Towards a Recovery Strategy for Garry Oak and Associated Ecosystems in Canada: Ecological Assessment and Literature Review

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Citation:

Fuchs, Marilyn A. 2001. Towards a Recovery Strategy for Garry Oak and Associated Ecosystems in Canada: Ecological Assessment and Literature Review. Technical Report GBEI/EC-00-030. Environment Canada, Canadian Wildlife Service, Pacific and Yukon Region.

Acknowledgements

Many people provided information and otherwise assisted in the preparation of this report. I thank Marsha Arbour, Syd Cannings, Adolf Ceska, Brenda Costanzo, Krista De Groot, George Douglas, Bob Duncan, Wayne Erickson, Matt Fairbarns, Richard Feldman, Tracy Fleming, Samantha Flynn, Dave Fraser, Tom Gillespie, Gail Harcombe, Jeanne Illingworth, Pam Krannitz, Carrina Maslovat, Karen Morrison, Jenifer Penny, Hans Roemer, Michael Shepard, and Fran Spencer. Wayne Erickson and Fran Spencer contributed the list of plant taxa (Table 1). Dave Fraser compiled a draft list of species at risk from Garry oak and associated ecosystems from which the final list (Tables 4 and 6) was adapted. The BC Ministry of Environment, Lands and Parks contributed range maps of Garry oak ecosystems (Figs. 1 and 2). The Nature Conservancy of Washington granted permission for reproduction of a stand development model (Fig. 3). Discussions of the Garry Oak Ecosystems Recovery Team provided the groundwork for much of the material in this report, particularly material relating to essential ecosystem characteristics. Former and current team members are Brenda Beckwith, Robb Bennett, Cheryl Bryce, Suzanne Caskenette, Adolf Ceska, Brenda Costanzo, Michael Dunn, Tim Ennis, Wayne Erickson, Matt Fairbarns, Tracy Fleming, Dave Fraser, Marilyn Fuchs, Hal Gibbard, Tom Gillespie, Andrew Harcombe, Richard Hebda, Brent Ingram, Pat Johnston, Pam Krannitz, Andrew MacDougall, Carrina Maslovat, Mike Meagher, John Olafson, Marlow Pellatt, Adriane Pollard, Brian Reader, George Sirk, Fran Spencer, Kate Stewart, and Joel Ussery. Review comments by Rob Cannings, Adolf Ceska, Trudy Chatwin, Tim Ennis, Wayne Erickson, Dave Fraser, Hal Gibbard, Richard Hebda, Jan Kirkby, Michael Meagher, Richard Ring, Hans Roemer, Nancy Turner, and Joel Ussery helped improve an earlier draft of this report. Silke Neve and Pam Whitehead coordinated final publication. This report was originally prepared for the Garry Oak Meadow Preservation Society and the Garry Oak Ecosystems Recovery Team. Funding from World Wildlife Fund Canada, Millennium Bureau of Canada, Environment Canada as part of the Georgia Basin Ecosystem Initiative, BC Ministry of Environment, Lands and Parks, and the Garry Oak Meadow Preservation Society is gratefully acknowledged.

Executive Summary

Garry oak ecosystems in Canada form mosaics with maritime meadows, coastal bluffs, vernal pools, grasslands, rock outcrops, and transitional forests. The current global distribution of Garry oak ecosystems spans an extensive north-south range, from southwestern British Columbia to southern California. The Canadian distribution is limited to southeastern Vancouver Island, the Gulf Islands, and outlier stands on Savary Island and in the Fraser Valley, all within British Columbia. A Mediterranean-like climate prevails over most of the Canadian range of Garry oak ecosystems. Different species associated with today's Garry oak ecosystems arrived at different times following the last glacial retreat. Current climate and ecosystem models predict that much of what is currently Douglas-fir forest in coastal British Columbia will likely be replaced by Garry oak and related ecosystems within the next half century.

The Garry oak landscape in British Columbia is located within the traditional territories of the Coast Salish First Peoples. Prior to European settlement, First Peoples used regular burning to maintain the open vegetation structure favourable to camas (*Camassia quamash* and *C. leichtlinii*), the primary vegetable food. Grazing of domestic animals, land clearing, and fire suppression followed European settlement. In the last 150 years, agricultural, residential, and industrial development have vastly reduced the extent of Garry oak ecosystems. Current estimates suggest that only about 1-5 % remains in a near-natural condition. Remnant habitat is under threat from continued urban development.

Garry oak is the only native oak in British Columbia. On moister sites, the oaks tend to be out-competed by faster-growing conifers unless maintained by disturbance. Acorns are dispersed primarily by Steller's jays (*Cyanocitta stelleri*) in British Columbia. Deep taproots confer a high degree of drought tolerance to Garry oak seedlings. Mature oaks are shade-intolerant. Oaks reproduce vegetatively by sprouting and from underground rhizomes as well as by seed. Oak regeneration may be a problem for Garry oaks in British Columbia, but this has not been documented.

Six hundred and ninety four plant taxa have been identified in Garry oak and associated ecosystems in British Columbia. Approaches to inventory and classification of the plant communities have varied widely. Roemer defined a *Quercus-Bromus* Alliance, comprised of 2 plant associations. The BC Ministry of Forest's Biogeoclimatic Ecosystem Classification system employs a site classification system known as site series. Two site series sometimes include a Garry oak component. The BC Conservation Data Centre tracks and ranks late-successional, rare plant communities. Eight relevant communities are currently tracked by the Conservation Data Centre. All are ranked as critically imperilled, imperilled, or imperilled/vulnerable. Erickson's classification defined 43 plant communities, including distinct early season and late season communities, and also including successional and disturbed communities. The Sensitive Ecosystems Inventory identified and mapped relatively unmodified remnants of select ecosystems in the Gulf Islands and southeastern Vancouver Island. Four of the 9 ecosystem types include Garry oak and associated ecosystems.

Sixty one plant taxa are listed as being at risk in Garry oak and associated ecosystems, including 11 designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as being at risk on a national scale. Twelve are at risk on

a global scale. Some of the taxa are associated with very specialized habitats, including seepages and vernal pools. Threats have yet to be assessed for most of the species. Habitat loss, encroachment of woody species as a consequence of fire suppression, and invasions of exotic species are the most common threats to the species that have been assessed.

