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A REVIEW OF THE HISTORY AND SCIENTIFIC BASIS OF SPECIES AT RISK ASSESSMENTS IN CANADA

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by

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PRESIDENT'S NOTE

The maintenance of biodiversity and the management of its related elements are important aspects of environmental resource management at the international, national, and local scales. When species populations decline to the point that extinction is a potential consequence, stopping and reversing that trend is an imperative. Understanding the science behind species extinction risk assessments and identifying specific actions that can help focus the assessment process to optimize its effectiveness, reliability, and accuracy, are key to improving species at risk listings as the foundation for effective conservation efforts.

This report examines the science behind assessing the risk of extinction for species, reviews the assessment process of the International Union for the Conservation of Nature's (IUCN) Red List of Threatened Species, and contrasts the globally-oriented IUCN process with the Committee on the Status of Endangered Wildlife (COSEWIC) in Canada's national assessment process.

The report suggests a number of elements that could be helpful in efforts to refine and strengthen the species risk assessment process in Canada, such as quantitatively determining the likelihood of "rescue effect" from outside Canada, taking global risk assessments into consideration when assessing species whose range is only marginal within Canada, and considering natural (versus altered) rarity of species that are being assessed.

Because of the wide array of species and their highly varied life histories, reproductive strategies, broad or narrow distributions, and interactions with other species (including humans), species risk assessments are complicated. Finding ways to adapt and apply new methodologies, increase understandings of ecology, and apply more and better data to species assessments can only result in more accurate estimates of extinction risk, enabling better and more effective long-term conservation measures.

Ronald A. Yeske

January 2013

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NOTE DU PRÉSIDENT

Le maintien de la biodiversité et la gestion des composantes qui s'y rattachent sont des aspects importants de gestion environnementale de la ressource à l'échelle internationale, nationale et locale. Lorsque les populations d'une espèce diminuent à un point tel que l'extinction est une conséquence possible, il faut absolument renverser cette tendance. Comprendre les aspects scientifiques qui influencent l'évaluation du risque d'extinction d'une espèce et trouver des moyens précis pouvant aider à orienter le processus d'évaluation afin d'en optimiser l'efficacité, la fiabilité et l'exactitude sont des éléments clés pour améliorer les inscriptions sur la liste des espèces en péril qui sont à la base des efforts de conservation.

Le présent rapport analyse les aspects scientifiques qui influencent une évaluation du risque d'extinction d'une espèce, examine le processus d'évaluation de la liste rouge (*Red List*) des espèces menacées de l'Union internationale pour la conservation de la nature (UICN) et dresse une comparaison entre le processus à caractère international de l'UICN et le processus national d'évaluation au Canada du Comité sur la situation des espèces en péril au Canada (COSEPAC).

Le rapport propose un certain nombre d'éléments qui pourraient être utiles pour améliorer et renforcer le processus d'évaluation des espèces en péril au Canada au moment d'évaluer une espèce, comme, par exemple, déterminer quantitativement la probabilité qu'il y ait une « immigration de source externe » provenant de l'extérieur du Canada, prendre en considération les évaluations de risque internationales dans l'évaluation d'espèces dont l'aire de répartition est marginale au Canada seulement, et considérer la rareté naturelle (vs la rareté due à une modification dans un écosystème).

Les évaluations de risque sur la situation des espèces en péril sont complexes en raison du grand nombre d'espèces et de leur évolution biologique très diversifiée, des stratégies de reproduction, de la distribution des espèces (étendue vs peu étendue) et de l'interaction avec d'autres espèces (y compris les humains). Trouver des façons d'adapter et d'appliquer de nouvelles méthodes, accroître les connaissances écologiques et utiliser plus de données ainsi que de meilleures données dans les évaluations de la situation des espèces ne peut que donner lieu qu'à des estimations plus précises du risque d'extinction, permettant ainsi de mettre en œuvre des mesures de conservation à long terme plus efficaces.

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A REVIEW OF THE HISTORY AND SCIENTIFIC BASIS OF SPECIES AT RISK ASSESSMENTS IN CANADA

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ABSTRACT

The maintenance of biodiversity and the management of its related elements are important aspects of environmental resource management at the international, national, and local scales. When species populations decline to the point that extinction is a potential consequence, stopping and reversing that trend is an imperative. Determining which species are in need of conservation action, which species are in more desperate need, and determining the tools that should be applied, is a complicated affair. Theoretical and practical efforts in the fields of ecology, genetics, and conservation biology have contributed significantly to our ability to assess, prioritize and manage species at risk.

Species at risk assessment, which took root in the late 1800s, is undertaken at the global scale by the International Union for the Conservation of Nature (IUCN) through its Red List of Threatened Species. IUCN is charged with determining the relative risk of extinction for all species on the planet. Within Canada, species are assessed as to their relative risk of extinction by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), which bases its species risk assessment process on the IUCN process, with some modifications.

This report reviews the science of species assessment and application of that science to both the IUCN and COSEWIC processes, and identifies a number of opportunities for strengthening the process in Canada. A more transparent and repeatable assessment process, and more effective incorporation of elements such as natural rarity, temporal and geographical scale, and marginal species dynamics, should serve to increase the reliability and accuracy of the assessment process, thereby increasing the efficiency and effectiveness of species at risk management in Canada.

KEYWORDS

biodiversity, criteria, endangered species, habitat, indicators, legislation, rarity, species at risk, surrogates, threat, values

RELATED NCASI PUBLICATIONS

Technical Bulletin No. 983 (October 2011). *The role of forest management in maintaining conservation values.*

Special Report No. 10-02. (October 2010). *Compendium of long-term wildlife monitoring programs in Canada*.

Technical Bulletin No. 885. (August 2004). *Managing elements of biodiversity in sustainable forestry programs: status and utility of NatureServe's information resources to forest managers*.

UNE REVUE DU FONDEMENT HISTORIQUE ET SCIENTIFIQUE DES ÉVALUATIONS DE RISQUE DE LA SITUATION DES ESPÈCES EN PÉRIL AU CANADA

BULLETIN TECHNIQUE N^{O} 1005
JANVIER 2013

RÉSUMÉ

Le maintien de la biodiversité et la gestion des composantes qui s'y rattachent sont des aspects importants de gestion environnementale de la ressource à l'échelle internationale, nationale et locale. Lorsque les populations d'une espèce diminuent à un point tel que l'extinction est une conséquence possible, il faut absolument renverser cette tendance. Cependant, l'identification des espèces qui nécessitent des mesures de conservation, l'identification des espèces qui ont un urgent besoin de protection et l'identification des outils à utiliser est une affaire complexe. Les travaux théoriques et pratiques réalisés jusqu'à ce jour en matière d'écologie, de génétique et de biologie de conservation ont grandement contribué à notre capacité d'évaluer, de prioriser et de gérer les espèces en péril.

À l'échelle internationale, les évaluations de la situation des espèces en péril, qui a commencé à la fin des années 1800, sont réalisées par l'Union internationale pour la conservation de la nature (UICN). L'UICN, par l'entremise de sa liste rouge (*Red List*) des espèces menacées, se charge de déterminer le risque relatif d'extinction de toutes les espèces sur la planète. Au Canada, le risque relatif d'extinction des espèces est évalué par le Comité sur la situation des espèces en péril au Canada (COSEPAC) dont le processus d'évaluation repose sur celui de l'UICN, mais avec certaines modifications.

Le présent rapport décrit les aspects scientifiques utilisés dans l'évaluation de la situation des espèces et l'application de ces aspects dans les processus d'évaluation de l'UICN et du COSEPAC, et propose un certain nombre de mesures pour renforcer le processus canadien. Un processus d'évaluation plus transparent et davantage reproductible ainsi qu'une intégration plus efficace d'éléments tels que la rareté naturelle, les échelles temporelle et géographique, la dynamique des espèces marginales contribueraient à accroître la fiabilité et la précision du processus d'évaluation, ce qui améliorerait l'efficacité de la gestion des espèces en péril au Canada.

MOTS-CLÉS

biodiversité, critères, espèces en péril, espèces menacées, habitat, indicateurs, législation, menace, rareté, substituts, valeurs

AUTRES PUBLICATIONS DE NCASI

Bulletin technique n° 983 (octobre 2011). *The role of forest management in maintaining conservation values.*

Rapport spécial n° 10-02. (octobre 2010). *Compendium of long-term wildlife monitoring programs in Canada*.

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1.0 INTRODUCTION AND OBJECTIVES

1.1 Biodiversity and Species at Risk

In Canada, as in much of the world, public interest has led to both national and international legislation and treaties aimed at conserving biodiversity and reducing its loss (Table 1). In addition to perceived value, biodiversity has been found to be strongly linked to both ecosystem functions and ecosystem services (Cardinale et al. 2012). One method by which several countries have chosen to help meet the goals of protecting and maintaining biodiversity is through the identification and protection of species at risk of becoming extinct. Thus, many countries, as well as jurisdictions within countries, have adopted policies to conserve species and prevent extirpations and extinctions using various ranking, tracking, and management tools and guidelines.

Table 1 Examples of International Conventions or Country-Specific Legislation Enacted with the Direct Purpose of Aiding in the Conservation or Recovery of Threatened and Endangered Species

Legislation and Conventions	Country	Year Enacted
Endangered Species Act (ESA)	United States	1973
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	International	1975
Endangered Species (Import and Export) Act	United Kingdom	1976
Council Regulation on the Implementation in the Community of the Convention on International Trade in Endangered Species of Wild Fauna and Flora	European Union	1982
Environment Protection and Biodiversity Conservation Act (EPBC)	Australia	1999
Species at Risk Act (SARA)	Canada	2003

The assessment, recovery, conservation, and management of species at risk are significant challenges in a world dominated by biological, economic, and social needs of the global human population. The loss of species contributes to shifts in ecosystems (e.g., changes to food webs or ecosystem functions), economies (e.g., changes in harvesting or other economic opportunities) and societies (e.g., loss of cultural icons, poverty for segments of society) (Adams et al. 2006), and may result in a local and global loss of biological diversity. In addition to intrinsic value (Ehrenfeld 1978; Taylor 1986), species may have unforeseen values that could contribute greatly to the welfare of the earth and its inhabitants (Farnsworth 1988; Spears 1988).

The Canadian Species at Risk Act was developed in part to help meet Canada's legal obligations under the Convention on Biological Diversity. Its primary goals are to "prevent Canadian indigenous species, subspecies and distinct populations of wildlife from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, to encourage the management of other species to prevent them from becoming at risk." (SARA 2002, summary). Since receiving Royal Assent in June of 2003, SARA has been used to officially list 493 species, subspecies, varieties, or Designatable Units[1] on Schedule 1 (the official list of species covered under the Act).

Estimating the threat of extinction to a species, its conservation status, and determining how a species should be managed for conservation on a regional basis is a complex process. By virtue of being rare, there is often a dearth of sound literature upon which to base assessments of the status and threats to listed species, a trend which may increase the more a species is at risk.

Understanding the strengths and weaknesses of the knowledge and scientific basis upon which a species' threat status is determined may help focus research efforts where they are most needed. This report critically reviews and evaluates some of the scientific aspects underpinning status assessments of species in Canada, with the purpose of identifying opportunities to strengthen the process and aid in meeting the objectives of SARA. The report focuses solely on the scientific aspects of the threat assessment system related to both the Committee on the Status of Endangered Wildlife (COSEWIC) and International Union for the Conservation of Nature (IUCN) systems, seeking to identify areas where methodology and analyses could be enhanced, and providing suggested means for doing so.

It is also important to note that this report does not consider all forms of, and processes for, species at risk assessment in Canada, as there are numerous provincial or stakeholder-driven processes that have merit in their own right but are not discussed here. For example, each province with its own species at risk legislations may either have its own process for evaluating extinction risk [e.g., Ontario's Committee On the Status of Species At Risk in Ontario (COSSARO), which has its own evaluation process] or it may rely on a neighboring jurisdiction for assessments (e.g., Prince Edward Island uses the same species at risk list as determined by New Brunswick). Such provincial processes may be more or less based on IUCN processes. Provincial governments may also track species at risk and biodiversity data through their respective Conservation Data Centers [CDCs (or Nature Heritage Program in Ontario)] whose assessments may or may not overlap with the federal process. Additionally, the Canadian Wildlife Service maintains a species at risk assessment program that may or may not overlap with the COSEWIC process. NatureServe is a non-profit organization that coordinates and supports a network of independent member programs across the Western Hemisphere. The NatureServe network's biodiversity databases includes a vast amount of location-specific records, which are used routinely by government agencies, foresters, consultants, university researchers, and local and regional planners. The NatureServe process has previously been described in detail by NCASI (2004) and is not considered further here.

2.0 EXTINCTION THEORY AND SPECIES ASSESSMENT

It is important to distinguish between threat assessment and priority setting. Threat assessments provide the likelihood of an assessed unit (e.g., species, subspecies, variety, or geographically or genetically distinct population) going extinct under prevailing circumstances. These assessments are based on scientifically derived information about population's viability and should be objective. Priority setting, on the other hand, is a system for setting priorities for action that should include the likelihood of extinction determined by the threat assessment, but which will also include numerous other factors, such as: the likelihood that restorative action will be successful; economic, political, and logistical considerations; and perhaps the taxonomic distinctiveness of the species under review (Mace and Lande 1991; literature reviewed in Bunnell, Fraser, and Harcombe 2009). In the past,

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[1] Designatable Unit (DU): A subspecies, variety, or geographically or genetically distinct population that may be assessed by COSEWIC, where such units are both discrete and evolutionarily significant (COSEWIC 2010d).

some threat assessment procedures have confounded these two distinct initiatives into a single system (Fitter and Fitter 1987; Munton 1987; Millsap et al. 1990); however, to devise one general system for both assessing threats and setting priorities is not useful because different concerns predominate within different taxonomic, ecological, geographical, and political units (Possingham et al. 2002). Both the IUCN and COSEWIC species risk assessment processes are primarily threat assessment processes.

The taxonomic category of "species" is the primary level at which extinction risk assessments are conducted. While science has generated numerous publications on the most practical and justifiable method of defining infraspecific[2] units, it often offers contradictory concepts. The definition of a species is one of the most debated concepts in evolutionary biology, and there are currently over two dozen definitions of the species concept in the scientific literature (Mayden 1997). The most popular working definition is that put forward by Ernst Mayr in 1942, which defines a species as a group of organisms that can breed only among themselves, excluding all other (the biological definition of species; Mayr 1942). Although this definition has significant limitations in terms of its utility in helping determine whether a new-found organism is in fact a "new" species (Hey 2001; Mallet 1995) or in determining the validity of genetic discreteness (Fallon 2007), species remains the standard taxonomic level for most extinction risk assessments. For example, as of 2008, COSEWIC had conducted 934 assessments, 799 of which were at the species level. At the global scale, the International Union for the Conservation of Nature (IUCN) has focused primarily on species. For mammals, the 2008 IUCN Red List includes 5,487 species, 412 subspecies, and 21 subpopulations (IUCN Mammal initiative; see Schipper et al. 2008). However, at the sub-global or regional scale, it is often thought necessary and desirable to evaluate taxonomic groups below the species level, such as subspecies, varieties, populations or other sub-specific units (Green 2005). Species at risk assessments (e.g., endangered, threatened) are intended to reflect the likelihood of a species going extinct (or extirpated) under prevailing circumstances (COSEWIC 2010a; IUCN 2011a). The criteria that place species into these categories are intended to identify symptoms of likely species extinction. Extinction occurs when the mortality (and emigration) rate is greater than the birth (and immigration) rate for a sufficiently long time that the population size reaches zero (Caughley and Gunn 1996). Typically, estimation of extinction probabilities is conducted at the species level because extinction is defined as the loss of a species. Species have been argued as the taxonomic unit of conservation, as genetic diversity and unique attributes of subspecies can be replaced, but the loss of an entire species cannot (Caughley and Gunn 1996). However, when assessments are conducted below the species level (e.g., sub-specifies, varieties, etc.) there is an underlying assumption that the biological processes used to determine extinction probabilities at the species level are transferable to the sub-species level. Whether or not sub-specific differences in extinction factors occur owing to evolutionary history or to smaller population size is an uncertainty to be considered. Further, when assessments are conducted on population units that are somehow disconnected from outside populations (e.g., lacking emigration and immigration), they may be assessed as part of a greater global population (i.e., its global risk of extinction) or as a unit unto itself (i.e., its local extirpation).

