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Combining phylogenetic rarity with species distribution and abundance for conservation: Applying the 'calculus of biodiversity' in Canadian butterflies.

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COMBINING PHYLOGENETIC RARITY WITH SPECIES DISTRIBUTION AND ABUNDANCE FOR CONSERVATION: APPLYING THE 'CALCULUS OF BIODIVERSITY' IN CANADIAN BUTTERFLIES

by

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ABSTRACT

Estimates of evolutionary rarity are important adjuncts to traditional parameters of biological rarity (distribution and abundance). I develop a taxonomic-based method for estimating ranked phylogenetic-abundance, using z-scores from natural-log-transformed species numbers at the sub-family level, for the two major superfamilies of Lepidoptera: Hesperioidea and Papilionoidea. These five categories of phylo-abundance were combined with equivalent estimates of geographic distribution and abundance ('geo-rarity'), at both global and sub-national (regional) scales using the Canadian butterflies (N=293 species). The model for prioritization used all nine possible combinations, (including global and regional, phylogenetic and geographic abundance values) gave priority co-equally to global geo-rarity and phylo-rarity, and then secondarily to regional rarity. *Papilio brevicauda* (Papilionidae) is Canada's overall highest priority for conservation (Group A). Evaluation of life history features revealed that wing span (increasing) dominates the discriminant function for global phylo-rarity and monophagy (presence) and sub-species numbers (decreasing) are discriminant functions for global geo-rarity.

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INTRODUCTION

Study of distribution and abundance of species and of individual organisms remains a major focus in ecology (e.g., Warman et al., 2004, McGill 2005, Balmford et al, 2005, Possingham and Wilson 2005), and there is also an emergent macroecological focus upon linkages between patterns of phylogenetic richness and individual species ecology (Brooks et al., 1992, Soutullo et al. 2005). Major hypotheses remain unresolved regarding notions of the niche and abundance and its distribution across a species range (see e.g., Kunin and Gaston 1997; Murray et al. 1999; Channell and Lomolino 2000; Sagarin and Gaines 2002; Murphy et al. 2005; Murphy and Lovett-Doust 2005; McGill 2005).

Rabinowitz (1981) distinguished seven forms of rarity based on ecological measures – geographic range, habitat specificity and local population size. Species which were less abundant or less widely distributed, or which had more specific habitat requirements were all rare, while only one general condition characterized commonness. Murray et al. (1999) and Murray and Lepschi (2004) have argued that most species are abundant in some part of their range, whereas few are not abundant anywhere, across any part of their range. Murray and his colleagues showed that more than 90% of plant species within two Australian woodland communities were rare within their regional sample area but abundant elsewhere in their geographical range. Similarly, Murphy et al. (2005) showed for 134 eastern North American trees that most species (88%) were abundant somewhere in their continental range, and moreover that species achieving relatively high abundance had larger range sizes. Murphy et al. (2005) tested the widely held assumption that species exhibit an 'abundant-centre' distribution (see

Sagarin and Gaines 2002), and concluded that this was not well supported for the majority of North American tree species.

McGill (2005) argues that the structure of abundance across a species range (SAASR) is often not gaussian or normal, but that abundance varies across the range of a species in a non-random manner. This structure of abundance can include one to a few distinct peaks in abundance followed by tails, areas within the range with very low abundance which he terms the "peak-and-tail" structure across a range. McGill (2005) demonstrated this peak-and-tail structure using 212 species of landbirds from the North American breeding bird survey.

Following a tenet that "rarity precedes extinction" (Darwin 1859), conservation biologists have identified the need to target rare species in order to focus efforts for preservation (Thomas and Abery 1995; Harcourt et al. 2002). This has become especially important in light of ongoing biodiversity losses (Wilson 1992). Preservation of biodiversity has tended to focus upon protection of geographically rare species, recognizing a need to preserve those most susceptible to extinction (Hartley and Kunin 2003; Harcourt et al. 2002). In practice, species regarded as rare based on measures of distribution and abundance are usually prioritized for conservation. Yet distribution and abundance alone provide an incomplete description of rarity. Biodiversity manifests at scales of genes, species, and ecosystems (Crozier 1997). Vane-wright (2003) attributes Whittaker (1972) as one of the first to appreciate that divergence between species as well as the genetic diversity within them would constitute a more complete measure of biological diversity.

The International Convention on Biological Diversity includes as their definition "diversity within species, between species, and of ecosystems". They advise conservation at the genetic, population, species, habitat, and ecosystem levels (Secretariat of the Convention on Biological Diversity 2001). Indeed, the ultimate object of preserving biodiversity is the genetic material contained ancestrally in species — the evolutionary information. The genetic material is expressed phenotypically in the structures, physiologies, behaviours and so forth of individuals, existing in particular ecosystems and having values there for ecosystem functioning (Faith 1994; Humphries et al. 1995; Jonsson and Malmqvist 2000; Cardinale et al. 2000; Faith et al. 2004; Nehring & Puppe 2004; Reich et al. 2004). A measure or index of genetic information would thus be useful in assessing the conservation value of species. Yet most measures of rarity and susceptibility-to-extinction used in conservation today do not incorporate any means of evaluating genetic or 'phylo' rarity (see Table 1). Thus for example, the IUCN Red Lists rank species based upon their geographic distribution and abundance as well as the rate of population decline and fragmentation, but does not include any measure of genetic rarity (Hartley & Kunin 2003, and Table 1).

Consider two species, equally rare in terms of their distribution and abundance. If one species is monotypic – the sole representative of a particular taxonomic rank and phylogenetic clade (monotypic), it should surely be regarded as *more* rare than a species present, say, as one of 300 species in its group (polytypic) (May 1990). A rarity index including a measure of phylogenetic rarity as well as an estimate of traditional ecological rarity, based on distribution and abundance, would provide a more complete and useful picture of a species' overall rarity.

May (1990) termed such an assessment of genetic information 'the calculus of biodiversity'. His suggestion to combine quantitative measures of taxonomic distinctiveness with more familiar ecological considerations underpins several methods to derive this (Vane-Wright et al. 1991;

Faith 1992 & 1994; Freitag & Van Haarsveld 1997; Posados 2001). Some advocate estimating the number of evolutionary nodes (May 1990), others use weighting by basal number of species (Vane-Wright et al. 1991) and the distance of branch lengths in a phylogeny (Faith 1992; Crozier 1992).

Faith (1994) proposed a phylogenetic diversity index that quantifies phenotypic features to derive an 'option value'; the greater the number of features, the greater the option value or worth of the species. Recognizing that most features typically remain unknown, Faith's method placed values equally for individual features, as shared features among species are best explained by shared ancestry (Faith 1994). The method subsequently became incorporated into software ("Diversity") for determining a prioritized subset of species spanning portions of a phylogenetic tree, from a set of areas or biota (Walker & Faith 1995).

Until recently, many of the methods suggested for estimating phylo-rarity have not yet been applied to significant numbers of species but have been used in hypothetical models and/or phylogenetic tree structures (Vane-Wright et al. 1991; Faith 1994). This is due in part to the paucity of accurate and complete phylogenies having derived-branch-lengths and nodal estimates necessary in particular biota to calculate phylo-rarity operationally. Recognizing the accelerated rate at which species continue to be lost to extinction (Balmford et al., 2005), effective and useful substitutes should be explored (Vane-Wright 2003).

Crozier (1997) showed that higher-taxon richness is an effective surrogate for phylogenetically-based branch-length measures, and others have supported this (Polasky et al. 2001; Rodrigues and Gaston 2002; Vane-Wright 2003). This method has been applied primarily to prioritizing natural areas for conservation (Posadas et al. 2001; Clarke and Warwick 2001; Rodrigues and Gaston 2002), but could also aid in development of a measure of species rarity.

Rodrigues and Gaston (2002) compared phylogenetic diversity and taxonomic richness for reserve selection and found nearly equivalent results. Most recently, Keith et al. (2005) compared Freitag and van Jaarsveld's (1992) measure of taxonomic diversity with that based on node counting and branch length measures of phylogenetic distinctness, using the comprehensive ordinal phylogenies for Chiroptera and Carnivora. They found no significant difference between the three methods, but recommended including phylogenetic diversity when complete phylogenies are available. However, recognizing that this is not the case for the majority of species, they concluded that including any measure of evolutionary history (including taxonomic diversity) when prioritizing species is preferred to distribution and abundance measures alone (Keith et al. 2005).

May's (1990) original suggestion was to *combine* taxonomic and ecological rarity. Efforts to date have involved *comparing* phylogenetic diversity to traditional ecological measures (May 1990; Vane-Wright et al. 1991; Faith 1992; Crozier 1992; Walker & Faith 1995), and have been mostly directed toward selecting the best natural reserve areas for protection (Humphries et al. 1995). Others have compared species and genus richness and critical species counts to newer methods of phylogenetic and genetic diversity, for evaluating priorities (e.g., Whiting et al. 2000) but there does not appear to be any empirical studies that combine estimates of phylogenetic rarity with those of traditional distribution/abundance measures of rarity, to give an overall priority index for species. In 2003, Vane-wright reiterated one of the goals from Vane-wright et al. (1991) which he still supports; that taxonomically-isolated (species-poor clades) species should be given higher priorities for conservation. A method for calculating an overall rarity scheme, incorporating both phylogenetic and ecological rarity could provide a useful conservation parameter on a species basis. This could then be applied to regional floras and faunas, and potential conservation areas, and provide important between-species insight.

Available databases for butterflies

The Butterflies of Canada provides a comprehensive list of 293 species (including two non-native species) occurring in Canada (Layberry et al. 1998). This was used in conjunction with a recent phylogeny of butterflies (Ackery et al. 1999). As the phylogenetic tree for the Lepidoptera remains incompletely resolved, I was limited to using species counts to determine phylogenetic rarity. I also recorded for each species the upper and lower wing span (mm) and the occurrence of monophagy (only one species of plant consumed by the larvae) or polyphagy (more than one species of plant consumed by the larvae) from Layberry et al. (1998). The ranges of wingspan provided by Layberry et al. (1998) were taken from the collection at the Canadian National Collection in Ottawa. The measurements were taken at the widest spread of the forewings when set at right angles to the body. If no Canadian specimens were available or were limited in number then samples from U.S. specimens collected as close to the Canadian border as was possible were utilized (Layberry et al. 1998). The number of subspecies listed by Layberry et al. (1998) for each species of Canadian butterfly was also recorded.

Geographic rarity assessments at global and sub-national (regional) levels

In the United States and Canada, the Network of Natural Heritage Programs and Conservation Data Centres (CDCs), in partnership with The Nature Conservancy (Arlington, Virginia) developed and applied a ranking scheme for assessing conservation status of species, based on distribution and abundance factors (Master 1991). The first program was established by The Nature Conservancy in 1974 (NatureServe 2006*b*) and over the next 20 years Heritage Programs or Conservation Data Centres were first initiated separately by state and provincial and national government agencies as well as NGOs (Master 1991). More recently, Latin American and Caribbean countries began doing so too (NatureServe 2006*b*). A nonprofit conservation organization, NatureServe (Arlington, Virginia), oversees these programs and centres (NatureServe 2006*b*). By 2005, Conservation Data Centres were present in all U.S. states, six Canadian provinces, one regional (Atlantic Canada Region) and one territory (Yukon) all having adopted the ranking system (NatureServe 2006*b*). Globally, species are ranked according to numbers of global occurrences (G-ranks), from G1 to G5 (see Table 2 for descriptions) (Master 1991; NatureServe 2006*b*). Sub-national rankings (S-ranks) are applied similarly, but at the regional scale (S1 to S5) by Heritage Programs or Conservation Data Centres (NatureServe 2006*b*).

NatureServe scientists evaluate records of species at both global (G-rank) and sub-national (S-rank) scales, based on distribution and abundance data, and other factors. These include total number and condition of occurrences (regarded as populations); population size; range extent and area of occupancy; short- and long-term trends in the above factors; scope, severity, and immediacy of threats; number of protected and managed occurrences; intrinsic vulnerability; and environmental specificity (NatureServe 2006*b*). These qualitative and quantitative criteria are provided as guidelines and NatureServe chooses the weighting assigned to each criterion based on available knowledge of the species (NatureServe 2006*b*). This method of subjectively weighing NatureServe criteria has been compared to a step-wise explicit method (Regan et al., 2004).

NatureServe in combination with local Conservation Data Centres provide the most comprehensive and current information available, including both global and regional status, for estimating species' risk of extinction probability (Regan et al., 2004). NatureServe assessments have been completed for more than 50,000 North American species including more than 1300 butterfly species (NatureServe 2006*d*).

Canadian butterflies (Superfamilies Hesperioidea and Papilionoidea) (Ackery et al. 1999) are a useful test case for developing prioritizations and focusing protection of biodiversity. There exists a reasonable phylogeny consistent with taxonomy (Ackery et al. 1999; Layberry et al. 1998), as well as reliable data on distribution and abundance (NatureServe 2006*d*). With current high rates of loss in butterflies (e.g., Thomas et al. 2004), there is a pressing need to rank them for targeted conservation. Thomas et al. (2004) supported the use of butterflies as realistic and practical indicators of change in other invertebrates, making them good candidates, especially in regard to the overall under-representation of invertebrates in the Canadian coverage by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Taxonomic overview of Canadian butterflies

Two superfamilies, Hesperioidea (skippers) and Papilionoidea (true butterflies) represent globally about 16,741 species of butterflies, or roughly 10% of all Lepidoptera (Ackery et al. 1999) (see Table 3). Ackery et al. (1999) recognize a third superfamily, the Hedyloidea (crepuscular moths) with a sole family (Hedylidae) having 40 species, all found in Central and South America. Ackery et al. (1999) acknowledged inclusion of this third superfamily was contentious, and this remains so (Vane-Wright 2003). Molecular (Weller and Pashley 1995) and morphological results (Yack & Fullard 2000) support Hedyloidea as a sister group to butterflies and so I have not included these species in the analyses. All lepidopteran species occurring in Canada (and also in North America) are in the Papilionoidea and Hesperioidea (Ackery et al. 1999).

The Hesperioidea has *c.* 3500 species, contained in a single family, Hesperiidae, with six sub-families: the Coeliadinae, Pyrrhopyginae, Pyrginae, Heteropterinae, Trapezitinae, and Hesperiinae. The largest sub-family, the Hesperiinae has *c.* 2000 species, followed by the Pyrginae with *c.* 1000 species while each of the remaining four sub-families has between 60-150 species (Table 3).

There are some 13,306 species of Papilionoidea contained in four families: the Papilionidae, Pieridae, Lycaenidae, and Nymphalidae. Both the two largest families, Lycaenidae and Nymphalidae, contain *c.* 6000 species. Ackery et al. (1999) included the Riodinidae within the Lycaenidae (Riodininae) and the Libytheidae (Libytheinae) within the Nymphalidae, although Layberry et al. (1998) recognized these as individual families. I followed Ackery et al. (1999) in this. The Papilionidae (swallowtails) consist of approximately 600 species with worldwide distribution. Ackery et al. (1999) recognized three subfamilies within the Papilionidae, the Baroniinae (one species), the Papilioninae (550 species) and the Parnassiinae (54-76 species). For the Parnassiinae, I used 76 species as the total (Table 3).

There are about 1000 species within the Pieridae (the whites and sulphurs) (with 39 in Canada) among four sub-families: the Pseudopontiinae (one species), Dismorphiinae (*c.* 100 species), Pierinae (*c.* 700 species; 17 in Canada), and Coliadinae (*c.* 250 species; 22 in Canada). Five sub-families are recognized within the Lycaenidae, with the largest sub-family, the Lycaeninae, composed of *c.* 4000 species (62 in Canada), followed by the Riodininae with *c.* 1250 species worldwide (one in Canada) (Table 3).

There are 530 species of Poritiinae and 18 species in the Curetinae (both with no Canadian representatives), and 150 species in the Miletinae (one in Canada).

The large Nymphalidae family, with *c.* 6000 species has 10 sub-families and 101 Canadian representatives (Table 3). The number of species within each sub-family ranges from the largest, the Satyrinae, with *c.* 2400 species (and 34 in Canada), to the tiny Calinaginae, with only 8 species (none in Canada).

The COSEWIC process and consequences for Canadian butterfly conservation

In Canada and elsewhere, jurisdictional agencies often evaluate species based on species rarity and potential for extinction or imperilment, and seek to prioritize for conservation. The mandate of the federal COSEWIC is to assess the national status of wild species, subspecies, varieties, or other units considered to be at risk in Canada (COSEWIC 2005*a*). All native mammals, birds, reptiles, amphibians, fish, molluscs, lepidopterans (including butterflies and moths), vascular plants, mosses and lichens are included in its present mandate (COSEWIC 2005*b*).

COSEWIC commissions status reports for species on the Candidate List through an open competition process (COSEWIC 2006). Status reports form the basis for a species' assessment and designation, based on information concerning distribution and abundance, as well as any known extinction threats. Assessments are reviewed by expert committees who assign status (extinct, extirpated, endangered, threatened, special concern), based on perceived national degree of risk.

As of May 2005, 519 species have been evaluated by COSEWIC (COSEWIC 2005*b*). Of these 519 species 13.9% are mammals (n=72), 11.7% birds (61), 6.7% reptiles (35), 3.7% amphibians (19), 20.2% fishs (105) 3.8% arthropods (20), 4.0% mollusks (21), 31.0% vascular plants (161), 3.1% mosses (16) and 1.7% lichen (9) (Table 4).

In 1995, COSEWIC expanded its mandate to include lepidopterans (Shank 1999). As of May 2005, a total of 15 butterfly species and subspecies (including two populations of *Apodemia mormo*) had been reviewed by COSEWIC and found to be extirpated, endangered, threatened or of special concern (Table 5). No arthropods are presently ranked 'at risk' or 'data deficient' (COSEWIC 2005*b*).

COSEWIC also maintains a Candidate List of species suspected of being at risk of extinction or extirpation, as priorities for assessment, including arthropods (n=46), fishes (27), mammals (1), mollusks (62), reptiles (2) and vascular plants (>800) (Table 6; COSEWIC 2006). A total of 46 arthropods (including 17 species, sub-species and populations of butterflies) are included on the most recent priority Candidate List (January 6, 2006).

The COSEWIC mandate provides the basis for establishing a formal list of species (Schedule 1) regarded legally as "at risk" in Canada, according to the Canadian Species at Risk Act (SARA) (proclaimed June 2003). SARA seeks "to prevent wildlife species from becoming extinct and secure the necessary actions for their recovery" (SARA 2005).

Butterflies belong to the Phylum Mandibulata (recently renamed from Arthropoda), characterized as having segmented bodies, jointed legs and an exoskeleton (Layberry et al. 1998). Within the Class Insecta, both butterflies and moths belong to the Order Lepidoptera. The butterflies belong to two Super-families, the Hesperioidea (skippers) and Papilionoidea (True butterflies) and include approximately 17,000 known species (Ackery et al. 1999). Butterflies retain many primitive and specialized characters for evolutionary studies (Ehrlich 1958 in Vane-wright 2003) and this work by Ehrlich in 1958 led to other evolutionary-based classifications by Carter, Kristensen and others in Ackery et al. (1999). All of the systematics in Ackery et al. (1999) were based on phylogenetic systematics (Carter and Kristensen 1999).

Butterflies are one of the most studied groups of insects and are model systems for studying many aspects of ecology and evolution including conservation biology and also as a tool for means to preserve biological diversity (Ehrlich 2003). They are also considered good models of coevolution with plants and make ideal candidates for measuring dietary niche breadth (Brandle et al. 2002).

Thesis objective

Here I present a straightforward taxonomy-based method to estimate phylo-abundance at the sub-family level, globally and regionally for Canadian butterflies, and use it to prioritize this fauna. I also evaluate an overall, composite index of species rarity, merging estimates of phylo-rarity with estimates of geographic-rarity. To my knowledge no other studies have attempted to unite measures of phylogenetic and geographic abundance. Next I compare these priority results with species flagged by COSEWIC. Finally, I examine how these patterns of phylo- and geo-abundance relate to variability in patterns of butterfly life history characteristics.

LITERATURE REVIEW

Why value phylogenetic diversity and incorporate estimates of phylo-rarity? It seems fair to ask why ecologists should argue for conservation of any measure of biological diversity?

Why preserve biodiversity?

Crozier (1997) identified three quite different kinds of reason for preserving biodiversity: moral (i.e., that other species should have the fundamental rights to exist); aesthetic (the beauty of species is equivalent to works of art, and destroying them would be foolish); and, utilitarian (including recognition of the human-derived benefits of species). Crozier recognized that making the argument for conservation of biodiversity based on moral or aesthetic arguments is difficult and fraught with problems of relevance in a scientific sense. Morality as a human construct, has little validity outside of human belief systems (Crozier 1997). And, as "beauty is in the eye of the beholder" and aesthetics is nothing if not subjective, making a case for preserving on the grounds of aesthetic worth also remains subjective and a matter of personal opinion.

Crozier's argument that preservation of biodiversity should be done for reasons of human benefit is more plausible. The IUCN (World Conservation Union) lists twelve natural 'goods and services' provided by ecosystems. These include the use of natural resources for food, fuel, and fibre, as well as important ecosystem services such as detoxification of pollutants and other compounds and decomposition of wastes (IUCN Secretariat 2001). According to this, protection of biodiversity has its major values through the economic value for humans.

This argument for preservation of biological diversity is obviously completely anthropocentric. This human-centred view, focused on human-derived values, carries over into many aspects of ecology. For instance, ecologists often consider that more biologically diverse landscapes are more productive, and in turn tend to be considered better. The initial positive correlation between ecosystem function and increased biodiversity is often attributed to Charles Darwin. He was first to correlate the increased number of plants with increased weight of dry herbage produced in communities having several species of plants, invoking earlier experimentation conducted by George Sinclair in 1826 (and see Purvis et al. 2000; Hector and Hooper 2000; Purvis and Hector 2000).

In 1959, Hutchinson posed Darwin's conclusion as a question, "Why are there so many kinds of species?" while observing waterbug species in the genus *Corixa* in a small limestone pool. Indeed much ecological research is conducted under the premise that increased biodiversity is the preferred state, yet perhaps because this assumption precedes much of ecology, little experimentation actually to demonstrate this has been conducted. Providing evidence that increased biodiversity results in more efficient ecosystem functioning (beyond human benefits) provides evidence for value of preserving biological diversity. This is consistent with niche theory that niche differentiation will result in communities with more diversity of species, and more efficient use of resources (Cardinale 2000). A small number of researchers have begun to address this question experimentally, relating biodiversity (species distribution and evenness) to ecosystem functioning through facilitation (e.g., Purvis and Hector 2000; Jonsson and Malmqvist 2000; Loreau et al., 2001; Cardinale et al., 2002).

Facilitation-type processes are defined as the intensification of a behaviour that is caused by the presence of another animal of the same species (intraspecific) or where each species benefits from the activity of another species (interspecific) (Jonsson and Malqvist 2000). Many initial experiments testing facilitation-type processes studied primary producers, and varied plant diversity in grassland communities beginning at a logical starting point (Loreau et al., 2001). Evidence of facilitative relationships can provide justification for the preservation of geo- and phylo-abundance.

Purvis and Hector (2000) recently restated Darwin's early conclusion that a more diverse mixture of plants should be more productive than a monoculture. They acknowledged that diverse plant communities often have a greater variety of positive and complementary interactions, and so outperform single species situations, whereby there is a greater chance that the 'right' species will exist at the right time.

In a notable paper in *Nature*, Cardinale et al. (2002) studied three species of caddisfly that co-occur in the United States. Cardinale et al. (2002) observed water flow and delivery of nutrients while varying aspects of species diversity, evenness, and richness patterns in the community. Following construction of catchnets used for feeding, Cardinale et al. (2002) measured resource consumption by individual larvae and related this to near-bottom velocity and bed roughness. They found that mixed assemblages had 66% greater consumption of suspended particulate matter, and exceeded total consumption in all species monocultures. The mixed assemblages facilitated the other species by increasing stream velocity, thus increasing the availability of food and consumption.

It is worth noting that the caddisfly species chosen are remarkably similar and it was only recently that two of the species were even designated as separate species (Wiggins 1998). However, it is important to test interactions between species from the same trophic level to eliminate variability caused by including species from different trophic levels, to account for spatial heterogenetity of habitat (Cardinale et al. 2000).

Prior to Cardinale et al. (2002), Jonsson and Malmqvist (2000) performed laboratory experiments manipulating species richness of stream shreds – common species in North European streams. They reared three species of leaf-eating stoneflies (Plecoptera) and varied the number of species (1, 2, or 3) while keeping total densities constant. Jonsson and Malmqvist (2000) tested rate of leaf breakdown as mass loss and found that the major factor determining amount of consumption was species number. Leaf breakdown was significantly greater in the three-species treatments than the two-species treatments.

Mulder et al. (1999) tested the hypothesis, that richness of herbivorous insects could affect the ecosystem functioning through the alteration of plant species richness. By manipulating plant diversity and insect richness and abundance, Mulder et al. (1999) provided support that insects could affect plant diversity and some ecosystem processes. Insects altered the positive relationship between diversity and biomass suggesting that increased interspecific biodiversity affects ecosystem functioning (Mulder et al. 1999).

Other studies have been conducted on the role of intraspecific social facilitation. Kurta (1982) demonstrated intraspecific social facilitation using the terrestrial hermit crab *Coenobita compressus* in Costa Rica, presenting turtle eggs on the beach and testing the hypothesis that hermit crabs respond to potential food source randomly. Kurta (1982) found that hermit crabs find food by observing clusters of feeding crabs. He concluded that social facilitation is an important mechanism for increased foraging ability.

It seems reasonable to say that relating experiments using a few aquatic insects to global impacts of the loss of biodiversity may be a giant leap. Yet these studies provide a basis for further research toward the role that facilitation plays in functioning of ecosystems. They also provide a basis for inclusion of phylogeny as well as species abundance when addressing preservation of biological diversity. These examples demonstrate that ecosystem function involves both intraspecific diversity (supporting the preservation numbers of species) as well as interspecifically (supporting the preservation species from different clades). Indeed it is also apparent that very little is known about the complex relationships of species and ecosystem functioning. Preservation of biological diversity is important for at least these reasons.

However, combining measures of phylo- and geo-rarity to determine prioritizations for conservation has not yet been included in many of the current protocols for prioritizing species for conservation (Table 1). The U.S. Fish and Wildlife Service use three variables including taxonomic distinctness when prioritizing species listed as Endangered or Threatened under the U.S. Endangered Species Act for recovery (Fish and Wildlife Service 1981). These variables include degree of threat (high, moderate, low), recovery potential (high, low) and taxonomy. Taxonomy is considered hierarchically according to the following: monotypic genus, species, and then subspecies. If a species then is the sole representative of a genus it receives higher priority than a species followed by a subspecies. This is in recognition that resources should be directed to species that are representatives of distinctive or isolated gene pools (Fish and Wildlife

Service 1981). The highest priority is a species with a high degree of threat, a high potential for recovery, and is the sole representative of a genus. The U.S. Fish and Wildlife Service utilizes a matrix outlining a numerical protocol prioritizing species similar to the proposed method. Although this is a good first step it is a much simpler protocol than the proposed method as no prioritization is distinguished between species beyond being the sole representative of a genus. A species that is one of two representatives is given the same priority as a species that is one of 300 representatives.

The rank values available from NatureServe are the most comprehensive assessment information that is available. Currently, assessment information is available for more than 50,000 species in North America (NatureServe 2006*d*). Although the IUCN redlist is the most globally recognized assessment system, only one Canadian species of arthropod has been assessed to date (World Conservation Monitoring Centre 1996). The NatureServe ranks incorporate qualitative and quantitative information on a species distribution and abundance, as well as total number and condition of occurrences (regarded as populations); population size; range extent and area of occupancy; short- and long-term trends in the above factors; scope, severity, and immediacy of threats; number of protected and managed occurrences; intrinsic vulnerability; and environmental specificity.

Many authors support using species richness as a surrogate for other estimates of phylogenetic rarity (Keith et al. 2005) but to my knowledge no methods for determining global phylogenetic rarity exist. There are a number of regional taxonomic based measures including taxonomic distinctiveness and taxonomic distinctness. Rodrigues and Gaston (2002) utilized generic richness and Polaskey et al. (2001) compared taxonomic distinctness versus richness.

Other approaches such as taxonomic distinctiveness and taxonomic distinctness have been proposed (Freitag and van Jaarsveld 1997).