Seven amphibians, 7 reptiles, 104 birds, and 33 mammals have been identified in Garry oak and associated ecosystems. Trees, shrubs, and open herbaceous areas provide different feeding, nesting, and roosting resources and are used by different species. Tree cavities, standing dead wood, and downed wood provide critical resources for 46 % of the vertebrate species. Some species are associated with the juxtaposition of patches of vegetation of contrasting structure. Acorns are among the most critical resources available to vertebrates in Garry oak ecosystems. Little is known about invertebrates in the ecosystems. At least 800 insect and mite species are associated with Garry oak trees. Approximately 140 of them feed on the oaks themselves, including 48 obligate species. Many butterflies depend upon open, sunny habitats. Habitat heterogeneity provides a variety of resources for a diverse assemblage of animal species as well as for varying seasonal needs within species.

One earthworm, 10 butterflies, and 7 other insects from the ecosystems are listed as being at risk. Vertebrates at risk are 2 reptiles, 9 birds, and 3 mammals. Seven animal taxa have been designated as being at risk by COSEWIC. Twelve are at risk on a global scale. All of the vertebrate species that historically relied exclusively on grassland and open Garry oak ecosystems in the region have been entirely or nearly extirpated. Habitat loss is the major cited threat to the animals at risk.

Three primary "essential ecosystem characteristics" have been identified by the Garry Oak Ecosystems Recovery Team. These characteristics are critically associated with the composition, structure, and function of Garry oak ecosystems, and are deemed to be at significant risk in the modern context. The characteristics are:

1. Spatial integrity, in terms of the consequences of habitat fragmentation;
2. The role of fire as a natural disturbance agent; and
3. Biotic integrity, in terms of the presence and effects of exotic species.

Minimal research has been conducted in Garry oak ecosystems in British Columbia that addresses these issues, so this review relies largely upon ecological theory and information from other localities.

Habitat fragmentation results in small parcels of ecosystems that are subject to risks related to patch size and patch isolation. The ability of larger patches to support larger populations of species is important for preventing local extinctions. In general, smaller animals require less space than larger animals. Carnivores tend to require more space than omnivores, who in turn require more space than herbivores. The ability of the surrounding landscape to help support species depends upon the characteristics of the landscape. In British Columbia, Garry oak patches surrounded by highly developed areas contain fewer species of birds than patches in less developed areas. Breeding populations of birds associated with oak and grassland habitats have declined in the urban Victoria area since the 1970's.

Closely related to issues of patch size are issues pertaining to patch isolation. Different organisms need to move between patches of suitable habitat for various reasons on a variety of temporal scales. Functional connectivity between patches depends upon both the distance between the patches and the nature of the intervening habitat. In general, larger animals and animals of higher trophic levels tend to disperse farther than smaller animals and animals of lower trophic levels. Corridors of natural or semi-natural habitat can ameliorate fragmentation effects. The functionality of corridors will depend on the responses of the various species to their attributes.

The history of oak-prairie ecosystems throughout North America is inextricably linked with fire. Relatively frequent, low-intensity fires were largely a result of landscape-management activities of local First Peoples. Fire suppression following European settlement has resulted in dramatic changes to the composition, structure, and function of the ecosystems. Without fire, many prairies convert to shrublands and savannahs, and savannahs convert to closed-canopy woodlands and conifer forests. Large-scale conversions of prairie and oak savannah have been documented in the United States. Fire has been described as the most serious ecological problem facing remnant Garry oak stands that are protected from development. Stand dynamics have not been described in any detail for Garry oak ecosystems in Canada, but similar patterns have been observed at some locations. Prescribed fire has been used as a restoration tool at some Garry oak sites in the United States. The efficacy of fire as a restoration tool is equivocal because some invasive plants are favoured by fire. The responses of vertebrates to a fire regime are largely mediated by fire effects on vegetation structure. Invertebrates are vulnerable to direct fire-caused mortality.

Biological invasions are among the most serious modern ecological problems. Invasions are most pernicious when they cause ecosystem-level changes. The prevalence of exotic plants in Garry oak and associated ecosystems in British Columbia has been documented in a number of studies. Sampling found up to 82 % of herbaceous cover composed of invasive species. Scotch broom (*Cytisus scoparius*) and other invasive shrubs pose some of the most serious threats to the ecosystems. Exotic grasses dominate the herbaceous flora at many if not most sites. A variety of management tools have been employed for control of different exotic plants. Overall, efforts have been resource-intensive and success has been limited. The European starling (*Sturnella neglecta*) has been implicated in the decline of native cavity-nesting bird species. Twenty one percent of all mammal species in Garry oak and associated ecosystems in British Columbia are exotic. The introduced eastern gray squirrel (*Sciurus carolinensis*) may potentially contribute to declines of the native red squirrel (*Tamiasciurus hudsonicus*) and compete with a number of native animal species for acorns. Four invasive insects have caused, or have the potential to cause, serious damage to Garry oak trees. Evidence for the potentially devastating impacts of introductions also exists in lesser-known taxonomic groups. Earthworms on southeastern Vancouver Island are almost exclusively introduced species. The introduced black slug (*Arion ater*) may be harming populations of some rare plants. In California, a fungus associated with an oak epidemic that has spread hundreds of miles in 5 years may be an introduced exotic species.

In conclusion, the range of biological and cultural values vested in Garry oak and associated ecosystems confers great significance to ecosystem conservation. The extent and rate of decline imparts an urgency to the development and implementation of conservation initiatives. Research is needed to fill the many information gaps, but conservation actions, based upon the best available knowledge, must be applied in the meantime.