Sinclair, Fryxell, and Caughley (2006) categorize two main modes of extinction: "driven extinction", whereby a population experiences environmental (natural or anthropogenic) changes which result in a rate of decline that cannot be overcome, or "stochastic extinction," whereby a population fails to overcome the challenges of a small population size and is vulnerable to random, demographic, or environmental events that cause extinction. Often, such random events would not likely lead to extinction of larger populations. Ultimately therefore, extinction is often a chance process, in that the final event leading to the loss of the last individuals of a species is most often a random event (e.g., the last population of the heath hen, *Tympanuchus cupido cupido*, went extinct in the 1930s after a

[2] Infraspecific refers to any taxon or category within a species, such as a subspecies or population.

wildfire consumed the last of their population and habitat, although protective measures had already been put in place to prevent their extinction due to over-exploitation as a game bird). Irrespective of the taxonomic level considered (e.g., species, subspecies, or local population), these two processes often act in combination, whereby forces drive populations (deterministically) to critically small numbers, after which the dynamics of small populations that are naturally more susceptible to extinction via chance (stochastic events) take over, leading to a much higher likelihood of extinction or extirpation (Caughley 1994; Richter-Dyn and Goel 1972; Goodman 1987 Sinclair, Fryxell, and Caughley 2006; Mace et al. 2008), as in the heath hen. Given that the number of mature individuals or the total area occupied can affect how significant either process will be, population size is a significant factor in determining a species' risk of extinction or extirpation. While local extirpation (the local loss of a species from a given jurisdiction) is not as biologically or ecologically serious as global extinction (the permanent loss of a species from the planet), the two concepts are equivalent in terms of conserving biodiversity at a regional scale (e.g., under SARA a species would be classified as endangered in Canada due to significant risk of either extinction from the planet or extirpation from Canada).

In addition to the final step in extinction being a relatively chance event, most extinctions are generally undocumented (e.g., the final demise of the last member of a species is not usually observed), or occur without significant knowledge of the species in question. Indeed, it is estimated that the highest extinction rates tend to occur in the tropics (Myers et al. 2000) where higher biodiversity levels occur, resulting in far greater numbers of species that are rare or occur in relatively low population densities (i.e., owing to established patterns of species abundance distributions, Preston 1962a, 1962b). Indeed, global documented extinction events (beyond the tropics) tend to be rare, and occur far more often on island ecosystems than on continental ecosystems (Loehle and Eschenbach 2011). In Canada, COSEWIC has assessed a total of 15 species as extinct since 1844, and none since 1989 (1.03 extinctions per decade) (COSEWIC 2012). Similarly, there have been 23 documented extirpations since 1828, and none since 1989 (1.42 extirpations per decade) (COSEWIC 2011; Figure 1). This, however, may be an underestimate, as COSEWIC has recently opted to assess *endangered* species over extinct and extirpated species and there is a lengthy time period, under COSEWIC's guidelines, before a species may be assigned an extinct or extirpated assessment (D. Fraser, pers. comm.)

Currently, the primary factors linked to increasing extinction risk for most species are of anthropogenic origin. Such factors may result in habitat loss and alteration, overexploitation, biotic exchange, introduced species, pollution, climate change, and the interactions amongst these (Diamond 1984; Sala et al. 2000; Millennium Ecosystem Assessment 2005; Thuiller 2007; Mace et al. 2008). A species may go extinct either because it is unable to evolve rapidly enough to meet changing circumstances, or because its niche disappears and no capacity for rapid evolution could have saved it (Norris 2004; Maynard Smith 1989). The way in which threatening processes affect extinction risk for species is variable and can be nonlinear with, or disconnected from, human population growth and development.

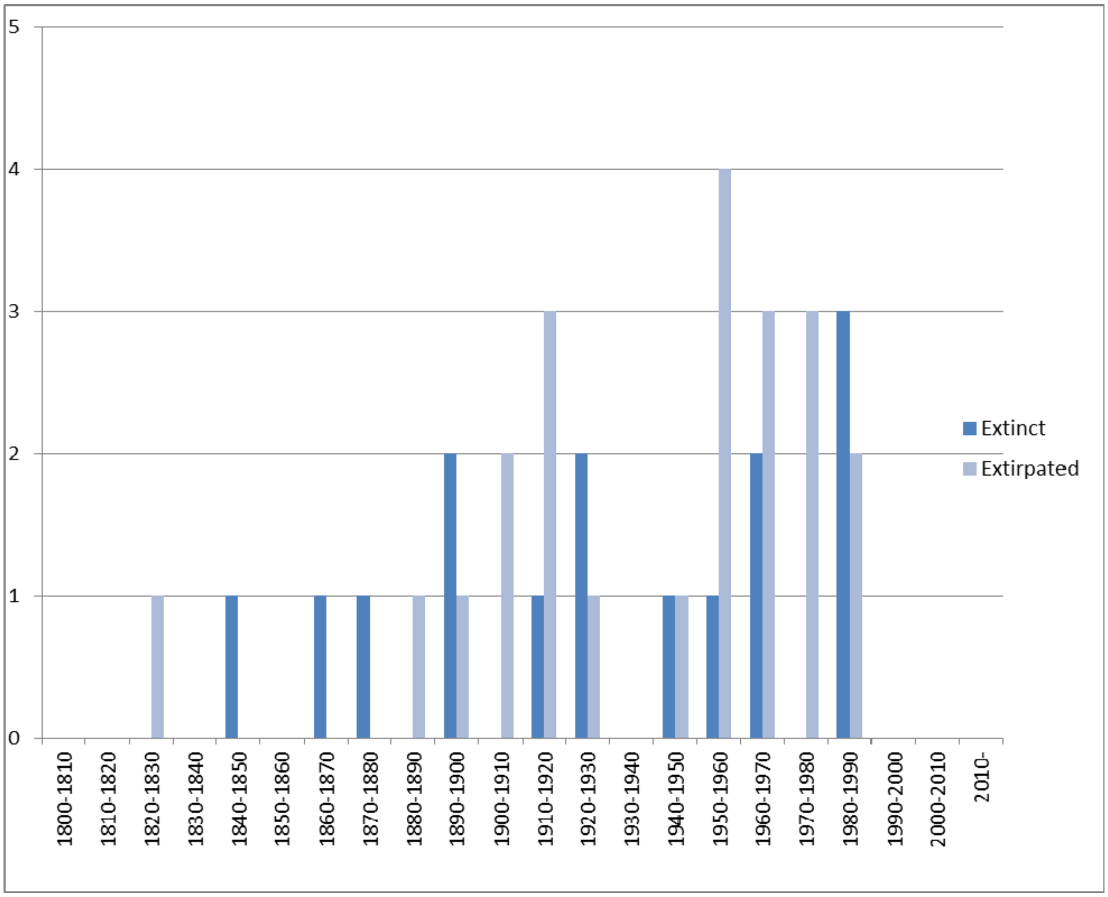

Figure 1 Number of Species Assessed by COSEWIC as Extinct or Extirpated in Canada, Whose Extinction or Extirpation Events Are Estimated to Have Occurred between 1800 to Present, by Decade

Further, threatening processes (e.g., over-harvesting, habitat conversion) are dependent upon time and place (Sinclair, Fryxell, and Caughley 2006), whereas symptoms of extinction are not. The purpose of extinction risk criteria is to detect symptoms of population extinction risk (e.g., decline rates, range size, abundance), but not the causes or consequences of these symptoms. (COSEWIC 2010b; Mace et al. 2008). After accounting for biological differences, species with the same symptoms are listed at the same threat level (category), regardless of the information available about purported threats. For example, two small populations with precipitous declines receive the same threat assessment even if we know precisely what is causing the decline for one of the species, but not the other. This is appropriate, as uncertainty or lack of knowledge about drivers or causes of declines does not alter the relative risk of species extinction, although lack of knowledge about drivers may hamper conservation efforts. While causes of declines (if known) are usually listed and described during the species risk assessment process, they are not directly addressed. Conservation action taken to address threats to the persistence of a species is generally taken outside the assessment process (i.e., neither the IUCN nor COSEWIC manage threats). In Canada, recovery strategies for species assigned to “at risk” categories are used to determine the causes of the population decline if unknown (through a schedule of studies). If causes are known and understood, recovery strategies include potential mitigation options that are intended to reduce or reverse declines (Government of Canada 2009). After recovery strategies are developed, action plans are created to design and target the implementation of recovery efforts and thereby reduce the likelihood of extinction.

A number of studies have noted that the interaction between threatening processes and biological traits is important. For example, the stability of fluctuating populations is reduced by exploitation (Beddington and May 1977). Hunting and introduced predators tend to increase extinction risk more so for large-bodied birds, whereas habitat loss increases extinction risk for all species, but particularly so for small-bodied habitat specialists (Owens and Bennett 2000). Extinction- or extirpation-prone species may share particular characteristics that cause them to be vulnerable (Angermeier 1995). Some of these characteristics include specialized diet, specialized habitat requirements or niches, migration, large body size, restricted ranges, a small number of occupied sites, high variability in total abundance, poor dispersal, and high population trend fluctuations (Angermeier 1995; Fisher and Owens 2004; Goodman 1987; Mace et al. 2008; Purvis et al. 2000; Richter-Dyn and Goel 1972; Sinclair, Fryxell, and Caughley 2006). Isaac and Cowlishaw (2004) used data from numerous studies of primates, and suggested that primate species with low ecological flexibility are negatively affected by selective logging practices in tropical regions. Low abundance and high habitat specialization among land-bridge island reptiles is more likely to result in extinction (Foufopoulos and Ives 1999). Larger home ranges for carnivores within reserves leads to a higher risk of extinction (Woodroffe and Ginsberg 1998). Previous exposure to a particular threat may result in the loss of more susceptible components, rendering a community more resilient (i.e., “extinction filters”; Balmford 1996). Although important to determining a species’ long-term population viability, simple measures of population size or geographic range may have low predictive power in determining extinction risk (Mace et al. 2008).

Estimating extinction risk is therefore complicated, and is linked to numerous interacting factors that are challenging to simplify. Further, some factors can dominate extinction risks for many species (e.g., habitat loss, Simberloff 1986; Harcourt 1995). These complexities result in the need to base the assessment of risk on symptoms rather than causes. While this is useful for simplicity, especially in the absence of sufficient data for a full estimate of extinction risk, it can lead to uncertainties. Nonetheless, detection of symptoms as a foundation for assessing species risk of extinction has come to dominate the process at the global scale (Mace et al. 2008). After accounting for biological and ecological differences, species with similar symptoms are assigned the same threat level, regardless of the amount of information available.

Estimates of extinction risk are typically conducted by looking at population demographics such as decline rate, population size, and population structure (e.g., age distribution), population fluctuations, population fragmentation, range size or extent of occurrence, and area of occupancy. Population growth rates or, conversely, decline rates, are typically derived from only a handful of variables. For species at risk of extinction these variables can be categorized into two classes: those that are dependent on population size and those that are independent of population size. A list of both population size-independent and population size-dependent variables that are usually considered during extinction risk assessments is provided in Appendix A.

Note that in the context of both population-dependent and -independent variables, “population size” refers to both a population’s abundance and its density. Probability of extinction tends to be greater under certain circumstances such as small population size, high rates of decline (the number of deaths exceeds the number of births), and when fluctuations in population size are large in relation to the population growth rate (increasing the likelihood that the population size reaches zero; Mace et al. 2008). Very small populations are susceptible to demographic stochasticity, increasing the risk of extinction even when population growth rate is positive (Richter-Dyn and Goel 1972; Goodman 1987; Sinclair, Fryxell, and Caughley 2006; Mace et al. 2008).

Extinction threat assessments are ideally determined quantitatively (e.g., using population viability assessment), incorporating data on population size, instantaneous or long-term population growth rates, recruitment rates, age-specific survival rates, and ongoing threats to survival. However, in most cases, and not simply for rare or hard to detect species, such data are not available. Without sufficient data, population viability analyses are thought to have low reliability and limited predictive power. For example, Fieberg and Ellner et al. (2000) argued that in order to obtain precise estimates of extinction probability over *t* years, between 5*t* and 10*t* years of data are required. Fortunately, some extinction factors afford the opportunity to make estimations of a population's viability. From basic ecological theory it is possible to draw broad generalizations about the relationships among population size, population growth rates, fluctuations in population growth rates, and extinction times (Lande 1993). For example, demographic stochasticity is unlikely to be important for any population that has more than about 100 individuals, but random environmental variation or catastrophes are important for populations of all sizes and become more significant as the effect of the variation becomes large in relation to the population growth rate (Mace et al. 2008).

3.0 THE HISTORY AND SCIENCE OF SPECIES RISK ASSESSMENT

3.1 The Origin of the International Union for the Conservation of Nature (IUCN)

Prior to development of official protocols and legislative tools for assessing and managing species at risk, the expert opinions of naturalists were the sole information about extinction risk of species. Public awareness of the demise of species was rare, and would only have been raised by individuals who were passionate about the natural world, observant enough to note declining species, and wealthy and educated enough to spend time thinking about and publicizing their opinions. In North America, early conservationists were concerned about the loss of wild spaces and wild species, particularly in the loss of big game (e.g., Hornaday 1889). The Boone and Crockett Club, founded in the late 1800s, was specifically formed to address the management and protection of big game and associated wildlife in North America, and included such notables as Theodore Roosevelt (the founder), George Bird Grinnell, and Gifford Pinchot (The Boone and Crockett Club 2008). It was not until significant and startling extinctions were observed that species at risk assessment began to have traction in the public mind.

The loss of the Passenger Pigeon (*Ectopistes migratorius*), was a focal event that raised the public's awareness of species extinction. The Pigeon, whose population was thought to be in the billions of individuals prior to European settlement in North America, could not be found in the wild by the early 1900s (The Smithsonian Institution 2001). The last known living Passenger Pigeon died in 1914. In spite of such a dramatic loss, a coordinated assessment of species' global risk of extinction was not attempted until the early 1940s with the founding of the International Union for the Protection of Nature (IUPN), which became the International Union for the Conservation of Nature (IUCN) in 1956. One of the first tasks of the IUCN was to assess the risk of extinction for species at a global level, and to assign a threat status to that risk. The initial species threat assessment process was subjective, and categorizations made by different authorities (e.g., regional to national) differed and may not have accurately reflected actual extinction risks, ultimately leading the misuse of scarce conservation resources (Mace and Lande 1991). Further, the process was not easy to use nor was it flexible enough to be applied to varying taxonomic scales or varying quantities of data/information (Mace et al. 1992).

In 1988, the Species Survival Commission (SSC) of the International Union for the Conservation of Nature (IUCN) started a new process by inviting Dr. G. Mace (Professor of Conservation Science at Imperial College London, and Director of the Natural Environment Research Council [NERC] Centre for Population Biology) to propose a new population-based system for the IUCN categories and criteria for risk designation and assessment. This work resulted in publication of "Assessing

Extinction Threats: Toward a Reevaluation of IUCN Threatened Species Categories" (Mace and Lande 1991). Implementing the revised approach to the IUCN assessment process would eventually inspire several national and regional authorities to develop similar risk assessment systems (including COSEWIC in Canada) and it was therefore important that the new system be flexible for varying level assessment and repeatable (Gärdenfors et al. 2001; Mace et al. 1992).

Mace and Lande's 1991 publication proposed redefining threat categories on the basis of probability of extinction within a specified time period derived from population-level variables. The newly defined categories had three revolutionary qualities. First, they were based on current theories of extinction to populations on meaningful time scales for conservation action. In geological time, all species are likely to go extinct at some point in the future, as species typically exist for 5-10 million years (May, Lawton, and Stork 1995). It is therefore necessary for the estimate of extinction to be based on some period of time that is biologically meaningful to most species, that humans can theoretically influence, and that legislative bodies can affect (e.g., 100 years). Second, the categories were defined with increasing levels of threat over decreasing time scale to emphasize the increased urgency of the extinction risk. And finally, the probability of extinction for any given species was based on objective and scientifically derived ecological variables related to species-specific symptoms of extinction and population decline. It is this third quality specifically that provides the objectivity and scientific basis of threat assessments. The proposed new reliance on scientifically derived estimates of extinction risk would make the IUCN system more objective, reproducible, and easier to apply to varying taxonomic scales.