Regional phylo-rarity

Taxonomic distinctiveness (Freitag and van Jaarsveld 1997) is a method for calculating the regional taxonomic rarity of a species whereby:

$$TD = \frac{1}{\sqrt{\text{no. of regionally represented Families x no. of Genera x no. of Species}}}$$

Taxonomic distinctiveness refers to the uniqueness of an individual species within a community. For this method, it is necessary to know which families are represented within a defined area as well as the number of genera and species within the family. For many groups of species this information is not known. This approach could not be utilized for calculating global phylogenetic rarity as it is not possible to apply the taxonomic distinctiveness method across a global scale.

Taxonomic distinctness (symbolized as Δ^+) is another method for determining the average degree of species relatedness whereby the path length between two species is used to determine how taxonomically distinct one species is from another. This method utilizes Linnean classifications as a proxy for branch lengths in cladograms. (Clarke and Warwicke 1998). Taxonomic distinctness involves comparing the taxonomic "breadth" to another community that is in a different habitat, biogeographic community, etc.

Freitag and van Jaarsveld (1997) and others (Keith et al., 2005) have then expanded TD values by incorporating them with other variables such as regional occupancy, relative endemism, and relative vulnerability (Keith et al. 2005).

Both taxonomic distinctness and taxonomic distinctiveness utilize phylogeny or a phylogenetic-based taxonomy and this is the next step towards including a measure of phylogenetic rarity, a closer representation of the genes that are targeted for preservation of biological diversity. Both measures (and the numerous variations of each method) are regionally-based at the community or species level and as such will have limited applications beyond area by area comparison. (Freitag and Van Jaarsveld 1997; Warwick and Clarke 2001). Unfortunately, global numbers of species within genera are not available for the Ackery et al. (1999) phylogeny so it was not possible to test the utility of this method.

Rabinowitz's seven forms of rarity

Rabinowitz's seven forms of rarity require local population size, area of a species range, and the number of different habitats utilized by a species (Rabinowitz, 1981). This information was then used to categorize species within the seven forms of rarity or the one form of commonness. This matrix organized species according to three variables: local abundance, habitat specificity, and geographic range.

Local population size

The NatureServe data provides information on occurrences or populations of a species. Each population/occurrence is delineated using a 'minimum criteria for an occurrence' on a species by species basis (NatureServe 2006*c*). These critera are often linked to the occurrence of the host plant. No information is provided regarding the number of individuals within these occurrences. Many species of butterflies (e.g., *Erora laeta*) have highly variable populations from year to year so inclusion of a variable based on local population size would have limited application for butterflies.

Habitat specificity

For some groups of species, such as mammals (Yu and Dobson 2000) information on habitat specificity can be found in existing literature. Some populations of butterflies have also been well researched such as the British butterfly fauna (Hodgson 1993; Thomas et al. 1995; Thomas et al. 2004). However, despite being the best-studied invertebrates, much of the autecology of individual species is not known. This is in part due to the remote habitats that some butterflies occupy. As such, habitat for butterflies is often defined in terms of the occurrence of the host or nectar plant species. However, some species occupy a range that is more restricted than the range of their host plant (Hodgson 1993). This may be related to unknown interactions with other species such as ants that is critical to the survival of larvae. This relationship is documented for the Lycaenid butterflies, for example the Karner Blue subspecies (*Lycaeides Melissa samuelis*) in Canada whereby attendant ants are required for survival of the larvae (Packer 1990). There is also variation in habitat during different times of life yet they may still remain very specific (Hodgson 1993). This makes assigning a group of habitat specificity difficult with some species. Canada's only group A species, the most rare group, would not be classified as high in the system outlined by Rabinowitz (1981). *Papilio brevicauda* is globally phylogenetically and geographically rare, as well as regionally phylogenetically and geographically rare. *Papilio brevicauda* has variable habitat however, including gardens, coastal areas, inland meadows and mountainous areas close to the treeline which would make it categorically less rare using the Rabinowitz system.

Geographic range

Emerging GIS and large scale census efforts have increased the knowledge on macroecological patterns (McGill 2005). Range size is difficult to measure and as such has played a lesser role than other macroecological variables (McGill 2005). Rabinowitz (1981) utilized information on the range of plants, and distinguished species into two groups, either large or small range. No numerical values of extent quantitatively defining large or small range were provided. Defining the value of large or small ranges is then arbitrary. This can create problems with defining the extent of range. Outlining the range of a plant species is a considerably different exercise when considering highly mobile and migratory species such as birds or butterflies. For species that utilize a southern habitat in winter and one or more northern habitats for breeding during the summer, defining a species range is not easily done. For Canadian butterflies, the occurrence within a specified grid area is known but the range size is not. Also, the range sizes for some species would extend across the Canadian border into the U.S. (both north and south) and it would be difficult to determine which regional S-rank should be used for analysis. The range for many northern species is unknown but it would be useful to develop a system that has fewer restrictions than the Rabinowitz matrix.

Arita et al. (1992) reported that local density and restricted distribution range were only valid and independent variables for determining rarity when phylogenetically-linked traits such as size, were held constant. If these two variables are indeed highly correlated than their application in determining rarity for a species is lessened. This relationship suggests that more phylogenetically rare species should be considered more highly when determining priorities for conservation.

COSEWIC

Under the Canadian Species at Risk Act, only species ranked by COSEWIC are covered by the Act and afforded protection (SARA 2005). Previously, species were not chosen for review by COSEWIC in an objective manner and as a result, disproportionate representation of ranking is evident within certain taxonomic groups (Shank 1999). Prioritizing species for assessment should be carried out in an objective manner in order to direct attention toward the species that are most rare and in turn most susceptible to extinction.

The COSEWIC Arthropod Specialist Subcommittee has developed for the butterflies a method for determining which species should be included on the Candidate List utilizing the NatureServe information. This scoring system utilizes the global and national ranks from NatureServe based on four factors:

$$\text{Total points} = (\text{Taxon points} + \text{Threat points}) \times (\text{Global points} + \text{National points})$$

Taxon points are based on the taxonomic level of the entity (species, subspecies, or population) whereby species are prioritized higher than subspecies and populations. 'Threat points' is based on the perceived seriousness of known threats. 'Global points' relates to the species geo-abundance and its global 'G' rank; and 'national points' refers to the species national general status rank. Both global points and national points are taken from the NatureServe website. National status can only be equal to or lower than global status and is assigned by NatureServe scientists (NatureServe 2006*c*). Using this formula, those having higher overall scores are prioritized higher. There does appear to be duplication in the use of the variable threat points as NatureServe includes an element of threat into the generation of global and national points, so including it twice would likely elevate the importance of threat. This process has not been applied to all Canadian butterfly species, and currently the COSEWIC prioritization list is clearly not comprehensive for the rarest Canadian butterflies as only 17 species and sub-species of arthropods are currently listed. Once available it would be useful to compare the list generated using this methodology with the list suggested here. The present results can be used to develop better lists of candidate species for assessment by COSEWIC. The list of the priority species (Groups A to F) provides a more accurate and comprehensive picture than only those species that have been assessed by COSEWIC to date. Of these 98 species, COSEWIC has assessed only five species identified as the highest priorities for conservation in Canada. An additional seven species are included on the candidate list for assessment. As species only gain protection under SARA following assessment by COSEWIC from this assessment of the 93 most geo- and phylo-rare species species are currently afforded no protection. Being listed is not only important for protection under SARA but one U.S. study found that being listed also has implications for which species than have a chance of recovery. In the U.S., the Endangered Species Act (16 U.S.C. §§ 1531-1544, [1988]; see Taylor et al. 2005) has a similar protocol to COSEWIC, whereby threatened species are listed and a recovery plan is implemented toward increasing populations. Factors contributing positively toward the recovery of species include the listing of species, dedicated species recovery plans, and protected critical habitat (Taylor et al. 2005).

METHODS

All available global determinations (G-ranks) for species found in Canada were accessed from NatureServe (2005*a*). I obtained sub-national (provincial/territorial) S-ranks for British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Newfoundland, Labrador, and Nova Scotia, from provincial/territorial Conservation Data Centres or Natural Heritage programs (for example, Natural Heritage Information Centre [NHIC] in Ontario). Québec rankings for butterflies exist in draft form only and are currently being finalized (Isabelle Gauthier, Ressources naturelles et faune, Québec (personal communication, November 25, 2004)). Both global and regional rankings were used here to compare rarity by jurisdictions in Canada. In the case of any G- and S-ranks of the form G_NG_{N+1} (typically present in cases of field uncertainty) I averaged both ranks.

The taxonomy from Layberry et al. (1998) was adjusted to the phylogeny from Ackery et al. (1999). Several taxonomic discrepancies exist between Layberry et al. (1998), Ackery et al. (1999), NatureServe, and the various provincial agencies such as NHIC. There are a number of spelling discrepancies between Layberry et al. and the various provincial conservation data centres. (For instance, *Callophrys polia, Callophrys grynea* and *Polities origines* in Layberry et al. (1998) are named *C. polios, C. gryneus,* and *P. origenes,* respectively, by NHIC in Ontario.) Also, one additional species, *Phyciodes pascoensis,* is not recognized by Layberry et al. (1998) but is listed as a species and ranked in Ontario by NHIC, and also by the Manitoba Conservation Data Centre, so I have included it in our analyses. Differences in species numbers did not affect results of P_G assignment, as these were made using sub-family sizes.

Estimating phylo-rarity ranks

To calculate global phylo-rarity values I arranged the global list of sub-families within the Hesperioidea and Papilionoidea by number of species (see Table 3). The Shapiro-Wilk W test was applied to test the data for normality (H_o W=1 (normality) vs. H_1 W<1 (non-normality)) (Shapiro and Wilk 1965). The null hypothesis was rejected for the untransformed data (W=0.69, p<0.0001). The W score for the transformed data was greatly improved (W=0.91, p=0.0227), allowing the acceptance of the hypothesis at α=0.01. The resultant z-score (i.e., the number of standard deviations above and below the standardized mean number of species), was used to group the data arbitrarily into five "P_G" categories.

When considering a means to prioritize species, most authors agree that objectivity is crucial (Master 1991; Crozier 1997; Whiting et al. 2000; Possingham et al. 2002; NatureServe 2004*a;* De Grammont and Cuarón 2006) otherwise species that are, for instance, larger, more attractive, or more charismatic will be disproportionately represented. By deriving a categorical value of phylogenetic rarity using the z-score I have insured objectivity. Although the current approach remains arbitrary, the division of categories is provided mathematically by utilizing the z-score. This methodology also has a readily understandable, common interpretation.

Sub-families having z-scores of -1.5 or less were regarded as P_G 1 (i.e., the most phylogenetically rare). Sub-families with $-1.5 < z <= -0.5$ were regarded as P_G 2; $-0.5 < z < = +0.5$ were P_G 3; and those having $+0.5 < z <= 1.0$ were P_G 4. Sub-families with $z > 1.0$ were grouped as P_G 5 (most phylo-abundant). This process divided species into five phylo-abundance ranks, analogous to the five-rank system of G- and S- ranks used both globally and sub-nationally by NatureServe, NHIC, etc. (Table 2).

The same method was followed for assigning regional phylo-rarity ranks whereby the number of species within each sub-family in Canada was used to create a 'trimmed' phylogenetic tree. These numbers of species ranging from 1 to 63 species within sixteen families were natural log transformed and then plotted on a normal probability plot. The resultant z-scores once again suggested breaks for five categories whereby a sub-family having only one species would be considered the rarest and assigned a ranking of P_S 1. As the standard deviation for the list of Canadian species is smaller, the z-score ranges had to be adjusted to create five categories. The z-score for a sub-family having only one species (-1.2) dictated the cut off value for P_S 1 (i.e., the most phylogenetically rare). Five sub-families were ranked P_S 1: Riodininae, Danainae, Heteropterinae, Libytheinae, and Miletinae. In contrast the sub-families with the highest number of species Hesperiinae (56 species) and Lycaeninae (63 species) would be considered the most common and were assigned the rank of P_S 5. This provided the upper limit of z-scores. Sub-families with $-1.0 < z <= 0.0$ were regarded as P_S 2; $0.0 < z <= +0.5$ were P_S 3; and those having $+0.5 < z <= 1.0$ were P_S 4. Sub-families with $z > 1.0$ were grouped as P_S 5 (most phylo-abundant).

Phylo-rarity ranks 1 and 2 are regarded as rare and ranks 4 and 5 are considered to be common. Phylo-rarity rank 3 includes sub-families with greater than the average number of species. This approach is taken, not only to be conservative, but also to duplicate the level of conservation used for the geo-rarity ranks whereby a rank of 3.5 is also considered rare. Although still termed 'rare' the phylo-rarity rank of 3 would be more appropriately termed 'borderline' or 'uncommon'.

Size of wingspan was used to justify the cut off of sub-families being deemed rare and common. Papilioninae, the sub-family with the largest average wingspan for those species occurring in Canada, was assigned the cutoff between rare and common both globally and regionally. Further justification for this cut off was provided by observing the percentage of geo-rare and.geo-common species regionally in Canada. Regionally geo-rare species (S1 to S3.5) represent 25.1% of all butterfly species in Canada. This percent is similar to the assignment of regional phylo-rarity in Canada of 15%.

A smaller percentage of globally geo-rare species (G1 to G3.5) are found in Canada (7.29%) whereas the percentage of species assigned to the first three categories of global phylo-abundance was 35.5%. This approach was taken for two reasons. Again the cut off between rare and common was established according to the sub-family with the largest average wingspan, Papilioninae. However, this decision is based on average wingspans within subfamilies for only those species within Canada and may be inadequate for determining global averages. A correlation between global subfamily size and average wingspan (Pearson's correlation coefficient $P<0.01$) suggested that wingspan should be an important variable for discriminating phylo-rarity. Biological data supports wingspan as an important variable for extinction pressure (Makarieva et al. 2005). Adjustment of percentage of global phylo-rare species closer to global geo-rare levels resulted in the elimination of wingspan being a discriminating variable. As information becomes available regarding average wingspans for more species of butterflies globally, this ranking may need to be adjusted. Because no wingspan information is available for the Riodininae sub-family it was tentatively included as a P_G3. As there are no representative species from Riodininae within Canada this assignment had no bearing on any further results.

Regional Rarity

I analysed separately the data for four provinces (all those having reasonably large percentages of S-ranked species) (Table 7). The S ranks exclude species considered exotic, breeding and non-breeding migrants or vagrants, historical occurrences, and those considered to occur in Canada accidentally (species occurrences outside of their expected range). Vagrants are considered species that do not appear in Canada every year. In Ontario, all 163 species reported by NHIC are ranked, with 126 species assigned S1-5 values, and the remaining 37 assigned the alternate exotic, etc. rankings (Table 7). Similar high proportions of species ranked S1-5 occur in British Columbia (161/180) (Table 4), Manitoba (119/141) (Table 7) and New Brunswick (52/78) (Table 7). Although a higher total number of species is found in Alberta, only 42/159 species have so far been ranked with S values.

Testing for independence of rarity ranks

Chi-squared tests were applied to the eleven sub-families having four or more representative species in Canada to test if the occurrence of rarity and commonness was occurring differentially across sub-families. For each of the sub-families the highest S-rank found across Canada was utilized. Correlation between geo- and phylo-rarity was tested tested with the Pearson's correlation coefficient.

Combining estimates of phylo- and geo-rarity for prioritization

For analyses that combined estimates of phylo- and geo-rarity, I excluded all exotic, extirpated, breeding and non-breeding accidental and falsely-reported species. Using a matrix-based model, the geo-and phylo-ranks were used to determine an overall category of priority. I followed these principles: first to give priority to global rarity (either geo- or phylo-) in species, and then to regional rarity (either geo- or phylo-) species (Table 8a). No weighting was applied between conditions of phylo-rarity and geo-rarity: these were regarded co-equally for prioritization. A geo-rarity rank of 1 and a phylo-rarity rank of 1 are not considered equivalent as it is not possible to determine the equivalent importance of either variable. They are also not necessarily equally important, however, as this method combining for prioritization, choosing P1 and G1 as highest priority ensure that the rarest species will be getting the highest prioritization.

Rarity was defined following the format used by NatureServe, where a value from one to 3.5 is regarded as rare and a value of four or greater is defined as common. For joint values (e.g., G2G3) an average value (G2.5) was used. Values such as G2G3 are considered "range ranks" by NatureServe and are assigned to species where there exists uncertainty in the rank that should be assigned. The prioritization model utilized all combinations of global geo-rarity and global phylo-rarity and regional geo-rarity and regional phylo-rarity. Three prioritization categories were identified for global geographical and phylogenetic abundance: rare in both global categories, rare in one category, and then common in both global categories. Three analogous regional categories were identified for each global category of geographical and phylogenetic abundance: regionally rare in both, rare in one regional category, and common in both regional categories. A total of nine prioritization groups were identified beginning with group A species: rare in all four categories (i.e., globally geo- and phylo-rare and regional geo- and phylo-rare); these rarest of the rare are followed by species (group B) which are globally geo- and phylo-rare but common in one of the two regional categories; then (group C) species which are globally geo- and phylo-rare, but common in both regional categories; then (D) species which are common in one of the two global categories but rare in both regional contexts; then (E) species which are rare in one global and one regional category and common in the other; then (F) species rare in one global category and common in the other three categories; then (G) species, which are common in both global categories and rare in both regional categories; then (H) species common in both global categories and rare in one regional category; finally group I species: common in all four categories. Only species with data in all four variables were considered in the analyses (e.g. for global priorities n = 223) (Table 8b).

Although global and regional phylo-rarity is correlated there are instances where a species that is globally phylo-common may be considered regionally phylo-rare or vice versa. For the first instance, this situation occurs when a sub-family has many representatives globally but very few are represented in Canada. The alternate instance can occur whereby a sub-family with fewer representatives may be well represented within Canada.

Equal priority for conservation was assigned to geo- and phylo-rarity within the global and regional groups. Groups D, E, and F can be further discriminated as being globally geo-rare and globally phylo-common (D_G, E_G, F_G) or globally phylo-rare and geo-common (D_P, E_P, F_P) (Table 8a and 8b).

For determining global priorities within Canada, the highest value of S-rank available from across Canada (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia, Labrador, New Brunswick, or Newfoundland) was used. This was necessary because species occurring in more than one geographic region in Canada could have more than one S-rank value. Using the highest value of S-rank ensures that species are assigned appropriate

prioritization. For instance, species which are regionally rare in one province (or territory) yet regionally common in another province should not become priorities for conservation on a national basis. Separately, this model was then applied to each of the four regions for which sufficient data were available (British Columbia, Ontario, Manitoba, and New Brunswick), using the S-ranks for each region separately and thereby generating four regional priority lists.
The method proposed in this thesis combines conditions at both regional and global levels for both geographic and phylogenetic abundance, providing an overall priority list for butterfly species within Canada.

The inclusion of a phylogenetic measure of rarity, combined with measures of distribution and abundance should further refine prioritization measures. The phylogenetic rarity values, both globally and regionally, combined with the global and regional distribution and abundance values from NatureServe can be applied to butterflies in other areas across North America. The method for determining phylogenetic rarity can be applied to other groups where species numbers at a cladistic level are known.

The current approach to estimating phylogenetic abundances, weights species by their extent of phylogenetic diversity based upon sub-family-level species richness alone. No occurrence information is required. For the regional phylogenetic rarity value I have parsed the phylogenetic tree, including only the numbers of species that occur within Canada to determine the regional phylogenetic rarity value. This method involves occurrence at a scale of the country of Canada. The method for determining regional phylogenetic rarity is consistent with the global phylogenetic rarity value.

Life history features

A number of life history features were analyzed using canonical discriminant function analysis (SPSS, Version 14.0) to determine the variables that discriminate phylo- and geo-abundance. For this analysis global estimates of phylo- and geo-abundance were used in order to increase sample numbers for each category. The three globally phylo-rare and globally geo-rare groups A, B, and C, were combined to form group 1 (Table 8b). The three globally phylo-common and globally geo-rare groups D_G, E_G, and F_G were combined to form group 2. Group 3 was formed by combining groups, D_P, E_P, and F_P, which were all globally phylo-rare and globally geo-common. Group 4 combined the three remaining groups, G, H, and I, the globally phylo- and geo-common species. The variables used in the calculation included upper wingspan (mm) as defined by Layberry et al. (1998), monophagy (utilizing one species of larval food plant) vs. polyphagy (utilizing more than one species of larval food plant), families (defined as the the number of families of larval food plants), and subspecies (the number of subspecies recorded for each species, according to Layberry et al. 1998). Monophagy and polyphagy were recorded as indicator variables (monophagy=1, polyphagy=2). These variables provided the most complete information available for Canadian butterflies (n=232). The prediction performance of the model was assessed using cross-validation or "jack-knifing." Briefly, a discriminant rule based on all observations but one is used to predict (classify) the missing observation and this process is repeated for all observations. The resulting summary of correctly predicted observations gives the estimated probabilities of correct and incorrect classifications.

RESULTS

Global phylo-abundances (P_G)

Two monotypic sub-families, Baroniinae (Papilionidae) and Pseudopontiinae (Pieridae), within the Papilionoidea are ranked P_G1 (Table 3). Three sub-families: Curetinae (18 species) (Lycaenidae), Libytheinae (12 species), and the Calinaginae (8 species) (both Nymphalidae) are ranked P_G2. Sixteen sub-families are ranked P_G3 with species numbers ranging from 40-580 (Table 3). Five of the remaining sub-families, Pierinae (700 species), Limenitidinae (1000 species), Pyrginae (1000 species), and Riodininae (1250 species), are ranked P_G4. The remaining three sub-families Hesperiinae (2000 species) and Satyrinae (2400 species), and Lycaeninae (Lycaenidae), the most phylo-common sub-families, are ranked P_G5 (4000 species).

Globally phylo-rare species that occur in Canada

No P_G1 species occur in Canada (Table 9). One P_G 2 species occurs in Canada, *Libytheana carinenta*, the American snout, appears to be the most phylo-rare species occurring in Canada (P_G 2, P_S 1; Table 9; Nymphalidae, Libytheinae). This species is recorded only in Ontario, as a breeding migrant (breeding migrant has an S rank of SZB) and as such does not have a regional geo-rarity rank S1-5 assigned. The next most globally phylo-rare species (P_G 3) are in the sub-families Coliadinae (with 122 Canadian species), Heliconiinae (43 Canadian species), Pierinae (17 Canadian species), Nymphalinae (16 Canadian species), Papilioninae (14 Canadian species), Pyrginae (13 Canadian species), Limenitidinae (four Canadian species), Parnassiinae (four Canadian species), Apaturinae (two Canadian species), Danainae, Heteropterinae, Miletinae, Riodininae (each with a single Canadian species) and Coeliadinae, Charaxinae, Dismorphiinae, Poritiinae, Pyrrhopyginae and Trapezitinae (with no Canadian representatives) (Table 3 & Table 9). The majority of species found in British Columbia, Ontario, Manitoba and New Brunswick are globally phylo-common (Table 4; Fig. 1). New Brunswick has the highest percentage of globally phylo-rare species (40.4%; n=52), followed by British Columbia (37.9%; n=161), Manitoba (37.0%; n=119), and Ontario (16.7%; n=128).

Regional phylo-abundance (Ps)

There are single species representing each of the five regionally most phylo-rare (P_S 1) sub-families in Canada: *Apodemia mormo* (P_G 3) (Riodininae); *Carterocephalus palaemon* (P_G3) (Heteropterinae); *Feniseca tarquinius* (P_G3) (Miletinae); *Danaus plexippus* (P_G3) (Danainae); *Libytheana carinenta* (P_G2) (Libytheinae) (Table 10). Three sub-families, Limenitidinae (P_G3) (4 Canadian species), Apaturinae (P_G3) (2 Canadian species), and Parnassiinae (P_G3) (4 Canadian species) all ranked P_S 2. Two sub-families are ranked P_S 3, Pyrginae (P_G4) (with 13 Canadian species) and Papilioninae (P_G3) (which includes 14 Canadian species (Table 10). All the remaining sub-families (including 251 Canadian species) are ranked P_S 4 and 5.

Regionally, the majority of species are phylo-common (Fig. 2). Manitoba has the greatest percentage of regionally phylo-common species (92.6%; n=121), followed by British Columbia (90.1%; n=161), Ontario (89.1%; n=128) and New Brunswick (86.5%; n=52) (Table 4: Fig. 2).

In the same four provinces, there are small percentages of regional phylo-rarity, with New Brunswick having the highest percentage (13.5%), followed by Ontario (10.9%), British Columbia (9.9%), and Manitoba (7.4%) (Table 4).

Global geographic rarity in Canada

For our assessment of globally geo-rare species found in Canada I include all species ranked G1 to G3 as well as species with combined ranks (i.e., G3G4=3.5). This is not only to be conservative in this approach of rarity, but also because these species are globally rounded by NatureServe (2005a) to the lower rank (i.e. G3G4=G3 nationally). In the case of *Colias johanseni,* where a combined rank of G1G3 has been assigned (NatureServe 2006*a*) I have used the rounded global rank of G2 for the assessment. Twenty globally geo-rare (G1-G3) butterfly species are found in Canada (Table 11). Only one G1-ranked species, *Coenonympha nipisiquit* (Satyrinae) is found in Canada. Five G2 species (including one G1G3 and three G2G3-ranked species) and fourteen G3 (including eight G3G4-ranked species) are found in Canada. The remaining 257 Canadian butterflies are ranked G4-G5. Twenty-three Canadian butterfly species have not been globally ranked by NatureServe or local CDC's.

Globally geo-rare species ranked by COSEWIC

Of the 20 Canadian butterfly species ranked globally as geo-rare (G1 to G3 and including those ranked G1G2, G2G3, and G3G4), only three of these most globally rare butterflies have been assessed by COSEWIC (two endangered, one extirpated) (Table 11). Canada's endemics appear not to be considered more highly by COSEWIC, as only one of the three has been assessed (Table 7). Of the remaining 17 globally geo-rarest Canadian butterflies, three are on the Candidate List for assessment. Of the butterfly species that have been assessed by COSEWIC they include both globally geo- and phylo-common and rare species (Table 7). The Candidate List also includes geo- and phylo-common and rare species (Table 8).

Variability within-Canada and regional geo-rarity

In general, the butterflies present in British Columbia, Ontario, Manitoba and New Brunswick are globally geographically-common, (Table 3; Fig. 3). New Brunswick has the highest percentage of globally geo-rare species (7.7%) followed by Ontario (3.9%), Manitoba (2.5%) and British Columbia (1.9%) (Table 3). The majority of species are also regionally geo-common (Table 3). New Brunswick (40.4%) and Ontario (33.6%) have the highest proportions of regionally geo-rare species followed by British Columbia (23.4%) and Manitoba (12.5%) (Fig. 4).

Regional geo-rarity (S-rank)

Six species are ranked S1 in British Columbia with an additional thirty-four ranked S2 to S3 (including S3S4) (Table 12a). The remaining 121 species are ranked S4 to S5. There is overlap between species that are ranked in British Columbia and the other three provinces. Sixty-three species ranked in British Columbia are also ranked in Ontario (39%), 75 in Manitoba (46.6%) and 32 in New Brunswick (19.9%).

In Ontario, seven species are ranked S1 (Table 12b). A further thirty-six species are ranked S2-S3 (including species ranked S3S4). The remaining 85 species are ranked S4 to S5. Of these, 97 species are also ranked in Manitoba (75.8%) and 49 species are also ranked in New Brunswick (38.3%).

Six species are ranked S1 in Manitoba (including one S1S2 species) (Table 12c). An additional nine species are ranked S2-S3 (including S3S4). The remaining 106 species are ranked S4 to S5. Forty-four species are ranked in New Brunswick (35.5%) as well as Manitoba.

In New Brunswick, five species are ranked S1 and an additional 16 species are ranked S2-S3 (including S3S4) (Table 12d). The remaining 31 species are ranked S4 to S5.