Sommaire

Les écosystèmes à chêne de Garry de la Colombie-Britannique forment une mosaïque où sont juxtaposés des prairies maritimes, des falaises littorales, des mares printanières, des herbages, des affleurements rocheux et des forêts de transition. L'aire d'extension des écosystèmes à chêne de Garry est en majeure partie soumise à l'influence d'un climat de type méditerranéen et couvre une longue bande nord-sud depuis l'île Savary, en Colombie-Britannique, jusqu'au sud de la Californie. L'aire de répartition canadienne est limitée au sud-est de l'île de Vancouver, aux îles Gulf ainsi qu'aux peuplements enclavés de l'île Savarey et de la vallée du Fraser, tous en Colombie-Britannique. Dans le cadre du présent rapport, l'expression « écosystèmes associés » désigne tous ces autres écosystèmes. Différentes espèces associées aux actuels écosystèmes à chêne de Garry ont fait leur apparition à différentes périodes après le dernier recul des glaciers. Selon les prévisions des modèles climatiques et écosystémiques, la majeure partie de l'actuelle forêt côtière de douglas de la Colombie-Britannique sera vraisemblablement remplacée par des écosystèmes à chêne de Garry et ses écosystèmes associés au cours des cinquante prochaines années.

En Colombie-Britannique, les écosystèmes à chêne de Garry sont situés sur les territoires traditionnels des Premières nations salish du littoral. Avant l'arrivée des Européens, ces Premières nations avaient recours à des brûlages réguliers pour conserver une structure de végétation claire, propice aux camassies (*Camassia quamash* et *C. leichtlinii*), les principales plantes consommées comme légumes. Après l'arrivée des Européens, des pâturages pour les animaux domestiques sont apparus, les terres ont été défrichées et les feux de végétation ont été supprimés. Au cours des 150 dernières années, l'expansion de l'agriculture, de l'industrie et du secteur résidentiel a énormément réduit l'étendue des écosystèmes à chêne de Garry. Selon les estimations actuelles, seulement 1 à 5 % de ces écosystèmes seraient encore dans un état quasi naturel. L'étalement urbain incessant menace l'habitat qui subsiste.

Le chêne de Garry est la seule essence de chêne indigène en Colombie-Britannique. Dans les stations plus mouillées, les chênes sont souvent supplantés par des conifères à croissance plus rapide, à moins qu'ils n'y soient perpétués par des perturbations. Les glands sont principalement dispersés par le geai de Steller (*Cyanocitta stelleri*). Grâce à leurs racines pivotantes, les semis du chêne de Garry ont une grande résistance à la sécheresse. Les chênes mûrs sont des essences de lumière. Ils se reproduisent par voie végétative, produisant des rejets de souche ou des drageons sur leurs rhizomes, ainsi que par voie sexuée, c.-à-d. par graines. La régénération du chêne de Garry dans la province pourrait être difficile, mais il n'existe aucune documentation à ce sujet.

Six cent quatre-vingt quatorze taxons végétaux ont été identifiés dans les écosystèmes à chêne de Garry et ses écosystèmes associés en Colombie-Britannique. Les méthodes d'inventaire et de classification des communautés végétales variaient considérablement. Roemer a défini une alliance *Quercus-Bromus*, comprenant deux associations végétales. Le ministère des Forêts de la province utilise un système de classification des stations appelé série stationnelle. Le chêne de Garry est parfois une composante de deux séries stationnelles. Le Centre des données sur la conservation de la Colombie-Britannique (BC Conservation Data Centre) repère et classe les communautés

végétales rares de fin de succession. Il s'intéresse actuellement à huit communautés distinctives. Il les classe dans les catégories suivantes : dangereusement en péril, en péril ou en péril/vulnérable. La classification d'Erickson définit 43 communautés végétales, y compris les communautés distinctives de début et de fin de saison, et englobe également les communautés évolutives et perturbées. L'Inventaire des écosystèmes fragiles a répertorié et cartographié des vestiges relativement intacts de certains écosystèmes dans les îles Gulf et dans le sud-est de l'île de Vancouver. Le chêne de Garry et ses écosystèmes associés se retrouvent dans quatre des neuf types d'écosystèmes.

Soixante et un taxons végétaux sont en péril dans les écosystèmes à chêne de Garry et ses écosystèmes associés, dont 11 taxons désignés en péril à l'échelon national par le Comité sur la situation des espèces en péril au Canada (COSEPAC). Douze d'entre eux sont en péril à l'échelle de la planète. Certains taxons sont associés à des habitats très spécialisés, dont les zones de suintement et les mares printanières. Il reste à évaluer la catégorie de danger applicable à la plupart de ces espèces. La perte d'habitat, l'empiétement d'essences ligneuses par suite de la suppression des incendies et l'invasion d'espèces exotiques sont les catégories de menace qui ont le plus souvent été répertoriées.

Sept espèces d'amphibiens, 7 reptiles, 104 oiseaux et 33 mammifères ont été recensées dans les peuplements de chênes de Garry et ses écosystèmes associés. Les arbres, les arbustes et les espaces herbacés découverts offrent des ressources différentes pour s'alimenter, nicher et se percher et sont utilisés par différentes espèces. Les cavités dans les arbres ainsi que le bois mort sur pied et gisant fournissent des habitats essentiels pour 46% de vertébrés. Certaines espèces sont associées à des secteurs où sont juxtaposés des îlots de végétation à structure contrastante. Les glands figurent parmi les ressources les plus essentielles aux vertébrés dans les écosystèmes à chêne de Garry. On possède très peu de données sur les invertébrés présents dans ces écosystèmes. Au moins 800 espèces d'insectes et d'acariens sont associées au chêne de Garry. Quelque 140 d'entre elles s'alimentent sur les chênes, dont 48 parasites obligatoires. De nombreux papillons sont tributaires d'habitats ensoleillés et ouverts. L'hétérogénéité de l'habitat offre une variété de ressources à un assemblage diversifié d'espèces et répond aux besoins variés d'une même espèce au cours de la saison.

Une espèce de lombric, 10 papillons et 7 autres insectes habitant ces écosystèmes figurent sur la liste des espèces en péril. Parmi les espèces de vertébrés en péril, deux sont des reptiles, 9 des oiseaux, et 3 des mammifères. Le COSEPAC a inscrit sept taxons sur la liste des animaux en péril. Douze de ces espèces sont en péril à l'échelle de la planète. Toutes les espèces de vertébrés qui ont toujours été exclusivement tributaires des herbages et des peuplements clairs de chêne de Garry de la région ont presque disparu ou totalement disparu. La perte d'habitat est le principal facteur menaçant les animaux en péril.