The Mace and Lande (1991) paper was not accepted blindly. In parallel, other authors had proposed criteria based on patterns of distribution, or patterns of use rather than on population characteristics alone, and some reconciliation of these approaches was needed. A technical workshop was held in London in November 1992 aimed at addressing the scientific aspects of the listing process. Several different experts were invited to prepare papers describing different options for listing species (Mace et al. 2008).

During the workshop, experts for higher vertebrates, lower vertebrates, invertebrates, and plants were divided into taxonomic working groups (Mace et al. 2008, 1992). Reviewing suggestions from these taxonomically based working groups revealed some interesting differences: those studying vertebrates tended to emphasize population size and structure; those working on plants emphasized geographic distribution area and life-history attributes; invertebrate biologists considered population fluctuations and habitat fragmentation to be paramount (Mace et al. 2008). Parallels between the taxonomic-based criteria existed as well. All working groups considered some form of continuing population decline to be an indicator of threatened status, and depending on the life history, some criteria developed for one taxonomic group were relevant to another (Mace et al. 2008).

The IUCN used the results of the workshop to consolidate the taxonomically based criteria from each working group into a single list, and to resolve inconsistencies among criteria within and between categories (Mace et al. 2008). The rationale provided was that there were many similarities between the criteria developed by different groups, and a single list was expected to function similarly to any taxon-specific one for almost all cases (Mace et al. 2008). In addition to revising the categories and criteria, the IUCN established Red List Authorities (RLAs) to ensure that all species within their jurisdiction are accurately assessed against the IUCN Red List Categories and Criteria at least once every 10 years and, if possible, every five years (IUCN 2011b). The intention is that no new species assessments will be included on the IUCN Red List of Threatened Species™ until it has been evaluated by at least two members of an appointed RLA, and thus this peer review system places greater responsibility on the SSC network and its partners to ensure that what appears on the IUCN Red List is credible and scientifically accurate (IUCN 2011b).

In 1994 a new set of rules (categories, criteria, and associated guidelines) was adopted by the IUCN (IUCN 2011c). The IUCN based these rules on Mace and Lande (1991) and the results of the technical workshop, incorporating a set of quantitative criteria to be used for classifying species into the categories of threat based on population-level variables related to extinction risk (Mace et al. 2008). The IUCN subsequently developed guidelines for applying the criteria at global, regional, and national levels (Gärdenfors et al. 2001; IUCN 2003). The guidelines and criteria have remained relatively unchanged over the last decade and have been adopted as the primary standard for of the assessment of threatened species (Akçakaya et al. 2000; Mace et al. 2008). The system provides assessors with a set of quantitative criteria, which improves the objectivity of the process and allows extinction threats to be estimated on the basis of observable symptoms of extinction or population decline derived from modern ecological theories.

3.1.1 *IUCN Assessment Process and Methodologies*

The IUCN extinction risk categories are determined through decision rules based on criteria thresholds of biological parameters such as distributional range, population size, population history, and risk of extinction (Akçakaya et al.2000). Categories are named to express the degree to which a species is threatened (e.g., critically endangered, threatened, vulnerable, etc.) (Akçakaya et al. 2000). Categories may also be referred to as risk designations for assessed species, and in fact are predictions about probable risk of extinction, given current data. A listing in a higher extinction risk category implies a higher probability of extinction and, over the time frames specified, more taxa listed in a higher category are expected to go extinct than those in a lower one without effective conservation action (IUCN 2001).

A species' threat status is a categorical description of its relative probability of going extinct, usually estimated over some time period. Both the probability of extinction and the time period considered may be arbitrary, depending on the acceptability of risk by proponents (Schaffer 1981). For example, the assessment may be based on a 95% chance of persistence over 100 years, or a 99% chance of persistence over 1,000 years. Probability of extinction (or its corollary – probability of persistence), is ideally estimated through a population viability analysis (PVA) (Gilpin and Soulé 1986), one of the primary tools for assessing the threat status of species (Mace and Lande 1991; Mace et al. 1992). After extinction risk analysis, species are assigned to one of several threat categories using risk thresholds of probability of persistence (e.g., a risk of extinction >10% over 100 years would be assigned to the "vulnerable" category for an evaluation undertaken by the IUCN).

The IUCN Red List uses a total of nine categories (Figure 2). Three categories are relatively simple determinations based on whether or not a species is extant (present) in the wild (Extinct, EX, or Extinct in the Wild, EW) or whether or not a species has been evaluated (Not Evaluated, NE). One category exists to indicate that available data are insufficient to complete an evaluation (Data Deficient, DD). Least Concern (LC) means a species has been evaluated but does not meet the criteria for any of the threatened categories, and Near Threatened (NT) means the species has been evaluated, does not meet the criteria for any of the threatened categories, but is very close to meeting one of more of them and therefore the species warrants revaluation often or at appropriate intervals. The remaining three categories, Vulnerable (VU), Endangered (EN) and Critically Endangered (CR) represent the detailed assessment of a species' relative probability of extinction and are based on set criteria.

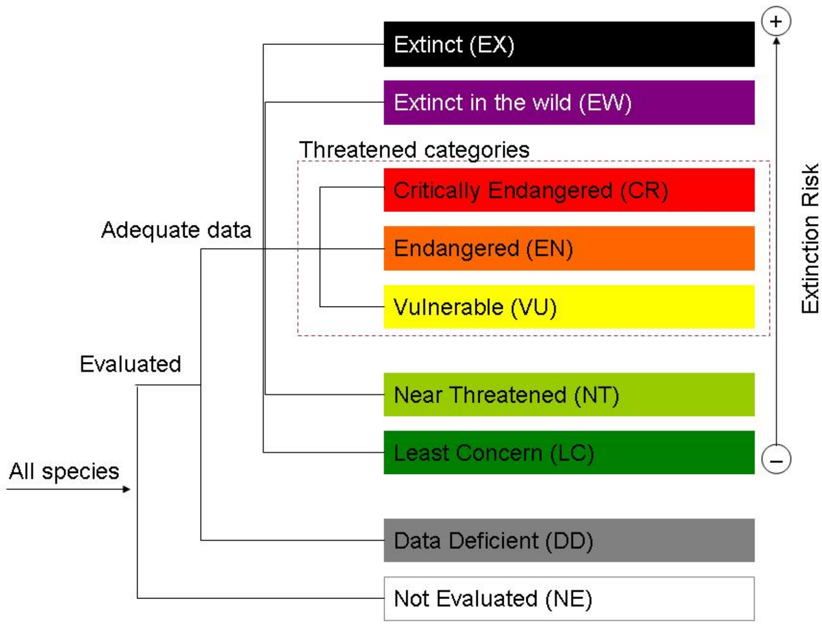

Figure 2 IUCN Red List Threat Categories, with Extinction Risk Increasing Vertically in the Figure. [Note that risk is only estimated for species that are evaluated and deemed to have adequate data. Species that are not evaluated or are data deficient are considered "extinction risk unknown".]

The IUCN Red List process uses five criteria for determining the relative probability of extinction: A) declining total population, B) a small geographic distribution and declining or fluctuating population, C) a small total population size that is declining, D) a very small population or a restricted distribution, or E) a quantitative analysis that is indicative of a probability of extinction within a pre-set time period (Figure 3).

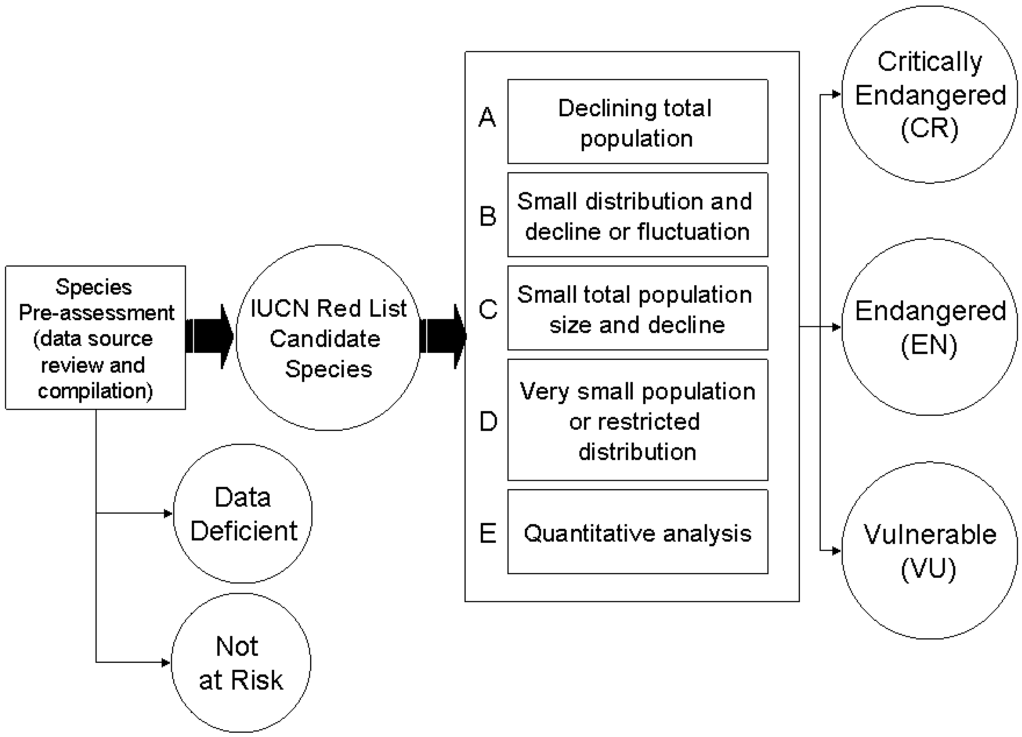

Figure 3 Schematic Diagram of the IUCN Red List Species Assessment Process for Threatened Categories, Which Used Criteria A – E to Assess Species as Critically Endangered (CR), Endangered (EN), or Vulnerable (VU)

These quantitative criteria are based on fundamental biological processes underlying population decline and extinction. Given the major differences between species, the threatening processes affecting them, and the paucity of knowledge relating to most species, the system is broad and flexible and can be applied to the majority of described species (Mace et al. 2008). Each criterion has three thresholds, qualifying a species for the risk categories CR, EN, or VU. Most criteria also include sub-criteria that must be used to justify more specifically the listing of a taxon under a particular category. For example, a taxon listed as “Vulnerable C2a(i)” has been placed in the *vulnerable* category because its population is fewer than 10,000 mature individuals (criterion C), the population is undergoing a continuing decline, and all its mature individuals are in one subpopulation (subcriterion a(i) of criterion C2). To list a particular taxon in any of the categories of threat (Figure 2), only one of the criteria (A, B, C, D, or E) needs to be met.

Any species, with the exception of microorganisms, can be assessed using the IUCN categories and criteria. Although the criteria for each of the categories of threat are based on quantitative thresholds, the system remains relatively flexible to ensure that taxa for which there is very little information can also be assessed. This has been achieved by incorporating inference and projection into the assessment process. Therefore, the person conducting an assessment is expected to use the best available information in combination with inference and projection to test a taxon against the criteria. If an assessment places a species into a threatened or vulnerable category (critically endangered, endangered, vulnerable) (Figure 1), then the species is placed on The IUCN Red List of Threatened

Species™, a process also known as being "red-listed". The majority of the Red List assessments are conducted by the Red List Authorities (RLAs) appointed by the IUCN SSC Specialist Groups or by participants of Global Biodiversity Assessment workshops, although anyone may submit assessments to IUCN for consideration.

3.2 The Origin of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC)

Species at risk assessments in Canada were carried out independently as early as the 1960s by various provincial and territorial agencies, independent conservation groups, and concerned individuals (Cook and Muir 1984). However, assessments were often unreliable with too few data or too small a regional focus, or reflected an individual's personal viewpoints or an organization's particular conservation motive. In their eagerness, conservationists often cited whichever list best supported their viewpoint and ignored others, although available lists were not based on scientific consensus. As a result, there was a need for a single, independent, scientifically sound and transparent process by which species are evaluated as to their national at threat status. This was expressed at a 1976 symposium (co-sponsored by the Canadian Nature Federation and the World Wildlife Fund) at Carleton University in Ottawa where it was recommended "that the Federal-Provincial Wildlife Conference strike a standing committee consisting of representatives of the Federal and Provincial governments and appropriate conservation and scientific organizations for the purpose of establishing the status of endangered and threatened species and habitats in Canada" (Mosquin and Suchal 1977, p. ix). Thus in 1977, at the next meeting of the Federal-Provincial Wildlife Conference held in Fredericton, New Brunswick, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was conceived, and established later that year. In 2002, COSEWIC was enshrined into the Canadian Species at Risk Act (SARA 2002) as an independent body of experts responsible for making recommendations to the Canadian government as to which species should be added to the official list of species under Schedule 1 of SARA.

The COSEWIC assessment process has been contributing to species conservation in Canada for almost 20 years, and has had broad acceptance within governmental, academic, industrial and environmental circles. Over this time period, however, various authors have expressed some concern with the effectiveness of the COSEWIC assessment process, such as the perceived lack of transparency, suggesting that there are secondary decision-making processes not described in COSEWIC's stated protocol, resulting in status designations that are not repeatable (Lukey and Crawford 2009).

The official SARA listing process is relatively straightforward, and is designed to include scientific, social, and economic considerations. The COSEWIC assessment process itself is comprised of two steps, species selection and threat status assessment, which are then followed by the SARA-legislated listing steps of governmental review, and final Governor in Council (GIC) review and decision. If a species is considered to be "at risk" (i.e., threatened or endangered) the process is then followed by recovery planning and action (Figure 3).

As species at risk are evaluated and managed in Canada, scientific resources are primarily brought to bear during the assessment and recovery processes. In addition to the scientific information regarding the overall assessment of a species' threat status, including its biology, ecology and threats to its population status, the recovery strategy is further mandated to include a schedule of studies to provide vital information to aid in recovery efforts. Other parts of the process (e.g., feedback from various agencies, or decision points) may be informed by scientifically collected data, but are not mandated to include scientific arguments. Government departments are primarily consulted to determine the impact on, interaction with and contribution to the management of a given species or its habitat, as SARA is above all a Federal Act, and therefore applies directly to Federal land (e.g., national parks, military bases, etc.). SARA applies indirectly to non-Federal lands, and should the responsible Minister be of the opinion that an endangered or threatened species is not receiving adequate protection on non-Federal lands, the Federal Government may choose to invoke SARA's "safety net" and assume management for that species in that jurisdiction.

3.2.1 *COSEWIC Assessment Process and Methodologies*

The first step in the COSEWIC assessment is a species evaluation process in which groups of species specialists (Specialist Sub-Committees, SSCs) annually prepare and maintain lists of species that meet the requirements for species assessment. These candidate species must be of a recognized taxonomy (i.e., a recognized species, subspecies, or variety), be a native wildlife species (occurring naturally in Canada, or having expanded its range into Canada naturally, and have persisted for at least 50 years), and must regularly or seasonally occur (or have occurred) in Canada. Special cases may be considered, such as taxonomic groups below the sub-species or variety level, but supporting evidence must be presented that the species qualifies as a "Designatable Unit" under COSEWIC's guidelines. Species may be suspected of being in decline as a result of data obtained through monitoring programs, designated as imperiled by international organizations (e.g., IUCN), or they may be species that have previously been designated by COSEWIC as *not at risk* or *data deficient* and for which new data have recently become available. Candidate species may also be brought forward from COSEWIC's Aboriginal Traditional Knowledge (ATK) subcommittee. Each subcommittee maintains a subcommittee candidate list of species it considers likely to be at risk nationally, but which have not yet been officially assessed. Species (sub-species, varieties, etc.) are then prioritized based on the preliminary perceived need for their conservation, and are delegated to technical authors who prepare status reports on the current condition of the species or population in question.

