraints, while in others, the authors decided to take the comment under advisement, but not incorporate it. Comments included below are those that were not incorporated into the paper.

Feedback on	Comment	Response
General	Nearly all reviewers commented on the limited utility of a paper designed specifically to provide options, but not recommendations. These comments included: ° *"the decision not to encourage these task teams to generate recommendations does a disservice to their work. I predict this will not be helpful to users of this document. It would have been very beneficial to see how the evidence gathered by the authors adds up to recommendations. This would also have forced some beneficial synthesis."* ° "I wish they [the authors] could have gone beyond ''pros and cons'' and be allowed to give actual recommendations. This would have been more useful to the NAP."	The goal of this paper was to provide options in an effort to aid the Pathway to Canada Target 1 National Advisory Panel and National Steering Committee as well as provide scientific background on this topic for the public. As such, it was not within the author's prevue to provide recommendations on how best to identify areas important for biodiversity and ecosystem services. However, in response to this comment, Suggested Actions were added to the paper. These are actions that can be taken to bolster the process of identifying important areas, regardless of the option selected.
Section 3.2.5 Genetic diversity	"It's important in this discussion to differentiate between genetic issues that arise when populations become really small and isolated, and those associated with maintaining or enhancing the evolutionary potential of a species. It seems this section kind of mixes these up a bit with more emphasis on the former where the genetic consequences become evident in more extreme cases"	The reviewer raises a good point that efforts should focus on enhancing population's evolutionary potential allowing them to more easily adapt to changes and keep them from ending up in "bottleneck" situations. This was not thoroughly addressed due to time constraints.
Section 3.3.4 - Red list of ecosystems	The only aspect that needs clarification relates to how ecosystems will be classified and whether there is a danger of reinventing the wheel. This is also distinct from the process of determining which ecosystems are in danger.	This comment was not addressed in the document due to a lack of time. Further information on this topic can be found on the Nature Serve website at Terrestrial Ecological Systems of the United States and in (Keith et al., 2013).

Section 3.3.4 - Red list of ecosystems	"Would be good to say more specifically what is available in Canada (very little) with a map—which ecosystems, where what percentage of the landbase. Also, what are the plans for developing this further and why not (is this because this one was led by US and the next one would have to be led by NS Canada, as implied by the textbox 4?)."	The authors felt that, while interesting, this was out of scope for this paper. Further details that will feed into this topic will be available in forthcoming publications from the team leading the Ecosystem Red List of the Americas initiative (Patrick Comer, NatureServe, etc.).
Section 3.8.3 Provincial and territorial survey	"So jurisdictions don't have a common standard and several think it would be advisable as long as it doesn't limit them, but one jurisdiction claims a standard would be needed before privately managed 'working' (undefined) lands could be integrated. From my perspective this seems inconsistent."	This was not changed as these were responses from survey respondents. Inconsistencies between the answers provided indicated the variability between jurisdictions or the need for a clearer, more consistent approach.
Section 3.9.1 – Selecting an indicator "Canada currently reports on terrestrial and inland freshwater jointly. Consideration should be given to moving towards reporting on these two separately. "	"…and Marine protected areas. Canada is not ready for this. CARTS has built the capacity to report on freshwater ecosystems but the task to implement is not a priority at this time."	The authors did not integrate this comment as this paper is only looking at terrestrial and freshwater, not marine.
Ecosystem Services and the link with human benefits (in several sections)	Several comments addressed the idea that ecosystem services should not only consider human benefits: ° "This suggests that there is no intrinsic value to ES. Services are provided to entire ecosystems. It's not only people who breathe oxygen provided by photosynthesis. Humans are only part of the natural landscape. The fact that we are choosing to focus on those "services" that benefit humans principally is a choice we are making." ° "Again, why suggest that beneficiaries be human only? Simply calling a natural process (e.g. sunlight) as a "service" shouldn't diminish or limit its intrinsic value, not its value to non-human elements. It may be that when we monetize these services, it is necessary to consider the financial benefits to humans, but I don't think it needs to be limited to that dimension. In other words, it's one thing to talk about ES and	The definition of ecosystem services used for this paper was based on the Millennium Ecosystem Assessment (2005) "the benefits that people derive from natural and semi-natural ecosystems". The discussion as to whether or not this definition should be expanded beyond only human benefit is outside the scope of this paper.

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	the valuation of these for economic purposes, it's another to talk about ES on a non-monetary, non-anthropogenically-centred basis. Both are valid. If the approach here is simply to think about ES in terms of their value to humans, that's fine, but the discussion needs to be better qualified as such up front."	