L'équipe de rétablissement des écosystèmes à chêne de Garry a cerné trois « caractéristiques essentielles de l'écosystème ». Ces dernières sont fondamentalement associées à la composition, à la structure et à la dynamique des écosystèmes à chêne de Garry et sont jugées considérablement menacées dans le contexte actuel. Ces caractéristiques sont les suivantes :

1. l'intégrité spatiale, du point de vue des conséquences du morcellement de l'habitat;
2. le rôle du feu comme agent de perturbation naturel;

3. l’intégrité biotique, du point de vue de la présence et des effets des espèces exotiques.

Puisque très peu de recherches sur ces enjeux ont été effectuées dans les écosystèmes à chêne de Garry de la Colombie-Britannique, le présent examen s’appuie en grande partie sur la théorie écologique et sur l’information compilée ailleurs.

Le morcellement de l’habitat a pour effet de partager les écosystèmes en petits îlots qui sont exposés aux risques liés à une faible superficie et à l’isolement. La capacité d’îlots plus grands de supporter des populations plus nombreuses est importante pour empêcher la disparition d’espèces à l’échelle locale. En règle générale, les animaux de plus petite taille ont besoin de moins d’espace que les animaux plus grands. Les carnivores ont habituellement besoin d’un plus vaste territoire que les omnivores qui ont eux-mêmes des besoins supérieurs à ceux des herbivores. La capacité du paysage environnant de contribuer au soutien des espèces dépend de ses caractéristiques. En Colombie-Britannique, les îlots de chênes de Garry entourés de secteurs fortement aménagés abritent moins d’espèces d’oiseaux que les îlots situés dans des régions moins développées. Les populations d’oiseaux nicheurs associées aux habitats des chênaies et des herbages ont diminué dans le secteur de la ville de Victoria depuis les années 1970.

Les problèmes liés à la superficie des îlots sont étroitement apparentés à ceux de l’isolement. Différents organismes doivent se déplacer entre des îlots d’habitat favorable pour des raisons variées et à diverses échelles temporelles. La connectivité fonctionnelle des îlots dépend à la fois de la distance qui les sépare et de la nature de l’habitat intermédiaire. En règle générale, les animaux de plus grande taille et ceux des niveaux trophiques supérieurs ont tendance à se disperser plus loin que les animaux plus petits ou de niveaux trophiques inférieurs. Les corridors offrant un habitat naturel ou semi-naturel peuvent atténuer les effets du morcellement. Leur fonctionnalité dépendra des réactions des diverses espèces aux attributs qu’elles y trouvent.

L’évolution historique des écosystèmes de chênes-prairies est inextricablement liée au feu partout en Amérique du Nord. Les incendies de faible intensité et relativement fréquents étaient principalement dus aux activités d’aménagement du paysage des Premières nations locales. Après l’arrivée des Européens, la suppression des incendies a entraîné des modifications spectaculaires de la composition, de la structure et de la dynamique des écosystèmes. En l’absence du feu, nombre de prairies se sont transformées en arbustaies et en prairies-parcs, ces dernières devenant des terrains boisés à couvert fermé et des forêts de conifères. Des conversions à grande échelle de prairies et de prairies-parcs à bosquets de chênes ont été documentées aux États-Unis. Le feu a été décrit comme le plus grave problème écologique auquel doivent faire face les peuplements résiduels de chênes de Garry qui sont protégés contre le développement. La dynamique de peuplement des écosystèmes à chêne de Garry n’a pas été décrite en détail au Canada, mais des modes d’évolution similaires ont été observés dans certains endroits. Le brûlage dirigé a été utilisé comme outil de rétablissement dans certaines stations de chêne de Garry aux États-Unis. Son efficacité est ambiguë, car le feu favorise l’établissement de certaines plantes envahissantes. Les réactions des vertébrés à un régime de feux sont en grande partie conditionnées par les effets du feu sur la structure de la végétation. Les invertébrés sont vulnérables à la mortalité directement causée par le feu.

Les invasions biologiques sont parmi les problèmes écologiques modernes les plus graves. Elles ont les effets les plus pernicieux lorsqu'elles provoquent des changements au niveau de l'écosystème. Certaines études ont documenté la prédominance de plantes exotiques dans les écosystèmes à chêne de Garry et ses écosystèmes associés en Colombie-Britannique. D'après les résultats de l'échantillonnage, jusqu'à 82 % de la couverture herbacée se compose d'espèces envahissantes. Le genêt à balais (*Cytisus scoparius*) et d'autres espèces arbustives envahissantes sont parmi les espèces les plus menaçantes dans ces écosystèmes. La flore herbacée est dominée par des espèces exotiques dans nombre des stations, sinon la totalité. Divers outils de gestion ont été utilisés pour lutter contre les plantes exotiques. Les efforts déployés ont généralement exigé beaucoup de ressources et ont eu plus ou moins de succès. L'étourneau sansonnet (*Sturnella neglecta*) a contribué au déclin d'espèces indigènes d'oiseaux nichant dans les cavités. Vingt et un pour cent de l'ensemble des espèces de mammifères des écosystèmes à chêne de Garry et ses écosystèmes associés de la Colombie-Britannique sont exotiques. L'écureuil gris (*Sciurus carolinensis*), une espèce introduite de l'Est, pourrait contribuer au déclin des populations indigènes de l'écureuil roux (*Tamiasciurus hudsonicus*) et concurrencer certains animaux indigènes pour les glands. Quatre espèces envahissantes d'insectes ont causé ou sont susceptibles de causer de graves dommages au chêne de Garry. Il est de plus en plus manifeste que l'introduction d'espèces exotiques peut avoir des répercussions dévastatrices sur certains groupes taxinomiques moins connus. Les espèces de lombric présentes dans le sud-est de l'île de Vancouver sont presque exclusivement introduites. La grande limace (*Arion ater*), une espèce introduite, fait probablement du tort à des populations de certaines plantes rares. En Californie, un champignon associé à une épiphytie, qui a frappé le chêne et s'est propagée sur un territoire de plusieurs centaines de milles en cinq ans, pourrait être une espèce exotique introduite.