The development of status reports is the information gathering step in the species risk assessment process. Most often, independent contractors are sought through a request for proposals process for which the COSEWIC secretariat posts the list of species to be assessed on the COSEWIC website (COSEWIC 2010c). Authors of status reports are paid different amounts depending on the quantity of information and literature anticipated to be available for synthesis related to the species in question (e.g., a larger body of literature or more complicated status report may warrant a higher contractual payment amount). In some notable cases, species whose assessments have been deemed highly political or controversial have had specific experts designated to write the report (e.g., the status report for Atlantic Cod was written by Dr. Jeffery Hutchins, Professor of Biology at Dalhousie University, a specialist on marine species and a member of the marine species subcommittee at the time). Status reports include a range of information (COSEWIC 2010e), and are intended to provide the following information on the species or Designatable Unit:

- i) a description of the species, its basic taxonomy and biology;
- ii) a description of the species' global range and population status;
- iii) a description of the species' range in Canada, including (if applicable) changes to the species' range over time;
- iv) a description of the species' population size and trend in Canada, including a quantitative analysis of the species' probability of persistence over some time period if possible (e.g., probability of persistence over the next 100 years);
- v) a description of the species' general habitat needs and ecology;
- vi) a list and description of threats to the species' persistence;

vii) a description of the likelihood that members of the species outside of its Canadian range may be able to immigrate into the Canadian range, either through natural or translocation means (i.e., rescue effect); and

viii) a description of the species' significance to Canadians, be it the species' spiritual or iconic symbolic status, its economic significance, or its historic significance.

Both the draft and revised versions of the status report are then reviewed by the relevant SSC, and the jurisdictions in which the species occurs. The third draft is forwarded to the COSEWIC general committee for evaluation and threat status assessment. Similar to the IUCN process (see Section 3.1.1), the COSEWIC assessment process uses the same five criteria and thresholds (A–E) for determining the relative probability of extinction. However, unlike the IUCN Global process, which uses one set of quantitative criteria to make the final assessment, COSEWIC follows the IUCN protocols for a regional assessment and employs an additional set of qualitative criteria that may alter the initial quantitative assessment (Figure 5). These modifying criteria, such as the probability of new individuals being recruited from other areas (rescue effect) (COSEWIC 2010a), ongoing threats to populations, or the perceived likelihood of trends continuing, are based on the information in the status report. There is sometimes a lack of available scientific evidence of threats or assessments of rescue effect, when expert opinion may be relied upon. These expert opinions may be accepted or discounted by COSEWIC during the peer review process depending upon the degree to which they are based on uncertain data.

The general assembly of COSEWIC makes the final decision regarding the proposed threat status. Just as in the IUCN process, COSEWIC may evaluate a species into one of seven separate categories (Figure 4, Table 2), each with a separate definition pertaining to the species' relative risk of extinction in Canada or to the amount of data available with which to assess the species. For the two COSEWIC at risk categories—endangered (EN), and threatened (TH)—each criterion A to E has a specific threshold which, when met by a species under review, immediately qualifies that species for that threat category (endangered or threatened). The highest category of threat met by any one criterion is taken as the overall threat category designation for that species. For example, species X has a population with 5,000 mature individuals (i.e., reproducing individuals, criterion C). The thresholds for TH and EN for criterion C are 10,000 and 2,500, respectively. Thus, species X would be designated as TH for criterion C. However, this same species occupies a range no larger than 3,000 km^2. The thresholds related to species range sizes, criterion B, are EN: <5,000 km^2 and TH: <20,000 km^2; thus, this species would be designated as EN for criterion B, qualifying for both TH and EN when criteria C and B are considered. If the species in question did not meet any other threshold in reviewing the other criteria (A, D or E), when all five criteria are taken together this species qualifies for the TH category twice (both under criterion B and criterion C), and the EN category once (only for criterion C). The resulting designation, which is forwarded to the Government of Canada with a recommendation for legal listing, is the highest threat category for which this species qualifies, in this case endangered (EN). This process of placing a species into the highest level of threat possible has been referred to as the *supremum effect* (Lukey 2009). It is inferred that the function of this supremum effect is to allow the criteria to be applied to a variety of taxonomic scales. While not all of the criteria are applicable to all taxonomic groups, when a species is assessed against all of the criteria, at least one criterion will catch a symptom of extinction risk (Lukey 2009; Mace et al. 2008).

The category of special concern (SC—Figure 4, Table 2) is a unique situation that is designated on a case-by-case basis. It lacks quantitative criteria and thus COSEWIC experts and assessors apply this category subjectively. COSEWIC defines species within this category as "…wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats" (COSEWIC 2011, Table 5, p. 14).

There are two categories that do not indicate a level of threat, and instead indicate that either the species is data deficient (DD) and an accurate level of threat cannot be estimated, or "not a risk" (NAR) indicating that the species was assessed against the criteria, did not meet any of the threat category thresholds, and was thus designated not to be at risk of extinction.

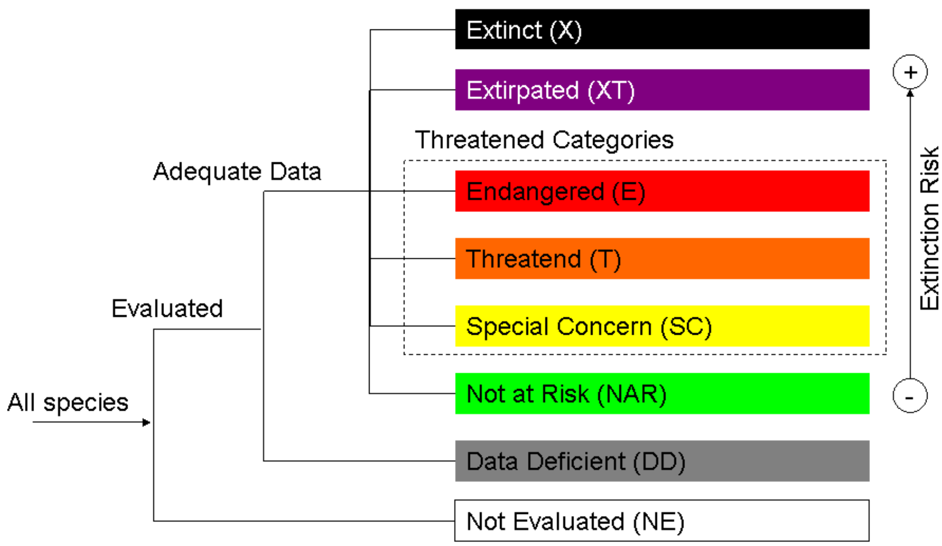

Figure 4 COSEWIC Extinction Threat Categories, with Extinction Risk Increasing Vertically in the Figure [Note that risk is only estimated for species that are evaluated and deemed to have adequate data. Species that are not evaluated or are data deficient are considered "extinction risk unknown within Canada".]

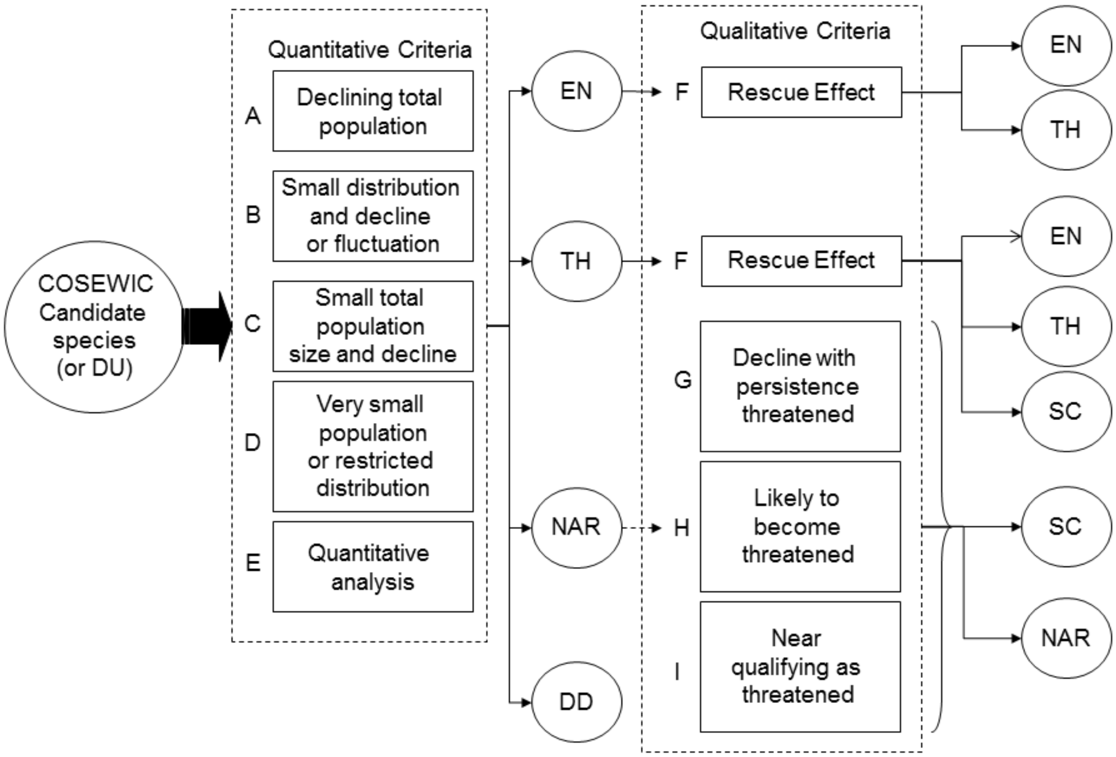

Figure 5 Theoretical Schematic Diagram of the COSEWIC Species Risk Assessment Process (modified from Lukey and Crawford 2009) [The two sets of criteria (quantitative and qualitative) are used to designate species as endangered (EN), threatened (TH), special concern (SC), data deficient (DD) or not at risk (NAR). In practice, however, the COSEWIC process is less linear, and considers all criteria available in a cooperative and open decision-making context.]

Table 2 Threat Categories, Acronyms and Their Definitions, as Applied by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010a)

Status	**Definition**
Extinct (EX)	No longer existing globally.
Extirpated (ET)	No longer existing in the wild in Canada.
Endangered (EN)	A wildlife species facing imminent extirpation or extinction.
Threatened (TH)	A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern (SC)	A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)	Having insufficient data to make a reasonable assessment.

3.2.2 *The Canadian Species at Risk Act and the Listing Process*

Once the species risk assessment process is complete, the species status report and proposed threat status are passed to the governmental review process. During this review, the Minister of Environment solicits feedback from staff within Environment Canada (EC), the Department of Fisheries and Oceans (DFO), Parks Canada (PC), and relevant provincial Wildlife Management Boards, depending on the species in question (e.g., if the species occurs within a national park or national marine protected area, feedback on the proposed listing is solicited from Parks Canada). The report is also forwarded by COSEWIC to the Canadian Endangered Species Conservation Council (CESCC). The CESCC, formed in 1998 under the Accord for the Protection of Species at Risk in Canada, is mandated to monitor and report every five years on the threat status of all species in Canada. It was formed by federal, provincial, and territorial Wildlife Ministers, and is composed of federal, provincial, and territorial ministers with responsibility for wildlife. Depending on whether or not they have concerns about a particular listing, CESCC may or may not provide further feedback to the Minister. It is also at this point that the status report and rationale for the assessment are posted on the SARA Public Registry, and are made available for public comment.

After collecting feedback from the various government departments and the CESCC, The Canadian Minister of the Environment forwards the threat status recommendation to the Governor in Council (GIC). Within 90 days of submittal, the GIC, upon recommendation by the Minister of the Environment, must issue a response with respect to the proposed listing describing how the government intends to act on COSEWIC's recommendation. Failure to respond would result in an automatic amendment to Schedule 1 of SARA. The GIC may choose to list the species on Schedule 1 of SARA, may decline to list the species, or may refer the species back to COSEWIC for further consideration.

Some authors have outlined concerns related to the SARA listing process, such as delays in the consultative process with northern Wildlife Management Boards and failing to account for economic benefits of listing species (e.g., non-commercial use, willingness to pay[3], and preventative benefits[4]) (Mooers et al. 2007). In a further analysis, Findlay et al. (2009) identified biases in the listing process related to whether or not the species is harvested or had commercial or subsistence hunting identified as threats, whether or not the species was found in the north generally and Nunavut specifically, whether or not the Department of Fisheries and Oceans (DFO) was the responsible authority, and whether or not the species was found mostly or entirely in Canada, all of which resulted in a lowered likelihood of being listed.

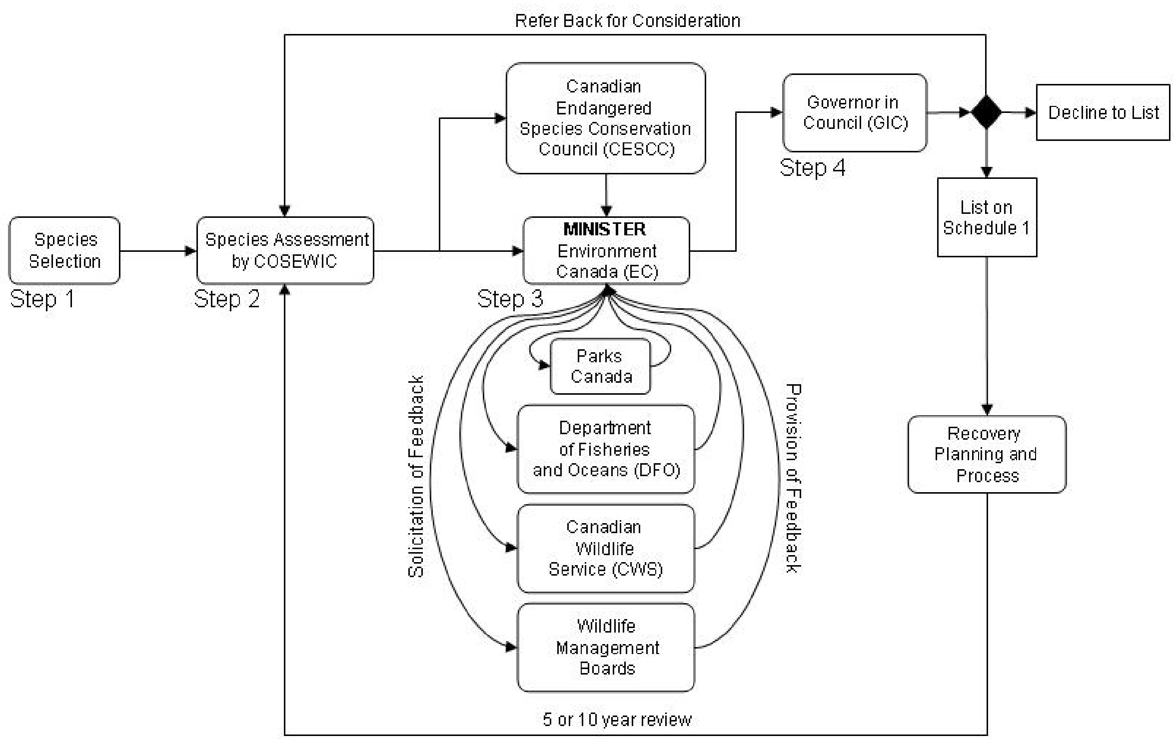

Figure 6 Schematic Diagram of the Species at Risk Listing Process under the Canadian Species at Risk Act (SARA)

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[3] In economics, the willingness to pay (WTP) is the maximum amount a person would be willing to pay, sacrifice or exchange in order to receive a good or to avoid something undesired, in this case to protect a species at risk of extinction.

[4] In terms of conservation, preventative benefits refers to the avoidance of unknown costs associated with the loss of a species to an ecosystem.

Nonetheless, species that are listed under SARA as *endangered* or *threatened* enter the legislatively mandated recovery process. Under this process, a mandatory recovery strategy is to be drafted and "critical habitat" must be identified for each listed species. Based on these recovery strategies, action and management plans must be developed and applied to help sustain and recover populations of listed species. Species listed under SARA as *special concern* require management plans to help prevent them from becoming further imperiled. Depending on the species, status reports are revisited by COSEWIC at five- or, more usually, 10-year intervals, at which point changes to the species threat status may or may not be warranted.