Regionally geo-rare species ranked by COSEWIC

In British Columbia (Table 12a), of the 40 species ranked S1 to S3 (including S3S4) one S1 species, *Apodemia mormo* (Riodinidae), is ranked endangered and one S3B/SZN species, *Danaus plexippus* (Nymphalidae), is ranked Special Concern, a species that is particularly sensitive to human activities or natural events but is not endangered or threatened (COSEWIC 2005). In Ontario, of the 43 species ranked S1 to S3 (including species ranked S3S4), only one species, *Euchloe ausonides* (Pieridae), has been ranked by COSEWIC (as extirpated in British Columbia; see Table 12b). This species was re-assessed by COSEWIC in 2000 and confirmed as extirpated on two islands off the west coast of British Columbia following the disappearance in 1910. In contrast, NatureServe ranks this species as S4S5 in British Columbia and does not list this species as extirpated in any state or province within the species' range which extends beyond 2.5 million square kilometers (NatureServe 2006*a*). Layberry et al. (1998) confirms that while *E. ausonides* is extinct on southern Vancouver Island, the Canadian range extends from the west coast to as far east as Manitoulin Island in Ontario. In Manitoba (Table 12c), of the 15 species ranked S1-S3, three are ranked by COSEWIC. *Hesperia ottoe* (S1) is ranked endangered and *Oarisma poweshiek* (S2) and *Hesperia dacotae* (S2S3) are ranked threatened. In New

Brunswick (Table 12d), of the 21 species ranked S1-3, one S1 species, *Coenonympha nipisiquit* (Nymphalidae) is ranked endangered. This species is considered globally rare (G1) by NatureServe. *Coenympha nipisiquit* is currently ranked S3 in Quebec. The monarch, *Danaus plexippus* (ranked S2B) is ranked Special Concern by COSEWIC. This rank is assigned to species thought to be particularily vulnerable due to special biological or environmental requirements. The monarch is assigned this rank due to the vulnerability of the over-wintering habitat in Mexico (COSEWIC 2005*a*).

Independence of rarity values

Of the 11 sub-families, Hesperiinae alone was found to be significantly different than the expected global geo-rarity (chi-squared value = 5.388>3.84 (p=0.05), p<=0.025).

While phylo-rarity was correlated at the global and regional scale (Pearson's = 0.629, p<0.01) and geo-rarity was correlated at the global and regional level (Pearson's = 0.380, p<0.01) phylo- and geo-rarity were not correlated (Pearson's ranged -0.079 to -0.173, p>0.05). Therefore it is possible to include phylo-rarity in the prioritization. For any further analysis the two measures of rarity (geo and phylo) were assumed to be independent of each other.

Combining phylo-abundance and geo-abundance estimates

The 98 butterfly species identified in the first six prioritization groups (A-F) should be considered as those requiring some level of conservation priority (Table 13). A single group "A" butterfly: *Papilio brevicauda* (Papilioninae) would be considered Canada's top priority for conservation among the butterfly species. Three group "B" species (globally phylo- and geo-rare, regionally either phylo or geo-rare): *Euphydryas gillettii* (Nymphalidae), *Boloria alberta* (Nymphalidae), and *Colias occidentalis* (Pieridae) exist in Canada. There are no group "C" (globally phylo- or geo- rare, regionally phylo- and geo-common) species. Five group "D" (either globally geo- or phylo-rare, regionally geo- and phylo-rare) species exist in Canada: species: *Parnassius phoebus* (Papilionidae), *Papilio indra* (Papilionidae), *Asterocampa celtis* (Nymphalidae), *Papilio cresphontes* (Papilionidae), and *Asterocampa clyton* (Nymphalidae). Thirty-two species fall within group "E" (i.e., either phylo- or geo-rare, both globally and regionally phylo- or geo-rare). Fifty-seven species fall within group "F" species (either globally phylo- or geo-rare and regionally phylo- or geo-common) (Table 10). *Apodemia mormo* (Riodinidae), Canada's only metalmark, and *Erynnis baptisae* are the only group "G" species (globally phylo- and geo- common, regionally phylo- and geo-rare). Forty-five group "H" (globally phylo- and geo-common, regionally phylo- or geo- rare). The remaining 99 species are considered group "I" (both globally phylo- and geo- common and regionally phylo- and geo-common).

Group A

The only group A species and Canada's highest priority for conservation, *Papilio brevicauda* (the short-tailed swallowtail) is found in the eastern maritime provinces and Quebec, in the area surrounding the Gulf of St. Lawrence (Layberry et al., 1998). This species is recognized by NatureServe (2005) as endemic to Canada and is ranked as G3G4 (averaged rank G 3.5). This species is a polyphagous feeder on a variety of plants in the parsley family (Apiaceae). As such, the habitat includes herb gardens (Layberry et al. 1998). It is also found in a variety of other habitats including grassy clifftops, rocky beaches, inland meadows and mountainous areas close to the treeline (Layberry et al. 1998). Three indiscrete sub-species are recognized and form a cline from east to west (Layberry et al. 1998). Although this species occurs in several eastern provinces, only one S-rank (S3) is available for this species from the province of Quebec (a tentative rank until confirmed). Ackery et al. (1999) estimates that 570 species belong to the papilionidae (Parnassians and Swallowtails) making it the smallest family of butterflies. The sub-family Papilioninae has 550 of these species and is assigned a P_G rank of 3. Only 14 Papilioninae species occur in Canada and as such, it is assigned a P_S rank of 3. This species' upper wing span of 73 mm is considerably greater than the average upper wingspan for all Canadian butterflies (43.44 mm).

Group B

A species in Group B would be globally geo- and phylo-rare and either regionally phylo-rare or geo-rare. Four Canadian species, *Euphydryas gillettii* (Nymphalinae), *Boloria alberta* (Heliconiinae), and *Colias occidentalis* (Coliadinae), are within this group. Within this group *Euphydryas gilletti*, Gillette's Checkerspot, is the most rare of the four species, with the lowest global rarity rank (G=2.5), the lowest S-rank (S=2.5), the same P_G rank as the other three species (P_G=3) and the same P_S rank (P_S=4). The range extends outside of British Columbia (S2S3) and Alberta (S2) into Idaho, Montana, Utah, and Wyoming but it has only been ranked in Montana (S2) while the other three states have either not yet ranked the species or it is under review. This species is considered by Layberry et al. (1998) as a medium-sized butterfly with a wingspan ranging from 36 to 45mm. This species usual larval food plant is Bracted honeysuckle (*Lonicera involucrate*) but several other plants may be utilized after hibernation making this a polyphagous species. Habitats of this species include moist meadows in mountain valleys (Layberry et al., 1998). *Boloria alberta* is monophagous and *Colias occidentalis*, the remaining species, is polyphagous. All of these species have southern distribution in Canada.

Group C

A species in group C is considered globally both geo- and phylo-rare and regionally both geo- and phylo-common. As no species of Canadian butterflies fall into this group there is no example species.

Group D

Group D species are either globally geo- (D_G) or globally phylo-rare (D_P) as well as being regionally geo- and phylo-rare. All five species of the Canadian butterfly representatives of this group are globally phylo-rare and geo-common. They include *Parnassius phoebus*, *Papilio indra*, *Papilio cresphontes*, *Asterocampa celtis*, and *Asterocampa clyton*. *Parnassius phoebus*, *Papilio indra* and *Papilio cresphontes* belong to the Papilioninae sub-family whereas *Asterocampa celtis* and *Asterocampa clyton* belong to the Apaturinae sub-family. These sub-families have 550 and 430 species, respectively. Both *Asterocampa celtis* and *Asterocampa clyton* feed on the same two species of Hackberry (*Celtis occidentalis* [G5, S1 in Manitoba, S4 in Ontario, S3 in Quebec] and *Celtis tenuifolia* [G5, S2 Ontario]).

Group E

Thirty-two species belong in Group E, being globally and regionally either phylo- or geo-rare. Of these, ten are globally geo-rare while the remaining 22 are globally phylo-rare species.

Canada's most globally geo-rare species, *Coenonympha nipisiquit,* a Canadian endemic, is a member of this group being geo-rare (G1) yet globally phylo-common (P_G 5, P_S 4). A second Canadian endemic *Lycaena dospassosi* is also within group E (G2, P_G 5, P_S 5). The only Canadian representative of the sub-family Miletinae, *Feniseca tarquinus* is within Group E. This sub-family is mostly African and Oriental and has carnivorous larvae which feed on aphids (Layberry et al. 1998).

Group F

Of the 57 species of group F species (globally either phylo- or geo-rare and regionally both phylo- and geo-rare), only one species (*Erora laeta*) are globally geo-rare. The remaining 56 group F species are globally phylo-rare.

Group G

Apodemia mormo (Riodinidae) is one of only two group "G" species (globally phylo- and geo-common, regionally phylo- and geo-rare). This species is at the extreme northern edge of its range in Canada and is widespread in the western U.S. and Mexico (Layberry et al. 1998). This is the only metalmark (Riodinidae) that reaches Canada of the 25 found in North America (Layberry et al. 1998). COSEWIC has ranked this species endangered. The second group G species, *Erynnis baptisiae,* is not well known (Layberry et al. 1998). It occurs only in extreme southwestern Ontario however, it is considered very common within the restricted range (Layberry et al. 1998).

Group H

Forty-five group "H" (globally phylo- and geo-common, regionally phylo- or geo- rare) are found in Canada. This group represents species that have few representative species within their sub-family or few populations in Canada. Species in this group may be considered regionally geo-rare because they are at the northern edge of their range. Many species in this group are considered regionally rare because they are southern species likely at the northern part of their range.

Group I

Group I is regarded as the most common group within the current matrix and most of the Canadian butterflies fall within this group. A species in this group would be common, globally and regionally, both phylogenetically and geographically. In general, species in this group should be polyphagous, have more subspecies, and be smaller in size. Of the 99 species in this group, 91 are polyphagous (two are monophagus and six are unknown). The two most common families of larval host plants are members of Poaceae (30 species), and Cypresaceae (10 species). These families of grasses and sedges are very geo-common species.

Regional patterns

In British Columbia, one group "A" *Colias occidentalis* and two group "B" species occur: *Euphydryas gillettii* and *Boloria alberta* exist. Five group "D" species are found in the province: *Papilio indra*, *Colias meadii*, *Parnassius phoebus*, *Danaus plexippus,* and Colias hecla (Table 14a). A further 20 group "E" species, 34 group "F", three group "G", 42 group "H", and 53 group "I" species occur.

No group "A", "B" or "C" species exist in Ontario (Table 14b). Two Dg species: *Erynnis martialis* and *Pieris virginiensis*, and five Dp species are found in Ontario: *Asterocampa celtis, Asterocampa clyton, Papilio cresphontes*, *Papilio machaon*, and *Colias gigantea. Euphydryas gillettii*, *Boloria alberta*, and *Colias occidentalis*. Nineteen group "E" species, 21 group "F", and 6 group "G" species occur. Twenty-nine group "H" and 44 group "I" species complete the list for Ontario.

In Manitoba, no species ranked in groups "A", "B", "C' or "D" are found (Table 14c). There are 20 group "E" species and 28 group "F" species. There are three group "G" species. Seventeen species are ranked group "H" and the remaining 50 species are ranked group "I".

In New Brunswick, there are no group "A", "B", or "C" ranked species and just one group "D" species, *Danaus plexippus* (Table 14d). Thirteen species are ranked group "E" and 11 species are ranked group "F". There are no group "G" species in New Brunswick. The remaining species are ranked group "H", 16 species and group "I", 11 species.

COSEWIC results

Butterflies are one of the most-studied insect groups, having mobility, visibility, and obvious beauty and charisma in comparison to many other groups (Ehrlich 2003). Presently, just 10 of 293 species of butterflies (as well as four sub-species and one species identified as two populations) occurring in Canada (3.4%) have been reviewed by COSEWIC for their current national status (Table 13). This highlights the necessity to prioritize species for assessment, in order to target for review those species that are the most susceptible to threat of loss. There is also a taxonomic discrepancy concerning *Coenonympha nipisiquit* (Layberry et al. 1998) which is considered a sub-species by COSEWIC (*Coenonympha tullia nipisiquit*). (Note that COSEWIC does not adhere to a single taxonomic authority but most closely follows Layberry et al. (1998) [P. Catling, (personal communication Apr. 20, 2005)]). A further 17 species and sub-species of butterfly are on the priority list for assessment by COSEWIC (COSEWIC 2006) (Table 14).

Canada's highest priority for conservation, *Papilio brevicauda* (the short-tailed swallowtail) (group A) is currently not ranked by COSEWIC (Table 7 and 13). This species is also not on the Candidate List for assessment (Table 8 and 13). The four group B and four D species have neither been ranked nor are on the Candidate List for assessment by COSEWIC. Five of the 32 group E species have been assessed by COSEWIC and another two group E species is on the Candidate List for assessment. No group F species have been assessed but three of the 57 group F species are on the Candidate List for assessment by COSEWIC. The first group G species, *Apodemia mormo*, has been ranked endangered by COSEWIC but *Erynnis baptisiae is unranked.* Two of the 45 group H species have been assessed; *Limenitis weidemeyerii* and *Satyrium behrii,* and four species are on the Candidate List. Of the 99 group I species, two have been assessed by COSEWIC, *Euchloe ausinodes* is ranked extirpated, and *Euphyes vestris* is ranked threatened. Two group I species are on the Candidate List for assessment.

Categories of COSEWIC species

No obvious trends exist in which species are chosen for assessment or prioritization by COSEWIC according to the current categorization system. The list of species (and sub-species but not populations) that have been assessed by COSEWIC includes representatives in categories ranging from E to I (Table 13). No group A, B or D species (the highest priorities) have been assessed. No trend is seen if global geo-rarity is considered solely either as species are globally geo-ranked from 1 up to 5. If the sub-species are also excluded, as they too may represent regional populations, there remains a range of global geo-rarity from 1-5 with four of the nine ranking 4 or 5 (globally geo-common).

Better congruence is seen in the three listings on the COSEWIC-assessed list of populations. These populations should be ranked regionally rare in the area where they are listed by NatureServe (S1-3) if there is congruence between NatureServe and COSEWIC. Two populations of *Apodemia mormo*, southern mountain and prairie population, have been assessed by COSEWIC and ranked endangered and threatened, respectively. These populations are ranked S3 in Saskatchewan and S1 in British Columbia (NatureServe 2006*a*) which correlates well with the COSEWIC rank. The *Euphyes vestris*, western population is ranked threatened by COSEWIC and is ranked S3 in British Columbia (NatureServe 2006*a*). As 119 further species are ranked S1-3 in British Columbia, Ontario, Manitoba and New Brunswick alone, clearly many vulnerable populations remain unprioritized and unassessed by COSEWIC.

The COSEWIC Candidate List includes species and sub-species from categories E to I, excluding G (Table 14). If the sub-species are again excluded there remains one group E_P species and one F_P (globally phylo-rare and globally geo-common) and two F_G species (globally geo-rare and phylo-common). As COSEWIC does not include a measure of phylo-rarity, it is unclear why these species are being prioritized for assessment. Canada's endemics appear to not be considered more highly by COSEWIC as only one of the four has been assessed (Table 13).

Life history features

Two functions were found using the four global categories of phylo- and geo-rarity (Table 5b). The first axis was dominated by upper wingspan (Table 15) allowing for discrimination of global phylo-rarity; wingspan increased for more phylo-rare species (Fig. 5). The first axis explained 80.2% of the variance due to the first discriminant function. Function two was dominated most highly with the occurrence of monophagy and number of sub-species (Table 15). This second axis explained a further 19.2% of the variance from the second discriminant function (cumulative variance 99.4%). This axis allowed for discrimation of global geo-rarity. Geo-rarity increased with decreasing number of sub-species and increasing proportion of species that are monophagous. Thirty-six ungrouped cases, which had at least one variable missing, were recorded in the discriminant function analysis. Cross-validation results indicate that 64.2% of cases were correctly classified. Cross-validation was re-run using only global categories two, three, and four. This increased the cross-validation results to 69.3% of cases correctly classified. Cross-validation results increased to 76.0% of cases correctly classified when only global categories three and four were used.

DISCUSSION

The importance of incorporating phylogenetic rarity with traditional measures of distribution and abundance is widely recognized (Vane-Wright et al. 1991; Fermon et al. 2005; Keith, M. et al. 2005; Robbins and Duarte 2005; Soutullo et al. 2005). According to Scientific Citatation Index Expanded, (January 2006) Vane-Wright et al. (1991) has been cited in journal articles 432 times to date. Clarke and Warwick (2001) give the example of grossly polluted sites which may have very diverse benthic fauna but contain a large number of highly related species. In contrast, undisturbed sites contain more distinct species belong to different phyla (Clarke and Warwick 2001). Purvis and Gittleman (2000) found that current extinction risk shows a strong phylogenetic component whereby those clades with lower numbers of species were at greater risk of extinction. Arita et al. (1990) found that traditional measures of distribution and abundance for determining rarity were influenced by phylogenetic history and species diet. Traditional measures of rarity then are not the only factors promoting extinction, various traits are related to extinction as well. This supports including phylogenetic abundance for determining risk of extinction as traits which increase extinction will contribute to smaller sub-family sizes.

One such trait is the body size of an animal (Peters 1993) and I have used this variable for determining rare/common cutoffs for phylo-abundance ranks. Much of this research on body size; however, has involved homeotherms, not poikilotherms. For example, Yu and Dobson (2000) included a measure of body size to see if this variable predisposes mammals to extinction. They found that Orders that included many larger mammals also had higher proportions of geo-rare species. Recent work by Makarieva et al. (2005) on poikilotherms found a temperature-associated upper limit for body size. This would suggest differential extinction pressures on larger poikilotherms. Makarieva et al. (2005) suggested that larger-sized poikilotherms were likely experiencing differential pressures due to mass specific metabolic rate limitations related to ambient temperature. The largest Lepidoptera occur in the tropics. *Ornithoptera alexandrae* (Papilionindae), the largest butterfly in the world, is found in Papau New Guinea and has a linear body size of 25 cm (Makarieva et al. 2005). In temperate Great Britain the largest species of Lepidoptera, *Papilio machaon,* also a member of the Papilioninae sub-family, reaches a size of 9.5 cm. Likewise in temperate Canada, the largest Lepidoptera, *Papilio cresphontes*, is also from the Papilioninae sub-family, with a wingspan of 11.3 cm. A larger poikilotherm in a temperate country such as Canada would have greater extinction pressure than smaller members of the taxon. Many members of this taxon are geographically rare. *Ornithoptera alexandrae* is listed as endangered by the IUCN and many other Papilioninae are also ranked endangered by the IUCN such as *Papilio aristophontes*, *Papilio chikae*, *Papilio homerus*, etc. Causes of butterfly extinction is primarily from habitat destruction, but several other extinction pressures such as climate change, natural enemies, human collection, and demographic and environmental stochasticity, are all known or likely causes (Hanski 2003). The overall large size of species within the Papilioninae sub-family likely lends itself to differential extinction from collection.

From 7 to 11 forms of rarity

The proposed 11 forms of rarity have been arranged in a manner mimicking that of Rabinowitz's seven forms of rarity (Rabinowitz 1981) (Table 5b). These 11 forms enable prioritization based on regional and global estimates of both geographic and phylogenetic rarity. These groups from A to I were assigned in a manner similar to the approach taken by Yu and Dobson (2000) who assigned letters to each of the cells in the Rabinowitz 8-celled matrix. Yu and Dobson (2000) using the existing three categories as per Rabinowitz (1981) but then added a classification of threat. The variables used in the proposed system utilize global abundance both geographically and phylogenetically as well as regional abundance both geographically and phylogenetically. This estimate of extinction threat is included in the NatureServe geo-ranks, however, there is no discrimination of specific cause. These variables are readily available from NatureServe and are arranged in a similar manner to that of Rabinowitz (1981) whereby the categories of the current matrix represent a continuum of rarity and commonness (Figure 5b).

Phylogenetic Rarity

The American snout (*Libytheana carinenta*) occurs in Canada as the most phylogenetically-rare butterfly, having a global phylo-rarity rank of P_G2 with 12 species within this sub-family globally. This butterfly is also regionally phylo-rare, Ps1 with only one species representing this sub-family in Canada. Geographically this species is globally common (G5) reaching the southernmost area of Canada for breeding only overwintering in the U.S. (Layberry et al., 1998). This is likely due to the restricted Canadian range of the sole hostplant for this species Hackberry (*Celtis occidentalis*) as its host plant. As such it is deemed a breeding migrant, with an S rank of SZB. This species drops off the priority list despite its global phylorarity as it does not have an S rank between 1 and 5. However, as this species is not considered a true resident species of Canada this species should not be a high prioritization for conservation in Canada.

Inclusion of phylogenetic rarity increases the number of species considered priorities for conservation in Canada. All of the geo-rare species (G1 to G3.5) were included within groups A to E; however, inclusion of aspects of phylo-rarity now includes phylo-rare species such as *Asterocampa celtis, Asterocampa clyton, Papilio cresphontes and Papilio indra.*

A number of cells in the matrix have no representative species in Canada. In general, cells A, B, and C, the rarest categories, have few representatives as there are few species, rare both phylogenetically and geographically in Canada. In the Rabinowitz (1981) matrix two cells had very few residents; species of narrow geographic range but broad habitat specificity. Rabinowitz (1981) suggests that this arrangement may be unfeasible due to some evolutionary or ecological reason such as demographic stochasticity. Demographic stochasticity, the variation in numbers or genders of offspring by chance, can lead to extinction in small populations. Two cells, C and Fg, within the proposed matrix may be examples of what Rabinowitz (1981) found. In this case it is more likely reflective of globally phylo-rarity, whereby it is very unlikely that these species would also be regionally phylo-common. In the regional phylo-rarity the number of species that are represented in Canada were all roughly 10% of their global species representation (Table 3). So in order for this case to occur, a sub-family would have to have a large percentage of their global species represented in Canada, and this does not appear to be the case. Indeed NatureServe methodology normally assigns S-rank at a level equal to or below that of the global G-rank (NatureServe 2006*d*). However, the one species within cell Fg, *Erora laeta*, appears to be an exceptional species in more than this aspect. Early larvae of *Erora laeta* feed off of the husks of beech nuts and later instars bore into the nut and eat developing seeds (Layberry et al. 1998). The larvae, as well as adults, primarily occupy the canopy of large beech trees and as such, are difficult to census (Layberry et al. 1998). The loss of beech trees due to beech canker (*Nectria* sp.) is also thought to have impacted populations of this species (NatureServe 2006*a*).

Canada's overall top priorities for conservation

The only member of the highest priority group, A, is *Papilio brevicauda*. This species is both globally phylo- and geo-rare as well as both regionally phylo- and geo-rare. The global rarity of this species (G3G4) is likely attributable to the limited range as well as the tendency for this species to fluctuate in numbers from year to year (Ferguson 1955 in NatureServe 2006*a*). This species is among Canada's largest species of butterfly (22/293). Of the B group species, *Boloria alberta*, is one of the largest members of the Heliconiinae sub-family (Layberry et al. 1998). It also has a restricted range, a short flight season for breeding, which occurs only in odd years and is restricted to high mountain habitat (Layberry et al. 1998). This species is considered a relic species that has survived from the last ice age (Layberry et al. 1998). The second group B species, *Colias occidentali*s, has a restricted range and a very localized and spotty distribution (Layberry et al. 1998). *Colias occidentalis* has habitat restricted to dry, open, coniferous forest, mainly inhabited by Douglas fir. This species is also one of the larger Coliadinae species. One larger member of this sub-family is ranked Fp while two larger-sized members of the Coliadinae family are unranked due to missing data. The third group B species, *Euphydryas gillettii*, also has a restricted range and very localized distribution (Layberry et al. 1998). This species is also considered to have a weak flight. *Euphydryas gillettii* is the second largest member of the Nymphalinae sub-family with the largest member, *Vanessa anabella*, being ranked Ep. Many of the larger members of each sub-family were assigned to the groups A to E, supporting the use of larger size as an indication of increased extinction pressure. For instance, *P. cresphontes*, the largest butterfly in Canada falls within group D. Interestingly many of these species (e.g., *P. brevicauda, Papilio indra, Asterocampa celtis*, etc.), are black or dark in colouration. Darker butterflies retain heat and absorb solar radiation better which is important for poikilotherms

(Layberry et al. 1998). This adaptation may allow species to extend further north into areas with cooler ambient temperatures.

Applying the matrix

Within the proposed matrix of twelve groups there exists a continuum of global and regional geo- and phylo-rarity. Groups A, followed by B, and then C, etc., are presented in the matrix as being the highest priorities for conservation because they are globally geo- and phylo-rare. I have given priority to global measures of geo- and phylo-rarity as this should be considered more highly when prioritizing species for conservation. The global extinction of a species is more important for tracking biodiversity (Gaston 2000), since measures of distribution and abundance across the entire range of the species are more important for determining the susceptibility of a species to extinction. Consideration of phylogeny should be considered in parallel to geographic distribution, utilizing species abundance within the entire taxonomic tree (cladogram) encompassing all species of butterflies. Likewise lower numbers of representative species with the global cladogram is more of an ecological concern than within the trimmed regional cladogram for Canada. G-ranks incorporate measures of distribution and abundance across the entire scale of the planet, while the P_G ranks incorporate the phylo-rarity of species in a sub-family for all known species within the two Superfamilies of butterflies.

The influence of scale has long been recognized as one of the most important considerations in ecology (Levin 1992). Hamilton et al. (2005) considered how scale-dependent processes interact to form large-scale patterns (richness, invasions, etc.) showing, for example, that plant invaders in eastern Australia spread faster at the continental scale than at a regional scale. Hamilton et al.

(2005) showed relative importance of dispersal, abiotic, and biotic factors to change across scales. Indeed, there is an influence of scale for most measures of distribution and abundance utilized for assessing extinction risk of species (Hartley and Kunin 2003). Hartley and Kunin (2003) outline how the IUCN utilizes three criteria for assessing extinction risk: extent of occurrence, area of occupancy, and numbers of individuals, whereby each can be placed along a continuum of scale from coarse to fine. These variables are analagous to those used by NatureServe in assigning global G-ranks and regional S-ranks; a coarse and a fine scale. Global rarity is ecologically more important than regional rarity due in large part to consideration of scale and should be given priority. However, measures of regional abundance remain important due to variation across a species domain. The mobility of butterflies as well as recognition of varying categories of butterflies, such as migratory or vagrant, suggest variable distribution across the range of a species. For butterfly species that breed a number of times while continuing to migrate north in between breeding stops, it is unlikely they would be normally distributed within their range, but perhaps rather would have peaks in populations throughout their entire range. These local patterns of status change are tracked by the Conservation Data Centre's and included in the regional ranks. They provide more precise local information as they are at a finer scale than global predictions.

Hartley and Kunin (2003) recommend addressing scale dependency of rarity, extinction risk, and conservation priority (using multiple scales) and then developing indices that combine information from these multiple scales. Regional abundance should be incorporated with global measures when developing methods for prioritizing species for conservation. The combined coarse (global) and fine (regional) scales will address, to some extent, scale dependent patterns and provide a prioritization at either or both scales. This combining of scales then begins to address the varying distribution across a species range (Murphy et al., 2005; De Grammont and Cuarón 2006). This pattern is seen in Canada where for example, in Ontario, British Columbia, Manitoba and Alberta, >90% of all species are globally geo-common. However, regional patterns of geo-rarity are more variable, with Ontario, British Columbia, and Manitoba all having a majority of regionally-common species (66.4-87.5% of species), while Alberta has a majority (97.6%) of regionally geo-rare species.

The matrix utilizes both global and sub-national (regional) rank values but can also be applied differentially across scales. Examining species within a particular political jurisdiction is not the best ecological approach for analysis of biological rarity. Indeed it would be better to examine species across their entire range (Murphy and Lovett-Doust 2005). S-ranks are based on provincial or territorial boundaries, yet they do encompass large areas of North America. The province of Ontario, for instance, encompasses more than one million square kilometers in area (Government of Ontario 2006). Yet for species that have the majority of their range outside of Canada, their S ranks may be very low (regionally rare) in a southern province, but are very abundant (S4-S5) south of the Canadian border. Yet conservation decisions are typically based on political jurisdictions, and as such any new approach for prioritization requires application within these boundaries. For instance, resource managers may wish to prioritize species regionally in order to target provincial or territorial resources toward the most regionally rare species. The matrix can still be utilized, as the matrix provides the opportunity for variable consideration (either globally or regionally) of the categories of rarity. This will involve choosing different groups for prioritization. Groups A, D_G, D_P, and G would be considered the highest priorities for conservation regionally, being regionally phylo- and geo-rare. Groups B, E_G, E_P, and H are the next prioritization groups as they are either regionally phylo- or geo-rare.

Finally, groups C, F_G, F_P, and I are the most common species and would be considered the last priority.

Prediction of the matrix

All 14 globally geo-rare species are within the first 40 identified priorities for conservation; this includes the three Canadian endemic species that have complete information. In addition, 26 species, which are globally phylo-rare are now included within the top 40 priorities for conservation. If the model is predicting correctly the species that are considered rare should be ranked the highest. This information can be verified using life history attributes that indicate rarity.