Section 5 - Linkages between biodiversity and ecosystem services: "Overall, while there exist many positive effects of biodiversity on services, a number of uncertainties limit current understanding (Balvanera et al., 2014)."	"What about scale of human benefits, whether local, regional or global?"	The authors felt that the scale would not impact on the uncertainties. Therefore the comment was not included in the edits.
Section 4.1- What are Ecosystem Services: "Similarly, the supply, demand, and flow framework is not always suitable for conceptualizing ES, especially many cultural ES or how Indigenous Peoples characterize their experiences and relationships with nature (Díaz et al., 2015; Chan et al., 2016)"	"Do Indigenous Peoples characterize their experience and relationships with nature in a manner consistent with the above description of biodiversity, ecological integrity, etc.? If not, why is this statement limited to ES rather than broader Western science perspectives of nature?"	This was felt to be out of scope for this paper as it will likely be addressed in the document being produced by the Indigenous Circle of Experts as part of the Pathway to Canada Target 1 process.
Section 6.2 – the "Three Canadas" for biodiversity conservation	"While this is a great framing of an approach, to my knowledge there is not data analysis behind it"	The authors decide to present this topic as a conceptual piece as it was thought to nicely highlight that a multifaceted approach to identifying areas important for biodiversity is needed.
Section 6.2.2 – The open landscape of middle Canada	"No examples provided for the effective conservation strategies. The south provides some objectives or targets and the north provides some recommendations but the middle doesn't have these."	The authors did not integrate this comment due to time constraints

8.3   Supplementary maps
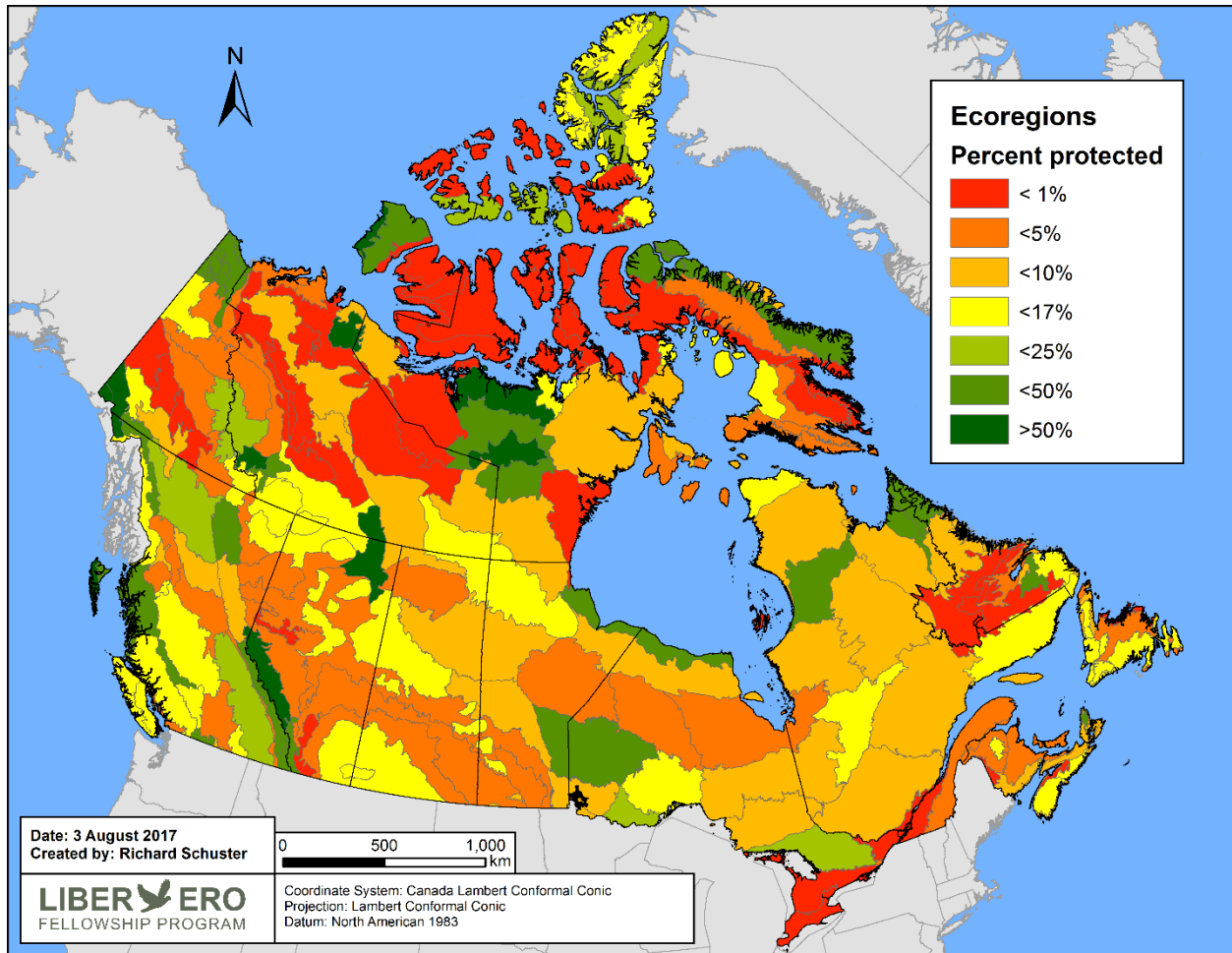
Figure 14. Percentage of each terrestrial ecoregion in Canada currently under protection. Data sources: Current protected areas (Conservation Areas Reporting and Tracking System, Canadian Council on Ecological Areas, http://www.ccea.org/download-carts-data/, for the Quebec portions of the dataset we requested data directly from Registre des aires protégées au Québec; date accessed: 15 December 2016); Ecoregions (Ecoregions of Canada 1996, National Ecological Framework for Canada, http://sis.agr.gc.ca/cansis/nsdb/ecostrat/region/ecoregion_shp.zip, date accessed: 18 May 2017)
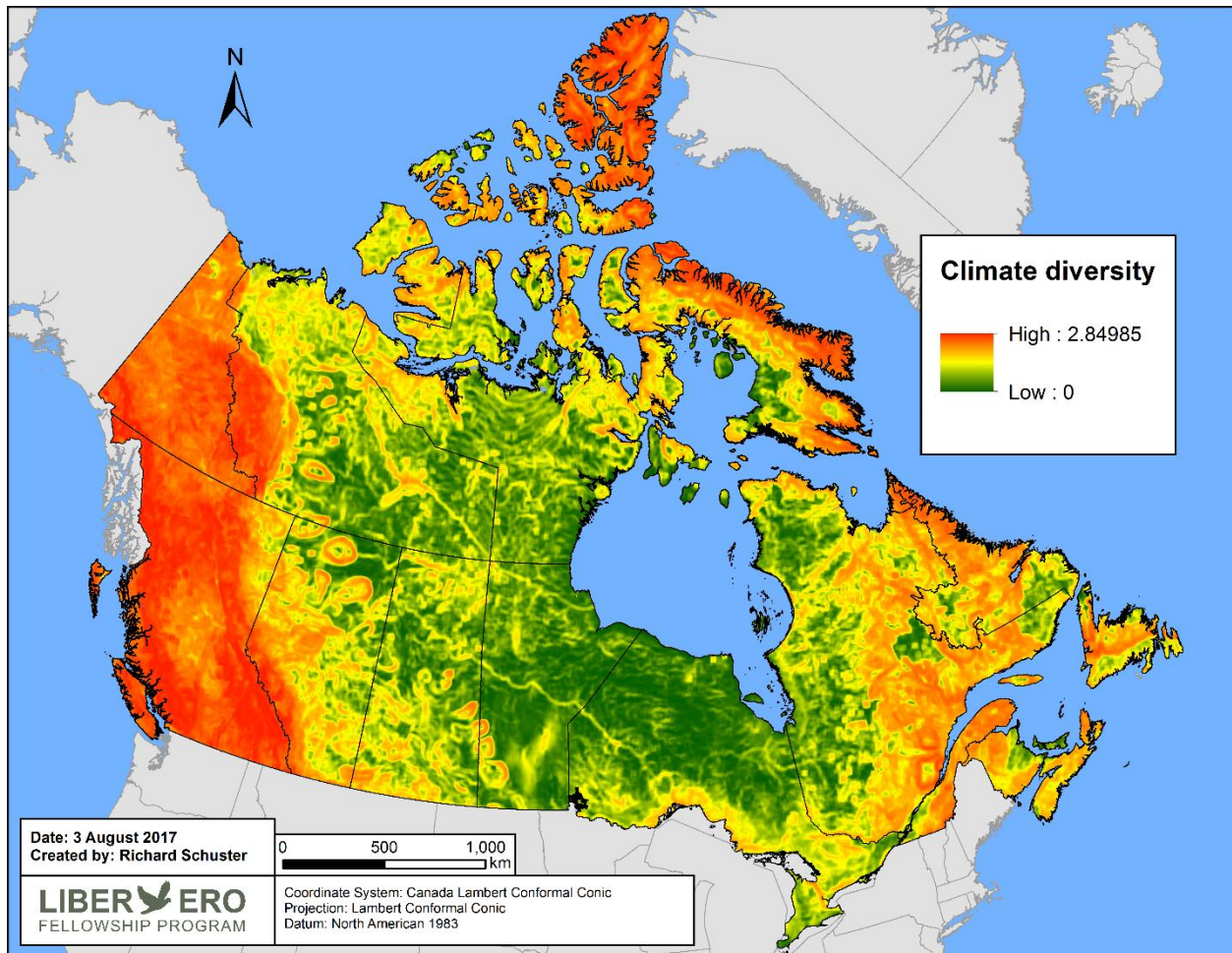
Figure 15. Current climatic diversity. (Carroll et al., 2017) Data source:
https://adaptwest.databasin.org/pages/environmental-diversity-north-america.