3.3 Contrasting and Comparing the IUCN and COSEWIC Processes

Several nations have developed species at risk threat ranking protocols based on methods developed by the International Union for Conservation of Nature (IUCN), including Canada through the use of the COSEWIC assessment process (Lukey and Crawford 2009). The IUCN's assessment process is necessarily designed to estimate the risk of extinction for species at the global scale, taking into consideration all populations of a species. In contrast, COSEWIC's assessment process is limited to estimating the risk of extinction for wild Canadian species, subspecies, varieties or other Designatable Units.

The two scales of assessment (national versus global), along with some modifications COSEWIC has made to the IUCN process (e.g., differences in category designations and thresholds to be consistent with the category changes), necessarily result in some discrepancies between the two processes. Assessments by COSEWIC do not necessarily result in risk categories identical to IUCN designations. In 2003, the IUCN published guidelines for the application of IUCN Red List criteria at regional levels, with the intention of helping rectify discrepancies and inaccurate risk designations between global and regional processes. As a result, the IUCN Red List of Threatened Species™ has become a major tool in conservation biology (Colyvan et al. 1999; de Grammont and Cuaron 2006), and the standard reference for regional assessment criteria.

The IUCN guidelines for regional assessments note that there are two ways to accurately apply the IUCN listing process at the regional scale (IUCN 2003). The first is to publish the Red List comprising only the species that have a significant presence or breeding territory within the region. This strategy is likely to work very well in any region with a high proportion of endemics or species for which data are deficient. However, in regions where there are relatively few endemic species, such as Canada (NCASI 2011), and reasonable amounts of data on the ecology of many species, another approach is needed. The second option is to assess a species' risk of extinction at a geographically or regionally defined scale. This entails some complicating factors, including the assessment of species that cross geopolitical borders (marginal species—see Section 4.6), species that spend significant portions of their life cycle outside of the region in question (e.g., migratory birds that breed in Canada but winter in South America), and non-indigenous taxa. Any regional assessment process must deal with each of these considerations in order to have a reliable assessment process.

The IUCN system and COSEWIC's ranking system in Canada both incorporate three major steps: 1) *characterization*—available information about a candidate species is compiled, and key ecological variables are quantitatively estimated (IUCN 2001; US Fish and Wildlife Service 2011; COSEWIC 2011); 2) *assessment*—estimated values of ecological variables are evaluated on the basis of information availability and/or information quality relative to predetermined thresholds; and 3) *designation*—species are assigned to one of several species risk categories, typically ranging between not at risk and endangered (Mace and Lande 1991; Hoffmann et al. 2008; COSEWIC 2009; Lukey et al. 2010). While the major steps are similar in both systems, there are some key differences worth noting. All differences are attributed to the alternate application of the system within Canada.

The IUCN has the capacity to assess all species proposed by anyone willing to submit data and an evaluation adhering to the IUCN standards and guidelines for the use of the IUCN categories and criteria. Submissions are accepted year-round, but may not result in immediate action by the IUCN. Although the majority of assessments appearing on the IUCN Red List of Threatened Species™ are carried out by members of the IUCN SSC Specialist Groups appointed Red List Authorities (RLAs) or by participants of Global Biodiversity Assessment workshops, those submitted by independent assessor(s) are checked for consistency and accuracy by an RLA before the species is considered for the "Red List" (IUCN 2011a, 2011b).

Similarly, under SARA, COSEWIC is obligated to assess any species after receiving an unsolicited status report. COSEWIC must assess the species within a year of having received the status report. More often, one of COSEWIC's subcommittees or the general assembly will first identify candidate wildlife species for further detailed assessment. Candidate wildlife species are species not yet assessed by COSEWIC and which have been identified by the SSCs (Species Specialist Subcommittees) or by the ATK SC (Aboriginal Traditional Knowledge Subcommittee) as candidates for detailed status assessment based on information suggesting a potential to be at risk (COSEWIC 2010f). Once a candidate species is identified, its eligibility as a Designatable Unit is evaluated based on certain criteria regarding taxonomic validity, native origin, regularity of occurrence and dependence on Canadian habitat. For each candidate species, a status report on the species is needed to form the basis from which threat status designation is determined (COSEWIC 2010b, 2010e).

The goal of the IUCN is to determine the conservation status of species globally at risk and to monitor global biodiversity. In contrast, due to its status as the risk assessment body for the Canadian Species at Risk Act, the goal of COSEWIC is to identify native species most in need of legal protection in Canada and, to a lesser degree, to propose conservation priorities for the government. This subtle difference in the respective goals of these two organizations may explain some of the differences in the species assessed annually insofar as COSEWIC may wish to allocate resources to priority species. There are some identifiable differences between the IUCN and COSEWIC systems. A select number of these differences are presented in Appendix A.

It may be useful to explore the specific effects of COSEWIC's criteria on the assessment process to help understand whether the COSEWIC criteria might ultimately benefit from being further aligned with the IUCN regional criteria. Differences may be significant, as the IUCN process deals strictly with species and global distributions and the COSEWIC process deals primarily with species native to Canada, but often having extant populations elsewhere.

4.0 CHALLENGES AND OPPORTUNITIES FOR SPECIES ASSESSMENT IN CANADA

4.1 The Use of Ecological Variables as a Proxy for Extinction Risk

Current theory suggests that a variety of factors can contribute to a higher probability of extinction occurring. The major extinction factors, with the exception of demographic stochasticity and genetic deterioration, can be divided into two categories: those associated with physical and biological changes in the environment (including changes to predation pressures), and those that are fundamental characteristics of the species or that describe a constant interaction between the species and the environment (Soulé 1983). Estimates of COSEWIC threat assessment criteria are predominantly based on fundamental characteristics of the species; however, there are risk factors that cannot be accounted for through this aspect of the assessment.

Although different extinction factors may be critical for different species, other noncritical factors cannot be ignored, and some factors may have cumulative or synergistic effects (e.g., the hunting of a species may not have been a problem before the population was fragmented by habitat loss or vice versa; Mace and Lande 1991). As a result of the complex nature of threatening processes and their interactions, all known extinction factors need to be considered in species risk assessments (Mace et al. 2008). Although COSEWIC species assessment reports do include a section on species threats (to their persistence), few reports include an exhaustive list of extinction factors, particularly if the species is poorly understood, or the risk factor is intrinsic to the species (part of the species' biology) and therefore deemed beyond the control of conservation efforts. In 2011, COSEWIC adopted a formalized threats assessment process that was developed by the Conservation Measures Partnership and will be using it in future status reports. A number of recent assessments have used this tool (D. Fraser, pers. comm). Deterministic exponential declines[5] are sometimes possible to estimate from basic population parameters. Such predictive tools as COSEWIC's quantitative analysis (criterion E, Figure 5) are therefore highly useful as warnings of imminent declines in threatened species, and can signal the need for immediate conservation action. However, in practice, criterion E is seldom applied in threat assessments as it requires population survey information of sufficient quality across a significant time scale, requiring between 5*t* and 10*t* years of data for a reliable assessment of viability over *t* years (Fieberg and Ellner 2000). As COSEWIC has only been in existence since 1977, and survey data greater than 50 years are non-existent for all but the most sought-after and exploited species (e.g., American bison, *Bison bison*; white-tailed deer, *Odocoilus virginianus*; moose, *Alces alces*; waterfowl) or for some species that capture certain interests among the public (e.g., birds of interest to bird-watchers), few species have sufficient data to generate precise estimates of extinction probability. Others have argued that although precise estimates are almost impossible to obtain, estimating extinction probability is still a useful exercise if results are interpreted with caution and are considered as only one factor in the overall risk assessment (Brook et al. 2002). Nonetheless, while criterion E is the preferable tool for risk assessment, increased data availability would be necessary for its use.

Some concern has been expressed that threat status as defined by a quantified probability of extinction over a defined time period (criterion E), may not match with surrogate measures of extinction risk A–D. This distinction is important because while species assessed based on criterion E are based on detailed population analyses, the vast majority of species are listed based on the surrogate criteria A–D, which could be seen as having less validity. Further, while these latter indices provide a relative measure of extinction risk and do not necessarily represent a quantified probability of extinction over a set time period (as does criterion E), there is a temptation in the literature to assign one that is equivalent to a criterion E analysis (Thomas et al. 2004), and to assume that the probability of extinction as defined under criterion E is equivalent to extinction risk under criteria A–D. (e.g., Mace 1994; Collar, Crosby, and Stattersield 994; Crosby et al. 1994; Thomas et al. 2004; Redding and Mooers 2006).

In order to test this assumption, Brooke (2009) did a preliminary analysis of the movement of species between extinction risk categories of IUCN criterion E-listed species (species with full quantitative analyses) as compared to species that have been listed using criteria A–D (Brooke 2009). Using a novel application of criterion E to predict rates of transition between threat categories (Brooke et al. 2008), and comparing them to Australian and global avian data sets over various time scales, the results suggested that at moderate levels of risk (e.g., vulnerable and threatened) quantitative analyses and surrogates matched up well, but at higher extinction risk (e.g., endangered and critically

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[5] In mathematics, a system that is characterized by very little variation or randomness is deemed to be deterministic, such that a population in any state of "deterministic" decline will continue to decline to extinction without changes to the current conditions.

endangered) the match between quantitative analyses and surrogates was more variable (i.e., criterion E-listed species were less likely to shift to lower risk categories than those listed by criteria A-D). The authors suggested this was likely because intense and often costly conservation efforts (e.g., captive breeding and release programs) significantly lower extinction risk, but are not usually applied until species reach higher risk levels. In order to rectify the mismatch, Brooke (2009) suggested that species listed at high extinction risk based on criterion E should be down-listed to bring them in line with surrogate-listed species (which far outnumber criterion E-listed species).

While it is possible to assign a probability of extinction on the basis of population parameters and the interaction amongst them as theorized by modern ecology, it is important to recognize that despite best estimates of probability, extinction is still a chance event. Large, stable populations that may qualify as not at risk by COSEWIC may still be susceptible to extinction. Conversely, small, unstable, declining populations designated endangered by COSEWIC may not experience extinction in the foreseeable future. It is important to remember that extinction risk estimates are based only on some (not all) extinction risk factors and current ecological theory of population dynamics.

A critical review of the influence of applying surrogates of extinction risk versus using direct estimates of extinction risk is needed to both evaluate the current reliability of surrogates to estimate extinction, and to ensure that currently listed species are correctly assessed. Species that are listed in greater risk categories than would be warranted by an estimation of extinction risk result in misplaced conservation efforts, and those that are under-listed may not receive required focus. In both cases, the mismatched assessment and management of species at risk may be less efficient and effective than they might otherwise be.

4.2 Geographic Scale

Sub-global assessments of species present unique challenges. Some of these challenges are a direct result of the geographic scale (e.g., regional, national, or global) used during the assessment. National assessment systems, like COSEWIC, aim to identify and assess species within the nation, which may, at times, result in conclusions that differ from or contradict global assessments. With the exclusion of endemic species (species whose entire population is restricted to only one region), species assessed at the national level with extant populations outside of Canada are essentially all subpopulation-level assessments. Subpopulation assessments that are restricted to political boundaries incur their own set of challenges, particularly related to the applicability of the criteria used by the IUCN and COSEWIC.

A COSEWIC assessment of a species’ status takes into consideration the possibility that outside populations could immigrate and bolster Canadian populations. As such, a threat status is not necessarily exclusive to the species’ Canadian range. However, its subsequent protection is limited to within Canada. National species priority lists may differ between countries, and therefore actions taken to prevent further decline of a species within a political region may have direct consequences on neighbouring political regions. The converse is also true, wherein the lack of conservation efforts in neighbouring political regions may have an effect on conservation efforts within Canada. This problem becomes even more profound in the marine environment where multiple nations are responsible for bordering marine regions, which is the case with the Grand Banks on the Atlantic coast of Canada. Migrating species exemplify this difficulty because often the site of ecological significance and/or the site most in need of conservation action may be outside of Canadian territory (e.g., breeding grounds for migratory birds). So while the species is at risk in Canada, options for meaningful domestic conservation action are sometimes limited.

Issues of geographic scale also affect the assessment process internally, as the resolution used to make the assessment can affect the calculated area of occupancy and therefore the final designation (IUCN 2010). Depending on the operating scale of the species in question (e.g., highly mobile with large territories versus sedentary with small territories) and the detectability of the species, fine-scaled resolution searches may lead to many cells with non-detects, and few cells with detections, leading to a conclusion of a small area of occupancy, leading to a greater estimated risk of extinction (Figure 7). Coarser-scaled resolution searches may blur detections with non-detects, yielding a larger estimate of areas of occupancy, resulting in lower estimate of extinction risk.

A species' occupancy and abundance can change relative to the scale examined (Hecnar and M'Closkey 1997), especially when studies are primarily conducted at local scales over short time periods (Schluter and Ricklefs 1993). The IUCN makes very specific recommendations regarding the spatial scale used to calculate a species' area of occupancy; however, it is difficult to generate a standardized method because of the differences between taxa that have different scale-area relationships (IUCN 2001). The overall effect of changing the spatial scale of analysis on the species risk assessment process is uncertain.

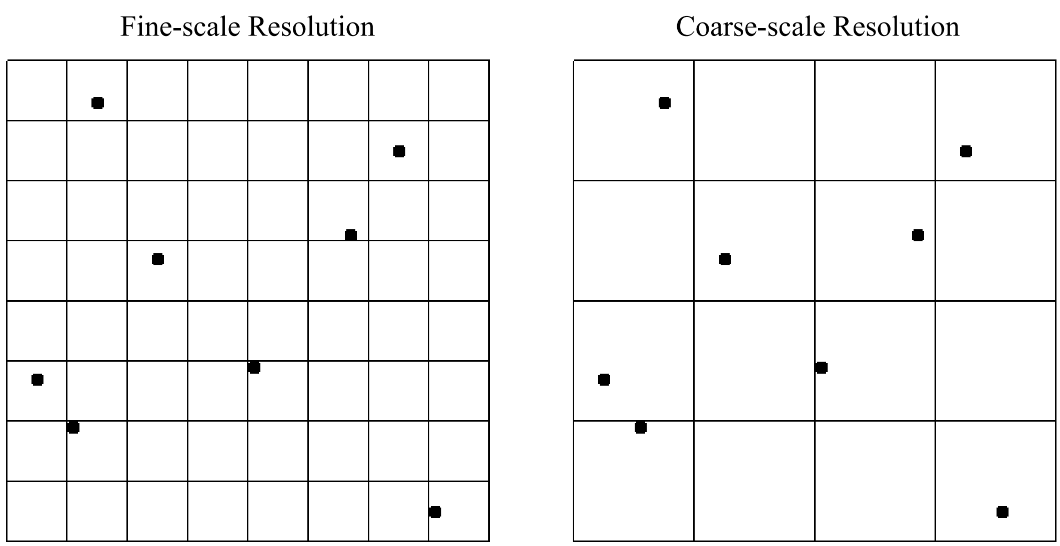

Figure 7 Schematic Representation of the Effect of Changing the Search Resolution on the Assessment of Area of Occupancy for Two Identical Distributions of Individuals [On the left (fine-scale resolution), individuals (black dots) are only detected on 12.5 percent of the total search area, with 87.5 percent of the area having no detections. On the right (coarse-scale resolution) individuals are detected on 50 percent of the total area. This difference in search resolution results in a different estimate of area of occupancy, and could therefore result in a difference in extinction risk assessment, even though both patterns of species distribution are identical.]

More work is needed to determine the contribution of extra-jurisdictional influences on species at risk in Canada, particularly when known threats to species persist beyond Canadian borders. Research is also needed to produce repeatable taxon-specific guidelines for species assessments at appropriate spatial and temporal scales.