When considering species based solely on global rarity (Table 16) it is possible to determine if the model is still placing the highest priorities within the appropriate category for conservation. Some refinement of global geo-rarity has been sacrificed in the current prioritization approach by considering species ranked G1 'as rare as' species ranked up to G3.5. Eight of the most geo-rare species would be considered in the first two groups for conservation (Groups A and B). However, ten additional geo-rare species fall within the fifth or sixth groups (Eg or Fg). One example is *Coenonympha nipisiquit*, the most globally geo-rare species in Canada (G1) and a Canadian endemic. As this species is within the sub-family Satyrinae, which has many representative species, *C. nipisiquit* falls within the fifth group for conservation, group E. This species is ranked S1 in the Maritime provinces and S3 in Québec, however its current status there will be re-evaluated following a field assessment in 2005 (Isabelle Gauthier, Ressources naturelles et faune, Québec (personal communication, January 21, 2005)). This species is within

Canada's fifth group for conservation, group Eg, as it is phylogenetically common both globally and regionally (P_G=5, P_S=4). This species has a very limited range in the salt marshes of Chaleur Bay in New Brunswick and Québec where the monophagous larvae, feed only on salt-meadow cordgrass (*Spartina patens*) (Layberry et al. 1998). The species is also only present where the adult food plant, Sea lavender (*Limonium nashii*) is also present. This species has a single generation per year (Layberry et al. 1988) but NatureServe reports a <10% variation in the species from year to year (NatureServe 2006*a*). Layberry et al. (1998) note that this species has been placed on the New Brunswick Endangered Species List as this species' habitat is limited and vulnerable, likely due to encroachment by housing development. This information suggests that this species should possibly be considered a higher priority than the fifth group considered for conservation.

A second Canadian endemic species, *Lycaena dospassosi*, is ranked G2 and S2 in New Brunswick and S3 in Québec (tentative) (NatureServe 2006*a*). *Lycaena dospassosi* also falls within group E as the Lycaeninae sub-family, being the most speciose sub-family both globally and regionally (P_G=5, P_S=5), drops a geo-rare species into a lower priority group. The range of *Lycaena dospassosi* is also within the salt marshes in the Bay of Chaleur and the Gaspé Peninsula in Québec. Also monophagous, *Lycaena dospassosi* larvae feed on Silverweed (*Potentilla egedii*) (Layberry et al. 1998). Layberry et al. (1998) note that this species only occurs where the adult foodplant Sea lavender (*Limonium nashii*) also occurs. It is considered a larger member of this sub-family with a wingspan range from 25 to 31 mm (Layberry et al. 1998).

Canada's third endemic, *Colias johanseni* (Johansen's Sulphur) has recently been reviewed by NatureServe (April 27, 2005) and is assigned a rank of G1G3 (rounded global status G2) while the regional species status in the Territory of Nunavut is under review (NatureServe 2006*a*). This species is considered very geographically rare, occurring only on a few hillsides in Bernard Harbour and Cape Kendall, in the Territory of Nunavut (Layberry et al. 1998; Troubridge and Philip 1990; Harry 2005). The species was recently re-discovered by Troubridge and Philip in 1988, following a 72 year absence since the original discovery (Troubridge and Philip 1990); it was next collected in 1998 both in Bernard Harbour and some 90 kilometers away, in Cape Kendall (Harry 2005). Harry (2005) collected a mating pair and provided the likely larval host plant *Hedysarum mackenziei* to the female for oviposition. *H. mackenziei,* a common and widespread arctic/alpine legume, is also the adult food plant of *C. johanseni* (Troubridge and Philip 1998). Troubridge and Philip (1990) attributed the restricted distribution of *C. johanseni* to the xeric habitat in Bernard Harbour. The collection at Cape Kendall indicates that the distribution is more widespread possibly adhering to the edge of the middle arctic tundra and low arctic tundra ecozones (Ricketts et al. 1999a). Larvae were reared and five instars described although Harry (2005) noted that all the larvae diapaused as fully grown third instars suggesting that, in natural populations, development may not exceed this stage. No other collections or sightings of this species have been recorded, possibly partly attributable to the remote location within a remote region. No regional (S) rank has been assigned to this species as it is thought to only occur in Nunavut which is currently reviewing their species ranks (NatureServe 2006*a*). Due to this incomplete data, an overall Canadian group for prioritization is not assigned. However, as S ranks are normally assigned at a rank level equal to or lower than G-ranks (NatureServe 2006*a*) it is likely this species would be assigned an S-rank of 2 or less and would then be assigned within group B (Table 16).

NatureServe (2005) recognizes a fourth endemic to Canada, *Papilio brevicauda*, which is ranked as G3G4 (averaged rank G 3.5) and falls within Group A. These four Canadian endemics have very localized ranges. A chi-squared test indicates that these endemics have a significantly greater chance of being geo-rare than non-endemics (chi-squared value 11.15>3.84 p>0.001 d.f.=1). This suggests that including information on political endemics for prioritization would duplicate distribution and abundance information from the geographical ranks. Other non-endemics may also have restricted ranges extending beyond the political border of Canada. The regional ranks (S-ranks) do not discriminate between species which have their entire range within the political boundary of Canada.

Endemism

Geographic endemism has been variously incorporated with estimates of phylogenetic rarity to prioritize sites for conservation (Walker and Faith 1995; Posadas et al. 2001). For example, Posadas et al. (2001) (but see Faith et al. 2004) modified the protocol of Vane-Wright et al. (1991) to take account of endemicity patterns, in prioritizing areas for conservation. Faith et al. (2004) proposed that the next step in prioritizing species should be using phylogenetic or evolutionary diversity, along with patterns of complementarity and endemism for choosing reserves.

Defining the geographical extent of an endemic species is difficult, and dependent on the scale of observation. Indeed an endemic species can be regarded as a species having a range which is restricted to a political or geographical spatial scale. For species that are restricted to a certain land area such as an island, it is easier to delineate them as an endemic species. However, once species are isolated within an extensive land mass the variable of geographic distribution or range alters the importance of designating a species an endemic. By this regard, species designated as a political endemic, occurring only within one political jurisdiction become more important for management than for ecological considerations. This is because geographic distribution muddies the definition of an "endemic" species. Endemism is a criterion that relates more to designating conservation priorities than defining conservation status (de Grammont and Cuaron 2006).

Ricketts et al. (1999a) report the occurrence of a single Canadian endemic butterfly species in the New England/Acadian forest ecoregion, on the east coast of Canada. The rest of Canada is reported as having no endemic butterfly species (Ricketts et al. 1999a) in contrast to Layberry et al. (1998) who report both *Coenonympha nipisiquit* and *Lycaena dospassosi* in the New England/Acadian forest ecoregion and a third political endemic (*Colias johanseni*), in the middle arctic tundra near the edge of the low arctic tundra ecoregion. Endemic species by definition have geographic distributions restricted to one area, however defining the extent of this geographical area is more important for conservation issues. This geographic restriction will be reflected, more appropriately, in the global distribution and abundance rarity values (G ranks). For instance, these three "political endemics" are also, not surprisingly, some of the most globally geo-rare species of butterflies found in Canada (Table 8). However, a further 17 species of Canadian butterflies are also considered globally rare (G-rank range G2G3 to G3G4) including a fourth political endemic, Canada's highest overall priority for conservation, *Papilio brevicauda* (NatureServe 2006*a*). Among these globally geographically rare species we see some of Canada's most phylo-rare species (Table 5) which in turn become Canada's overall highest priorities for conservation (Table 10).

Endemism will also contribute to higher taxon richness (which I am using as a surrogate for other phylogenetic methods). Similar patterns of endemism and species richness within taxa have been demonstrated within North America (Kerr 1997). Other authors have suggested using endemism as an indicator of rarity (Posadas et al. 2001; Faith et al. 2004), but Posadas et al. (2001) did not find consistent patterns in ranking by adding endemicity. Likewise Orme et al. (2005) found little congruence between endemism, species richness, and threat for discerning biodiversity hotspots, even within a single taxonomic class. Keith et al. (2005) caution that endemism is influenced by scale. The country of Canada, although being geographically restricted within the northern hemisphere incorporates a vast spatial scale longitudinally, latitudinally, and vertically, as well as numerous habitats and ecoregions. However, as only four butterflies have their entire range within the country (*Coenonympha nipisiquit, Colias johanseni, Lycaena dospassosi, Papilio brevicauda*), the use of endemism for determining Canada's rarest species or areas would have only limited utility.

The inclusion of endemism for higher prioritization would overlook other globally geo-rare species whose entire range does not occur entirely within Canada. For instance, *Hesperia dacotae, Oarisma Poweshiek, Euphyes dukesi, Hesperia ottoe, Callophrys lanoraieensis, Oeneis rosovi, Erynnis martialis,* and *Pieris virginiensis* all have a restricted range size but are not endemics. However, the inclusion of a measure of geographic range may be a good indicator of extinction threat for future inclusion in order to refine the prioritization of species.

Of the remaining globally geo-rare species, three species have a range which is only limited within Canada: *Colias occidentalis, Hesperia ottoe,* and *Erynnis martialis.* In this aspect, these species may be regarded as false positives. However, this depends on the interpretation of conservation priorities. While the majority of their range is outside of Canada they are considered globally geo-rare and may still be considered higher priorities for conservation for Canada. All of the group D species, have limited range within Canada as well.

Group D - Distribution of rare species in Canada – north and south

Asterocampa clyton (Dp) and *Asterocampa celtis* (Dp) have very restricted ranges in Canada due to the restricted range of their larval host plant in Canada, the Common Hackberry (Layberry et al. 1998). These species are each specialized on different stages of leaves of the shrub, whereby *A. clyton* feeds on mature leaves and *A. celtis* feeds only on the young leaves of the Hackberry. This allows these two specialized butterflies to co-exist on the same host plant.

A number of Canadian butterfly species are regarded as species existing at the northern edge of their range, and this influences perception of the actual rarity and the resulting ecological importance of these populations. For instance, a species that is regionally rare in Ontario, may be regionally abundant south of the political border in a northern U.S. state and the S value is giving an inflated importance of this populations. This suggests that regionally rare, northern populations are a less important conservation priority as well as a less important population ecologically. This belief stems from untested theories that as species become more rare, and more likely to become extinct, their ranges contract and core populations are the last to persist. This then has led to the belief that these core populations should be considered more highly in conservation prioritizations. However, in a review of the ranges of 245 various species, Channell and Lomolino (2000) found that 98% of species retained populations in at least part of the periphery of their range. These populations have been found to be particularily important for conservation of endangered wildlife (Channell and Lomolino 2000) and these peripheral Canadian populations may aid U.S. populations in their survival (Kerr and Deguise 2004). If so, the more northern populations may have equal or possibly more important ecological implications that have not been considered, as they were previously thought to be seemingly less important than the core of the population. Within this range there is also varying distribution. Recent research has shown that species distributions may not follow the Gaussian or normal distribution (McGill 2005; Murphy and Lovett-Doust 2005). This adds supports to the notion that populations occurring at the edge of their distribution may be more important ecologically than thought of previously. Already these peripheral populations have been important for research into global climate change whereby Canadian butterflies have been utilized as a test case for demonstrating effects of climate change on species distributions (Kerr 2001).

It should also be recognized that these more southerly parts of Canada, such as southern provinces (i.e., Ontario) contain more diverse ecoregions. According to the overall index of Ricketts et al. (1999b) Ecoregion 10, surrounding the lower Great Lakes, including parts of Michigan, Indiana, Ohio, Pennsylvania, New York, and Ontario, is the most biodiverse ecoregion in Canada. Looking at the number of butterfly species present within ecoregions, ecoregion #10 is 35th out of 110 ecoregions in North America and has the fourth highest number of butterfly species for ecoregions wholly or partly within Canada (Rickett's et al. 1999b). Ecoregions 58 (187 butterflies), 56 (160 butterflies), and 57 (157 species) have the highest number of species of butterflies in Canada. These three ecoregions cross the Canadian/ U.S border into the southern one-third of Alberta (#57), Alberta and Saskatchewan (#58) and Alberta, Saskatchewan, and Manitoba (#56).

Further to this, Kerr and Deguise (2004) found many of the rare species in southern Ontario are also threatened in the northern states of the U.S. Kerr and Deguise (2004) used the COSEWIC assessed species to provide the list of threatened species and this does not provide a complete representation of rare species in Canada. As a result only seven lepidopterans were included in this analysis. However, some general conclusions can be made from their research. It is also not possible to perform a comparison when considering the butterflies (and skippers) listed on the U.S. Endangered Species list as those listed that are found in both U.S. and Canada are sub-species. These cannot be compared directly to the current research which includes only species. A better comparison would be to utilize NatureServe data for all the North American species and this data is currently not compiled. However, there is one example, the Karner Blue butterfly (*Lycaeides melissa samuelis* [Lycaenidae]), which suggests that species that are rare in Canada may also be rare in the U.S. This sub-species is listed in Canada as extirpated, and is listed as "endangered in the entire range" under the U.S. Endangered Species Act (US Fish and Wildlife Service 2005). This includes all seven of the eight Great Lakes states (OH, IL, IN, NY, WI, MI, not in PA) where it is known to occur. The Karner Blue is currently ranked by NatureServe as S1 in MN, WI, IN, NY, MI, NH, and as extirpated from IL, OH, ON, PA, and MA (NatureServe 2006*a*). All of the group Dp species appear to be at the northern part of their range, however, as they are globally phylo-rare these populations become priorities for conservation.

Niche breadth

Because of the coevolution of butterflies and plants, niche breadth, the extent of a species niche, has been utilized for demonstration of relationships between life history characteristics (Thompson 1998; Komomen et al., 2004). Larval and adult food choices have been used to categorize niche breadth for butterflies as specialists (monophagous) or generalists (polyphagous) (Brown 1984: 1995).

Specialists have a confined niche breadth whereas generalists have broader niche parameters. As such, specialists should be rare because the conditions necessary to sustain them will be widely separated and thinly spread in nature (Brown 1984; 1995). In contrast, generalists should be widespread and abundant because of the environmental flexibility that generalization entails (Brown 1984; 1995). Brown proposed that as a result we should see high degrees of commonness and rarity whereby the distribution of rare and common species would be in a bimodal pattern. Yu and Dobson (2000) found this pattern amongst populations of mammals. In general, butterflies that feed on more widely distributed hosts are more widely distributed; however, this relationship breaks down (Quinn et al. 1998). This distribution of species, for butterflies occurring in Canada, does not adhere to this distribution either geographically (Fig. 3) nor phylogenetically (Fig 1). The distribution of rare and common species both globally and regionally does also not suggest a bimodal pattern (Fig. 6). A bimodal pattern is also not seen when global phylo- and geo-rarity and commonness are combined (Fig. 7).

Monophagy/Polyphagy

It has been theorized that butterflies originated 60-70 million years ago with major diversification of butterflies linked to the co-evolution with flowering plants (Vane-wright 2004). Vane-wright (2004) explains that for some reason species becomes locked with their sole host plant and are then forced to co-evolve with it. Erhlich and Raven (1964) were the first to examine coevolution of plants and herbivorous butterflies. They argued that related butterflies tend to feed on related groups of plants. They outlined a pattern whereby plants evolve defenses against natural enemies, such as herbivorous butterfly larvae. Eventually some of these enemies evolve the cabability to overcome this new defense providing an opportunity for these enemies to rapidly diversify. This research pre-dated abilities to distinguish the phylogenetic relationships of the study plants or butterflies. Later Janz and Nylin (1998) observed the coevolution of butterflies and plants using phylogenetically-derived relationships. They concurred with Erhlich and Raven (1964) that related butterflies do tend to feed on related plants and that host shifts to different species of plants have been to more closely related plants than between more distantly related plants (Janz and Nylin 1998). Koh et al. (2004) demonstrated a strong relationship (r^2= 0.984) between the extinction of butterflies and the decline and extinction of species of vascular plants recorded as potential host plants. For the Canadian butterflies, a relationship exists between geographical rarity and monophagy whereby more globally geo-rarity species are more likely to be monophagous. This relationship is likely related to aspects of geo- and phylo-rarity of the host plant. It is plausible that the rarity of some host plants would contribute to the geo-rarity of some species. Likewise the phylo-rarity of plants may contribute to the phylo-rarity of some butterfly species. The current results indicate a relationship between between phylo-rarity and incidence of monophagy whereby species belonging to sub-families with fewer species are more likely to be monophagous (Fig. 8). The linear pattern exhibited in Fig. 8 is the result of an indicator variable used for occurence of either monophagy or polyphagy. However, caution must be exercised when applying this variable across sub-families. Firstly, the current information is specific only to Canadian members of the sub-families, not comprehensive within sub-families. Secondly, a monophagous species, one which feeds on only one species of larval host plant, would be considered a specialist. Specialists would likely experience greater extinction pressure. In order to apply this variable it would be necessary to have historic information on extinction patterns over long periods of time. Information regarding phylo- and geo-rarity patterns of host plants would provide a rich area for further research. Relation of phylo-rare and geo-rare patterns of host plants within rare or threatened habitats may also reveal importance for classifying species as more threatened. Many of the geo-rare species utilize rare or threatened habitats such as salt marshes or tallgrass prairie. Including an aspect of rarity based on rare habitat may be one approach toward better discriminating more threatened species.

Speciation

Brown (1984) found an absence of trade-offs between the generalist and the specialist species and described how this suggests a wide distribution of evolutionary success among species. This success is analogous to fitness of individuals whereby generalists should be generally abundant, widespread and more successful than rare, restricted ones. If rare species are more prone to extinction then Brown (1984) questioned where their descendants were originating. He concluded that generalists, being more widespread and abundant, were continuously expanding into new populations through allopatric speciation. The current data supports this relationship whereby speciation is lower amongst more geographically rare species (Fig. 8).

Hodgson (1993) typified common butterflies in Britain as belonging to one of two groups. The first common group is multi-voltine, polyphagous, utilizing larval plants from disturbed habitats and having a short-lived adult. The second group of common butterflies is univoltine, monophagous, have a short-lived adult, and the larvae exploit species of food plants of undisturbed sites. In contrast, the rarest butterflies tend to be the largest or smallest species, occur in ‘closed’ populations (regionally geo-rare), are univoltine, exploit larval host plants of unproductive habitats, and produce long-lived larvae which typically feed on only one species or genus of food plant (Hodgson 1993).

The current data suggests that geo-common butterflies would be polyphagous and have many sub-species. The phylo-common species would be smaller in body size as the larger representatives within sub-families are appearing in the matrix at a higher group level than smaller representatives.

Regional priorities

By reapplying the matrix using S ranks for species within British Columbia, Ontario, Manitoba, and New Brunswick, the priorities for conservation within each province are identified (Tables 14a to d). These higher or lower S ranks within each of these provinces then identify corresponding priorities within the A to I groups specific to each province. This provides the opportunity for managers to target those species for conservation at a regional level. Decisions made at a regional level will ultimately lead to conservation of the species. Tracking of species at a regional level is important not only for overall conservation of the species but has also shown to be important for other research such as climate change (Parmesan 2003).

Higher taxon richness – field application

Higher taxon richness has been shown to be a good surrogate for species richness when assessing sites for biodiversity (Gaston 2000). Site assessment at the level of species is costly, time-consuming, and often incomplete (Gaston 2000). Site assessment can be carried out at a higher taxonomic level providing opportunity for easier and quicker field identification, quicker assessments, and overall cost savings. Gaston (2000) rationalizes this approach using the following arguments: fewer higher taxa will need to be counted for an assessment; it is easier to identify higher taxa; the disproportionate numbers of species within higher taxa will not require disproportionate time in assessment to the level of species; and higher taxa are already known in many areas. This approach is based on the assumption of a positive correlation between species numbers and higher taxa. Using a different taxonomy, Williams and Gaston (1994) demonstrated that family richness was a good predictor of species richness in butterflies. The current method, then, has practical field application for site comparison since censuses can be completed very quickly and it is then easily determined which of the sub-families are the most phylo- and geo-rare, and should be the priorities at a particular site.

COSEWIC

There is one plausible explanation for why the COSEWIC assessed and candidate species are not similar to the geo-rare species. This likely extends from the formerly ad-hoc prioritization and assessment process carried out by COSEWIC.

Protection of critical habitat is an element of weakness in the Canadian SARA legislation whereby protection is currently only automatically afforded on federal lands (SARA 2005). As well, federally-protected lands are concentrated in northern regions where very few COSEWIC-ranked endangered species occur (Kerr & Cihlar 2004; Warman et al. 2004). According to Kerr & Cihlar (2004) among the eleven watersheds across Canada with ≥25 endangered species, there exists only ~44km^2 or 0.14% total protected areas. These higher densities of COSEWIC-ranked endangered species were found primarily in southern Canada (southern Vancouver Island, southern British Columbia, southwestern prairies and southern Ontario). Habitat loss and variation in numbers of endangered species across Canada are highly correlated (Kerr and Deguise 2004). This lack of protected lands in southern areas of Canada is impacting any hopes of recovery for a number of endangered Canadian species.

Research involving only COSEWIC-assessed species will provide an incomplete picture of the real rarity of Canadian species. Other authors have cautioned against utilizing threatened species lists beyond their intention (Possingham et al. 2002; De Grammont and Cuarón 2006) yet COSEWIC assessed species lists continue to be utilized in research involving rare species (Kerr and Cihlar 2004; Warman et al., 2004; Deguise and Kerr 2006). One must also be cognizant of that the listing of species may be specific to populations within certain areas as this is not always obvious in the information provided by COSEWIC on listed species. This current priority list provides a more complete picture of species rarity in Canada and should be utilized for research or management goals toward preserving biodiversity in Canada.

Next steps

The logical next steps for this work are the development of a means to test if the current approach is indeed prioritizing species in their rightful prioritization. It not possible to compare the current list with that of COSEWIC until their method for determining candidates is applied to all species. It is also not possible to compare the current list with identified priorities for phylo-rarity until a global phylogeny is developed. The current method could then be compared to the node-based or branch length approaches (May 1990; Vane-wright et al., 1991; Faith 1992;

Crozier 1992). Cross-validation of the life history traits indicated that 64.2% of cases were correctly classified (Appendix I). This value, while acceptable, may be the result of the life history traits which are available for the correlation. Results indicate that groups 1 (globally geo- and phylo-rare) and 2 (globally geo-rare and phylo-common) were predicting poorly. This may be due to the low numbers of species that fell within these groups (n=4 and 11, respectively). In contrast groups 3 (phylo-rare and geo-common) (n=81) and 4 (phylo- and geo-common) (n=136) were predicting well. The increase in percentage of cases that were correctly classified when the cross-validation was re-run, omitting either one (69.3%) or both groups one and two (79.3%), suggest that a lack of points in these categories may be influencing the results. Although this may be a reflection of the greater numbers of species within these two groups, it may also be indicative of the ability to predict that common species, especially geo-common species, are indeed common.

The phylo-rarity of a sub-family of butterflies may be due to many environmental and life history factors such as as voltinism, number of eggs laid, duration of flight (breeding time) and dispersal ability. Identifying additional life history traits which contribute to differential extinction would further delineate species which should be considered priorities for conservation. Unfortunately, much of the information on the basic biology of many species is unknown. As well, the paucity of fossils of Lepitoperans does not provide comprehensive information for determining accurate extinction rates over time specific to each sub-family.

A comparison of the rare Canadian species in relation to other countries may provide the ability to refine the phylo-rarity division between rare and common. Canada has many representative species from sub-families with a mid-range number of representatives. This may in part be due to the larger number of sub-families with a mid-range of species or it may be specific to climatic or geographic factors specific to Canada. Further exploration into other life history aspects such as observed range sizes and extent, and relation of these factors to either geo- or phylo-rarity will provide on-going insight into the causes and consequences of differential extinction pressures for butterflies.

With any study utilizing a current biological inventory there must be recognition that the current knowledge of species remains inadequate. The government of Canada acknowledges gross gaps in knowledge of Canada's biological inventory (EC, 2000). Of the 71,000 identified species, Canadian scientists predict another 68,000 are undiscovered and unclassified (EC, 2000). Further, the ecological role and extinction probability is known for less than 3 percent of the recorded species (EC, 2000). Prioritizing the known 71,000 species seems a daunting task; however, the proposed method can provide time-saving, objective surrogates toward prioritizing species for preservation.

Phylo-rarity ranks could also be utilized to address The Convention on Biological Diversity's 2010 Target third goal to promote the conservation of genetic diversity by providing a quantitative measure of phylo-rarity (Convention on Biological Diversity 2005). Recognizing this weakness in the identification of the earth's biodiversity, Balmford et al. (2005) recommended utilizing indicators of biodiversity to ensure some meaningful contribution toward the 2010 target. The Canadian government is in a good position to utilize butterflies as indicators of Canadian biodiversity. Butterflies are the most well studied of invertebrates (Layberry et al. 1998) and have been proposed as good indicators of other invertebrate declines (Thomas et al., 2004).

SUMMARY

Most estimates of biological rarity utilize ranked values describing geographic distribution and abundance. In the standard five point ranking scheme that is most widely used (e.g., Master 1991), scores of 1-3 are defined as “rare” and scores of 4-5 as “common”. No national jurisdictions and few non-governmental organizations include estimates of evolutionary rarity in prioritizing species for conservation purposes. Here I argue that estimates of evolutionary rarity are important adjuncts to traditional parameters of biological rarity, namely the distribution and abundance of organisms. I present a simple, taxonomic-based method for estimating evolutionary, or phylogenetic-rarity, and use species richness at the sub-family level to examine this for the two superfamilies of Lepidoptera: the Hesperioidea and Papilionoidea. Species numbers per sub-family were natural log transformed and the resultant z-scores used to separate sub-families into five categories, analagous to the five point ranking scheme for distribution and abundance. The separation into phylo-rare and phylo-common was validated using sub-family upper wingspan, a variable indicative of increased extinction pressures. Measures of phylo-rarity were combined with estimates of geographic distribution and abundance (‘geo-rarity’) for the Canadian butterflies (N=293 species), using widely available, standarized ranked values of global and regional rarity, as used by many federal and provincial authorities.

The prioritization model utilized all combinations of global geo-rarity, global phylo-rarity, regional geo-rarity, and regional phylo-rarity. Global rarity was regarded as having in principle, greater conservation priority than regional rarity, though phylo- and geo-abundances were weighted co-equally. Three prioritization categories were identified for geographical and phylogenetic abundance, at the global scale: rare in both categories, rare in one group, or

common in both categories. Similarily, three regional categories were identified for each group of global geo- and phylo-abundance: regionally rare in both categories, rare in one regional group, or common in both regional categories. Thus nine prioritization groups (A to I) were identified beginning with species rare in all four categories, group A (i.e., geo- and phylo-rare globally, and regionally geo- and phylo-rare); followed by group B species which are globally geo- and phylo-rare but common in one of the two regional categories; then (C) those species that were geo- and phylo-rare globally, but common in both regional categories; then (D) species common in one of the two global categories but rare in both regional contexts; then (E) species that were rare in one global and one regional group and common in the other; then (F) species rare in one global group and common in the other three categories; then (G) species that were common in both global categories and rare in both regional categories; then (H) species common in both global categories and rare in one regional group; and finally (I) species common in all four categories.

Results indicate that *Papilio brevicauda* (Papilionidae) is Canada's highest priority for conservation (Group A, above) followed by *Euphydryas gillettii* (Nymphalidae), *Erynnis martialis* (Pyrginae), and *Boloria alberta* (Nymphalidae), in the B group. No group C species are found in Canada. Regionally, in Ontario, British Columbia, Manitoba, and Alberta >90% of all species are globally geo-common. Patterns of regional geo-abundance were more variable with Ontario, British Columbia, and Manitoba all having a majority of regionally-common species (66.4-87.5% of species), while the preponderance of species in Alberta (97.6%) were regionally geo-rare. The Maritime ringlet (*Coenonympha nipisiquit* [Nymphalidae]) is the most geo-rare butterfly in Canada (G1), with a further nineteen species ranked G2-G3G4. The majority of species found in British Columbia, Ontario, Manitoba, and New Brunswick are globally phylo-common. The American snout (*Libytheana carinenta*), a breeding migrant, occurs as the most phylogenetically-rare butterfly, having a global phylo-rarity rank of P_G2. Another 103 species are ranked P_G3.

Using the recent Canadian Species at Risk legislation as a base, I developed for the butterflies a list of the highest priorities for conservation. Within the six highest categories, of the nine categories for prioritization, above, 98 species of Canadian butterflies should be considered top priorities for conservation incrementally (categories A to F).

The first of two discriminant functions was dominated by wingspan (increasing) dominates the discriminant function of global phylo-rarity. A second discriminant function was dominated by monophagy (presence) and to a lesser extent by sub-species number (decreasing) allowing for the discrimination of global geo-rarity. Cross-validation of these functions revealed that 64.2% of the groupings were well predicted.