En conclusion, la conservation de l'écosystème revêt une grande importance en raison de l'éventail de valeurs biologiques et culturelles inhérentes au chêne de Garry et à ses écosystèmes associés. Compte tenu de l'ampleur et de la rapidité du déclin de ces écosystèmes, il est impératif d'élaborer et de mettre en œuvre des initiatives de conservation. Des recherches s'imposent pour combler les nombreuses lacunes dans nos connaissances, mais il faut dans l'intervalle appliquer des mesures de conservation fondées sur les données disponibles.

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Introduction

This report provides an overview of information about Garry oak (*Quercus garryana*) and associated ecosystems in British Columbia. It is based primarily upon the published literature and to a limited extent upon unpublished documents and consultation with experts. The report stresses ecological information relevant to conservation planning. The intention is to encapsulate the priority issues, summarize the current state of knowledge, and identify knowledge gaps pertaining to biological conservation. Coverage of each topic is, of necessity, brief and not all relevant issues are discussed. The reader is referred to an earlier review by Erickson (1994) for coverage of some topics not addressed in this report and additional discussion of some of the topics addressed herein.

The Garry Oak Landscape in British Columbia

Garry oak ecosystems are part of a mosaic of ecosystems located in southwestern British Columbia and extending southward into the United States. Garry oak ecosystems in British Columbia vary from savannah to parkland, to open and closed woodland, and also include forests with mixed canopies comprised of various proportions of Garry oak, arbutus (*Arbutus menziesii*), Douglas-fir (*Pseudotsuga menziesii*), and other trees. In some Garry oak stands, shrub cover is extensive and dense, in some stands it is patchy, and in others it is virtually absent. Various proportions of forbs, including dazzling arrays of showy spring wildflowers, grasses and grass-like plants, bryophytes, lichens, and fungi inhabit Garry oak stands. Moisture regimes of Garry oak ecosystems also range widely, and include riparian areas, moist flat meadows, drier upland areas, and extremely dry rocky outcrops on south-facing slopes with shallow soils.

Interspersed among the Garry oak ecosystems are other ecosystems. These ecosystems share characteristics in common with Garry oak ecosystems, such as numerous species in common, similar climatic influences, disturbance regimes and ecological processes, and many of the same threats to long-term survival. Maritime meadows, coastal bluffs, vernal pools, grasslands, and rock outcrops without oak cover fall within this category. These ecosystems are included as “associated ecosystems” within the scope of this report. Also included are transitional forests that include an oak component. Other ecosystems, such as coniferous forests and riparian areas without oak cover, wetlands, and agricultural, urban, and suburban areas are also integral components of the landscape. Although these ecosystems are not addressed directly in this report, they are considered to the extent that they play a role in the dynamics and sustainability of Garry oak ecosystems. Within the Garry oak landscape of British Columbia, biotic and abiotic interrelationships among patches of differing habitat are complex. Water, nutrients, and many organisms move among them. Some processes and some species are dependent upon the juxtaposition of patches of different kinds of habitats for their persistence and survival. In contrast, some processes and species are stressed by influences of adjacent habitats. Consequently, the composition, structure, and function of the various patches depend not only upon the internal attributes of the patches themselves, but also upon the relationships among the patches within the greater landscape.

Climate

Garry oak ecosystems occupy diverse climatic regions throughout their range in North America, ranging from cool, moderated coastal climates to interior climates with greater extremes. Average annual temperatures spanning 8 ° to 18 °C and average annual precipitation levels ranging from 170 to 2630 mm have been recorded at sites within, or adjacent to, Garry oak stands (Stein 1990). Within British Columbia, the majority of the range of Garry oak ecosystems lies within the rainshadow of the Olympic Mountains of Washington State and the Vancouver Island Ranges. The interaction of terrestrial topography and maritime weather processes confers a Mediterranean-like climate upon the area, with mild, wet winters and warm, dry summers. Mean annual temperature in Victoria, the heart of the British Columbia range of Garry oaks, is 10 °C. Mean daily temperatures range between 4 °C in December and 15.6 °C in July. A critical determinant of the character of the vegetation is the pronounced summer drought. Of the 690 mm of average annual precipitation in Victoria (Station Gonzales), less than 5 % falls during July and August. Annual moisture deficit exceeds 350 mm. West and north from Victoria, the influence of the rainshadow lessens, and the climate becomes progressively less Mediterranean in character, with higher annual precipitation and less pronounced summer drought (Roemer 1972, McMinn *et al.* 1976).

Geology and Soils

The bedrock underlying southeastern Vancouver Island is primarily igneous, metamorphic, and to some extent sedimentary in origin, dating from the Mesozoic and Quaternary Eras (McMinn *et al.* 1976). Glacial action during the Ice Ages, the most recent receding approximately 10,000 years ago, scoured and rounded the land formations. What are now coastal areas were also at times depressed by the weight of the glaciers so that they lay below sea level upon glacial retreat. Surficial materials left behind as the last glacial advance began to melt included unsorted morainal deposits at higher elevations, colluvial materials at the base of moderate to steep slopes, alluvial materials in some valley floors, and glacio-marine deposits covering most of the lowland area that was depressed below sea level. As these last glaciers melted, the depressed landforms began to rebound. Much of this glacio-marine material gradually became exposed as more and more of the surface came to exceed sea level.

The soils that have developed from these different parent materials differ in characteristics such as nutrient content, depth, texture, and consequent water-holding capacity, which in turn greatly influence the composition of the vegetation (Roemer 1972). Typical soils of Garry oak ecosystems are Orthic Sombric and Lithic Sombric Brunisols, with a well-developed Ah horizon and Moder to weak Mor humus formations (Roemer 1972).

Current, Past, and Future Distribution of Garry Oak Ecosystems

Garry oak ecosystems span an extensive north-south range, from southwestern British Columbia to southern California (Fig. 1). Elevation ranges from sea level to 2290 m

Figure 1. Global distribution of Garry oak ecosystems. Modified from Erickson (1993a). Used with permission.