4.3 Species with Very Long and Very Short Generation Times

As mentioned, the IUCN and COSEWIC criteria were formulated by experts on the basis of taxonomic groupings of plants, invertebrates, lower vertebrates, and higher vertebrates (e.g., mammals, reptiles, and birds). Further, the original proposal for the current COSEWIC criteria was that of the IUCN developed by Mace and Lande (1991). However, the Mace and Lande criteria are most appropriate for higher vertebrate species (e.g., vertebrates without a larval stage). This is simply a result of the longer generation times of higher vertebrate species, defined as the time between the birth of a mother to the birth of her first offspring. There is also a significant variation of life span within taxonomic groups, including higher vertebrates. All else being equal, longer generation times result in smaller intrinsic population growth rates, and shorter generation times mean larger intrinsic population growth rates (Begon, Harper, and Townsend 1996). When a species' generation time is very long (e.g., decades) smaller intrinsic growth rates may result in more stable populations, but present challenges for estimating reliable population trends for use in threat assessments. For example, *extreme population fluctuations*, defined by COSEWIC as "changes in distribution or in the total number of mature individuals of a wildlife species (or Designatable Unit) that occur rapidly and frequently, and are typically of more than one order of magnitude" (COSEWIC 2011, Table 6, p. 16) may occur over 100 years or more for longer-lived species. This means two things: first, as generation times are longer, assessments are relying on older survey data that are less dependable than current population trend data; and second, an extreme population fluctuation may be mistaken as a simple gradual population decline (e.g., having a Type 2 error[6]).

It is generally accepted that long-lived species are more threatened by higher adult mortality (measured as percentage of loss per year) than shorter-lived species because breeding adults experience this mortality over more breeding cycles (Mace et al. 2008), with greater effects on populations. While the IUCN and COSEWIC systems both account for differences in generation length, some variables, such as *reduction over time*, cannot be corrected for the difference in generation length because they are measured on a time scale of years. For long-lived species this may result in a population reduction over time failing to indicate a reduction across generations through the loss of reproduction capacity (e.g., having a Type 1 error[7]).

Further still, long-lived species are often associated with specific life history trade-offs. The most notable trade-off relates to reproductive success with respect to costs paid in survival and costs paid in future reproduction (Stearns 1989). Longer-lived species may invest in parental care strategies rather than having a high fecundity rate. This is seen when juveniles remain with a parent (typically the mother) until sexual maturity. In physically larger vertebrates, the age at sexual maturity can be in the order of decades. Conversely, smaller species may prefer to invest that energy into factors that contribute to maximum fecundity rates (e.g., short gestation periods, larger litters, and less parental care; Krebs and Davies 1978). This difference in fecundity strategies is important to the accuracy of the IUCN and COSEWIC assessment processes, where the loss of a single mature individual within a population of long-lived species has a more profound impact on the population's viability than it would for a short-lived species. While the use of generation length within the IUCN and COSEWIC criteria does account for this difference in effect on viability, it becomes more difficult to accurately utilize generation length for species with extremely long generation lengths. Whales, for instance,

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[6] Type 2 Error (or an error of the second kind): In statistics, this term refers to a flaw in the testing process whereby a hypothesis of no effect that should have been rejected was accepted (e.g., failing to find an effect that was actually occurring).

[7] Type 1 Error (or an error of the first kind): In statistics, this term refers to a flaw in the testing process whereby a hypothesis of no effect that should have been accepted was rejected (e.g., finding an effect that was actually not occurring).

have generation lengths that stretch 10 to 60 years (Taylor et al. 2007) and to estimate a reduction in abundance across three generations, as suggested by the criteria, would be quite difficult (30-180 years).

Accuracy also may be difficult to obtain with short-lived species. COSEWIC and the IUCN use the same variables for all taxa, including population fluctuations, population abundance estimates, and decline rates. Extreme fluctuation in a population, for example, is an indicator that the population is vulnerable due to environmental and demographic stochasticity. Further, wild species with short generation times may have significant population fluctuations that mask directional population changes such as continuing declines or increases (IUCN 2010).

All other things being equal, extinction rates will be greater in small populations than in large populations. However, small-bodied, fast-growing, short-lived species are more susceptible to extinction at low population densities, and large-bodied, slow-growing, long-lived species are more susceptible at high population densities (Pimm, Jones, and Diamond 1988). On the other hand, r-selected species (species with high potential growth rates) may recover faster from population declines. Given that the threat assessment system is reliant on simple estimates of ecological variables, it is almost certain that consideration of these complex life history traits is not justified simply by inclusion of generation length into the criteria.

In the development of the current system it was determined that a single criterion that can be applied across all taxonomic groups would be the most appropriate for the various uses of the system. However, there are significant differences in the life histories within and between taxonomic groups that alter their probability of extinction (Purvis et al. 2000). It may be useful to explore the possibility of taxon-specific and life history-specific threat assessment systems, especially as the field of endangered species biology grows in sophistication, and measurable attributes of species biology and ecology can be related directly to their probability of long-term persistence, as suggested by others (Kotiaho et al. 2005). Further research is needed to determine the usefulness of including aspects such as general life history traits to modify threat assessment criteria. In addition, better modeling tools are needed to accurately assess extinction risk for long-lived and long-generation time species, such that risk assessment is more reliable and addresses the conservation needs for these species.

4.4 Taxonomic Scale and Designatable Units

Both the IUCN and COSEWIC rely primarily on the biological species definition, but may assess groups of organisms below the species level (e.g., subspecies, varieties, or Designatable Units). Generally speaking, the biological definition of species offers the IUCN a reasonable, although somewhat controversial, justification as the appropriate taxonomic level for assessment. COSEWIC, as a national-level organization, is not afforded this readily available justification for species as the taxonomic level for assessment, as many species have substantial populations beyond Canadian borders. As a result, the Species at Risk Act (SARA 2002) mandates that COSEWIC assess wildlife species that occur in Canada, stating "a 'wildlife species' can include subspecies, varieties, or geographically or genetically distinct populations". This provides COSEWIC with the opportunity to assess threats to units at various taxonomic scales both at and below the species level. Nonetheless, the species level is often chosen by default, unless available information suggests that a subspecies-level threat assessment is warranted. Such a determination is made if the unit is a recognized subspecies or variety or 1) a subunit of the population is considered discrete, and 2) the subunit is considered significant. Discreteness is determined by 1) evidence of genetic distinctiveness, 2) a natural disjunction between segments of the population's range such that movement of individuals between segments is unlikely, and/or 2) occupation of separate eco-geographic regions that may represent genetic adaptation (COSEWIC 2009). Significance is determined based on 1) a relatively significant genetic differentiation, 2) persistence of the discrete population in an ecological setting that is unusual or unique to the species, 3) evidence that the segment of the population represents the only naturally occurring population of the species, and/or 4) evidence that the loss of the segment would represent a significant gap in the species' range (COSEWIC 2009). While such Designatable Units (DUs) are assessed using the same criteria, indicators, and thresholds as for species, the guidelines for determining the acceptance of a DU are deliberately flexible.

A precursor to the DU was the evolutionarily significant unit (ESU) concept, which was developed to provide a rational basis for prioritizing taxa for conservation effort (Moritz 1994). The ESU concept affords a wealth of scientific literature on the methods used to recognize taxonomically significantly discrete units below the species level. It is a parallel concept to the DU and is used internationally with many criticisms. Competing criteria have been suggested to define ESUs, each emphasizing different aspects of the nature of species and criteria for recognizing them (Fraser and Bernatchez 2001; Green 2005; Moritz 2002; Waples 2005). Most definitions suggest that an ESU should be geographically discrete, and proposed genetic criteria have included significant divergence of allele frequencies, levels of genetic distance, and congruently structured phylogenies among genes, to name only three.

Regardless of the assessment system (IUCN or COSEWIC) and the unit being assessed, it is of the utmost importance that the taxonomic level or unit being assessed is justified, given that vague justifications allow critics to question the credibility of the system. Such criticisms may be warranted when considering that the original aim of the quantitative criteria (IUCN and COSEWIC) was to identify symptoms of threat to global populations. Thus, they excluded ecological considerations that might be needed at the subspecies level (e.g., dispersal, rescue effect, etc.).

Because threats to species vary across time and space, it is expected that not all species' subpopulations within Canada will be affected uniformly by environmental or anthropogenic threats. The use of DUs allows species assessments to reflect the varying degrees of risk caused by disproportional threats. Thiemann, Derocher, and Stirling (2008) found that threats to the conservation of polar bears are not spatially uniform, concluding that the use of DUs provided a biologically sound framework for conservation of polar bears. Threats to fish species on the Pacific coast and Atlantic coast are likely not identical. In addition to the non-uniform distribution of threats across a landscape, DUs may also reflect direct threats that are coincident with specific management units or stocks of wildlife species, as is the case for Atlantic cod (*Gadus morhua*).

Employing the DU concept also allows for addressing and legally protecting units within species that may be at greater risk, while not unnecessarily interfering with the remainder of the species. This consideration is important when dealing with commercially valuable species, as legal protection has some major implications for natural resource utilization. In practice, however, it is argued that such an arbitrary and subjective method of dividing species populations into DUs creates inconsistencies and opportunities to refute the assessment system (O'Brien and Mayr 1991). Some of these drawbacks include inherent biases in the application of quantitative criteria, inconsistencies in partitioning species into units, and questionable validity of proposed units.

COSEWIC relies on the Precautionary Approach[8] and assigns extinction risk to both national species populations and subpopulations (or DUs) without having to resolve what defines a species or evolutionarily significant unit. Allowing this degree of interpretation to exist in the system introduces subjectivity that could have profound effects on species risk assessments and, ultimately, conservation efforts.

When COSEWIC assessments are performed at the DU level, the distribution and abundance of the unit being considered are necessarily smaller than at the species level, and likely closer to the risk thresholds used in the quantitative criteria (e.g., a reduction of mature individuals of 70% over 10 years or three generations for endangered, or 50% for threatened, COSEWIC 2010b). It is possible that a modification in taxonomic level of assessment without a corresponding modification in quantitative criteria thresholds may have an important effect on the probability of risk designations for organisms assessed as DUs rather than species, and research is needed to assess the significance of this effect, most notably when population size is the primary criterion being considered in the assessment.

The necessity of conducting extinction risk assessments on groups of organisms below the species level creates uncertainty in the repeatability and reliability of the assessment process. Analyses are needed to determine what effect, if any, the use of sub-specific groupings has on results of the assessment process, and whether or not removing a subset of the total population for separate assessment has negative consequences for assessment of the remaining population. Such an analysis would not only test implications of standardizing the process for all groups, but would provide assurances that assessment results are systematic and efficient. It may also indicate opportunities for improvement where results appear irregular. To be effective, the assessment process should estimate risk of extinction with reasonable precision for whatever unit assessed, and take into account the fewer mature individuals in an inherently smaller population.

4.5 Species Rarity

Species assessed as being “at risk” (e.g., threatened or endangered) by COSEWIC are by definition either rare or becoming more so, leading to a risk of extirpation from Canada or to complete extinction. However, it is generally accepted that relatively few species are common (Bruno 2002; Drever, Drever, and Sleep 2012; Fisher, Corbet, and Williams 1943; MacArthur 1957; Preston 1948; Rabinowitz 1981; Rabinowitz, Cairns, and Dillon 1986). It is well understood that rarity may bring with it increased probability of extinction owing to 1) intrinsic ecological and biological characteristics (Davies, Margules, and Lawrence 2000), and/or 2) the consequences of having few individuals, such as demographic variation (Goodman 1987), catastrophes (Shaffer 1987), or inbreeding and loss of genetic variation (Lande and Barrowclough 1987). Ironically, while rarity in and of itself carries some ecological risk, rare species are not necessarily prone to extinction.

Several COSEWIC criteria for species assessment pertain to population size (e.g., qualitative criteria B, C, and D; see Figure 5). Species that are rare either have small populations spread over large areas, are clustered in relatively small and infrequent patches, or may be rare in one location or jurisdiction while being abundant elsewhere. Such differences in distributions contribute to the various types of rarity, as described by Rabinowitz (1981) and Rabinowitz, Cairns, and Dillon (1986) and shown in Table 3.

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[8] The Precautionary Principle, as related to the environment, states that if an action or policy has a suspected risk of causing harm, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent such harm.

Table 3 Seven Types of Rarity (Rabinowitz 1981; Rabinowitz, Cairns, and Dillon 1986)

		Geographic Range			
		Large		Small	
Population Size	Somewhere Large*	Common.	Locally abundant over a large range in a specific habitat.	Locally abundant in several habitats, but restricted geographically.	Locally abundant in specific habitat, but restricted.
	Everywhere Small*	Constantly sparse over a large range and several habitats.	Constantly sparse in a specific habitat, but over a large range.	Constantly sparse and geographically restricted in several habitats.	Constantly sparse and restricted to a specific habitat.

*"Somewhere Large" and, "Everywhere Small" refers to the global distribution of population sizes of a particular species. While on average a species may be distributed in scattered small populations, the existence of one very large population (e.g., wildebeests on the Serengeti) changes the profile of a species' conservation status.

The evolutionary forces or common traits that result in a species being rare are uncertain, in spite of significant research efforts (e.g., Kruckeberg and Rabinowitz 1985; Kunin and Gaston 1993; Hedge and Ellstrand 1999; Bruno 2002, Pilgrim, Crawley, and Dolphin 2004; Kelly, Woodward, and Crawley 2005). More recently, it has been suggested that rare species could be the result of benign environments (Harrison et al. 2008).

Because many species are rare and in some cases may have never been at greater abundances than at present, some species could be assessed as at risk in the absence of any known threat. As a means of reducing ambiguity in the assessment process, such naturally rare species could be assessed based on a population profile that is the result of natural processes and evolutionary forces only. Naturally rare species would then be assessed under COSEWIC quantitative criterion D1, having a very small or restricted total number of mature individuals, with less than 1,000 individuals (threatened) or less than 250 individuals (endangered). COSEWIC's current rubric (Figure 5) does not consider natural rarity as a modifying criterion, but such an assessment criterion could be used to reduce conservation attention for species that are thought to be, and are likely to continue to be, rare, by reducing the extinction risk category assigned initially to such species. While naturally rare species should continue to be monitored (as small populations carry inherent extinction risks, including genetic issues), it is unlikely that significant conservation activities are needed to maintain them, as they have presumably managed to persist at low abundances for a significant amount of time without human assistance. This would allow conservation efforts and resources to be redirected towards species at greater risk or in decline.

4.6 Rescue Effects and Marginal Species

Two elements pertinent to the probability of extinction that relate to the geographic location of a local population at risk with respect to the distribution of the rest of the species population are *rescue effect* and *marginal species*. In turn, both of these concepts are tied to extensive bodies of research related to island biogeography and metapopulation dynamics.

Many natural populations that are widely dispersed (e.g., at the country or continental scale) will be made up of numerous local populations (Andrewartha and Birch 1954), each of which interact (e.g., compete or interbreed) more often within populations than between. In 1970, Levins coined the term "metapopulation" to describe an assemblage of such local populations that are connected through migration (Levins 1970). Metapopulation dynamics, as a science, experienced significant attention in the 1980s and 1990s in population ecology (Hanski 1985; Hastings 1990; Gilpin and Hanski 1991) and conservation biology (Quinn and Hastings 1987; Gilpin 1988), and has particular relevance to the persistence or extirpation of species at risk.

Closely related to metapopulation theory is the theory of island biogeography, as originally proposed by MacArthur and Wilson (1967). Island biogeography was originally postulated to explain the varying levels of species richness on islands within archipelagos, but has since been used to explain patterns of diversity among any patches of suitable habitat surrounded by unsuitable habitat. Simplistically speaking, the theory of island biogeography suggests that the probability of a new species colonizing an island is inversely related to the island's distance from the mainland, and directly related to the size of the island in question. The theory assumes that there is a source of new species richness in the form of abundant new species from the mainland (where higher levels of speciation are thought to occur owing to significantly larger landmass) to colonize the islands. In this way, equilibrium is thought to be reached on islands that are smaller but closer to the mainland, whereby higher extinction rates are offset by colonization. This pattern has been confirmed in a majority of empirical analyses, although some distributions do not conform (e.g., Barbour and Brown 1974; Diamond 1972; Terborgh 1975). For the purposes of assessing extirpation risk of local populations, local populations that are declining may be bolstered by immigrants from other populations—the rescue effect—and thereby prevent extirpation.