Empirical patterns of phylo- and geo-rarity were compared with current recommendations and prioritizations of COSEWIC (Committee on the Status of Endangered Wildlife in Canada), responsible for conservation recommendations. Only 5 of the 98 highest priority butterflies have been evaluated by COSEWIC and afforded protection under the Species At Risk Act (SARA 2005).

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Table 1. Representative lists for priority-ranking of species for conservation, and whether they incorporate extinction susceptibility including phylogenetic or taxonomic rarity as criterion.

Rank list	Domain	Extinction susceptibility?	Phylogenetic or taxonomic rarity component?	Reference
IUCN Red List	International	Yes	No	IUCN 2001
COSEWIC	Canada	Yes	No	COSEWIC 2003
NatureServe	North America	Yes	No	NatureServe 2006c
Environmental Conservation and Biodiversity Act	Australia	Yes	No	Australian Government 2005
U.S. Fish and Wildlife Service	United States	Yes	Yes	USFWS, 2005

Table 2: Global ("G") ranking system for species (from NatureServe 2006*b*) and sub-national ("S") ranking system for Ontario species (NHIC 2005). Occurrences are regarded as populations.

Rank	Rarity Description	Number of Occurrences
G1	Critically imperiled globally – at very high risk of extinction due to extreme rarity, very steep declines, or other factors	Often 5 or fewer
G2	Imperiled globally – at high risk of extinction due to very restricted range, very few populations, steep declines, or other factors.	Often 6 to 20
G3	Vulnerable – at moderate risk of extinction due to a restricted range, relatively few populations, recent and widespread declines, or other factors.	Often 80 or fewer
G4	Apparently secure – not rare; apparently secure, but with cause for long-term concern.	
G5	Secure – demonstrably widespread, abundant, and secure.	
S1	Extremely rare in Ontario; often especially vulnerable to extirpation	Usually 5 or fewer in the province; or very few remaining individuals
S2	Very rare in Ontario; often susceptible to extirpation.	Usually between 5 and 20 in the province or with many individuals in fewer occurrences.
S3	Rare to uncommon in Ontario; may be susceptible to large-scale disturbances. Most S3 species are assigned to the watch list, unless they have a relatively high global rank.	Usually between 20 and 100 in the province; may have fewer; but with a large number of individuals in some populations.
S4	Common and apparently secure in Ontario.	Usually with >100 in the province
S5	Very common and demonstrably secure in Ontario.	
SAN	Non-breeding accidental.	
SZB	Breeding migrants/vagrants.	
SZN	Non-breeding migrants/vagrants.	

Table 3. Butterflies in the world and Canada and estimates of species numbers within subfamilies (following Ackery et al. 1999). P_G is the global phylogenetic rarity rank (1-5) and Ps is the regional (within province) phylogenetic rarity for species occurring in Canada.

Super-family	Family	Sub-family	No. of species globally	No. of species in Canada	P_G	Ps
Hesperioidea	Hesperiidae	Coeliadinae	75	0	3	-
		Pyrrhopyginae	150	0	3	-
		Pyrginae	1000	13	3	3
		Heteropterinae	150	1	3	1
		Trapezitinae	60	0	3	-
		Hesperiinae	2000	56	5	5
		Total	3435	69		
Papilionoidea	Papilionidae	Baroniinae	1	0	1	-
		Parnassiinae	54-76[a]	4	3	2
		Papilioninae	550	14	3	3
		Total	627	18		
	Pieridae	Pseudopontiinae	1	0	1	-
		Dismorphiinae	100	0	3	-
		Pierinae	700	17	4	4
		Coliadinae	250	22	3	4
		Total	1051	39		
	Lycaenidae	Riodininae	1250	1	4	1
		Poritiinae	530	0	4	-
		Miletinae	150	1	3	1

		Curetinae	18	0	2	-
		Lycaeninae	4000	63	5	5
		Total	5948	65		
	Nymphalidae	Libytheinae	12	1	2	1
		Heliconiinae	400	43	3	4
		Nymphalinae	350	16	3	4
		Limenitidinae	1000	4	4	2
		Charaxinae	400	0	3	-
		Apaturinae	430	2	3	2
		Morphinae	230	0	3	-
		Satyrinae	2400	34	5	4
		Calinaginae	8	0	2	-
		Danainae	450	1	3	1
		Total	5680	101		
Total			13306			
Total			16741	293		

[a] Ackery et al. (1999), give the number of species in the Parnassiinae as 54-76; I used 76 for calculations.

Table 4. The number of taxa assessed, by COSEWIC group, in 2005 (modified from COSEWIC 2005b). Totals are all taxa assessed to May 2005. Numbers are species (where species as defined by COSEWIC includes subspecies, variety, or geographically or genetically distinct population of wild fauna and flora).

TAXON	EXTINCT	EXTIRPATED	ENDANGERED	THREATENED	SPECIAL CONCERN	TOTAL	NOT AT RISK	DATA DEFICIENT	GRAND TOTAL
Mammals	2	4	18	17	28	**69**	43	10	**122**
Birds	3	2	24	10	22	**61**	35	2	**98**
Reptiles	0	4	8	13	9	**34**	4	2	**40**
Amphibians	0	1	6	5	7	**19**	14	0	**33**
Fishes	6	3	26	24	36	**95**	34	12	**141**
Arthropods	0	3	8	6	2	**19**	0	1	**20**
Molluscs	1	2	12	2	4	**21**	2	4	**27**
Vascular Plants	0	2	74	48	35	**159**	16	4	**179**
Mosses	1	1	6	3	4	**15**	0	1	**16**
Lichens	0	0	2	1	5	**8**	0	3	**11**
Totals	**13**	**22**	**184**	**129**	**152**	**500**	**148**	**39**	**687**

Table 5. Butterflies assessed and designated in a COSEWIC risk category (Extirpated, Endangered, Threatened, or Special Concern) (COSEWIC 2005a).

COSEWIC Category	**Species or Sub-species**	**G**	**P_G**
Extirpated	*Lycaeides melissa samuelis* (Karner Blue)	5T*	5
	Callophrys irus (Frosted Elfin)	2	5
	Euchloe ausonides (Large Marble)	5	4
Endangered	*Plebejus saepiolus insulanus* (Greenish Blue)	5	5
	Euphydryas editha taylori (Edith's Checkerspot)	5T	4
	Apodemia mormo (Mormon Metalmark) – Southern mountain population	5	4
	Coenonympha nipisiquit (Maritime Ringlet)	1	5
	Hesperia ottoe (Ottoe Skipper)	3	5
Threatened	*Satyrium behrii columbia* (Behr's Hairstreak)	5T	5
	Apodemia mormo (Mormon Metalmark) – Prairie population	5	4
	Hesperia dacotae (Dakota Skipper)	2-3	5
	Euphyes vestris (Dun Skipper) – Western population	5	5
	Oarisma poweshiek (Poweshiek Skipperling)	2-3	5
Special Concern	*Danaus plexippus* (Monarch)	4	3
	Limenitis weidemeyerii (Weidemeyer's Admiral)	5	4

* Note that G ranks are assigned to the species. Subspecies are designated with a T.

Table 6. COSEWIC's priority candidate list for status evaluation (COSEWIC 2005a), and global geo-rarity and phylo-rarity values. Taxonomy has been adjusted to Layberry et al. (1998) for scientific names and Ackery et al. (1999) for sub-families.

Sub-family	Scientific Name	Common Name	Province/ Territory	G-Rank	P_G-Rank	P_S-Rank
	Group 1 - High priority candidates					
Pyrginae	*Erynnis martialis*	Mottled Duskywing	MB, ON	G3G4	4	3
Heliconiinae	*Speyeria mormonia erinna*	Mormon Fritillary	BC	G5TNR	3	4
	Megathymus streckeri[1]	Strecker's Giant Skipper	AB	G5		
	Group 2 - Mid priority candidates					
Nymphalinae	*Euphydryas chalcedona anicia*		AB, SK	G5T5	3	4
Nymphalinae	*Euphydryas editha hutchinsi*	Edith's Checkerspot	AB, SK	G5TNR[3]	3	4
	Group 3 - Low priority candidates					
Lycaeninae	*Callophrys mossii mossii*	Moss's Elfin	BC	G4T4	5	5
Nymphalinae	*Chlosyne hoffmanni*	Hoffmann's Checkerspot	BC	G4	3	4
Lycaeninae	*Everes comyntas*	Eastern Tailed Blue	BC	G5	5	5
Lycaeninae	*Erora laeta*	Early Hairstreak	ON, QC, NB, NS	G3G4	5	5
Hesperiinae	*Erynnis propertius*	Propertius Duskywing	BC	G5	5	5
Lycaeninae	*Euphilotes ancilla*	Rocky Mountain Dotted Blue	AB, SK	G5	5	5
Lycaeninae	*Icaricia icarioides*	Blackmore's Blue	BC	G5T3	5	5
Lycaeninae	*Callophrys johnsoni*	Johnson's Hairstreak	BC	G3G4	5	5
Lycaeninae	*Lycaena dione*	Grey Copper	BC, AB	G5	5	5
Hesperiinae	*Polites sabuleti*	Sandhill Skipper	BC	G5	5	5
Heliconiinae	*Speyeria zerene*[2]	Great Basin Fritillary	AB	G5	3	4
Heliconiinae	*Speyeria zerene bremnerii*		BC	G45TNR	3	4

[1]*Megathymus streckeri* is not listed by the Alberta Conservation Data Centre, NatureServe 2006*a* or by Layberry et al. (1998) as occurring in Canada.
[2]*Speyeria egleis* is included under *Speyeria zerene* by Layberry et al. (1998).
[3]TNR designates a subspecies not yet ranked by NatureServe (2005*a*).

Table 7. Summary of sub-national (S) and global (G) geo-rarity and sub-nationally (P_S) and globally (P_G) phylo-rarity ranks for Canadian butterflies. S and G values are from provincial natural heritage information centres (e.g. NHIC 2005 in Ontario), and NatureServe (2005d), respectively.

Region	S 1-3	% S 1-3 of total no.	S4-5	% S 4-5	Total no.
BC	40	24.8	121	75.2	161
ON	42	33.3	84	66.7	126
MN	15	12.5	106	87.5	119
NB	21	40.4	31	59.6	52
Region	**G 1-3**	**% G 1-3 of total no.**	**G4-5**	**% G 4-5**	**Total no.**
BC	4	2.5	156	97.5	160*
ON	5	4.0	121	96.0	126
MN	3	2.5	116	97.5	117*
NB	4	7.7	48	92.3	52
Region	**P_S 1-3**	**% P_S 1-3 of total no.**	**P_S 4-5**	**% P_S 4-5**	**Total no.**
BC	21	13.0	140	87.0	161
ON	42	33.3	84	66.7	126
MB	16	13.4	103	86.6	119
NB	7	13.5	45	86.5	52
Region	**P_G 1-3**	**% P_G 1-3 of total no.**	**P_G 4-5**	**% P_G 4-5**	**Total no.**
BC	61	37.9	100	62.1	161
ON	21	16.7	105	83.3	126
MB	44	37.0	75	63	119
NB	21	40.4	31	59.6	52

* two species found only in Manitoba and one species found only in British Columbia do not have a G ranks.

Table 8a. The matrix prioritization model. For each of the four regions (British Columbia, Ontario, Manitoba, and New Brunswick) the S-Geo represents the regional S-rank. For determining Canadian global priorities, the value for S-Geo is the highest S-rank available across Canada.

Group	G-Geo	G-Phylo	S-Geo	S-Phylo	
A	Rare	Rare	Rare	Rare	Highest priority
B	Rare	Rare	Rare	Common	
B	Rare	Rare	Common	Rare	
C	Rare	Rare	Common	Common	
D_G	Rare	Common	Rare	Rare	
D_P	Common	Rare	Rare	Rare	
E_G	Rare	Common	Rare	Common	
E_G	Rare	Common	Common	Rare	
E_P	Common	Rare	Rare	Common	
E_P	Common	Rare	Common	Rare	
F_G	Rare	Common	Common	Common	
F_P	Common	Rare	Common	Common	
G	Common	Common	Rare	Rare	
H	Common	Common	Rare	Common	
H	Common	Common	Common	Rare	
I	Common	Common	Common	Common	Lowest priority

Table 8b. From 7 to 11 forms of rarity. The various categories of global and regional phylo- and geo-abundance organized into groups A to I. Subscripts denote either global geo- or phylo-rarity.

		Global geographical abundance					
		Common			*Rare*		
Global phylo-abundance	*Common*	I	H	G	F_G	E_G	D_G
	Rare	F_P	E_P	D_P	C	B	A
		Both geo & phylo common	*Either geo or phylo rare*	*Both geo & phylo rare*	*Both geo & phylo common*	*Either geo or phylo rare*	*Both geo & phylo rare*
		Regional geographical rarity					

Table 9. Summary of globally phylo-rare (P_G1-3) Canadian butterfly species, listed by P_G-ranks.

Sub-Family	Scientific Name	P_G	P_S	G-rank	S-rank Ontario	S-rank Québec *	S-rank BC	S-rank Manitoba	S-rank Alberta	S-rank Saskatch-ewan	S-rank Nova Scotia	S-rank Labrador	S-rank New Brunswick	S-rank New-found-land	COSEWIC
Libytheinae	*Libytheana carinenta*	2	1	G5	SZB										
Danainae	*Danaus plexippus*	3	1	G4	S4		S3B, SZN	S5		S3B			S2B	S2B	SC
Miletinae	*Feniseca tarquinius*	3	1	G4	S4			S4					S4		
Heteropterinae	*Carterocephalus palaemon*	3	1	G5	S5		S5	S4S5			S5	S4	S5	S4?	
Parnassiinae	*Parnassius eversmanni*	3	2	G5			S4?								
Parnassiinae	*Parnassius clodius*	3	2	G5			S5		S1						
Parnassiinae	*Parnassius phoebus*	3	2	G5			S3S4								
Parnassiinae	*Parnassius smintheus*	3	2	G5			S5								
Apaturinae	*Asterocampa clyton*	3	2	G5	S2S3	S2									
Apaturinae	*Asterocampa celtis*	3	2	G5	S2	S3		SR							
Papilioninae	*Papilio brevicauda*	3	3	G3G4		S3						S?			
Papilioninae	*Papilio zelicaon*	3	3	G5			S5			S3					

Papilioninae	*Papilio indra*	3	3	G5			S2							
Papilioninae	*Papilio rutulus*	3	3	G5			S5							
Papilioninae	*Papilio eurymedon*	3	3	G5			S5		S2					
Papilioninae	*Papilio multicaudatus*	3	3	G5			S4?		S1	S1				
Papilioninae	*Papilio canadensis*	3	3	G5	S5		S5						S5	S5
Papilioninae	*Battus philenor*	3	3	G5	SZB			SA						
Papilioninae	*Eurytides marcellus*	3	3	G5	SZB									
Papilioninae	*Papilio polyxenes*	3	3	G5	S5			S5						
Papilioninae	*Papilio machaon*	3	3	G5	S2S3		S4?	S5						
Papilioninae	*Papilio cresphontes*	3	3	G5	S2			SA						
Papilioninae	*Papilio glaucus*	3	3	G5	S4S5			S5						
Papilioninae	*Papilio troilus*	3	3	G5	S4									
Nymphalinae	*Euphydryas gillettii*	3	4	G2G3			S2S3		S2					
Heliconiinae	*Boloria alberta*	3	4	G3			S3							
Heliconiinae	*Speyeria idalia*	3	4	G3	SAN			SA						
Coliadinae	*Colias occidentalis*	3	4	G3G4			S3S4							

Pierinae	*Pieris virginiensis*	3	4	G3G4	S3	S3							
Nymphalinae	*Chlosyne hoffmanni*	3	4	G4			S2S3						
Nymphalinae	*Euphydryas phaeton*	3	4	G4	S4			S1				S4	
Nymphalinae	*Phyciodes batesii*	3	4	G4	S4	S4	S3	S4S5					
Nymphalinae	*Chlosyne harrisii*	3	4	G4	S4			S5				S4	
Pierinae	*Pontia protodice*	3	4	G4	SZB		SAB	S4	SZB	S1			
Coliadinae	*Colias meadii*	3	4	G4G5			S3						
Coliadinae	*Colias canadensis*	3	4	G4G5			S4S5						
Heliconiinae	*Speyeria hydaspe*	3	4	G4G5			S4S5			S1			
Nymphalinae	*Chlosyne acastus*	3	4	G4G5					S2				
Nymphalinae	*Chlosyne damoetas*	3	4	G4G5			S4						
Pierinae	*Euchloe olympia*	3	4	G4G5	S4?	S4		S1	S2S3				
Pierinae	*Pieris oleracea*	3	4	G4G5	S4		S4S5	S5			S?	S4	S2S3
Pierinae	*Euchloe lotta*	3	4	G4G5			S4						
Coliadinae	*Colias alexandra*	3	4	G5			S5	S5					
Coliadinae	*Colias christina*	3	4	G5			S5						

Coliadinae	*Colias hecla*	3	4	G5	S3	S5		S?			
Coliadinae	*Colias nastes*	3	4	G5	S5	S5		S?			
Heliconiinae	*Boloria napaea*	3	4	G5	S4		S2				
Heliconiinae	*Boloria improba*	3	4	G5	S4		S2				
Heliconiinae	*Boloria epithore*	3	4	G5	S5		S2				
Heliconiinae	*Boloria polaris*	3	4	G5	S4	S5		S2S3			
Heliconiinae	*Boloria astarte*	3	4	G5			S2				
Heliconiinae	*Phyciodes cocyta*	3	4	G5	S5			S?	S5	S5	
Heliconiinae	*Speyeria zerene*	3	4	G5	S5		S1				
Heliconiinae	*Speyeria callippe*	3	4	G5	S5	S4					
Heliconiinae	*Speyeria hesperis*	3	4	G5	S5	S5					
Heliconiinae	*Speyeria mormonia*	3	4	G5	S5	S3S4					
Nymphalinae	*Euphydryas chalcedona*	3	4	G5	S5	SH					
Nymphalinae	*Euphydryas editha*	3	4	G5	S5						
Nymphalinae	*Phyciodes pratensis*	3	4	G5	S5						
Nymphalinae	*Phyciodes pallidus*	3	4	G5	S4						
Nymphalinae	*Phyciodes mylitta*	3	4	G5	S5						
Nymphalinae	*Chlosyne palla*	3	4	G5			S3S4				

Nymphalinae	*Nymphalis californica*	3	4	G5			S4B,S ZN	SA						
Nymphalinae	*Polygonia oreas*	3	4	G5			S4		S2					
Coliadinae	*Colias palaeno*	3	4	G5	S4?			S5	S1S2			S?		
Coliadinae	*Colias philodice*	3	4	G5	S5		S5	S5					S5	S4
Coliadinae	*Colias eurytheme*	3	4	G5	S5		SZB	S5					SZB	S3B
Coliadinae	*Colias pelidne*	3	4	G5	S4?							S?		S3S4
Coliadinae	*Colias interior*	3	4	G5	S5		S5	S5				S?	S5	S5
Coliadinae	*Nathalis iole*	3	4	G5	SAN			SA						
Coliadinae	*Eurema nicippe*	3	4	G5	SAN									
Coliadinae	*Eurema lisa*	3	4	G5	SZB	S5		SR			SA			
Coliadinae	*Eurema mexicanum*	3	4	G5	SAN			SA						
Coliadinae	*Phoebis philea*	3	4	G5	SAN									
Coliadinae	*Phoebis sennae*	3	4	G5	SAN									
Coliadinae	*Zerene cesonia*	3	4	G5	SAN									
Coliadinae	*Colias gigantea*	3	4	G5	S2?		S5	S4S5						
Heliconiinae	*Boloria selene*	3	4	G5	S5		S5	S5						

Heliconiinae	*Boloria bellona*	3	4	G5	S5		S5	S5				S4	
Heliconiinae	*Boloria chariclea*	3	4	G5	S4		S5	S5			S?		
Heliconiinae	*Boloria freija*	3	4	G5	S4		S5	S5			S3S4		S2
Heliconiinae	*Boloria frigga*	3	4	G5	S4		S5	S5			S4?		
Heliconiinae	*Phyciodes tharos*	3	4	G5	S4	S3		S5					
Heliconiinae	*Boloria eunomia*	3	4	G5	S3S4		S5	S5				S1?	
Heliconiinae	*Euptoieta claudia*	3	4	G5	SZB	S3	SA	S5				SZB	
Heliconiinae	*Speyeria atlantis*	3	4	G5	S5		S5	S5			S3?	S5	S5
Heliconiinae	*Speyeria aphrodite*	3	4	G5	S5		S5	S5				S4	
Heliconiinae	*Speyeria cybele*	3	4	G5	S5		S5	S5					
Nymphalinae	*Chlosyne nycteis*	3	4	G5	S4S5			S5					
Nymphalinae	*Polygonia comma*	3	4	G5	S5			S5		S2		S3	SU
Nymphalinae	*Polygonia interrogationis*	3	4	G5	S5			S4S5	SU	S1		SZB	SZB?
Nymphalinae	*Phyciodes pascoensis*	3	4	G5	S5			S5					
Nymphalinae	*Chlosyne gorgone*	3	4	G5	S2				S2				
Nymphalinae	*Polygonia satyrus*	3	4	G5	S3S4		S5	S5				S3	SU

Nymphalinae	*Vanessa virginiensis*	3	4	G5	S5		SAN	S5		S2		S?	S5	S3B
Nymphalinae	*Junonia coenia*	3	4	G5	SZB			SZN						SA
Nymphalinae	*Polygonia gracilis*	3	4	G5	S3		S5	S5				S?	S4	
Nymphalinae	*Polygonia progne*	3	4	G5	S5		S5	S5					S4	S3S4
Nymphalinae	*Nymphalis vaualbum*	3	4	G5	S5		S5	S5						
Nymphalinae	*Nymphalis antiopa*	3	4	G5	S5		S5	S5				S?	S5	S5
Nymphalinae	*Nymphalis milberti*	3	4	G5	S5			S5				S?	S3	S5
Nymphalinae	*Polygonia faunus*	3	4	G5	S4		S5	S5				S?	S5	S4
Nymphalinae	*Vanessa cardui*	3	4	G5	SZB		S5	S5			SA?	S?	SZB	S5B
Nymphalinae	*Vanessa annabella*	3	4	G5	SR		S?	SA		S1				
Coliadinae	*Colias johanseni*	3	4											
Coliadinae	*Colias tyche*	3	4											
Heliconiinae	*Boloria natazhati*	3	4											
Heliconiinae	*Speyeria edwardsii*	3	4											
Heliconiinae	*Euptoieta hegesia*	3	4											
Heliconiinae	*Agraulis vanillae*	3	4					SA						

* Québec S rankings are in draft form and will be confirmed following a field assessment during 2005.

Table 10. Regionally phylo-rare species (P_S1-3), listed by P_S rank in British Columbia, Ontario, Manitoba, and New Brunswick, and associated COSEWIC ranking. Taxonomy follows Layberry et al. (1998) for scientific names and Ackery et al. (1999) for sub-families.

Sub-Family	Scientific Name	Common Name	P_S	P_G	G-Rank	S-Rank B.C.	S-Rank Ontario	S-Rank Manitoba	S-Rank New Brunswick	COSEWIC
Libytheinae	*Libytheana carinenta*	American Snout	1	2	G5		SZB			
Heteropterinae	*Carterocephalus palaemon*	Arctic Skipper	1	3	G5	S5	S5	S4S5	S5	
Miletinae	*Feniseca tarquinius*	Harvester	1	3	G4		S4	S4	S4	
Danainae	*Danaus plexippus*	Monarch	1	3	G4	S3B, SZN	S4	S5	S2B	SC
Riodininae	*Apodemia mormo*	Mormon metalmark	1	4	G5	S1				END
Apaturinae	*Asterocampa clyton*	Tawny Emperor	2	3	G5		S2S3			
Limenitidinae	*Limenitis arthemis*	White Admiral	2	4	G5	S5	S5	S5	S5	
Limenitidinae	*Limenitis archippus*	Viceroy	2	4	G5	SX	S5	S5	S5	
Limenitidinae	*Limenitis weidemeyerii*	Weidemeyer's Admiral	2	4	G5		SAN			SC
Limenitidinae	*Limenitis lorquini*	Lorquin's Admiral	2	4	G5	S5				
Apaturinae	*Asterocampa celtis*	Hackberry Emperor	2	3	G5		S2	SR		
Parnassiinae	*Parnassius eversmanni*	Eversmann's Parnassian	2	3	G5	S4?				
Parnassiinae	*Parnassius clodius*	Clodius Parnassian	2	3	G5	S5				

Parnassiinae	*Parnassius phoebus*	Phoebus Parnassian	2	3	G5	S3S4			
Parnassiinae	*Parnassius smintheus*	Rocky Mountain Parnassian	2	3	G5	S5			
Papilioninae	*Papilio canadensis*	Canadian Tiger Swallowtail	3	3	G5	S5	S5		S5
Papilioninae	*Battus philenor*	Pipevine Swallowtail	3	3	G5		SZB	SA	
Papilioninae	*Eurytides marcellus*	Zebra Swallowtail	3	3	G5		SZB		
Papilioninae	*Papilio polyxenes*	Black Swallowtail	3	3	G5		S5	S5	
Papilioninae	*Papilio machaon*	Old World Swallowtail	3	3	G5	S4?	S2S3	S5	
Papilioninae	*Papilio brevicauda*	Short-tailed Swallowtail	3	3	G3G4				
Papilioninae	*Papilio zelicaon*	Anise Swallowtail	3	3	G5	S5			
Papilioninae	*Papilio cresphontes*	Giant Swallowtail	3	3	G5		S2	SA	
Papilioninae	*Papilio glaucus*	Eastern Tiger Swallowtail	3	3	G5		S4S5	S5	
Papilioninae	*Papilio troilus*	Spicebush Swallowtail	3	3	G5		S4		
Papilioninae	*Papilio indra*	Indra Swallowtail	3	3	G5	S2			
Papilioninae	*Papilio rutulus*	Western Tiger Swallowtail	3	3	G5	S5			
Papilioninae	*Papilio eurymedon*	Pale Swallowtail	3	3	G5	S5			
Papilioninae	*Papilio multicaudatus*	Two-tailed Swallowtail	3	3	G5	S4?			

Table 11. Canadian globally geo-rare species (G1-3), listed by G-rank, and associated phylo-rarity values, and any associated COSEWIC designation. Taxonomy follows Layberry et al. (1998) for scientific name and Ackery et al. (1999) for sub-family.

Sub-family	Scientific Name	Common Name	G-Rank	P_G-Rank	P_S-Rank	COSEWIC
Satyrinae	*Coenonympha nipisiquit*	Maritime Ringlet	G1	5	4	END[1]
Coliadinae	*Colias johanseni*	Johansen's Sulphur	G1G3*	3	4	
Lycaeninae	*Lycaena dospassosi*	Maritime Copper	G2	5	5	
Hesperiinae	*Oarisma poweshiek*	Poweshiek Skipperling	G2G3	5	5	THR
Melitaeinae	*Euphydryas gillettii*	Gillette's Checkerspot	G2G3	3	4	
Hesperiinae	*Hesperia dacotae*	Dakota Skipper	G2G3	5	5	THR
Argynninae	*Boloria alberta*	Alberta Fritillary	G3	3	4	
Argynninae	*Speyeria idalia*	Regal Fritillary	G3	3	4	
Heliconiinae	*Boloria natazhati*	Beringian Fritillary	G3	3	4	
Hesperiinae	*Euphyes dukesi*	Duke's Skipper	G3	5	5	
Hesperiinae	*Hesperia ottoe*	Ottoe Skipper	G3	5	5	END
Theclinae	*Callophrys irus*	Frosted Elfin	G3	5	5	EXP[2]
Papilioninae	*Papilio brevicauda*	Short-tailed Swallowtail	G3G4	3	3	
Coliadinae	*Colias occidentalis*	Western Sulphur	G3G4	3	4	
Pierinae	*Pieris virginiensis*	West Virginia White	G3G4	4	4	
Pyrginae	*Erynnis martialis*	Mottled Duskywing	G3G4	4	3	Candidate list - high priority (Jan 2005)
Satyrinae	*Oeneis rosovi*	Philip's Arctic	G3G4	5	4	
Theclinae	*Callophrys lanoraieensis*	Bog Elfin	G3G4	5	5	
Theclinae	*Erora laeta*	Early Hairstreak	G3G4	5	5	Candidate list – low priority (Jan 2006)
Lycaeninae	*Callophrys johnsoni*	Johnson's Hairstreak	G3G4	5	5	Candidate list – low priority (Aug 2005)

* currently under review by Nunavut but assigned rank by NatureServe of G1G3 (April 27, 2005)
[1]END = endangered, [2]EXP = extirpated

Table 12a. Regionally geo-rare species listed by S-rank (S1-3) in British Columbia, and associated COSEWIC ranking. Taxonomy follows Layberry et al. (1998) for scientific names and Ackery et al. (1999) for sub-families.