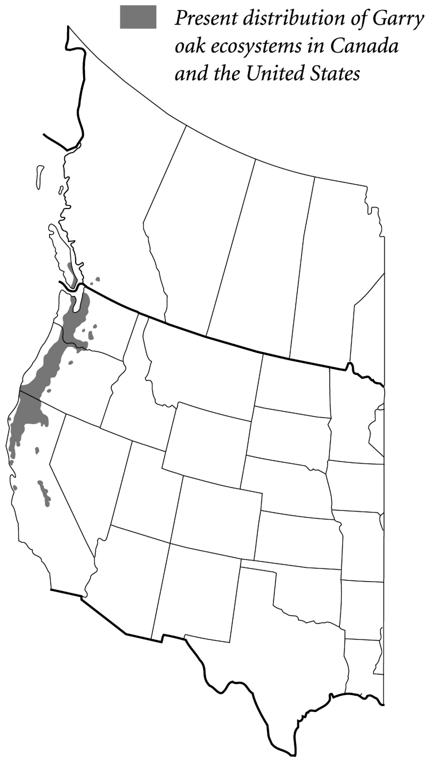
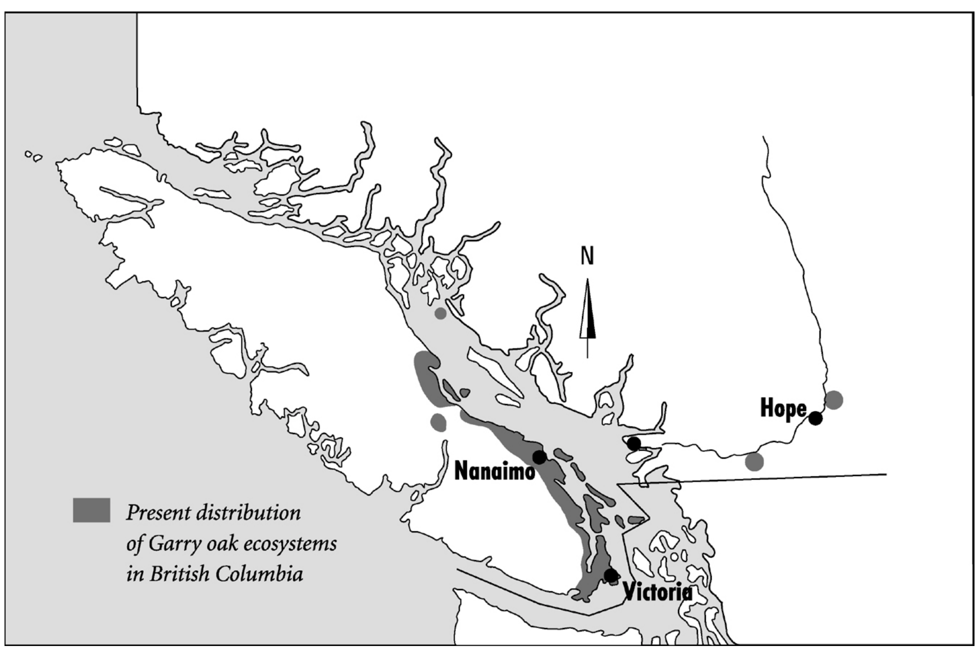


Figure 2. Distribution of Garry oak ecosystems in British Columbia. Modified from Erickson (1993a). Used with permission.



(Stein 1990). In British Columbia, Garry oak ecosystems occur on southeast Vancouver Island as far north as Comox and on the Gulf Islands (Fig. 2). This distribution falls within the Nanaimo Lowlands, Southern Gulf Islands, and Strait of Georgia Ecosections of the Georgia Depression Ecoprovince (Ward *et al*. 1998). Outlier stands are also located on Sumas Mountain and near Yale, both in the lower Fraser Valley within the Fraser Lowland Ecosection, and on Savary Island in the Strait of Georgia Ecosection, which represents the northern limit of the distribution of Garry oaks (Fig. 2) (Ward *et al*. 1998). Elevation in British Columbia does not exceed approximately 200 m (Stein 1990).

Pollen analysis has provided clues to the floristic history of southeastern Vancouver Island (Hebda 1993b, Hebda *et al.* in press). In some places, the glaciers had retreated by about 13,000 years ago. During the cool period following glacial retreat, the newly exposed landscape was initially colonized by lodgepole pine (*Pinus contorta*), willow (*Salix* spp.) soapberry (*Shepherdia canadensis*), and a variety of herbaceous species that occupied the open patches, including some species that are still present in the meadows. As the climate continued to become warmer and drier, different species characteristic of Garry oak and associated ecosystems arrived at different times. Garry oak did not arrive until about 8,000 years ago. Open meadow ecosystems reached their maximum extent from about 10,000 to about 6,000 years ago, declined until about 3,000 years ago when the climate again warmed and meadows expanded, and have been declining with a cooling trend for the last millennium. Current distributions are essentially remnants of a much wider historical range.

Current climate and ecosystem models predict dramatic changes in Pacific Northwest ecosystems with the progression of global warming. Mean annual temperatures in southern British Columbia are expected to rise approximately 2-3 °C by about 2050 AD (Hebda 1997). Much of what is currently Douglas-fir forest in coastal British Columbia is predicted to be replaced by Garry oak and related ecosystems within the next half century, although these predictions are vague in terms of structure and composition as a consequence of uncertainty about moisture relations. In addition, elevational shifts combined with overall range expansion of Garry oak savannas are expected throughout the Pacific Northwest (Franklin *et al.* 1991). Hence, component species of Garry oak and related ecosystems are expected to play increasingly important roles within the regional landscape if climate change proceeds as predicted.