"Rescue effect" is the "immigration of gametes or individuals that have a high probability of reproducing successfully, such that extirpation or decline of a wildlife species can be mitigated" (COSEWIC 2010a). The probability of rescue will depend on individuals or gametes being available outside of the species' local population, and the ability of those individuals to immigrate to the local area in question. These factors are therefore analogous to MacArthur and Wilson's (1967) theory. For the rescue effect to offset declining species in insular local populations, individuals or gametes from the remaining metapopulation must be physically close enough to immigrate and abundant enough within their own local populations to make the risk of moving to a new local population worthwhile. If other populations are too far or separated by a physical barrier, immigration cannot occur.

The rescue effect may either offset the loss of genetic variability or inbreeding in small populations (genetic rescue), or simply bolster flagging populations with new individuals immigrating to the population. Examples include natural immigrations (e.g., Scandinavian wolves) (Ingvarsson 2002; Vilà et al. 2003) and immigrations assisted through the actions of conservationists [e.g., Florida panthers, *Puma concolor coryi* (Pimm, Dollar, and Bass 2006) and prairie chickens, *Tympanuchus cupido pinnatus* in Illinois (Westemeier et al. 1998)]. However, the contributions of such movements to population trends can be hard to prove, as confounding factors may also play a part in the local population's increasing fortunes (Creel 2006; Maehr et al. 2006; Mills 2006).

Within the COSEWIC process, rescue effect is a modifying criterion, and is determined by expert opinion (see Figure 5). In theory, rescue effect has high potential to influence the risk of extirpation in Canada, as many species within Canada (owing to its latitude within North America) are subpopulations (or fringe populations) of much larger populations within the US or elsewhere. Such marginal species still make up an important part of Canada's biodiversity, and therefore remain conservation priorities for protection. The protection of species that are locally rare but globally secure often results when an edge of a species range cuts across jurisdictional boundaries. In these cases, rescue effect of marginal species warrants significant analysis, especially where the “colonizing distance” may be effectively zero.

In practice, the importance of the rescue effect is often minimally considered within status reports. Status reports generally lack details on the analysis of potential for rescue effect, if an analysis has been conducted at all. If habitat loss in Canada is the primary cause of decline, then it is accurate to assume that rescue effect has limited value, as new immigrants will have little opportunity to flourish. However, in those cases where habitat loss is not the problem or has been halted, and the potential for rescue is high, the risk of extirpation may be significantly reduced.

The management of rare and marginal species may also be complicated by jurisdictional boundaries and where boundaries transect the global or continental population. All species are likely to be rare in some part of their distribution, and distributions may vary in a systematic way (Brown, Mehlman, and Stevens 1995; but see Sagarin and Gaines 2002). If populations are less dense at the periphery, jurisdictional boundaries can create jurisdictional rarity (Bunnell, Fraser, and Harcombe 2009), whereby a population may be considered at risk within a jurisdiction, whereas the population is abundant and not at risk beyond the jurisdiction’s boundary.

For the most part, assessments of jurisdictional rarity may be unavoidable, as some high-level policy strategies are aimed at maintaining all biodiversity, irrespective of that particular species’ populations beyond local borders (e.g., B.C. Ministry of Environment, Lands and Parks 1994, 1996; Environment Canada 1995). However, such parochial conservation efforts carry financial and efficiency-related costs to global conservation efforts (Hunter and Hutchinson 1994), and it would be helpful if the costs and utility of managing jurisdictionally rare species were assessed and acknowledged. Whether or not a species or group could be considered “marginal” would be a useful modifying criterion, similar to that suggested in Section 4.5 (rare species). Such a modification to the assessment process would help focus conservation efforts on species of greater global concern, while continuing to track species that are clearly important in the Canadian context. COSEWIC’s priority setting process for identifying new species for assessment takes this into account, giving lower priority to species at the edge of the range, that are otherwise secure.

4.7 Threats to Species

Among more abundant species, risk of extinction is generally lower. However, while theoretical ecology suggests a number of population-level variables tend to be very reliable in assessing a population’s risk of extinction, there are additional factors that can, alone or in combination, contribute to the extinction process, irrespective of population size, such as environmental change, introduction of exotic predators or competitors, unsustainable harvesting, habitat loss, etc. Extrinsic environmental changes are therefore a significant driver of the probability of species extinction regardless of initial population size.

Beyond these intrinsic (biological) and extrinsic (environmental) factors, if the intention is to halt the decline of a species population and thereby prevent its extirpation or extinction, it is important to identify the specific major factors influencing populations, and to understand the ecological mechanisms that result in population decline (Swain et al. 2009). Generally speaking, the most frequently cited cause of species decline is loss of habitat or living space (Venter et al. 2006; Wilcove and Chen 1998), which has obvious ramifications on species. However, other threats may have consequences to population productivity (e.g., Shelton et al. 2006) through various mechanisms such as changes to composition of populations (Olsen et al. 2004) or changes to their ecosystems (Swain and Sinclair 2000). Geographic features may also play a significant part in driving extinction risk. Recent work by Loehle and Eschenbach (2011) documented all historic (since 1500) bird and mammal extinction events, and suggested that islands (including Australia) have higher extinction rates of native fauna (95% of extinctions occurred on islands), and that the majority of recorded extinctions are related to overexploitation and species invasion (including human), rather than habitat loss *per se*.

Threats to species, as listed within individual COSEWIC status reports, may be listed with, and in many cases without, published references or inferred from documented activities that occur sympatric with declining populations. Status reports and consequential recovery and action planning would benefit significantly from well documented, detailed reviews of threats to the species' or population's persistence and, where possible, incorporation of mechanistic explanations (or hypothesized explanations) for how threats influence populations. Such mechanistic explanations can help focus conservation efforts while reducing actions in areas that are unlikely to result in conservation gains (improving both efficiency and effectiveness). Further, mechanistic explanations may help improve mitigation efforts in areas where threats from human activities are unavoidable (e.g., in the case of necessary activities such as flood or fire control), or where they may continue in areas where a species previously persisted and may re-occupy after recovery. Mechanistic explanations of threats—rather than simplistic descriptions of potential threat patterns (e.g., species A is in decline in urban areas)—would also spur focused research into declining species, thereby contributing to development of improved and more effective mitigation and recovery efforts. The adoption by COSEWIC of a new threats assessment process using the Conservation Measures Partnership scoring system and the IUCN threats classification system is a positive step in this direction (Master et al. 2009).

4.8 Data Sourcing and Suitability

For many species, most notably those that are rare, there is often a dearth of relevant scientific literature with which to assess a species' risk of extinction. Further, data that do exist for rare species are often sparse or error-ridden, or limited to only a segment of the population (geographically or demographically).Seasonal or year-to-year variation, when combined with the aforementioned limitations, will often mean that the information available is not easily used, necessitating the development of novel analytical approaches (Heppell, Caswell, and Crowder 2000; Holmes 2001). As a result of this data poverty, there is a temptation to use any and all data available without a critical evaluation as to whether or not the data are suitable for determining population trend, the magnitude of the population trend, or determining presence/absence. For example, data from Breeding Bird Survey data, which are commonly used in evaluating long-term trends of many passerine species, produce variable results (with variable error rates) depending on the time period considered and how the data are used (e.g., presence/absence by route vs. presence/absence by station vs. number of individuals detected per route) (Bart and Klosiewski 1989). Changing sampling intensity, observers, or locations can alter the representativeness of the data from one period to the next. Standards for data quality and use across common data sets (e.g., Breeding Bird Survey for birds) would be useful for ensuring consistency across assessments. A lack of critical evaluation of the data for the species in question and failure to meet data quality standards could be a reasonable way to qualify a species as data-deficient.

Across Canada there are many national, provincial and regional wildlife monitoring programs that could contribute data to the assessment process of candidate species (NCASI 2010). It is currently unclear how many of these monitoring programs are considered during species assessments. Given their limited time and resources, contractors assigned to prepare status reports may miss data sources that could clarify and contribute to effective species assessments. Long-term data-gathering programs are highly useful for understanding the population dynamics of many vertebrate species and, once consideration is given to data quality and reliability, should be considered during the assessment process.

4.9 Application of Expert Opinion (Mathematical vs. Behavioural)

Expert opinion is a significant aspect of the extinction risk evaluation process of COSEWIC (see Section 3.2.1). In addition to the involvement of experts on species subcommittees, the qualitative criteria within the COSEWIC assessment process (see Figure 4, e.g., assessment of the probability of the rescue effect occurring or whether or not a species is near to qualifying as threatened) are based in part on the scientific literature and in part on expert opinion. Expert opinion is gathered through participation of specialists in the COSEWIC committee process, and via solicitation of expertise from other agencies, public consultations, and submitted comments. COSEWIC committees and sub-committees make their decisions by consensus, or rely on a two-thirds majority vote when consensus cannot be reached (COSEWIC 2010b).

The use of consensus-based decision-making in the application of expert opinion to conservation is useful in that it may help identify experts' errors and misunderstandings during the process (Ouchi 2004), but there are generally few rules as how to reconcile differences of opinion when consensus is hard to achieve. Research has found that group conformity methods tend to suffer from less confident experts limiting their participation, dominant personalities having greater influence, and overly hasty conclusions (Mosleh, Bier, and Apostolakis 1988). If dialogue is unrestricted, there is potential for manipulation of the process (Genest and Zidek 1986) and group interaction has been found to produce more extreme risk probabilities (Cooke 1991). These concerns, along with others, have led some to speculate that consensus-based decisions should be replaced with argumentative-based approaches in conservation (Peterson, Peterson, and Peterson 2004). While there are more structured means to incorporate and compile expert opinion, such as the Delphi method[9], open, less structured discussion in a controlled environment is generally the preferred method to achieve consensus (Gustafson et al. 1973).

Alternatively, mathematical approaches have been used to gather and aggregate expert opinion, and generally produce more accurate and transparent results (Clemen and Winkler 1999; Mosleh, Bier, and Apostolakis 1988). Such systematic approaches have been developed, along with formal protocols and guidelines for handling the expert opinion data, to improve consideration for uncertainty (Winkler, Hora, and Baca 1992; von Winterfeld 1989; Cooke and Goosens 2000). Established modeling methods such as Bayesian models and psychological scaling models (paired comparisons) have been used to aggregate expert opinion for risk analysis and may be useful in determining risk of extinction. Some agencies have chosen to document disagreements during deliberations to improve transparency (USFWS 1994). While not without some challenges, it may be useful for COSEWIC to explore alternative expert opinion systems that could be applied during the assessment process, to help mitigate possible bias in establishing species threat status.

4.10 Evaluating Uncertainty

Assessment of threat status for a given species—or the ability to determine the probability of a species' persistence over some time period given some information on population size, trend, ongoing threats—is far from a precise undertaking. In this context, it is important to distinguish between "risk" (as in "species at risk") and uncertainty. Risk, in terms of species extinction probability, can be defined as an event with a known probability (or statistical uncertainty), whereas true uncertainty is an event with an unknown probability (or an "indeterminacy") (Costanza and Cornwell 1992). This

[9] The Delphi method (named after the Oracle of Delphi) is structured communication technique that uses an iterative process where a group of experts are anonymously and repeatedly polled, with results of the previous round's results provided between rounds. The process ends after a set number of rounds or variation in results reach a pre-determined minimum (Linstone and Turoff 2002).

latter uncertainty is primarily driven by four factors, namely errors, variability, semantics (Akçakaya et al. 2000), and unknowns.

"Errors" refers to imperfect knowledge owing to poor quality and/or low quantities of reliable data. Poor or low-quality data is often the case for many rare species. Uncertainty driven by error can in theory be reduced through the collection of more and better data. "Variability" refers to changes in parameters on a spatial and temporal scale, which may result from ecological and/or stochastic factors. Variability can only be estimated based on predictions from models which will carry with them some amount of statistical uncertainty. Variability is reduced through the collection of more and better data, such that the predictive outcomes of models are more accurate. "Semantic" uncertainty is related to ambiguous and variable terminology and definitions. An example of this within COSEWIC criteria (based on IUCN criteria) is the reference to "suspected" population reductions, which could be interpreted differently depending on the perspective of the assessor. While in theory such uncertainty can be reduced through the use of more precise definitions, it may limit application across a broad range of species and situations, and as a result, some amount of semantic uncertainty is likely to remain. Finally, "unknowns" simply refers to factors either related directly to the species, such as some undiscovered aspect of their biology, or ecological relationships such as an unknown predator or some other factor influencing survival or reproduction. Such unknowns may exist because technology is not available to explore them, or because research has not yet discovered them.

In application of the threat categories used in the COSEWIC assessments, as well as in the application of the concept of locations, uncertainty is handled by encouraging COSEWIC to use range ranks that cover the range of likely values, to adequately reflect the uncertainty with the scoring generated. Despite the lack of precision inherently associated with assessing species' threat status, some ecological aspects of species' population dynamics contain elements that could be targeted to help reduce uncertainty or better incorporate variability in the assessment process. Use of IUCN criteria and thresholds at appropriate scales, incorporation of types of rarity into the assessment process, increased evaluation of jurisdictional species and rescue effect, improved assessment of threats to species, and a higher and more transparent standard for the determination of Designatable Units all have the potential to decrease uncertainty. This should result in more efficient use of the species risk assessment process, more accurate assessments, and more rigorous and transparent use of expert opinion.

4.11 The Precautionary Principle and Adaptive Management

The Precautionary Principle is enshrined in Canada's Species at Risk Act, appearing in the preamble. It notes that "the Government of Canada is committed to conserving biological diversity and to the principle that, if there are threats of serious or irreversible damage to a wildlife species, cost-effective measures to prevent the reduction or loss of the species should not be postponed for a lack of full scientific certainty" (SARA 2002). In its discussion of recovery actions and planning, SARA also notes in Section 38 that "in preparing a recovery strategy, action plan or management plan, the competent minister must consider the commitment of the Government of Canada to conserving biological diversity and to the principle that, if there are threats of serious or irreversible damage to the listed wildlife species, cost-effective measures to prevent the reduction or loss of the species should not be postponed for a lack of full scientific certainty." Both statements paraphrase Principle 15 of the United Nations Rio Declaration on Environment and Development (commonly known as "The Earth Summit"), which states that "in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (UN 1972). The Rio Declaration was endorsed by all participating countries, and is a non-binding agreement intended to guide future sustainable development around the world.

Despite the inherent appeal of the Precautionary Principle in avoiding irreversible errors and avoiding stalled action when the science is uncertain, the principle is most effective when applied cautiously, as a number of criticisms of its use have been documented (Nowak 2009; Seethaler 2009; Sunstein 2003). While the extinction risk assessment procedures used by COSEWIC (and the IUCN) are grounded in science and the Precautionary Principle, some conservation scientists have expressed concern that there is a tension between the two (Nowak 2009). For example, despite poor or limited available data, a precautionary approach might suggest listing a species as being at greater risk of extinction than is actually warranted. When the time comes to revaluate the species' threat status, specialist groups may require higher levels of quality data to lower the risk evaluation, resulting in an inability to downlist or remove the species from the list of imperiled species. Others have suggested that the application of the principle may have negative consequences unless both sides of the risk evaluation are examined closely (i.e., the effects of both higher and lower threat assessments), as one of two options is often considered "risk-free," which is often not the case (Seethaler 2009). Failing to consider all sides equally can have significant opportunity costs to both society and the environment at a larger scale (Sunstein 2003). Indeed, the direct cost of managing species at risk in the US has been estimated at over $32-42 million per year (Wilcove and Chen 2008). Further, the inclusion of "full" scientific certainty within the Principle limits its value in decision-making, as science presents probabilities rather than certainties, and therefore "full scientific certainty" rarely exists (Freudenburg, Gramling, and Davidson 2008).