Sub-family	Scientific Name	Common Name	S-Rank British Columbia	P_G-Rank	P_S-Rank	G-Rank	COSEWIC
Riodininae	*Apodemia mormo*	Mormon metalmark	S1	4	1	G5	END[1]/THR[2]
Hesperiinae	*Atalopedes campestris*	Sachem	S1	5	5	G5	
Hesperiinae	*Erynnis afranius*	Afranius Duskywing	S1	5	5	G5	
Lycaeninae	*Lycaena dione*	Grey Copper	S1	5	5	G5	Candidate[3]
Hesperiinae	*Polites sonora*	Sonoran Skipper	S1	5	5	G4	
Lycaeninae	*Satyrium fuliginosum*	Sooty Hairstreak	S1	5	5	G4	
Lycaeninae	*Callophrys niphon*	Eastern Pine Elfin	S2	5	5	G5	
Papilioninae	*Papilio indra*	Indra Swallowtail	S2	3	3	G5	
Lycaeninae	*Satyrium behrii*	Behr's Hairstreak	S2	5	5	G5	THR
Nymphalinae	*Chlosyne hoffmanni*	Hoffmann's Checkerspot	S2S3	3	4	G4	Candidate
Nymphalinae	*Euphydryas gillettii*	Gillette's Checkerspot	S2S3	3	4	G2G3	
Satyrinae	*Oeneis alberta*	Alberta Arctic	S2S3	5	4	G4	
Hesperiinae	*Amblyscirtes vialis*	Common Roadside Skipper	S3	5	5	G5	
Heliconiinae	*Boloria alberta*	Alberta Fritillary	S3	3	4	G3	
Lycaeninae	*Callophrys affinis*	Western Green Hairstreak	S3	5	5	G5	
Coliadinae	*Colias hecla*	Hecla's Sulphur	S3	3	4	G5	

Coliadinae	*Colias meadii*	Mead's Sulphur	S3	3	4	G4G5	
Satyrinae	*Erebia mackinleyensis*	Mt. McKinley Alpine	S3	5	4	G4	
Satyrinae	*Erebia magdalena*	Magdalena Alpine	S3	5	4	G5	
Hesperiinae	*Erynnis propertius*	Propertius Duskywing	S3	5	5	G5	Candidate
Pierinae	*Euchloe naina*	Green Marble	S3	4	4	GU	
Hesperiinae	*Euphyes vestris*	Dun Skipper	S3	5	4	G5	THR
Lycaeninae	*Everes comyntas*	Eastern Tailed Blue	S3	5	5	G5	Candidate
Lycaeninae	*Lycaena hyllus*	Bronze Copper	S3	5	5	G5	
Lycaeninae	*Lycaena nivalis*	Lilac-bordered Copper	S3	5	5	G5	
Satyrinae	*Oeneis rosovi*	Philip's Arctic	S3	5	4	G3G4	
Satyrinae	*Oeneis uhleri*	Uhler's Arctic	S3	5	4	G5	
Nymphalinae	*Phyciodes batesii*	Tawny Crescent	S3	3	4	G4	
Pierinae	*Pieris angelika*	Arctic White	S3	4	4	G5	
Hesperiinae	*Polites draco*	Draco Skipper	S3	5	5	G5	
Hesperiinae	*Polites sabuleti*	Sandhill Skipper	S3	5	5	G5	Candidate
Pyrginae	*Pyrgus communis*	Common Checkered Skipper	S3	4	3	G5	
Lycaeninae	*Satyrium californicum*	California Hairstreak	S3	5	5	G5	
Lycaeninae	*Satyrium liparops*	Striped Hairstreak	S3	5	5	G5	

Lycaeninae	*Vacciniina optilete*	Cranberry Blue	S3	5	5	G5	
Danainae	*Danaus plexippus*	Monarch	S3B, SZN	3	1	G4	SC[4]
Coliadinae	*Colias occidentalis*	Western Sulphur	S3S4	3	4	G3G4	
Satyrinae	*Erebia discoidalis*	Red-disked Alpine	S3S4	5	4	G5	
Lycaeninae	*Glaucopsyche piasus*	Arrowhead Blue	S3S4	5	5	G5	
Parnassiinae	*Parnassius phoebus*	Phoebus Parnassian	S3S4	3	2	G5	

[1]Endangered, [2]Threatened, [3]Candidate species for review by COSEWIC, [4]Special Concern

Table 12b. Regionally geo-rare species listed by S-rank (S1-3) in Ontario, and associated COSEWIC ranking. Taxonomy follows Layberry et al. (1998) for scientific names and Ackery et al. (1999) for sub-families.

Sub-family	Scientific Name	Common Name	S-Rank Ontario	P_G-Rank	P_S-Rank	G-Rank	COSEWIC
Hesperiinae	*Atrytonopsis hianna*	Dusted Skipper	S1	5	5	G4G5	
Lycaeninae	*Callophrys lanoraieensis*	Bog Elfin	S1	5	5	G3G4	
Lycaeninae	*Erora laeta*	Early Hairstreak	S1	5	5	G3G4	Candidate[1]
Pyrginae	*Erynnis baptisiae*	Wild Indigo Duskywing	S1	4	3	G5	
Pyrginae	*Erynnis brizo*	Sleepy Duskywing	S1	4	3	G5	
Hesperiinae	*Oarisma garita*	Garita Skipperling	S1	5	5	G5	
Hesperiinae	*Staphylus hayhurstii*	Hayhurst's Scallopwing	S1	5	5	G5	
Apaturinae	*Asterocampa celtis*	Hackberry Emperor	S2	3	2	G5	
Lycaeninae	*Callophrys grynea*	Juniper Hairstreak	S2	5	5	G5	
Nymphalinae	*Chlosyne gorgone*	Gorgone Checkerspot	S2	3	4	G5	
Pyrginae	*Erynnis martialis*	Mottled Duskywing	S2	4	3	G3G4	Candidate
Hesperiinae	*Euphyes dukesi*	Duke's Skipper	S2	5	5	G3	
Papilioninae	*Papilio cresphontes*	Giant Swallowtail	S2	3	3	G5	
Coliadinae	*Colias gigantea*	Giant Sulphur	S2?	3	4	G5	
Apaturinae	*Asterocampa clyton*	Tawny Emperor	S2S3	3	2	G5	
Papilioninae	*Papilio machaon*	Old World Swallowtail	S2S3	3	3	G5	
Hesperiinae	*Thorybes bathyllus*	Southern Cloudywing	S2S3	5	5	G5	

Satyrinae	*Erebia discoidalis*	Red-disked Alpine	S3	5	4	G5	
Satyrinae	*Erebia mancinus*	Taiga Alpine	S3	5	4	G5	
Pierinae	*Euchloe ausonides*	Large Marble	S3	4	4	G5	EXP[2]
Lycaeninae	*Lycaena helloides*	Purplish Copper	S3	5	5	G5	
Satyrinae	*Oeneis macounii*	Macoun's Arctic	S3	5	4	G5	
Pierinae	*Pieris virginiensis*	West Virginia White	S3	4	4	G3G4	
Hesperiinae	*Poanes massasoit*	Mulberry Wing	S3	5	5	G4	
Nymphalinae	*Polygonia gracilis*	Hoary Comma	S3	3	4	G5	
Pierinae	*Pontia occidentalis*	Western White	S3	4	4	G5	
Lycaeninae	*Strymon melinus*	Grey Hairstreak	S3	5	5	G5	
Hesperiinae	*Amblyscirtes hegon*	Pepper and Salt Skipper	S3?	5	5	G5	
Satyrinae	*Oeneis bore*	White-veined Arctic	S3?	5	4	G5	
Satyrinae	*Oeneis melissa*	Melissa Arctic	S3?	5	4	G5	
Satyrinae	*Oeneis polixenes*	Polixenes Arctic	S3?	5	4	G5	
Hesperiinae	*Anatrytone logan*	Delaware Skipper	S3S4	5	4	G5	
Heliconiinae	*Boloria eunomia*	Bog Fritillary	S3S4	3	4	G5	
Hesperiinae	*Euphyes conspicua*	Black Dash	S3S4	5	5	G4	
Hesperiinae	*Euphyes dion*	Dion Skipper	S3S4	5	5	G4	
Lycaeninae	*Everes amyntula*	Western Tailed Blue	S3S4	5	5	G5	
Lycaeninae	*Lycaeides idas*	Northern Blue	S3S4	5	5	G5	

Pyrginae	*Pholisora catullus*	Common Sootywing	S3S4	4	3	G5
Nymphalinae	*Polygonia satyrus*	Satyr Comma	S3S4	3	4	G5
Hesperiinae	*Pompeius verna*	Little Glassywing	S3S4	5	5	G5
Pyrginae	*Pyrgus centaureae*	Grizzled Skipper	S3S4	4	3	G5
Lycaeninae	*Satyrium caryaevorum*	Hickory Hairstreak	S3S4	5	5	G4

1Candidate species for assessment by COSEWIC, 2Extirpated

Table 12c. Regionally geo-rare species listed by S-rank (S1-3) in Manitoba, and associated COSEWIC ranking. Taxonomy follows Layberry et al. (1998) for scientific names and Ackery et al. (1999) for sub-families.

Sub-family	Scientific Name	Common Name	S-Rank Manitoba	P_G-Rank	P_S-Rank	G-Rank	COSEWIC
Pierinae	*Euchloe olympia*	Broad-winged Skipper	S1	4	4	G4G5	
Nymphalinae	*Euphydryas phaeton*	Common Sootywing	S1	3	4	G4	
Hesperiinae	*Hesperia ottoe*	Ottoe Skipper	S1	5	5	G3	END
Pyrginae	*Pholisora catullus*	Baltimore Checkerspot	S1	4	3	G5	
Hesperiinae	*Poanes viator*	Olympia Marble	S1	5	5	G5	
Hesperiinae	*Hesperia uncas*	Uncas Skipper	S1S2	5	5	G5	
Hesperiinae	*Oarisma poweshiek*	Poweshiek Skipperling	S2	5	5	G2G3	THR
Pyrginae	*Erynnis lucilius*	Columbine Duskywing	S2S3	4	3	G4	
Hesperiinae	*Hesperia dacotae*	Dakota Skipper	S2S3	5	5	G2G3	THR
Lycaeninae	*Callophrys eryphon*	Grey Hairstreak	S3	5	5	G5	
Satyrinae	*Oeneis alberta*	Western Pine Elfin	S3	5	4	G4	
Lycaeninae	*Strymon melinus*	Alberta Arctic	S3	5	5	G5	
Hesperiinae	*Atrytonopsis hianna*	Dusted Skipper	S3S4	5	5	G4G5	
Hesperiinae	*Hesperia leonardus*	Leonard's Skipper	S3S4	5	5	G4	
Heliconiinae	*Speyeria mormonia*	Mormon Fritillary	S3S4	3	4	G5	

[1]Endangered, [2]Threatened

Table 12d. Regionally geo-rare species listed by S-rank (1-3) in New Brunswick, and associated COSEWIC ranking. Taxonomy follows Layberry et al. (1998) for scientific names and Ackery et al. (1999) for sub-families.

Sub-family	Scientific Name	Common Name	S-Rank New Brunswick	P_G-Rank	P_S-Rank	G-Rank	COSEWIC
Satyrinae	*Coenonympha nipisiquit*	Maritime Ringlet	S1	5	4	G1	END[1]
Lycaeninae	*Erora laeta*	Early Hairstreak	S1	5	5	G3G4	Candidate[2]
Lycaeninae	*Lycaena hyllus*	Bronze Copper	S1	5	5	G5	
Heliconiinae	*Boloria eunomia*	Bog Fritillary	S1?	3	4	G5	
Lycaeninae	*Callophrys henrici*	Henry's Elfin	S1?	5	5	G5	
Hesperiinae	*Euphyes bimacula*	Two-spotted Skipper	S2	5	5	G4	
Hesperiinae	*Hesperia sassacus*	Indian Skipper	S2	5	5	G5	
Lycaeninae	*Lycaena dospassosi*	Maritime Copper	S2	5	5	G2	
Lycaeninae	*Strymon melinus*	Grey Hairstreak	S2	5	5	G5	
Danainae	*Danaus plexippus*	Monarch	S2B	3	1	G4	SC[3]
Lycaeninae	*Satyrium acadicum*	Acadian Hairstreak	S2S3	5	5	G5	
Hesperiinae	*Amblyscirtes vialis*	Common Roadside Skipper	S3	5	5	G5	
Hesperiinae	*Ancyloxypha numitor*	Least Skipper	S3	5	5	G5	
Lycaeninae	*Callophrys eryphon*	Western Pine Elfin	S3	5	5	G5	
Lycaeninae	*Callophrys lanoraieensis*	Bog Elfin	S3	5	5	G3G4	
Lycaeninae	*Callophrys polia*	Hoary Elfin	S3	5	5	G5	
Nymphalinae	*Nymphalis milberti*	Milbert's Tortoiseshell	S3	3	4	G5	

Lycaeninae	*Plebejus saepiolus*	Greenish Blue	S3	5	5	G5
Nymphalinae	*Polygonia comma*	Eastern Comma	S3	3	4	G5
Nymphalinae	*Polygonia satyrus*	Satyr Comma	S3	3	4	G5
Hesperiinae	*Thorybes pylades*	Northern Cloudywing	S3S4	5	5	G5

[1] Endangered, [2] Candidate for assessment by COSEWIC, [3]Special Concern

Table 13: The overall Canadian butterfly priorities for conservation using combined geo- and phylo-rarity. S-rank is the highest found in either British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia, Labrador, New Brunswick, or Newfoundland. S-ranks in Quebec are tentative.

Ackery Sub-family	Scientic Name	Common Name	P_G	P_S	G-rank	S-rank	COSEWIC	Group
Papilioninae	*Papilio brevicauda*	Short-tailed Swallowtail	3	3	3.5	3.0		A
Heliconiinae	*Boloria alberta*	Alberta Fritillary	3	4	3.0	3.0		B
Coliadinae	*Colias occidentalis*	Western Sulphur	3	4	3.5	3.5		B
Nymphalinae	*Euphydryas gillettii*	Gillette's Checkerspot	3	4	2.5	2.5		B
Apaturinae	*Asterocampa celtis*	Hackberry Emperor	3	2	5.0	3.0		Dp
Apaturinae	*Asterocampa clyton*	Tawny Emperor	3	2	5.0	2.5		Dp
Papilioninae	*Papilio cresphontes*	Giant Swallowtail	3	3	5.0	2.0		Dp
Papilioninae	*Papilio indra*	Indra Swallowtail	3	3	5.0	2.0		Dp
Parnassiinae	*Parnassius phoebus*	Phoebus Parnassian	3	2	5.0	3.5		Dp
Lycaeninae	*Callophrys lanoraieensis*	Bog Elfin	5	5	3.5	3.0		Eg
Satyrinae	*Coenonympha nipisiquit*	Maritime Ringlet	5	4	1.0	3.0	END[1]	Eg
Pyrginae	*Erynnis martialis*	Mottled Duskywing	4	3	3.5	4.5	Candidate[2]	Eg
Hesperiinae	*Euphyes dukesi*	Duke's Skipper	5	5	3.0	2.0		Eg
Hesperiinae	*Hesperia dacotae*	Dakota Skipper	5	5	2.5	2.5	THR[3]	Eg
Hesperiinae	*Hesperia ottoe*	Ottoe Skipper	5	5	3.0	1.0	END	Eg
Lycaeninae	*Lycaena dospassosi*	Maritime Copper	5	5	2.0	3.0		Eg
Hesperiinae	*Oarisma poweshiek*	Poweshiek Skipperling	5	5	2.5	2.0	THR	Eg
Satyrinae	*Oeneis rosovi*	Philip's Arctic	5	4	3.5	3.0		Eg
Pierinae	*Pieris virginiensis*	West Virginia White	4	4	3.5	3.0		Eg
Heliconiinae	*Boloria astarte*	Astarte Fritillary	3	4	5.0	2.0		Ep
Heteropterinae	*Carterocephalus palaemon*	Arctic Skipper	3	1	5.0	5.0		Ep
Nymphalinae	*Chlosyne acastus*	Sagebrush Checkerspot	3	4	4.5	2.0		Ep
Nymphalinae	*Chlosyne gorgone*	Gorgone Checkerspot	3	4	5.0	2.0		Ep
Nymphalinae	*Chlosyne hoffmanni*	Hoffmann's Checkerspot	3	4	4.0	2.5	Candidate	Ep
Nymphalinae	*Chlosyne palla*	Northern Checkerspot	3	4	5.0	3.5		Ep
Coliadinae	*Colias meadii*	Mead's Sulphur	3	4	4.5	3.0		Ep
Danainae	*Danaus plexippus*	Monarch	3	1	4.0	5.0	SC[4]	Ep
Miletinae	*Feniseca tarquinius*	Harvester	3	1	4.0	4.0		Ep
Papilioninae	*Papilio canadensis*	Canadian Tiger Swallowtail	3	3	5.0	5.0		Ep
Papilioninae	*Papilio eurymedon*	Pale Swallowtail	3	3	5.0	5.0		Ep
Papilioninae	*Papilio glaucus*	Eastern Tiger Swallowtail	3	3	5.0	5.0		Ep
Papilioninae	*Papilio machaon*	Old World Swallowtail	3	3	5.0	5.0		Ep
Papilioninae	*Papilio multicaudatus*	Two-tailed Swallowtail	3	3	5.0	4.0		Ep
Papilioninae	*Papilio polyxenes*	Black Swallowtail	3	3	5.0	5.0		Ep
Papilioninae	*Papilio rutulus*	Western Tiger Swallowtail	3	3	5.0	5.0		Ep
Papilioninae	*Papilio troilus*	Spicebush Swallowtail	3	3	5.0	4.0		Ep

Papilioninae	*Papilio zelicaon*	Anise Swallowtail	3	3	5.0	5.0		Ep
Parnassiinae	*Parnassius clodius*	Clodius Parnassian	3	2	5.0	5.0		Ep
Parnassiinae	*Parnassius eversmanni*	Eversmann's Parnassian	3	2	5.0	4.0		Ep
Parnassiinae	*Parnassius smintheus*	Rocky Mountain Parnassian	3	2	5.0	5.0		Ep
Nymphalinae	*Vanessa annabella*	West Coast Lady	3	4	5.0	1.0		Ep
Lycaeninae	*Erora laeta*	Early Hairstreak	5	5	3.5	4.0	Candidate	Fg
Heliconiinae	*Boloria bellona*	Meadow Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Boloria chariclea*	Arctic Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Boloria epithore*	Pacific Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Boloria eunomia*	Bog Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Boloria freija*	Freija Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Boloria frigga*	Frigga Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Boloria improba*	Dingy Fritillary	3	4	5.0	4.0		Fp
Heliconiinae	*Boloria napaea*	Mountain Fritillary	3	4	5.0	4.0		Fp
Heliconiinae	*Boloria polaris*	Polaris Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Boloria selene*	Silver-bordered Fritillary	3	4	5.0	5.0		Fp
Nymphalinae	*Chlosyne damoetas*	Damoetas Checkerspot	3	4	4.5	4.0		Fp
Nymphalinae	*Chlosyne harrisii*	Harris's Checkerspot	3	4	4.0	5.0		Fp
Nymphalinae	*Chlosyne nycteis*	Silvery Checkerspot	3	4	5.0	5.0		Fp
Coliadinae	*Colias alexandra*	Queen Alexandra's Sulphur	3	4	5.0	5.0		Fp
Coliadinae	*Colias canadensis*	Canada Sulphur	3	4	4.5	4.5		Fp
Coliadinae	*Colias christina*	Christina Sulphur	3	4	5.0	5.0		Fp
Coliadinae	*Colias eurytheme*	Orange Sulphur	3	4	5.0	5.0		Fp
Coliadinae	*Colias gigantea*	Giant Sulphur	3	4	5.0	5.0		Fp
Coliadinae	*Colias hecla*	Hecla's Sulphur	3	4	5.0	5.0		Fp
Coliadinae	*Colias interior*	Pink-edged Sulphur	3	4	5.0	5.0		Fp
Coliadinae	*Colias nastes*	Labrador Sulphur	3	4	5.0	5.0		Fp
Coliadinae	*Colias palaeno*	Palaeno Sulphur	3	4	5.0	5.0		Fp
Coliadinae	*Colias pelidne*	Pelidne Sulphur	3	4	5.0	4.0		Fp
Coliadinae	*Colias philodice*	Clouded Sulphur	3	4	5.0	5.0		Fp
Nymphalinae	*Euphydryas chalcedona*	Variable Checkerspot	3	4	5.0	5.0	Candidate	Fp
Nymphalinae	*Euphydryas editha*	Edith's Checkerspot	3	4	5.0	5.0	Candidate	Fp
Nymphalinae	*Euphydryas phaeton*	Baltimore Checkerspot	3	4	4.0	4.0		Fp
Heliconiinae	*Euptoieta claudia*	Variegated Fritillary	3	4	5.0	5.0		Fp
Coliadinae	*Eurema lisa*	Little Yellow	3	4	5.0	5.0		Fp
Nymphalinae	*Nymphalis antiopa*	Mourning Cloak	3	4	5.0	5.0		Fp
Nymphalinae	*Nymphalis californica*	California Tortoiseshell	3	4	5.0	4.0		Fp
Nymphalinae	*Nymphalis milberti*	Milbert's Tortoiseshell	3	4	5.0	5.0		Fp
Nymphalinae	*Nymphalis vaualbum*	Compton Tortoiseshell	3	4	5.0	5.0		Fp
Nymphalinae	*Phyciodes batesii*	Tawny Crescent	3	4	4.0	4.5		Fp
Heliconiinae	*Phyciodes cocyta*	Northern Crescent	3	4	5.0	5.0		Fp
Nymphalinae	*Phyciodes mylitta*	Mylitta Crescent	3	4	5.0	5.0		Fp
Nymphalinae	*Phyciodes pallidus*	Pale Crescent	3	4	5.0	4.0		Fp
Nymphalinae	*Phyciodes pratensis*	Field Crescent	3	4	5.0	5.0		Fp
Heliconiinae	*Phyciodes tharos*	Pearl Crescent	3	4	5.0	5.0		Fp

Nymphalinae	*Polygonia comma*	Eastern Comma	3	4	5.0	5.0		Fp
Nymphalinae	*Polygonia faunus*	Green Comma	3	4	5.0	5.0		Fp
Nymphalinae	*Polygonia gracilis*	Hoary Comma	3	4	5.0	5.0		Fp
Nymphalinae	*Polygonia interrogationis*	Question Mark	3	4	5.0	5.0		Fp
Nymphalinae	*Polygonia oreas*	Oreas Comma	3	4	5.0	4.0		Fp
Nymphalinae	*Polygonia progne*	Grey Comma	3	4	5.0	5.0		Fp
Nymphalinae	*Polygonia satyrus*	Satyr Comma	3	4	5.0	5.0		Fp
Heliconiinae	*Speyeria aphrodite*	Aphrodite Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Speyeria atlantis*	Atlantis Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Speyeria callippe*	Callippe Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Speyeria cybele*	Great Spangled Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Speyeria hesperis*	Northwestern Fritillary	3	4	5.0	5.0		Fp
Heliconiinae	*Speyeria hydaspe*	Hydaspe Fritillary	3	4	4.5	4.5		Fp
Heliconiinae	*Speyeria mormonia*	Mormon Fritillary	3	4	5.0	5.0	Candidate	Fp
Heliconiinae	*Speyeria zerene*	Zerene Fritillary	3	4	5.0	5.0	Candidate	Fp
Nymphalinae	*Vanessa cardui*	Painted Lady	3	4	5.0	5.0		Fp
Nymphalinae	*Vanessa virginiensis*	American Lady	3	4	5.0	5.0		Fp

*[1] Endangered, [2] Candidate species for assessment by COSEWIC, [3] Threatened, [4] Special concern.

Table 14a: Highest regional priorities for conservation in British Columbia.

Sub-family	**Scientific Name**	**Common Name**	**P_G**	**P_S**	**G-rank**	**S-rank B.C.**	**B.C. Group**
Coliadinae	*Colias occidentalis*	Western Sulphur	3	4	3.5	3.5	A
Heliconiinae	*Boloria alberta*	Alberta Fritillary	3	4	3.0	3.0	B
Nymphalinae	*Euphydryas gillettii*	Gillette's Checkerspot	3	4	2.5	2.5	B
Papilioninae	*Papilio indra*	Indra Swallowtail	3	3	5.0	2.0	Dp
Parnassiinae	*Parnassius phoebus*	Phoebus Parnassian	3	2	5.0	3.5	Dp
Coliadinae	*Colias meadii*	Mead's Sulphur	3	4	4.5	3.0	Dp
Danainae	*Danaus plexippus*	Monarch	3	1	4.0	5.0	Dp
Coliadinae	*Colias hecla*	Hecla's Sulphur	3	4	5.0	5.0	Dp
Satyrinae	*Oeneis rosovi*	Philip's Arctic	5	4	3.5	3.0	Eg
Heteropterinae	*Carterocephalus palaemon*	Arctic Skipper	3	1	5.0	5.0	Ep
Nymphalinae	*Chlosyne hoffmanni*	Hoffmann's Checkerspot	3	4	4.0	2.5	Ep
Papilioninae	*Papilio canadensis*	Canadian Tiger Swallowtail	3	3	5.0	5.0	Ep
Papilioninae	*Papilio eurymedon*	Pale Swallowtail	3	3	5.0	5.0	Ep
Papilioninae	*Papilio machaon*	Old World Swallowtail	3	3	5.0	5.0	Ep
Papilioninae	*Papilio multicaudatus*	Two-tailed Swallowtail	3	3	5.0	4.0	Ep
Papilioninae	*Papilio rutulus*	Western Tiger Swallowtail	3	3	5.0	5.0	Ep
Papilioninae	*Papilio zelicaon*	Anise Swallowtail	3	3	5.0	5.0	Ep
Parnassiinae	*Parnassius clodius*	Clodius Parnassian	3	2	5.0	5.0	Ep
Parnassiinae	*Parnassius eversmanni*	Eversmann's Parnassian	3	2	5.0	4.0	Ep
Parnassiinae	*Parnassius smintheus*	Rocky Mountain Parnassian	3	2	5.0	5.0	Ep
Coliadinae	*Colias alexandra*	Queen Alexandra's Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias canadensis*	Canada Sulphur	3	4	4.5	4.5	Ep
Coliadinae	*Colias christina*	Christina Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias gigantea*	Giant Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias interior*	Pink-edged Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias nastes*	Labrador Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias philodice*	Clouded Sulphur	3	4	5.0	5.0	Ep
Nymphalinae	*Phyciodes batesii*	Tawny Crescent	3	4	4.0	4.5	Ep
Heliconiinae	*Boloria bellona*	Meadow Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria chariclea*	Arctic Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria epithore*	Pacific Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria eunomia*	Bog Fritillary	3	4	5.0	5.0	Fp

Heliconiinae	*Boloria freija*	Freija Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria frigga*	Frigga Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria improba*	Dingy Fritillary	3	4	5.0	4.0	Fp
Heliconiinae	*Boloria napaea*	Mountain Fritillary	3	4	5.0	4.0	Fp
Heliconiinae	*Boloria polaris*	Polaris Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria selene*	Silver-bordered Fritillary	3	4	5.0	5.0	Fp
Nymphalinae	*Chlosyne damoetas*	Damoetas Checkerspot	3	4	4.5	4.0	Fp
Nymphalinae	*Euphydryas chalcedona*	Variable Checkerspot	3	4	5.0	5.0	Fp
Nymphalinae	*Euphydryas editha*	Edith's Checkerspot	3	4	5.0	5.0	Fp
Nymphalinae	*Nymphalis antiopa*	Mourning Cloak	3	4	5.0	5.0	Fp
Nymphalinae	*Nymphalis californica*	California Tortoiseshell	3	4	5.0	4.0	Fp
Nymphalinae	*Nymphalis vaualbum*	Compton Tortoiseshell	3	4	5.0	5.0	Fp
Heliconiinae	*Phyciodes cocyta*	Northern Crescent	3	4	5.0	5.0	Fp
Nymphalinae	*Phyciodes mylitta*	Mylitta Crescent	3	4	5.0	5.0	Fp
Nymphalinae	*Phyciodes pallidus*	Pale Crescent	3	4	5.0	4.0	Fp
Nymphalinae	*Phyciodes pratensis*	Field Crescent	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia faunus*	Green Comma	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia gracilis*	Hoary Comma	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia oreas*	Oreas Comma	3	4	5.0	4.0	Fp
Nymphalinae	*Polygonia progne*	Grey Comma	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia satyrus*	Satyr Comma	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria aphrodite*	Aphrodite Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria atlantis*	Atlantis Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria callippe*	Callippe Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria cybele*	Great Spangled Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria hesperis*	Northwestern Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria hydaspe*	Hydaspe Fritillary	3	4	4.5	4.5	Fp
Heliconiinae	*Speyeria mormonia*	Mormon Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria zerene*	Zerene Fritillary	3	4	5.0	5.0	Fp
Nymphalinae	*Vanessa cardui*	Painted Lady	3	4	5.0	5.0	Fp

Table 14b: Highest regional priorities for conservation in Ontario.