Past and Current Human Management of the Garry Oak Landscape

The Garry oak landscape in British Columbia is located within the traditional territories of the Coast Salish First Peoples. Prior to European settlement, First Peoples used a number of landscape-management practices to enhance availability and productivity of resources within this landscape (Suttles 1951, Turner and Bell 1971, Norton 1979, Turner 1991, Agee 1993, Lutz 1995, Turner 1999). A number of bulbs were consumed by the people, including Hooker's onion (*Allium acuminatum*), nodding onion (*Allium cernuum*), harvest brodiaea (*Brodiaea coronaria*), chocolate lily (*Fritillaria lanceolata*), and others. Bulbs of camas (*Camassia quamash* and *C. leichtlinii*) plants comprised the primary vegetable food and a valued trade item. Camas beds were cleared of stones, weeds, and brush. In addition, regular burning of camas beds helped to eliminate competing shrubs and tree seedlings, maintained the open vegetation structure favourable to camas and a number of the other bulb-forming food plants, and helped to promote an abundant crop. Landscape burning may also have served additional functions, such as promoting the growth of edible bracken fern (*Pteridium aquilinum*) and other vegetables, enhancing berry crops, controlling insects, and enhancing deer and elk forage. These landscape management activities had profound effects upon the composition and structure of Garry oak and associated ecosystems, which are discussed later in this report.

The first European settlement on Vancouver Island was established in 1843, in the territory of the Lekwungen First People (Lutz 1995). Fort Victoria was the primary depot for the Hudson's Bay Company on the west coast of North America. The selection of southern Vancouver Island as the location for Fort Victoria was based largely upon the open, park-like character of the Garry oak landscape. The landscape held great aesthetic appeal to the British settlers, but little recognition was give to the human hand in its creation and maintenance. Following settlement, grazing of domestic animals and land clearing quickly encroached upon lands formerly managed by First Nations and marked a new landscape-management regime (Lutz 1995, Turner 1999). Fire soon started to be actively suppressed. In the 150 years since European settlement, agricultural, residential, and industrial development have vastly reduced the extent of Garry oak ecosystems. The extent of habitat loss has not been rigorously calculated, but rough estimates suggest that only about 1-5 % of the original Garry oak habitat, perhaps totalling less than 1,000 hectares (Erickson 2000), remains in a near-natural condition (Hebda and Aitkens 1993, Westland Resource Group 1999). Today, urban Victoria is centred on the heart of Garry oak habitat in British Columbia. Population growth within the region is among the fastest in North America (CRD Regional Planning Services and Westland Resource Group 1999). Current projections predict a population increase of approximately 30 % within 30 years in the Victoria area. As a result, burgeoning urban development is extending an ever-greater influence over the remnant sites of natural habitat.

Plant Species of Garry Oak and Associated Ecosystems

Garry Oak

Garry oak is the only native oak in British Columbia. It is a member of the subgenus *Lepidobalanus*, also known as the white oak group. Garry oak is also known as Oregon white oak, Pacific oak, prairie oak, western oak, post oak, and shin oak, and a shrubby variety endemic to severe sites in the Siskiyou Mountains is known as Brewer's oak (*Q. garryana* var. *breweri*) (Stein 1990, Pavlik *et al.* 1991, A. Ceska pers. comm.). Garry oak is also the only native oak in Washington and the dominant species of oak in Oregon. It achieves its largest stature in Oregon, where the largest recorded oak was 36.6 m tall, had a crown spread of 38.4 m, and was 246 cm in diameter (Stein 1990). The British Columbia Register of Big Trees reports record dimensions (height 35.0 m, crown spread 26 or more m, diameter 264 cm) distributed among 3 different trees (BC Conservation Data Centre 2000h). Little is known about ages of Garry oaks, but maximum ages likely exceed 400 years (Pavlik *et al* 1991). Some trees in the Victoria area have reached at least 350-375 years of age (Hebda 1993a, Anonymous 2000). Garry oaks grow on various sites and soil types, and can tolerate some degree of flooding and drought (Silen 1958, Stein 1990). On xeric sites or sites that experience seasonal drought, they are often the climax species. On more mesic sites, they tend to be out-competed by faster-growing trees, primarily conifers, unless maintained by disturbance (*e.g.* Thilenius 1968, Roemer 1972, Sugihara and Reed 1987b, Stein 1990, Agee 1993, Hanna and Dunn 1996, Hastings *et al.* 1997).

All oaks are monoecious, with each tree producing separate male and female flowers in spring, and are self-incompatible (Stein 1990, Ducousso *et al*. 1993). Pollen is wind-dispersed. Following pollination, Garry oak acorns mature over summer. Like all others of its genus, Garry oak is a mast fruiter, producing acorn yields that are highly variable among years (Coblentz 1980, Stein 1990, Peter and Harrington 2000, Fuchs unpubl. data). Acorn yields also vary tremendously among trees. Site conditions account for some of the spatial variation in acorn yield. Open-grown trees, and trees on moist, well-drained sites tend to produce more acorns than crowded trees and trees growing in wetlands or dry, rocky sites (Peter and Harrington 2000). Among oaks in general, variation in acorn production among years appears to be an evolved strategy, in which individual trees channel resources into reproduction in particular years in synchrony with others of the same species (Koenig *et al.* 1994, Koenig and Knops 1995, Koenig and Knops 2000). Functionally, this re-allocation of resources increases the probability of pollination success, which in turn increases the probability of seed set. Masting is also a successful strategy to satiate acorn predators. Keeping predator numbers low in poor acorn years increases the probability of having enough acorns survive predation in good acorn years to produce oak offspring.

Numerous vertebrate and invertebrate predators consume Garry oak acorns. The filbert weevil (*Curculio occidentis*) and the filbertworm (*Cydia latiferreana*) are the primary invertebrate predators. Larvae of these species develop within the acorn and consume it as they develop. In a study conducted on southeastern Vancouver Island over 3 years, 51- 81 % of acorns were infested with one or both of these species (Rohlfs 1999). Vertebrate predators are discussed later in this report. Losses of acorns to predators can be extremely high, resulting in decimation of the acorn crop in some years and in some habitats (Fuchs 1998).

Acorns ripen and fall in September and October. Steller’s jays (C*yanocitta stelleri*) are the primary dispersers of Garry oak acorns in British Columbia (Fuchs 1998). The birds hoard acorns in scattered locations in the ground to use as food during the fall and winter. Those acorns that escape recovery by the hoarder are thereby dispersed to hoarding locations. Oaks that establish from caches of Steller’s jays tend to be in open locations along the edges of dense patches of vegetation (Fuchs 1998). Acorns of Garry oaks in other regions, and indeed acorns of oaks around the world, are dispersed primarily by various rodents and corvids (crows, jays, and their allies) (Vander Wall 1990).