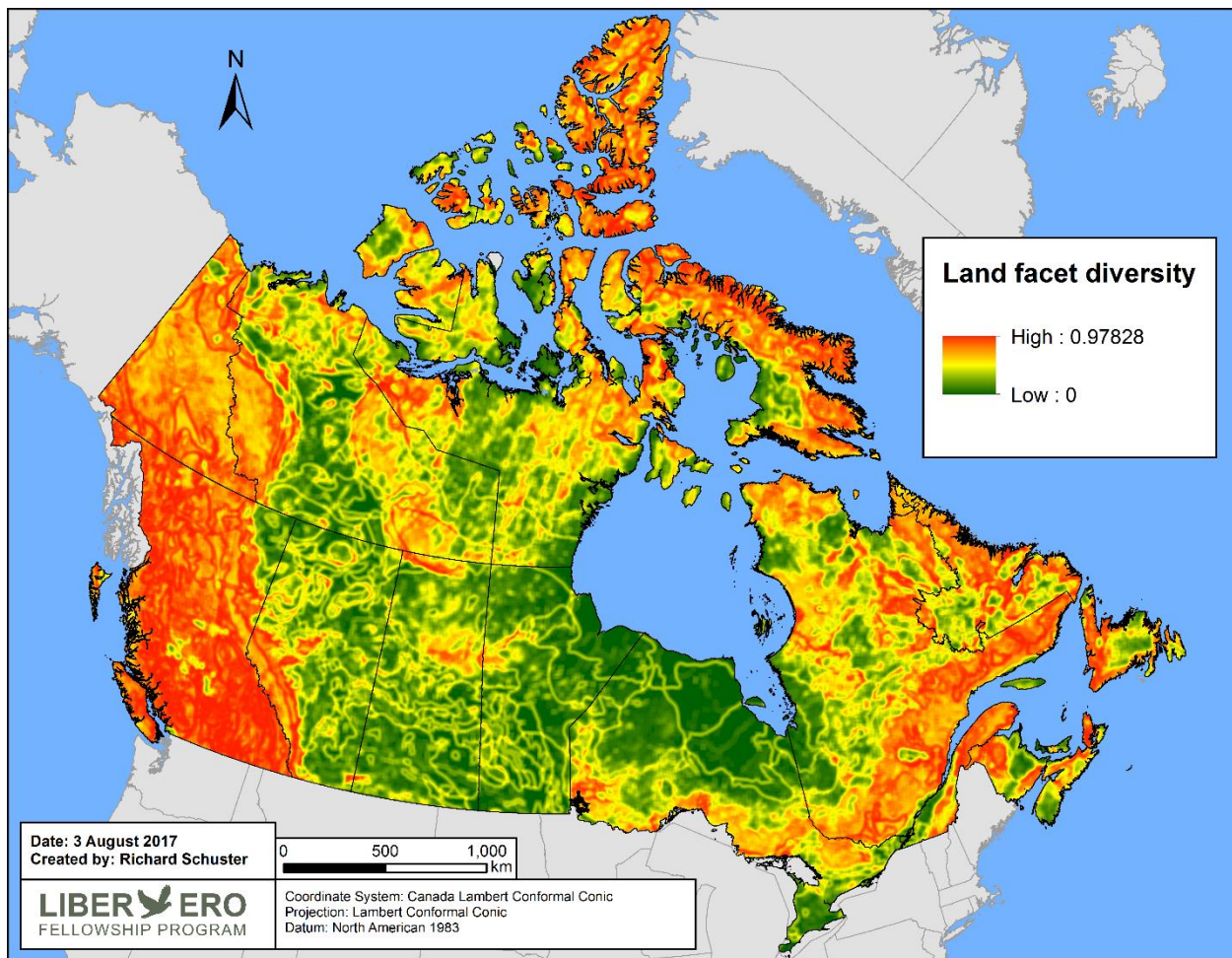
Figure 16. Land facet diversity, representing landscape units derived from topographic and soil or geologic data (Carroll et al., 2017) Data source: https://adaptwest.databasin.org/pages/environmental-diversity-north-america.