Sub-family	Scientific Name	Common Name	P_G	P_S	G-rank	S-rank ON	ON Group
Pyrginae	*Erynnis martialis*	Mottled Duskywing	4	3	3.5	4.5	Dg
Pierinae	*Pieris virginiensis*	West Virginia White	4	4	3.5	3.0	Dg
Apaturinae	*Asterocampa celtis*	Hackberry Emperor	3	2	5.0	3.0	Dp
Apaturinae	*Asterocampa clyton*	Tawny Emperor	3	2	5.0	2.5	Dp
Papilioninae	*Papilio cresphontes*	Giant Swallowtail	3	3	5.0	2.0	Dp
Papilioninae	*Papilio machaon*	Old World Swallowtail	3	3	5.0	5.0	Dp
Coliadinae	*Colias gigantea*	Giant Sulphur	3	4	5.0	5.0	Dp
Lycaeninae	*Callophrys lanoraieensis*	Bog Elfin	5	5	3.5	3.0	Eg
Hesperiinae	*Euphyes dukesi*	Duke's Skipper	5	5	3.0	2.0	Eg
Lycaeninae	*Erora laeta*	Early Hairstreak	5	5	3.5	4.0	Eg
Nymphalinae	*Chlosyne gorgone*	Gorgone Checkerspot	3	4	5.0	2.0	Ep
Miletinae	*Feniseca tarquinius*	Harvester	3	1	4.0	4.0	Ep
Papilioninae	*Papilio glaucus*	Eastern Tiger Swallowtail	3	3	5.0	5.0	Ep
Papilioninae	*Papilio polyxenes*	Black Swallowtail	3	3	5.0	5.0	Ep
Papilioninae	*Papilio troilus*	Spicebush Swallowtail	3	3	5.0	4.0	Ep
Coliadinae	*Colias eurytheme*	Orange Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias palaeno*	Palaeno Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias pelidne*	Pelidne Sulphur	3	4	5.0	4.0	Ep
Danainae	*Danaus plexippus*	Monarch	3	1	4.0	5.0	Ep
Heteropterinae	*Carterocephalus palaemon*	Arctic Skipper	3	1	5.0	5.0	Ep
Papilioninae	*Papilio canadensis*	Canadian Tiger Swallowtail	3	3	5.0	5.0	Ep
Coliadinae	*Colias interior*	Pink-edged Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias philodice*	Clouded Sulphur	3	4	5.0	5.0	Ep
Heliconiinae	*Boloria eunomia*	Bog Fritillary	3	4	5.0	5.0	Ep
Nymphalinae	*Polygonia gracilis*	Hoary Comma	3	4	5.0	5.0	Ep
Nymphalinae	*Polygonia satyrus*	Satyr Comma	3	4	5.0	5.0	Ep
Nymphalinae	*Chlosyne harrisii*	Harris's Checkerspot	3	4	4.0	5.0	Fp
Nymphalinae	*Chlosyne nycteis*	Silvery Checkerspot	3	4	5.0	5.0	Fp
Nymphalinae	*Euphydryas phaeton*	Baltimore Checkerspot	3	4	4.0	4.0	Fp
Nymphalinae	*Nymphalis milberti*	Milbert's Tortoiseshell	3	4	5.0	5.0	Fp
Heliconiinae	*Phyciodes tharos*	Pearl Crescent	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia comma*	Eastern Comma	3	4	5.0	5.0	Fp

Nymphalinae	*Polygonia interrogationis*	Question Mark	3	4	5.0	5.0	Fp
Nymphalinae	*Vanessa virginiensis*	American Lady	3	4	5.0	5.0	Fp
Nymphalinae	*Phyciodes batesii*	Tawny Crescent	3	4	4.0	4.5	Fp
Heliconiinae	*Boloria bellona*	Meadow Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria chariclea*	Arctic Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria freija*	Freija Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria frigga*	Frigga Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria selene*	Silver-bordered Fritillary	3	4	5.0	5.0	Fp
Nymphalinae	*Nymphalis antiopa*	Mourning Cloak	3	4	5.0	5.0	Fp
Nymphalinae	*Nymphalis vaualbum*	Compton Tortoiseshell	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia faunus*	Green Comma	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia progne*	Grey Comma	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria aphrodite*	Aphrodite Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria atlantis*	Atlantis Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria cybele*	Great Spangled Fritillary	3	4	5.0	5.0	Fp

Table 14c: Highest regional priorities for conservation in Manitoba.

Sub-family	Scientific Name	Common Name	P_G	P_S	G-rank	S-rank MAN	MAN Group
Hesperiinae	*Hesperia dacotae*	Dakota Skipper	5	5	2.5	2.5	Eg
Hesperiinae	*Hesperia ottoe*	Ottoe Skipper	5	5	3.0	1.0	Eg
Hesperiinae	*Oarisma poweshiek*	Poweshiek Skipperling	5	5	2.5	2.0	Eg
Pyrginae	*Erynnis martialis*	Mottled Duskywing	4	3	3.5	4.5	Eg
Coliadinae	*Colias hecla*	Hecla's Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias alexandra*	Queen Alexandra's Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias nastes*	Labrador Sulphur	3	4	5.0	5.0	Ep
Heliconiinae	*Speyeria mormonia*	Mormon Fritillary	3	4	5.0	5.0	Ep
Papilioninae	*Papilio machaon*	Old World Swallowtail	3	3	5.0	5.0	Ep
Coliadinae	*Colias gigantea*	Giant Sulphur	3	4	5.0	5.0	Ep
Miletinae	*Feniseca tarquinius*	Harvester	3	1	4.0	4.0	Ep
Papilioninae	*Papilio glaucus*	Eastern Tiger Swallowtail	3	3	5.0	5.0	Ep
Papilioninae	*Papilio polyxenes*	Black Swallowtail	3	3	5.0	5.0	Ep
Coliadinae	*Colias eurytheme*	Orange Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias palaeno*	Palaeno Sulphur	3	4	5.0	5.0	Ep
Danainae	*Danaus plexippus*	Monarch	3	1	4.0	5.0	Ep
Heteropterinae	*Carterocephalus palaemon*	Arctic Skipper	3	1	5.0	5.0	Ep
Coliadinae	*Colias interior*	Pink-edged Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias philodice*	Clouded Sulphur	3	4	5.0	5.0	Ep
Nymphalinae	*Euphydryas phaeton*	Baltimore Checkerspot	3	4	4.0	4.0	Ep
Heliconiinae	*Euptoieta claudia*	Variegated Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria polaris*	Polaris Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria callippe*	Callippe Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria hesperis*	Northwestern Fritillary	3	4	5.0	5.0	Fp
Nymphalinae	*Vanessa cardui*	Painted Lady	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria eunomia*	Bog Fritillary	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia gracilis*	Hoary Comma	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia satyrus*	Satyr Comma	3	4	5.0	5.0	Fp
Nymphalinae	*Chlosyne harrisii*	Harris's Checkerspot	3	4	4.0	5.0	Fp
Nymphalinae	*Chlosyne nycteis*	Silvery Checkerspot	3	4	5.0	5.0	Fp
Nymphalinae	*Nymphalis milberti*	Milbert's Tortoiseshell	3	4	5.0	5.0	Fp
Heliconiinae	*Phyciodes tharos*	Pearl Crescent	3	4	5.0	5.0	Fp

Nymphalinae	*Polygonia comma*	Eastern Comma	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia interrogationis*	Question Mark	3	4	5.0	5.0	Fp
Nymphalinae	*Vanessa virginiensis*	American Lady	3	4	5.0	5.0	Fp
Nymphalinae	*Phyciodes batesii*	Tawny Crescent	3	4	4.0	4.5	Fp
Heliconiinae	*Boloria bellona*	Meadow Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria chariclea*	Arctic Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria freija*	Freija Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria frigga*	Frigga Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria selene*	Silver-bordered Fritillary	3	4	5.0	5.0	Fp
Nymphalinae	*Nymphalis antiopa*	Mourning Cloak	3	4	5.0	5.0	Fp
Nymphalinae	*Nymphalis vaualbum*	Compton Tortoiseshell	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia faunus*	Green Comma	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia progne*	Grey Comma	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria aphrodite*	Aphrodite Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria atlantis*	Atlantis Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	*Speyeria cybele*	Great Spangled Fritillary	3	4	5.0	5.0	Fp

Table 14d: Highest regional priorities for conservation in New Brunswick.

Sub-family	Scientific Name	Common Name	P_G	P_S	G-rank	S-rank NBR	NBR Group
Danainae	*Danaus plexippus*	Monarch	3	1	4.0	5.0	Dp
Satyrinae	*Coenonympha nipisiquit**	Maritime Ringlet	5	4	1.0	3.0	Eg
Lycaeninae	*Lycaena dospassosi**	Maritime Copper	5	5	2.0	3.0	Eg
Lycaeninae	*Callophrys lanoraieensis*	Bog Elfin	5	5	3.5	3.0	Eg
Lycaeninae	*Erora laeta*	Early Hairstreak	5	5	3.5	4.0	Eg
Papilioninae	*Papilio canadensis*	Canadian Tiger Swallowtail	3	3	5.0	5.0	Ep
Miletinae	*Feniseca tarquinius*	Harvester	3	1	4.0	4.0	Ep
Heteropterinae	*Carterocephalus palaemon*	Arctic Skipper	3	1	5.0	5.0	Ep
Coliadinae	*Colias interior*	Pink-edged Sulphur	3	4	5.0	5.0	Ep
Coliadinae	*Colias philodice*	Clouded Sulphur	3	4	5.0	5.0	Ep
Heliconiinae	*Boloria eunomia*	Bog Fritillary	3	4	5.0	5.0	Ep
Nymphalinae	*Polygonia satyrus*	Satyr Comma	3	4	5.0	5.0	Ep
Nymphalinae	*Nymphalis milberti*	Milbert's Tortoiseshell	3	4	5.0	5.0	Ep
Nymphalinae	*Polygonia comma*	Eastern Comma	3	4	5.0	5.0	Ep
Heliconiinae	*Phyciodes cocyta*	Northern Crescent	3	4	5.0	5.0	Fp
Nymphalinae	*Euphydryas phaeton*	Baltimore Checkerspot	3	4	4.0	4.0	Fp
Nymphalinae	*Polygonia gracilis*	Hoary Comma	3	4	5.0	5.0	Fp
Nymphalinae	*Chlosyne harrisii*	Harris's Checkerspot	3	4	4.0	5.0	Fp
Nymphalinae	*Vanessa virginiensis*	American Lady	3	4	5.0	5.0	Fp
Heliconiinae	*Boloria bellona*	Meadow Fritillary	3	4	5.0	5.0	Fp
Nymphalinae	*Nymphalis antiopa*	Mourning Cloak	3	4	5.0	5.0	Fp
Nymphalinae	*Polygonia faunus*	Green Comma	3	4	5.0	5.0	Fp
Nymphalinae	Polygonia progne	Grey Comma	3	4	5.0	5.0	Fp
Heliconiinae	Speyeria aphrodite	Aphrodite Fritillary	3	4	5.0	5.0	Fp
Heliconiinae	Speyeria atlantis	Atlantis Fritillary	3	4	5.0	5.0	Fp

* endemic species

Table 15. Standardized canonical function coefficients for the various life history variables for Canadian butterflies.

Variable	Function	
	1 (Variance 80.2%)	2 (Variance 19.2%)
Family number	0.087	-0.086
Wingspan - Upper (mm)	0.965	0.259
Number of subspecies	0.160	-0.493
Monophagy/polyphagy {range 1,2)	0.039	0.866

Table 16. Assignment of globally geo-rare species found in Canada.

Sub-family	**Scientific Name**	**G-rank**	**Highest S-rank**	P_G	P_S	**COSEWIC**	**Group**
Satyrinae	*Coenonympha nipisiquit*	1	3	4	4	END	Eg
Coliadinae	*Colias johanseni*	2	Un-ranked	3	4		***B****
Lycaeninae	*Lycaena dospassosi*	2	3	5	5		Eg
Nymphalinae	*Euphydryas gillettii*	2.5	2.5	3	4	THR	B
Hesperiinae	*Hesperia dacotae*	2.5	2.5	4	4	THR	Eg
Hesperiinae	*Oarisma poweshiek*	2.5	2	4	4		Eg
Heliconiinae	*Boloria alberta*	3	3	3	4		B
Heliconiinae	*Boloria natazhati*	3	Un-ranked	3	4		***B****
Lycaeninae	*Callophrys irus*	3	SX	5	5	EXP	
Hesperiinae	*Euphyes dukesi*	3	2	4	4		Eg
Hesperiinae	*Hesperia ottoe*	3	1	4	4	END	Eg
Heliconiinae	*Speyeria idalia*	3	SAN	3	4		
Lycaeninae	*Callophrys johnsoni*	3.5	Un-ranked	5	5	Candidate	***Eg****
Lycaeninae	*Callophrys lanoraieensis*	3.5	3	5	5		Eg
Coliadinae	*Colias occidentalis*	3.5	3.5	3	4		B
Lycaeninae	*Erora laeta*	3.5	4	5	5	Candidate	Fg
Pyrginae	*Erynnis martialis*	3.5	4.5	3	3	Candidate	Eg
Satyrinae	*Oeneis rosovi*	3.5	3	4	4		Eg
Papilioninae	*Papilio brevicauda*	3.5	3	3	3		A
Pierinae	*Pieris virginiensis*	3.5	3	4	4		Eg

SX - extirpated in Canada
SAN - non-breeding accidental in Canada
* likely groupings following assignment of S-rank
END – endangered, THR – threatened, EXP- extirpated in Canada, Candidate – Candidate species for assessment

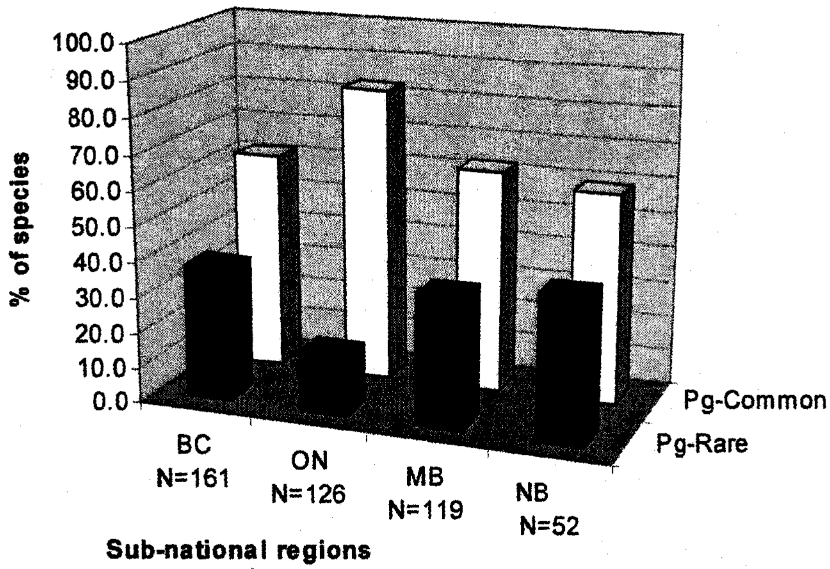

Figure 1. Percentage of globally phylo-rare (PG 1-3) and phylo-common (PG 4-5) butterfly species in British Columbia, Ontario, Manitoba and New Brunswick, Canada.

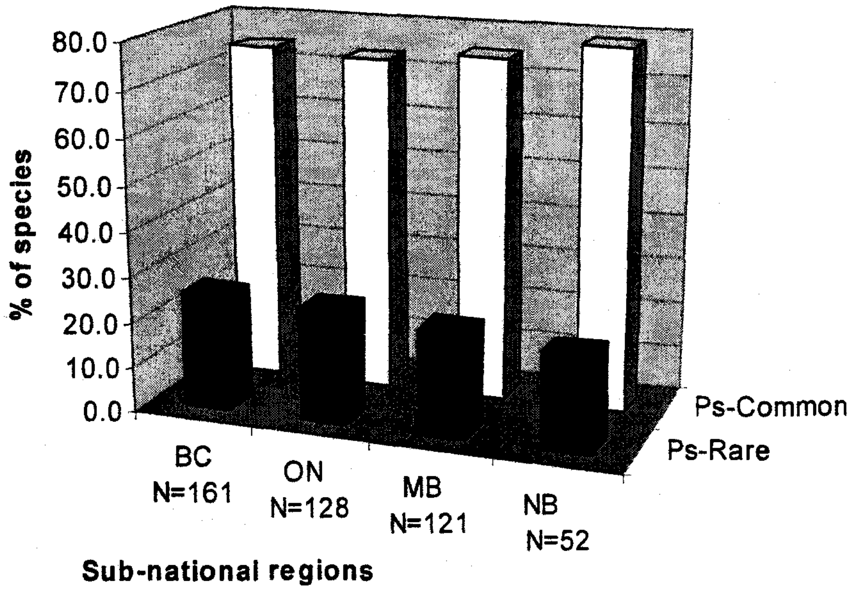

Figure 2. Percentage of regionally phylo-rare (PS 1-3) and phylo-common (PS 4-5) butterfly species in British Columbia, Ontario, Manitoba and New Brunswick, Canada.

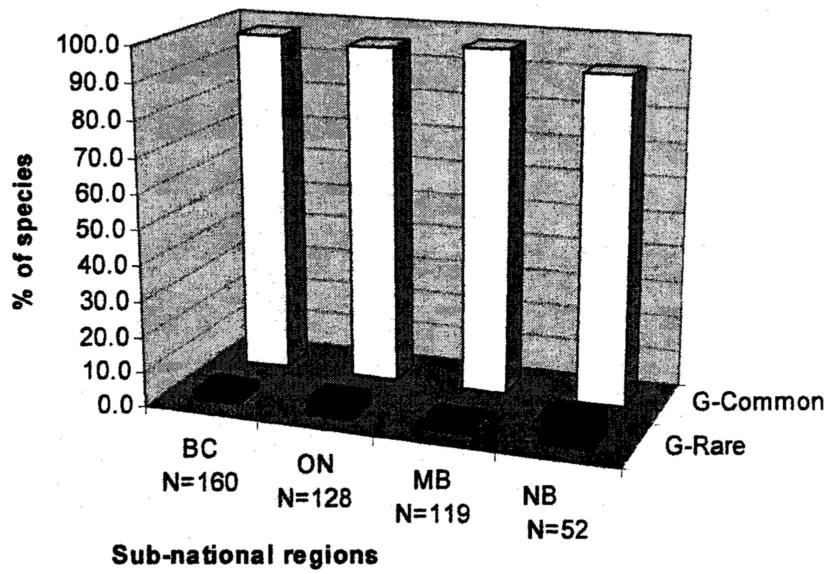

Figure 3. Percent of globally rare (G1-3) and common (G4-5) butterfly species in Canada. G values are from NatureServe (2005).

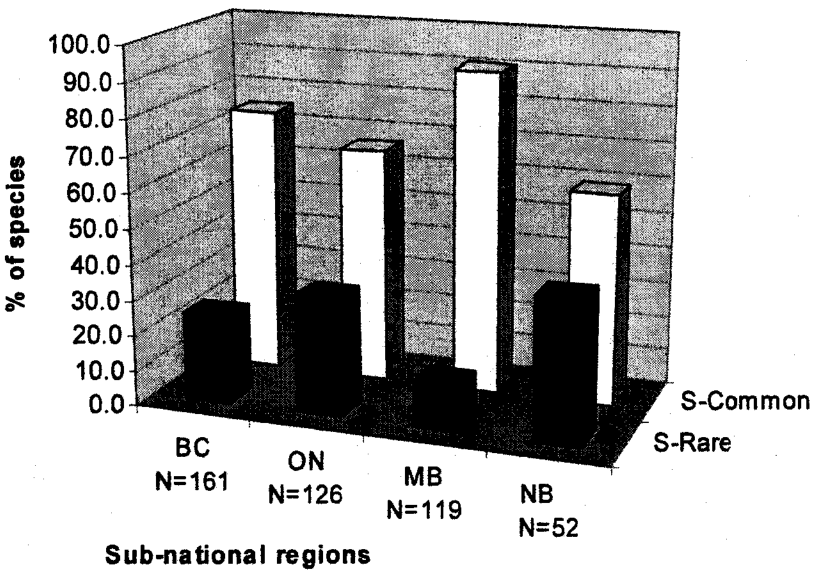

Figure 4. Numbers and percentage of sub-nationally geographically rare (S1-3) and common (S4-5) butterfly species in Canada. S values are provided by various provincial natural heritage information centres.

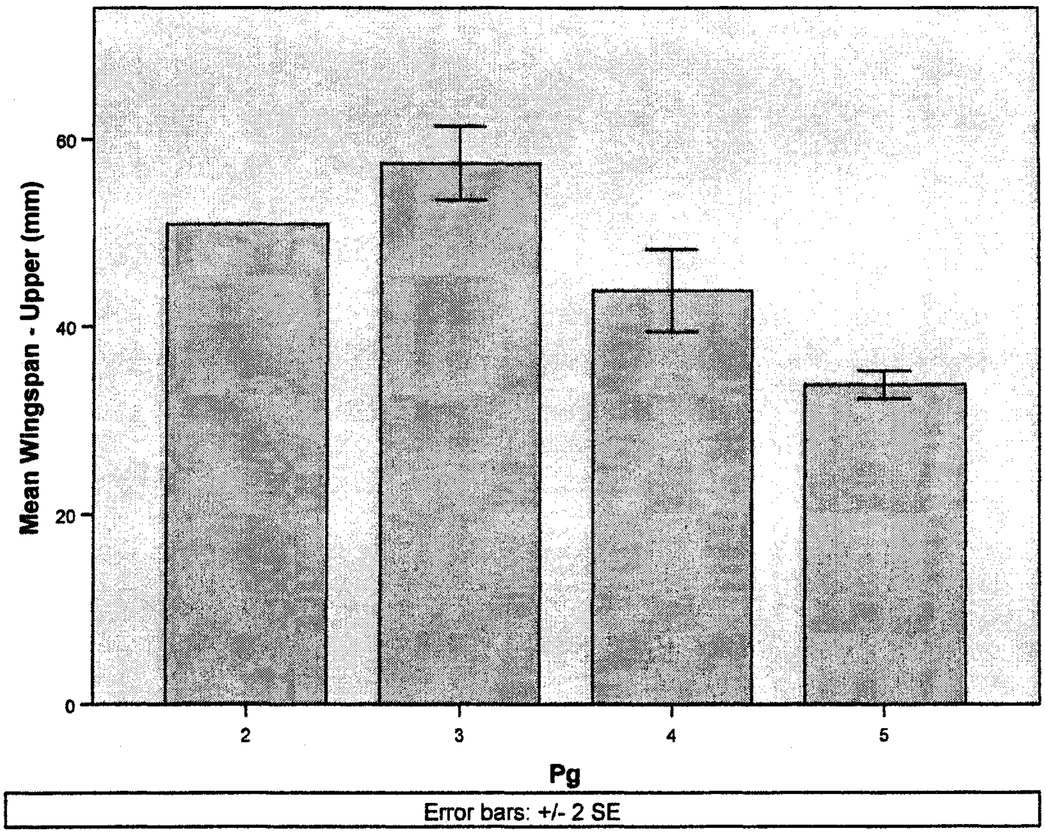

Figure 5. Distribution of mean upper wingspan across the phylo-abundance groups.

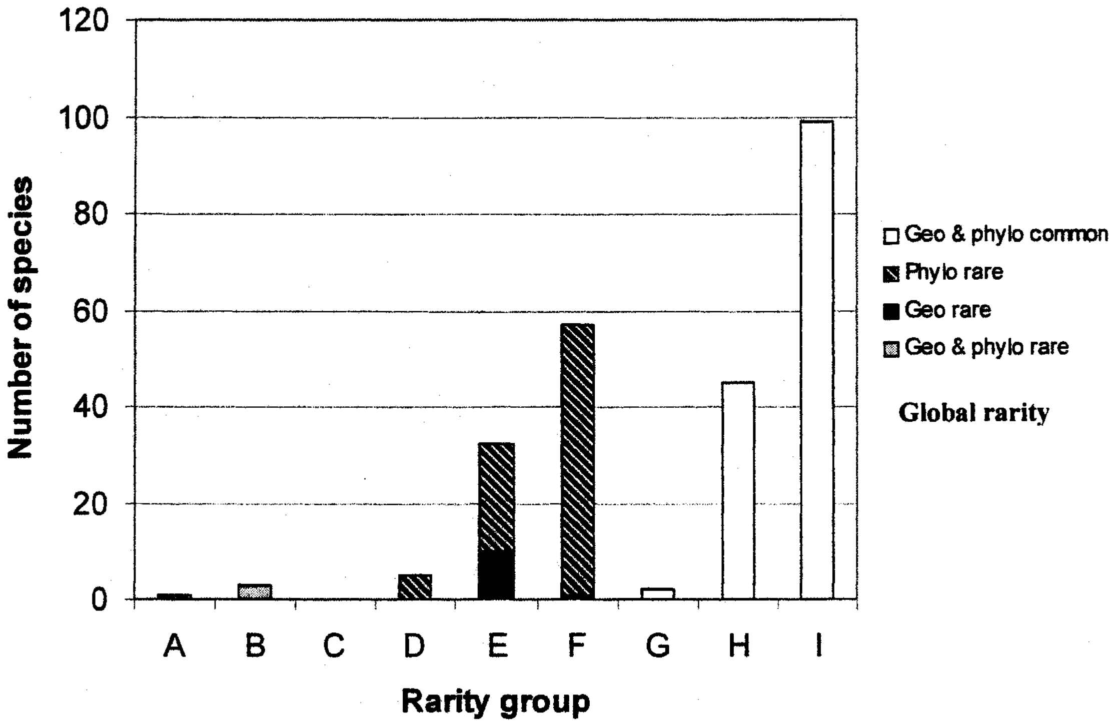

Figure 6. Distribution of Canadian butterfly species within each of the 9 rarity groups. Groups A, D, and G are regionally both geo- and phylo-rare. Groups B, E, and H are regionally either geo- or phylo-rare and groups C, F, and I are both geo- and phylo- common.

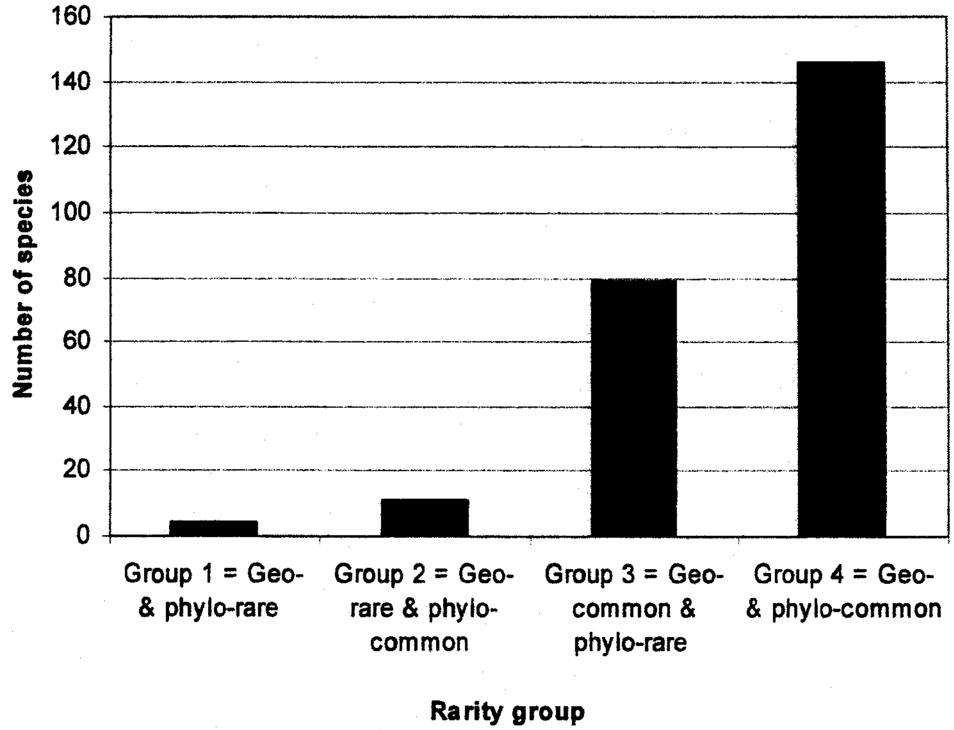

Figure 7. Distribution of species within each of the four groups of global geo- and phylo-abundance.