The Precautionary Principle has been referenced in many aspects of Canadian government policy development, and its application in decision-making is set out in *A Framework for the Application of Precaution in Science-Based Decision Making About Risk* (Government of Canada 2003). The purpose of the framework is to provide guidance for coherent and cohesive application of precaution to decision-making about risk where scientific certainty is lacking. Among other related topics, the framework includes guidance on transparency of decision-making under precaution, and the level of precaution vis-à-vis the level of risk. "Risk", as previously described, can be defined as an event with a known probability (or statistical uncertainty), whereas true uncertainty is unknown (Costanza and Cornwell 1992). It is this latter uncertainty for which reduction is sought. "Adaptive management" is one such tool to help reduce this uncertainty. As used by Holling (1978) and Walters (1986), the term adaptive management has been described as "experimentation to the design and implementation of natural resource and environmental management policy" (Halbert 1993, p. 262). In effect, adaptive management seeks to test the limits of uncertainty for the purposes of generating better information to better inform policy. The process is iterative, in that as new information is gained, the policies are adjusted and retested. While this is a useful process in theory, it has met with limited success owing to the overreliance on linear models, and the discounting of non-scientific forms of knowledge (McLain and Lee 1996). Further, the use of adaptive management to effect a reduction in uncertainty may at times run counter to the Precautionary Principle, which tends to reject testing ideas if there is a risk of harm. Ultimately, however, it is society's chosen level of protection against risk that is the guiding directive in precaution-based decision making.

The nature of species at risk assessment and management is such that more decisions must be made in an uncertain and, depending on the current population size and trajectory as well as threats to the species, urgent environment. When a species is rare and in decline, and there has been little research, the consequences of poor policy decisions (e.g., a decision to incorrectly assess a species as "not at risk") may result in further imperilment or extinction. Costs may also be incurred on conservation actions directed toward unnecessarily listed species. It is very difficult to predict the outcome of such decisions, and adaptive policies informed by new research may be the only way to reduce uncertainty and increase the capacity to predict the outcome of management.

5.0 SUMMARY

The assessment of a species' probability of extinction is in theory a relatively straightforward analysis, whether assessments are based on detailed aspects of population biology or surrogates of extinction risk factors. However, limited data and significant uncertainty surrounding the role of surrogates increase the challenge of making sound, repeatable assessments. Some of this challenge lies in determining how expert opinion will be used to make recommendations in the absence of good information. When good data are available, complexity may arise in modelling habitat relationships, such as when predicting 1) effects of habitat conditions on population metrics, and 2) effects of land use on future habitat conditions. Fortunately, ongoing developments in the fields of biology, ecology, population ecology, genetics, and conservation biology continue to produce new tools and elements that aid in development of more accurate and reasonable assessments.

The IUCN assessment process has a long history, and has evolved and seen several modifications as new ideas and scientific understandings around extinction risk and species/subgroup assessment have surfaced. In some sense, the assessment process is a "living" process, able to incorporate new findings as they are presented. Nonetheless, the IUCN process is not without criticism, particularly as peculiar listings (e.g., extremely large global populations listed as threatened vs. relatively small populations not listed) appear from time to time (Nowak 2009). That said, it is still viewed as the "gold standard" for global extinction risk assessment. The COSEWIC process, which is used to inform the Species at Risk Act, is based primarily on the IUCN process, with some modifications. In order to maintain its high reliability and precision, the COSEWIC process, as originally conceived, strives to be repeatable and transparent, and most importantly, open and adaptable as new tools and techniques become available.

This report reviewed a number of scientific aspects of the species risk assessment process in Canada that bear close scrutiny in the context of understanding where the assessment process may be strengthened, and where it may inadvertently produce results in the listing process that are inconsistent with the actual risk of extinction for the species in question. Assessment results may vary owing to disparities in taxonomic, geological, or temporal scales. Species may also be listed owing to artifacts of geography, jurisdictional boundaries, and natural history. Application of inefficient or inaccurate assessment results can lead to inappropriate listings that may result in wasted recovery effort and costs (e.g., Possingham et al. 2002), restricted economic development, and/or which may have no effect on conserving species.

In reviewing the assessment processes used by both the IUCN and COSEWIC, along with the ecological and biological literature underpinning them, this report suggests there may be a number of ways to strengthen the species risk assessment process in Canada. Implementing these suggested enhancements should increase the precision and accuracy of the assessment conclusions, and increase the breadth and depth of information available about species at risk, thereby decreasing the true uncertainty inherent in the process and optimizing the outcome from applying conservation efforts and funding.

The current assessment process relies substantially on surrogates of extinction risk rather than true estimates of extinction risk. This may be due to lack of information, but in some cases could lead to inconsistencies between assigned threat categories and actual extinction risk. While the ideal solution to this problem is to gather more and better data, the assessment process itself could in the meantime be informed using alternative statistical approaches incorporating known data with informed priors from experts (e.g., Bayesian approaches). Such approaches would reduce uncertainty in the application of expert opinion and, if combined with substantial species monitoring programs in an adaptive management context, could lead to significant strides forward in improving the assessment process.

The assessment process could also be strengthened through incorporation of several modifying criteria that would help differentiate between species that are at risk and in need of substantial conservation, mitigation, and recovery efforts, and those that may be lower priorities. Modifying criteria that incorporate the natural rarity of a species, the taxonomic, geographic, or reproductive scale of a species, and the global versus Canadian range of the species (beyond the rescue effect), would help reduce the number of broadly secure species that are classified at risk, by moving them to a lower priority classification. Applying mechanistic-based explanations of threats to species more consistently across the assessment process would allow for more targeted and effective conservation actions. Finally, the process may benefit from increased transparency, allowing experts outside the assessment process a more complete understanding of assessment results.

The COSEWIC process and SARA legislation work together to help manage species at risk in Canada, and to prevent or reverse the loss of biodiversity at a national scale. However, the Act is not without opportunities for enhancement. The risk of incorrect listings can result in several unnecessary costs. There are costs associated with ensuring successful conservation efforts for seriously imperiled species, such as the dedication of limited resources to spurious or less critical listings. Further, there are opportunity costs associated with limiting development (agricultural, recreational, industrial, etc.) or redirecting it in cases where there would be no net conservation benefit.

Perhaps the greatest concern regarding incorrect listing may lie in the loss of public confidence in the listing process, as species continue to be added to the list with very few delistings. Delistings (or down-listings) that have occurred seem relatively unrelated to protective measures instituted by virtue of the listing process, and appear to be more related to novel management approaches or increased data on the range, distribution, or demographics of the delisted species. This creates the impression, whether real or perceived, that species listing and associated administrative activities have less to do with the effectiveness of "on the ground" conservation of species, biodiversity, or ecosystems, and more to do with the effectiveness of the tools and approaches employed to prioritize and assess potential species at risk.

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APPENDIX A

COMPARISON OF CRITERIA AND THRESHOLDS USED BY THE IUCN AND COSEWIC

Assessment System Attribute	IUCN (2001)	COSEWIC (2010a)
Categories	Critically Endangered (CR)	-
	Endangered (EN)	Endangered (EN)
	Vulnerable (VU)	Threatened (TH)
	Near Threatened (NT)	Special Concern (SC)
	Least Concern (LC)	Not At Risk (NAR)
	Data Deficient (DD)	Data Deficient (DD)
Criteria	A: Reduction in population size	A: Reduction in population size
	B: Geographic range	B: Geographic range
	C: Population size	C: Population size
	D: Very small population size	D: Very small or restricted populations
	E: Quantitative analysis	E: Quantitative analysis
Thresholds	IUCN thresholds within the criteria (A – E) for Critically Endangered and Endangered (EN) are equivalent to COSEWIC thresholds for Endangered (EN)	
	IUCN thresholds within the criteria (A – E) for Vulnerable (VU) are equivalent to COSEWIC thresholds for Threatened (TH)	
Selected defined terms associated with criteria	**Population:** Geographically or otherwise distinct group within a wildlife species that has little demographic or genetic exchange with other such groups. Theoretically, populations maintain genetic distinction if there is typically less than one successful breeding immigrant individual or gamete per generation.	**Population:** Geographically or otherwise distinct group within a wildlife species that has little demographic or genetic exchange with other such groups. Theoretically, populations maintain genetic distinction if there is typically less than one successful breeding immigrant individual or gamete per generation. Equivalent to the term “subpopulation” as employed by the IUCN. (Source: adapted from IUCN 2010)

Selected defined terms associated with criteria (cont'd)	**Subpopulation:** Geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less).	Subpopulation is not defined by COSEWIC; however, it is inferred that Designatable Unit is an equivalent. **Designatable Unit:** Subspecies, variety, or geographically or genetically distinct population that may be assessed by COSEWIC, where such units are both discrete and evolutionarily significant (see Guidelines for Recognizing Designatable Units, COSEWIC 2010b).
	Extreme Fluctuations can be said to occur in a number of taxa when population size or distribution area varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude (i.e., a tenfold increase or decrease).	**Extreme Fluctuations:** Changes in distribution of in the total number of mature individuals of a wildlife species (Designatable Unit) that occur rapidly and frequently, and are typically of more than one order of magnitude.
	Severely Fragmented: A situation in which increased extinction risk to the taxon results from the fact that most of its individuals are found in small and relatively isolated subpopulations (in certain circumstances this may be inferred from habitat information). These small subpopulations may go extinct, with a reduced probability of recolonization.	**Severely Fragmented:** A situation where most individuals are found in small and relatively isolated populations (in certain circumstances this may be inferred from habitat information). Severe fragmentation results in a reduced probability of recolonization of habitat patches where populations go extinct, which increases extinction risk for the wildlife species. A taxon can be considered to be severely fragmented if most (>50%) of its total area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance. Fragmentation must be assessed at a scale that is appropriate to biological isolation in the taxon under consideration. For complete guidance, see IUCN 2010.

Selected defined terms associated with criteria (cont'd)	**Extent of Occurrence:** The area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a taxon, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of taxa (e.g., large areas of obviously unsuitable habitat) (but see "area of occupancy"). Extent of occurrence can often be measured by a minimum convex polygon (the smallest polygon in which no internal angle exceeds 180° and which contains all the sites of occurrence).	**Extent of Occurrence:** The area included in a polygon without concave angles that encompasses the geographic distribution of all known populations of a wildlife species.
	Area of occupancy: The area within "extent of occurrence" that is occupied by a taxon, excluding cases of vagrancy. The measure reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats. In some cases (e.g., irreplaceable colonial nesting sites, crucial feeding sites for migratory taxa) the area of occupancy is the smallest area essential at any stage to the survival of existing populations of a taxon. The size of the area of occupancy will be a function of the scale at which it is measured, and should be at a scale appropriate to relevant biological aspects of the taxon, the nature of threats, and the available data. To avoid inconsistencies and bias in assessments caused by estimating area of occupancy at different scales, it may be necessary to standardize estimates by applying a scale-correction factor.	**Area of Occupancy:** The area within "extent of occurrence" that is occupied by a taxon, excluding cases of vagrancy. The measure reflects the fact that the extent of occurrence may contain unsuitable or unoccupied habitats. In some cases (e.g., irreplaceable colonial nesting sites, crucial feeding sites for migratory taxa) the area of occupancy is the smallest area essential at any stage to the survival of existing populations of a taxon (in such cases, this area of occupancy does not need to occur within Canada). The size of the area of occupancy will be a function of the scale at which it is measured, and should be at a scale appropriate to relevant biological aspects of the taxon, the nature of threats and the available data. To avoid inconsistencies and bias in assessments caused by estimating area of occupancy at different scales, it may be necessary to standardize estimates by applying a scale-correction factor. Different types of taxa have different scale-area relationships.

Selected defined terms associated with criteria (cont'd)	**Quantitative Analysis:** Any form of analysis which estimates the extinction probability of a taxon based on known life history, habitat requirements, threats, and any specified management options. Population viability analysis (PVA) is one such technique. Quantitative analyses should make full use of all relevant available data. In a situation in which there is limited information, such data as are available can be used to provide an estimate of extinction risk (for instance, estimating the impact of stochastic events on habitat). In presenting the results of quantitative analyses, the assumptions (which must be appropriate and defensible), the data used and the uncertainty in the data or quantitative model must be documented.	**Quantitative Analysis:** An estimate of the extinction probability of a taxon based on known life history, habitat requirements, threats, and any specified management options. Population viability analysis (PVA) is one such technique. Quantitative analyses should make full use of all relevant available data. If there is limited information, available data can be used to provide an estimate of extinction risk (for instance, estimating the impact of stochastic events on habitat). In presenting quantitative analyses, the assumptions, the data used, and the uncertainty in the data or quantitative model must be documented. (Source: adapted from IUCN 2010)

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APPENDIX B

POPULATION-DEPENDENT AND -INDEPENDENT EFFECTS THAT CAN AFFECT THE RISK OF EXTINCTION OF A SPECIES

B2

Population size-dependent variables:	
Demographic stochasticity:	Demography deals with the likelihood of individuals living or dying, and the likelihood that they will reproduce. These, in part, determine the likely trajectory of a population. Demographic stochasticity refers to populations that do not have a stable age distribution or small populations that might have a rate of increase or decline that varies markedly from year to year. With large populations, an average of individual fates will narrow the variation in annual population growth/decline. Naturally, when a population is small, it may be more likely to reach extinction simply due to misfortunes even if the individuals are healthy and the environment is favourable (Sinclair, Fryxell, and Caughley 2006).
Effective population size:	Demographic effective population size (determined demographically or genetically) is the size of a population with an even sex ratio and a stable age distribution that has the same net change in numbers over a year as the population of interest. The estimate of demographic effective population size ultimately yields an abundance value that can be compared to actual estimates of population abundance obtained from census data. The difference between the two estimated values acts as an indicator of the population's ability to remain stable or increase. Genetic effective population size is the size of an ideal population that loses genetic variance at the same rate as the real population. A population's genetic effective size will be less than its census size except in special and unusual circumstances. The aim of the genetic effective population size estimate is to indicate the lower limit at which the population may suffer from genetic limitations, e.g., genetic drift (Shaffer 1981; Sinclair, Fryxell, and Caughley 2006).
Genetic effects:	Small populations can suffer disproportionately from genetic effects, such as accumulation of recessive deleterious alleles under inbreeding, loss of quantitative characters that allow adaptation, or accumulation of mildly deleterious mutations (Soulé 1980; Hedrick 1992; Frankham 1995; Mace et al. 2008)
Allee effect:	For very small populations, the reproduction and survival rates of individuals increase with population density. In contrast, as populations increase, individuals experience decreased reproduction and survival rates, which reduces the growth rate of the population, typically due to increased competition for resources. This is known as the Allee effect, and also includes various other behavioural, social, and demographic factors (Allee et al. 1949; Courchamp, Clutton-Brock, and Grenfell 1999; Mace et al. 2008).

Population size-independent variables:	
Environmental stochasticity:	Weather has a direct effect on demography, particularly for invertebrates, lower vertebrates, and plants, or indirectly through food supply. The major influence of environmental stochasticity on the probability of extinction is its interaction with the effect of individual variation. Thus, it becomes progressively more important with decreasing population size, even though its average effect is independent of population size (Sinclair, Fryxell, and Caughley 2006).
Genetic diversity:	Genetic variance is the proportion of a population that is heterozygous versus homozygous[10] for a given locus[11]. A population is said to be better off when there is variation the genotypic frequency of alleles[12]. Genes form the basic code for proteins, which play an important role in adaptation. Genotypic frequency translates into frequency of protein variants present within a population, with higher values suggesting greater adaptive flexibility, should it be required. While individual genetic diversity is not population size dependent, populations considered at risk due to a threatening process are more likely required to adapt to threatening circumstances (Sinclair, Fryxell, and Caughley 2006).
Random genetic drift:	In the absence of immigration and genetic mutation, the number of different alleles at a locus in the population as a whole can only either remain constant or decrease. It cannot increase (Sinclair, Fryxell, and Caughley 2006). This loss of additive genetic variance is called random genetic drift and occurs independent of population size. However, the rate at which genetic variation is lost is related to population size, with larger populations experiencing lower rates of loss.

[10] In genetics, these terms refer to whether an individual having paired chromosomes (diploid) carries two different copies of the same gene (heterozygous) or two identical copies (homozygous).
[11] A specific location of a gene or DNA sequence on a chromosome.
[12] One of two or more forms of a gene or a group of genes.

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