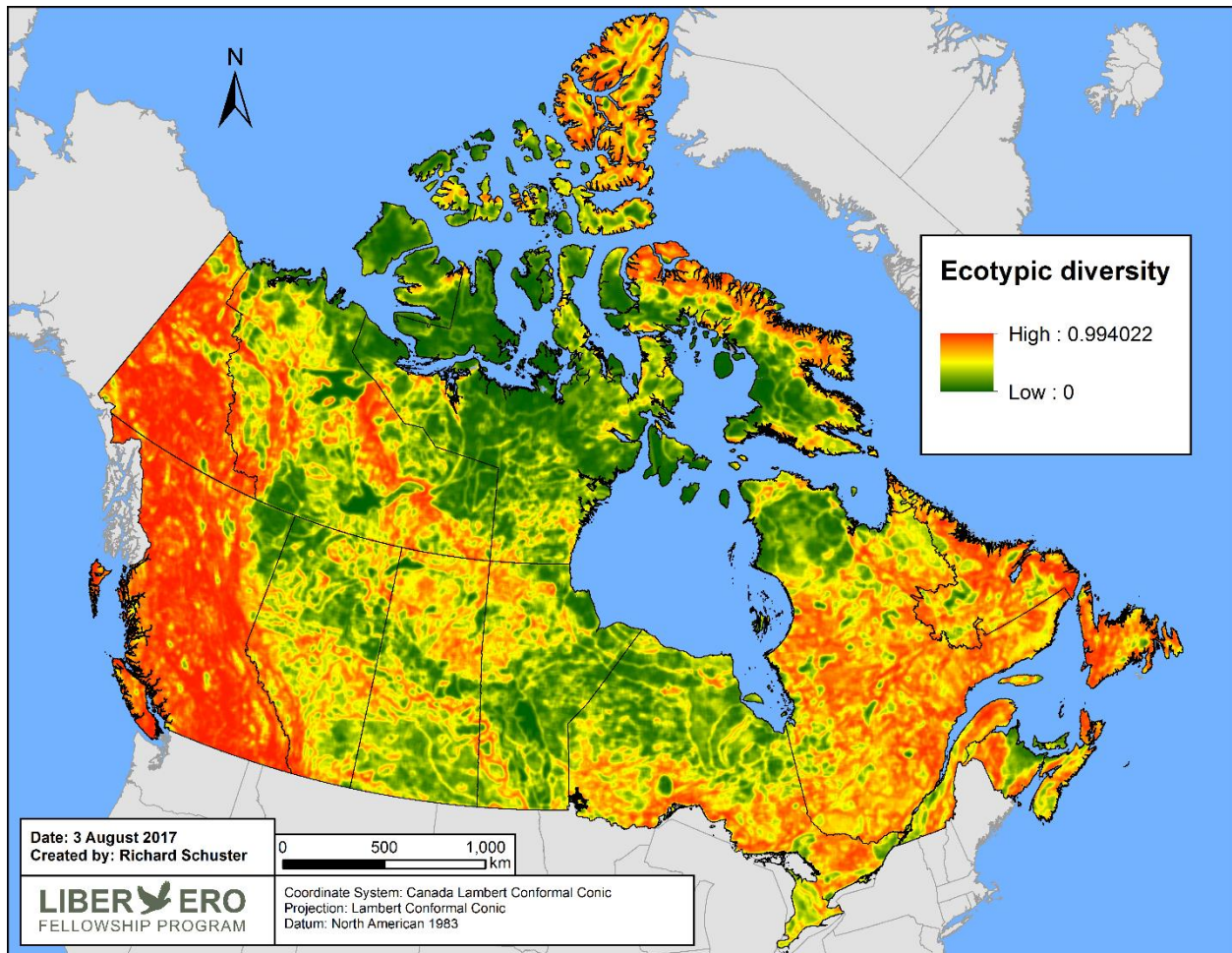
Figure 17. Ecotypic diversity represent an alternative to a classification based purely on physical features as for land facet diversity and is derived from growing degree days, an aridity index, landform, lithology, and land cover type (Carroll et al., 2017) Data source: https://adaptwest.databasin.org/pages/environmental-diversity-north-america.