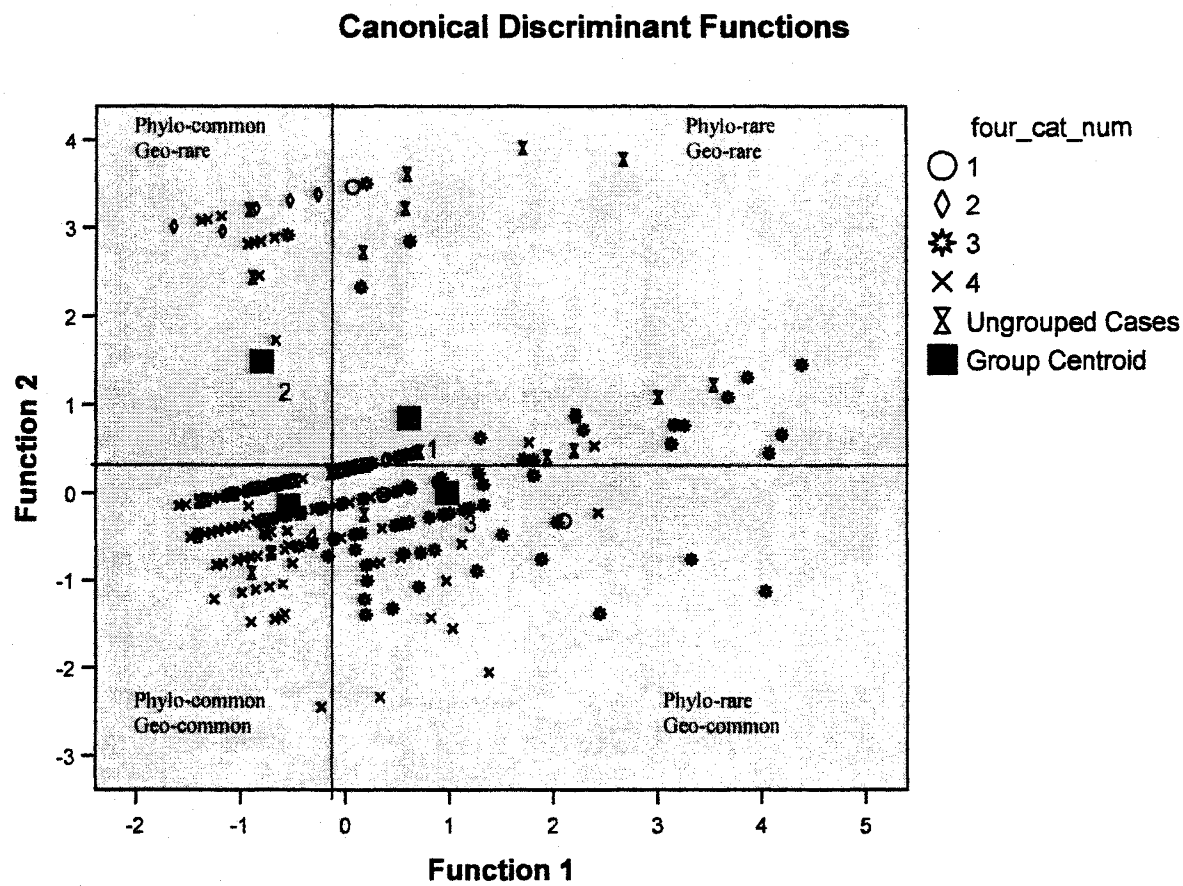

Figure 8. Canonical discriminant functions using the four categories of global phylo- and geo-rarity. Group 1 is phylo-rare and geo-rare species. Group 2 is phylo-common and geo-rare species. Group 3 is phylo-rare and geo-common species. Group 4 is both phylo- and geo-common.

Appendix A. Cross-validation results for highest grouping of Canadian butterfly. Ungrouped cases are data with missing values in any of the four categories.

	Case Number	Actual Group	Predicted Group	P(D>d | G=g) p	df	P(G=g | D=d)	Squared Mahalanobis Distance to Centroid
Achalarus lyciades	1	ungrouped	1	0.926642446	3	0.337698731	0.464388649
Agraulis vanillae	2	ungrouped	1	0.027912559	3	0.524815837	9.106133821
Battus philenor	4	ungrouped	1	0.004774974	3	0.851179269	12.93694261
Callophrys barryi	6	ungrouped	2	0.820901949	3	0.836210093	0.91874527
Callophrys johnsoni	8	ungrouped	2	0.398612578	3	0.917374939	2.955018387
Callophrys rosneri	9	ungrouped	2	0.820901949	3	0.836210093	0.91874527
Calpodes ethlius	10	ungrouped	2	0.089396285	3	0.625403697	6.506760067
Calycopis cecrops	11	ungrouped	4	0.989707679	3	0.504305973	0.117111927
Colias johanseni	12	ungrouped	4	0.98792797	3	0.470387731	0.130599748
Colias tyche	13	ungrouped	2	0.469250676	3	0.608702528	2.533592885
Erynnis funeralis	19	ungrouped	4	0.922729893	3	0.343258899	0.482449584
Erynnis horatius	20	ungrouped	4	0.984960113	3	0.452820738	0.151850443
Erynnis zarucco	21	ungrouped	4	0.98792797	3	0.470387731	0.130599748
Euptoieta hegesia	23	ungrouped	3	0.614184107	3	0.510000673	1.803451646
Eurema mexicanum	24	ungrouped	4	0.939586508	3	0.361622106	0.403171754
Eurema nicippe	25	ungrouped	1	0.908586916	3	0.324979499	0.546393586
Eurytides marcellus	26	ungrouped	1	0.014273259	3	0.681395378	10.57308024
Fixsenia favonius	27	ungrouped	4	0.98966728	3	0.521172946	0.117425498
Hemiargus isola	28	ungrouped	4	0.828092581	3	0.749421313	0.88895413
Hesperia colorado	29	ungrouped	4	0.937319717	3	0.672857111	0.41407552
Hesperia pahaska	30	ungrouped	4	0.987626734	3	0.614801123	0.132821978
Hylephila phyleus	31	ungrouped	4	0.982368973	3	0.551412124	0.169414114
Icaricia acmon	32	ungrouped	4	0.451607128	3	0.765868933	2.633728708
Junonia coenia	33	ungrouped	4	0.575093341	3	0.402900254	1.987076563
Leptotes marina	34	ungrouped	4	0.865079938	3	0.650715637	0.734418941
Libytheana carinenta	35	ungrouped	2	0.172757713	3	0.557148588	4.986916229
Nathalis iole	36	ungrouped	4	0.958373198	3	0.593250497	0.308757005

Panoquina ocola	39	ungrouped	4	0.982368973	3	0.551412124	0.169414114
Parrhasius m-album	40	ungrouped	4	0.986316377	3	0.536264692	0.142308863
Phoebis philea	41	ungrouped	1	0.43698352	3	0.521569747	2.719145479
Phoebis sennae	42	ungrouped	3	0.467980087	3	0.519878146	2.540702672
Pieris rapae	43	ungrouped	1	0.88766451	3	0.312012317	0.638069711
Speyeria idalia	46	ungrouped	1	0.107447662	3	0.526331266	6.087121401
Thymelicus lineola	47	ungrouped	4	0.889544411	3	0.640416553	0.629944175
Urbanus proteus	48	ungrouped	4	0.902947636	3	0.325047064	0.571398603
Zerene cesonia	49	ungrouped	1	0.984284079	3	0.42521837	0.156511969
Papilio brevicauda	50	1	3	0.505493969	3	0.649199133	2.336872349
Boloria alberta	51	1	2	0.195864937	3	0.769277907	4.691100302
Colias occidentalis	52	1	3	0.889655116	3	0.343436951	0.629465075
Euphydryas gillettii	53	1	4	0.922729893	3	0.343258899	0.482449584
Asterocampa celtis	54	3	4	0.873439896	3	0.334215296	0.698996758
Asterocampa clyton	55	3	3	0.88784108	3	0.468434077	0.637307327
Papilio cresphontes	56	3	1	0.001553721	3	0.519515944	15.33214634
Papilio indra	57	3	3	0.683920772	3	0.503897902	1.492853268
Parnassius phoebus	58	3	3	0.939862583	3	0.425904187	0.40183782
Callophrys lanoraieensis	59	2	2	0.381730979	3	0.957006707	3.064871712
Coenonympha nipisiquit	60	2	2	0.335536877	3	0.875307024	3.388329043
Erynnis martialis	61	2	4	0.945448811	3	0.605961247	0.374547014
Euphyes dukesi	62	2	4	0.989461084	3	0.487568347	0.119020243
Hesperia dacotae	63	2	4	0.945448811	3	0.605961247	0.374547014
Hesperia ottoe	64	2	4	0.988693728	3	0.520551714	0.1248748
Lycaena dospassosi	65	2	2	0.391153801	3	0.911633742	3.003058857
Oarisma poweshiek	66	2	4	0.958373198	3	0.593250497	0.308757005
Oeneis rosovi	67	2	1	0.964403946	3	0.373852935	0.276400975
Pieris virginiensis	68	2	2	0.275777261	3	0.835360109	3.870626599
Boloria astarte	69	3	1	0.259865878	3	0.46367115	4.014842349
Carterocephalus palaemon	70	3	4	0.976583797	3	0.565969178	0.206190555
Chlosyne acastus	71	3	4	0.93647881	3	0.396191631	0.418098968
Chlosyne gorgone	72	3	4	0.98966728	3	0.521172946	0.117425498
Chlosyne hoffmanni	73	3	4	0.992480925	3	0.56037064	0.094570522
Chlosyne palla	74	3	4	0.56420669	3	0.477176612	2.039705608
Colias meadii	75	3	4	0.93647881	3	0.396191631	0.418098968
Danaus plexippus	76	3	1	0.010174976	3	0.52303795	11.30733023

Papilio canadensis	78	3	3	0.015181261	3	0.845388557	10.43888456
Papilio eurymedon	79	3	3	0.033216427	3	0.696568515	8.72255433
Papilio glaucus	80	3	3	3.71363E-05	3	0.952605737	23.17460748
Papilio machaon	81	3	3	0.013505103	3	0.931626169	10.69334188
Papilio multicaudatus	82	3	3	0.002052712	3	0.890424765	14.74016575
Papilio polyxenes	83	3	3	0.070724716	3	0.541775529	7.037097057
Papilio rutulus	84	3	3	0.152423349	3	0.747880882	5.279726223
Papilio troilus	85	3	3	0.152423349	3	0.747880882	5.279726223
Papilio zelicaon	86	3	1	0.43698352	3	0.521569747	2.719145479
Parnassius clodius	87	3	3	0.536484605	3	0.645832178	2.1770416
Parnassius eversmanni	88	3	3	0.932225605	3	0.388256612	0.438281933
Parnassius smintheus	89	3	3	0.494856011	3	0.690968052	2.393444942
Vanessa annabella	90	3	3	0.046687803	3	0.531859466	7.967517978
Erora laeta	91	2	2	0.150852992	3	0.958159938	5.303846502
Boloria bellona	92	3	4	0.724564149	3	0.424620686	1.319262576
Boloria chariclea	93	3	3	0.394871283	3	0.502819882	2.979019488
Boloria epithore	94	3	4	0.867671927	3	0.416403224	0.723462576
Boloria eunomia	95	3	4	0.360718652	3	0.510666087	3.207549702
Boloria freija	96	3	4	0.941337704	3	0.552226564	0.394687642
Boloria frigga	97	3	4	0.915461049	3	0.484926729	0.515554757
Boloria improba	98	3	2	0.548343297	3	0.8365262	2.117684824
Boloria polaris	100	3	4	0.575453844	3	0.568011985	1.985345605
Boloria selene	101	3	3	0.88124432	3	0.416307426	0.66568335
Chlosyne damoetas	102	3	4	0.973584089	3	0.459395903	0.224241882
Chlosyne harrisii	103	3	2	0.631948584	3	0.530999429	1.722475535
Chlosyne nycteis	104	3	4	0.846568927	3	0.39380802	0.812107561
Colias alexandra	105	3	3	0.913795825	3	0.484706966	0.523064373
Colias canadensis	106	3	2	0.165537146	3	0.737523389	5.086988108
Colias christina	107	3	3	0.79849924	3	0.488093837	1.011376362
Colias eurytheme	108	3	1	0.981451064	3	0.406160676	0.175454003
Colias gigantea	109	3	3	0.911824964	3	0.464094642	0.531919275
Colias hecla	110	3	4	0.846568927	3	0.39380802	0.812107561
Colias interior	111	3	1	0.88766451	3	0.312012317	0.638069711
Colias nastes	112	3	4	0.564456874	3	0.472428111	2.038488259
Colias palaeno	113	3	4	0.846568927	3	0.39380802	0.812107561
Colias pelidne	114	3	4	0.867671927	3	0.416403224	0.723462576

Colias philodice	115	3	3	0.812414101	3	0.514065861	0.953861479
Euphydryas chalcedona	116	3	3	0.067641311	3	0.769095648	7.137521052
Euphydryas editha	117	3	4	0.473299607	3	0.47357208	2.511037804
Euphydryas phaeton	118	3	3	0.693748406	3	0.693707287	1.450468597
Euptoieta claudia	119	3	3	0.000341279	3	0.776154399	18.53392811
Eurema lisa	120	3	4	0.989707679	3	0.504305973	0.117111927
Nymphalis antiopa	121	3	3	0.411979337	3	0.66429273	2.870786693
Nymphalis californica	122	3	3	0.891514292	3	0.519321711	0.62140884
Nymphalis milberti	123	3	3	0.892360492	3	0.429037383	0.617735547
Nymphalis vaualbum	124	3	3	0.693748406	3	0.693707287	1.450468597
Phyciodes batesii	125	3	4	0.941337704	3	0.552226564	0.394687642
Phyciodes cocyta	126	3	4	0.988693728	3	0.520551714	0.1248748
Phyciodes mylitta	127	3	4	0.983043999	3	0.631588037	0.164914841
Phyciodes pallidus	128	3	4	0.93647881	3	0.396191631	0.418098968
Phyciodes pratensis	129	3	4	0.947882279	3	0.595036409	0.362465511
Phyciodes tharos	130	3	4	0.990560787	3	0.597310483	0.110400303
Polygonia comma	131	3	3	0.058534851	3	0.622881884	7.462308761
Polygonia faunus	132	3	3	0.046961455	3	0.565461836	7.954500833
Polygonia gracilis	133	3	3	0.867709795	3	0.403100982	0.723302342
Polygonia interrogationis	134	3	3	0.064736481	3	0.765921662	7.236267943
Polygonia oreas	135	3	3	0.915687584	3	0.366666243	0.514531125
Polygonia progne	136	3	1	0.941878832	3	0.350115811	0.392054902
Polygonia satyrus	137	3	1	0.977680972	3	0.395869832	0.199431804
Speyeria aphrodite	138	3	3	0.135357786	3	0.810830548	5.555478526
Speyeria atlantis	139	3	3	0.741860683	3	0.606977381	1.246558421
Speyeria callippe	140	3	3	0.866455263	3	0.533529588	0.728608209
Speyeria cybele	141	3	3	0.048325783	3	0.793228977	7.890684673
Speyeria hesperis	142	3	3	0.911551828	3	0.49417462	0.533143706
Speyeria hydaspe	143	3	3	0.900468531	3	0.511468639	0.58231594
Speyeria mormonia	144	3	3	0.618797255	3	0.512821708	1.782286054
Speyeria zerene	145	3	3	0.741860683	3	0.606977381	1.246558421
Vanessa cardui	146	3	1	0.907777795	3	0.485981854	0.549996681
Vanessa virginiensis	147	3	1	0.983603355	3	0.415947372	0.161147391
Apodemia mormo	148	4	4	0.983043999	3	0.631588037	0.164914841
Erynnis baptisiae	149	4	4	0.986316377	3	0.536264692	0.142308863
Amblyscirtes oslari	150	4	2	0.41378754	3	0.93620628	2.859568402

Amblyscirtes simius	151	4	2	0.408973196	3	0.94670557	2.889528399
Atalopedes campestris	152	4	4	0.958373198	3	0.593250497	0.308757005
Atrytonopsis hianna	153	4	4	0.992117956	3	0.579151782	0.097649818
Callophrys affinis	154	4	2	0.620975331	3	0.887272584	1.772326975
Erebia mackinleyensis	155	4	1	0.972080107	3	0.385092545	0.233080795
Erebia magdalena	156	4	4	0.918438523	3	0.37526556	0.502060376
Erynnis afranius	157	4	4	0.968675082	3	0.57991865	0.252638186
Erynnis brizo	158	4	4	0.992117956	3	0.579151782	0.097649818
Erynnis icelus	159	4	4	0.497014074	3	0.628409397	2.381893327
Erynnis juvenalis	160	4	4	0.989461084	3	0.487568347	0.119020243
Erynnis lucilius	161	4	4	0.945448811	3	0.605961247	0.374547014
Erynnis persius	162	4	4	0.545229456	3	0.674142814	2.133179934
Erynnis propertius	163	4	4	0.98792797	3	0.470387731	0.130599748
Euphilotes ancilla	164	4	4	0.828092581	3	0.749421313	0.88895413
Euphyes conspicua	165	4	2	0.579937125	3	0.855920582	1.963880784
Euphyes dion	166	4	4	0.992117956	3	0.579151782	0.097649818
Glaucopsyche piasus	167	4	4	0.937319717	3	0.672857111	0.41407552
Hesperia uncas	168	4	4	0.968675082	3	0.57991865	0.252638186
Icaricia shasta	169	4	4	0.796954938	3	0.759012312	1.017758886
Limenitis archippus	170	4	3	0.362498868	3	0.525692214	3.195188429
Limenitis arthemis	171	4	3	0.350282697	3	0.662622695	3.281093933
Limenitis lorquini	172	4	3	0.622931742	3	0.632237449	1.763399832
Limenitis weidemeyerii	173	4	3	0.683920772	3	0.503897902	1.492853268
Lycaena dione	174	4	4	0.989707679	3	0.504305973	0.117111927
Lycaena nivalis	175	4	2	0.61369346	3	0.880292704	1.805708643
Lycaena rubida	176	4	4	0.983043999	3	0.631588037	0.164914841
Neominois ridingsii	177	4	4	0.918438523	3	0.37526556	0.502060376
Pholisora catullus	179	4	4	0.929728812	3	0.618053337	0.450008212
Poanes massasoit	181	4	4	0.956373994	3	0.677512322	0.319220568
Polites draco	182	4	4	0.958373198	3	0.593250497	0.308757005
Polites rhesus	183	4	4	0.958373198	3	0.593250497	0.308757005
Polites sabuleti	184	4	4	0.807934264	3	0.669642639	0.97238204
Polites sonora	185	4	4	0.925334417	3	0.704366788	0.470446998
Pompeius verna	186	4	4	0.982368973	3	0.551412124	0.169414114
Pyrgus centaureae	187	4	2	0.814039633	3	0.827348368	0.947139327
Pyrgus communis	188	4	4	0.945448811	3	0.605961247	0.374547014

Pyrgus scriptura	189	4	4	0.775657144	3	0.678314973	1.105870374
Satyrium behrii	190	4	2	0.620975331	3	0.887272584	1.772326975
Satyrium californicum	191	4	4	0.025841097	3	0.65838431	9.275712353
Satyrium fuliginosum	192	4	4	0.919350848	3	0.707064038	0.49790766
Staphylus hayhurstii	193	4	2	0.412126757	3	0.943503775	2.869870544
Thorybes bathyllus	194	4	4	0.98792797	3	0.470387731	0.130599748
Agriades glandon	195	4	4	0.012790518	3	0.823371007	10.81142578
Amblyscirtes hegon	196	4	4	0.775657144	3	0.678314973	1.105870374
Amblyscirtes vialis	197	4	4	0.865079938	3	0.650715637	0.734418941
Anatrytone logan	198	4	4	0.919350848	3	0.707064038	0.49790766
Ancyloxypha numitor	199	4	4	0.889544411	3	0.640416553	0.629944175
Anthocharis sara	200	4	4	0.902088683	3	0.462074465	0.575186174
Anthocharis stella	201	4	4	0.973584089	3	0.459395903	0.224241882
Callophrys augustinus	202	4	4	0.730767013	3	0.79261088	1.293121819
Callophrys eryphon	203	4	4	0.942300797	3	0.691313687	0.389998188
Callophrys grynea	204	4	4	0.83103853	3	0.777835105	0.876733823
Callophrys henrici	205	4	4	0.882486066	3	0.728283972	0.660358185
Callophrys mossii	206	4	4	0.83103853	3	0.777835105	0.876733823
Callophrys niphon	207	4	4	0.925334417	3	0.704366788	0.470446998
Callophrys sheridanii	209	4	4	0.805725232	3	0.789539117	0.981512623
Callophrys spinetorum	210	4	4	0.967703448	3	0.66295607	0.258114136
Celastrina ladon	211	4	4	0.018196138	3	0.750988096	10.04395929
Celastrina neglecta	212	4	4	4.77408E-05	3	0.651338514	22.65115397
Celastrina sp 2	213	4	4	0.01939336	3	0.653405036	9.90475362
Cercyonis oetus	214	4	4	0.951589217	3	0.417255503	0.34380875
Cercyonis pegala	215	4	3	0.812166334	3	0.558432315	0.954885985
Cercyonis sthenele	216	4	4	0.93647881	3	0.396191631	0.418098968
Coenonympha tullia	217	4	4	0.102652488	3	0.509895397	6.191579988
Enodia anthedon	218	4	3	0.92509126	3	0.377679734	0.471570935
Epargyreus clarus	219	4	4	0.918438523	3	0.37526556	0.502060376
Erebia discoidalis	221	4	4	0.867671927	3	0.416403224	0.723462576
Erebia epipsodea	222	4	4	0.702585971	3	0.40105493	1.412591138
Erebia rossii	224	4	4	0.867671927	3	0.416403224	0.723462576
Erebia vidleri	225	4	4	0.922729893	3	0.343258899	0.482449584
Erynnis pacuvius	226	4	4	0.982368973	3	0.551412124	0.169414114
Euchloe ausonides	227	4	3	0.833249887	3	0.375420283	0.867553893

Euchloe lotta	229	4	4	0.980321316	3	0.434931143	0.182772326
Euchloe olympia	230	4	4	0.980321316	3	0.434931143	0.182772326
Euphilotes battoides	231	4	4	0.905397263	3	0.716684288	0.560566997
Euphyes bimacula	232	4	2	0.604381804	3	0.872760304	1.848761501
Euphyes vestris	233	4	4	0.925334417	3	0.704366788	0.470446998
Everes amyntula	234	4	4	0.874099781	3	0.752031762	0.69618979
Everes comyntas	235	4	4	0.905397263	3	0.716684288	0.560566997
Glaucopsyche lygdamus	236	4	4	0.942300797	3	0.691313687	0.389998188
Hesperia assiniboia	237	4	4	0.958373198	3	0.593250497	0.308757005
Hesperia comma	238	4	4	0.604372681	3	0.740593634	1.848803888
Hesperia juba	239	4	4	0.986316377	3	0.536264692	0.142308863
Hesperia leonardus	240	4	4	0.946583703	3	0.635410492	0.368928137
Hesperia nevada	241	4	4	0.958373198	3	0.593250497	0.308757005
Hesperia sassacus	242	4	4	0.958373198	3	0.593250497	0.308757005
Icaricia icarioides	243	4	4	0.812459781	3	0.694777595	0.953672592
Lycaeides melissa	244	4	4	0.005436296	3	0.713859652	12.65856203
Lycaena cuprea	246	4	4	0.967703448	3	0.66295607	0.258114136
Lycaena dorcas	247	4	2	0.987966814	3	0.645380814	0.130311999
Lycaena epixanthe	248	4	4	0.634081824	3	0.84026851	1.712845089
Lycaena helloides	249	4	4	0.982368973	3	0.551412124	0.169414114
Lycaena heteronea	250	4	4	0.982368973	3	0.551412124	0.169414114
Lycaena mariposa	251	4	4	0.98792797	3	0.470387731	0.130599748
Lycaena phlaeas	253	4	4	0.79444393	3	0.73100437	1.028137578
Megisto cymela	254	4	4	0.963893607	3	0.438357014	0.279189721
Neophasia menapia	255	4	3	0.889655116	3	0.343436951	0.629465075
Oarisma garita	256	4	4	0.865079938	3	0.650715637	0.734418941
Ochlodes sylvanoides	257	4	4	0.906802996	3	0.722902304	0.554330514
Oeneis bore	258	4	3	0.760164274	3	0.444757881	1.170182605
Oeneis chryxus	259	4	3	0.648711732	3	0.570697932	1.647305842
Oeneis macounii	260	4	3	0.140157219	3	0.723270121	5.474740939
Oeneis melissa	262	4	3	0.432226725	3	0.56205821	2.7474325
Oeneis polixenes	263	4	3	0.380634498	3	0.681988652	3.072148602
Oeneis uhleri	264	4	3	0.701781654	3	0.397142039	1.416029552
Pieris marginalis	265	4	4	0.873439896	3	0.334215296	0.698996758
Pieris oleracea	266	4	3	0.867709795	3	0.403100982	0.723302342
Plebejus saepiolus	267	4	4	0.89174113	3	0.737889817	0.620424558

Poanes hobomok	268	4	4	0.983043999	3	0.631588037	0.164914841
Poanes viator	269	4	4	0.990560787	3	0.597310483	0.110400303
Polites mystic	270	4	4	0.945448811	3	0.605961247	0.374547014
Polites origines	271	4	4	0.958373198	3	0.593250497	0.308757005
Polites peckius	272	4	4	0.911106063	3	0.629534404	0.535140599
Polites themistocles	273	4	4	0.929728812	3	0.618053337	0.450008212
Pontia beckerii	274	4	1	0.908586916	3	0.324979499	0.546393586
Pontia occidentalis	275	4	3	0.833249887	3	0.375420283	0.867553893
Pontia protodice	276	4	1	0.926642446	3	0.337698731	0.464388649
Pyrgus ruralis	277	4	4	0.980911392	3	0.480273754	0.178965231
Satyrium acadicum	279	4	4	0.937319717	3	0.672857111	0.41407552
Satyrium calanus	280	4	4	0.584469034	3	0.62540588	1.942297446
Satyrium caryaevorum	281	4	4	4.40005E-05	3	0.664244943	22.82121907
Satyrium edwardsii	282	4	4	0.968675082	3	0.57991865	0.252638186
Satyrium liparops	283	4	4	0.767117653	3	0.763621069	1.14128732
Satyrium saepium	284	4	4	0.919350848	3	0.707064038	0.49790766
Satyrium sylvinum	285	4	4	0.967703448	3	0.66295607	0.258114136
Satyrium titus	286	4	4	0.54486507	3	0.669947426	2.134997359
Satyrodes appalachia	287	4	3	0.903906863	3	0.355241444	0.567162505
Satyrodes eurydice	288	4	3	0.853508743	3	0.318846088	0.783083781
Strymon melinus	289	4	4	0.594300153	3	0.758121061	1.895859587
Thorybes pylades	290	4	4	0.98792797	3	0.470387731	0.130599748
Vacciniina optilete	291	4	4	0.856671089	3	0.739187853	0.769820563
Vanessa atalanta	292	4	3	0.792560988	3	0.578093163	1.035921233
Wallengrenia egeremet	293	4	4	0.945448811	3	0.605961247	0.374547014

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