As with other members of the subgenus *Lepidobalanus* (Barnett 1977, Fox 1982), Garry oak acorns are not dormant and usually germinate within weeks of falling if they retain sufficient moisture (Silen 1958, Stein 1990, Fuchs 1998). They rapidly develop deep taproots that grow over the winter. Shoots emerge the following spring. Young seedlings depend upon reserves stored in the cotyledons for early growth (Crow 1988, Fuchs 1998, Fuchs *et al.* 2000). Roots and shoots are browsed by a number of mammals, including the deer mouse (*Peromyscus maniculatus*), Townsend’s vole (*Microtus* *townsendii*), black-tailed deer (*Odocoileus hemionus*), and introduced eastern cottontail (*Sylvilagus floridanus*) (Fuchs 1998). Invertebrate herbivores are numerous (Stein 1990). Some of the most damaging invertebrate herbivores of seedlings as well as mature oaks are 3 introduced insects: the jumping gall wasp (*Neuroterus saltatorius*), oak leaf phylloxeran (*Phylloxera glabra*), and gypsy moth (*Lymantria dispar*). Deep taproots confer a high degree of drought tolerance to the seedlings, but seedlings at xeric sites are susceptible to mortality from water stress (Fuchs 1998). Mature oaks are shade intolerant, but Garry oak seedlings are shade tolerant for at least the first 2 years of life (Bell and Papanikolas 1997, Papanikolas 1997, Fuchs 1998, Fuchs *et al.* 2000). Dormant buds on the root collar of Garry oak seedlings can sprout in response to browsing, stem die-back, or other causes (Stein 1990, Hibbs and Yoder 1993, Fuchs 1998, Fuchs *et al.* 2000).

Garry oaks reproduce vegetatively, by sprouting from the root collar or from underground rhizomes, as well as by seed (Sugihara and Reed 1987b, Stein 1990, Hanna and Dunn 1996). Oaks are stimulated to sprout by damage from fire, cutting, or other disturbance. A study in California concluded that most Garry oak regeneration was of sprout origin (Sugihara and Reed 1987a), but the relative contributions of seed and sprout to within-stand regeneration under a range of conditions are not well understood (Agee 1993). Although both seeds and sprouts have the potential to produce offspring within stands, seeds are required for movement of offspring away from parents and hence for reproduction of oaks at the landscape level.

Regeneration of oaks is a common problem at a wide range of locations throughout the world, such as California (Muick and Bartolome 1987), eastern and central United States (Loftis and McGee 1993), the Mediterranean (Herrera 1995), and other locations. Studies have examined the effects of predation, herbivory, competition, water and heat stress, and shading on survival and germination of acorns as well as survival and growth of seedlings (*e.g.* Plumb and Pillsbury 1987, Standiford 1991, Loftis and McGee 1993, Herrera 1995, Fuchs 1998, Fuchs *et al*. 2000). Results of these studies vary depending upon oak species, acorn burial depth, site (geographical location, slope, aspect, habitat), and year (weather, populations of acorn predators and herbivores). Concern has also been expressed that regeneration of Garry oaks in British Columbia may not be adequate (Pojar 1980, Hebda 1993a, Erickson 1996, Fuchs 1998), but this has not been documented. Fuchs (1998) found that, depending on burial depth and habitat, 0-85 % of experimentally dispersed acorns produced seedlings that survived at least 1 year post-emergence. Erickson (1996) found substantial cover of Garry oaks < 2 m tall in some Garry oak stands and sparse to absent cover in other stands. Further information is needed to evaluate these data in relation to site conditions and historic regeneration patterns. Studies indicate that regeneration of Garry oaks is linked with the disturbance regime (Sugihara and Reed 1987a, Sugihara and Reed 1987b, Agee 1993, Hanna and Dunn 1996). Under a regime of frequent, low-intensity fire, oak recruitment is gradual. Many oak seedlings and sprouts are killed by fire, but some escape early fire mortality and hence are able to reach a fire-resistant age. Depending on site conditions, cessation of burning may result in an initial pulse of regeneration from increased survival of seedlings and sprouts, resulting in oak density greatly exceeding density prior to the change in the disturbance regime. Subsequent recruitment varies, again depending upon disturbance and site conditions. Evaluations of regeneration must consider recruitment rates in relation to historic and current stand structure. Recruitment rates that perpetuate current stand densities may not be possible due to the shade-intolerance of Garry oaks, and may not be optimal in a conservation context. Stand dynamics are discussed further later in this report in relation to the role of fire as a natural disturbance agent.

Garry oaks reach reproductive maturity at about 20-25 years of age (Peter and Harrington 2000). Acorn production increases until about age 80-85. After age 80, production reaches a plateau, although very old trees appear to be poor producers of acorns. Trees have a well-developed taproot and also a well-developed lateral root system. This confers a high degree of windfirmness. Surprisingly, a relatively high percentage of Garry oak roots are found in the upper soil layers (Stein 1990).

Analysis from Washington revealed little correlation between morphological or genetic variation of Garry oaks and geographical distribution (Taylor and Boss 1975). Oaks were surprisingly genetically similar throughout Washington. In contrast, genetic analysis revealed considerable genetic variation across the range of Garry oak (Edwards *et al.* in press). Canadian oaks and oaks from the United States grouped separately. Within Canada, genetic differences were generally correlated with geographic distance. Current oak distributions largely reflect movements in response to climate change (Hebda 1993b, Hebda *et al.* in press), likely mediated primarily by dispersal by acorn-caching animals (Vander Wall 1990, Fuchs 1998). These movements may also have been punctuated by long-distance dispersal events from the activities of humans (Taylor and Boss 1975) or germination of an occasional undigested acorn, carried in the crop of a band-tailed pigeon (*Columba fasciata*), after the pigeon died (Glendenning 1944, Webb 1986). Since the Pleistocene, Garry oak ranges have expanded and contracted with shifts in climatic conditions and extent of the glacial ice sheets (Hebda 1993a, Hebda *et al.* 1999). Current distributions may also reflect periodic occupancy of refugia from the great masses of ice (Voeks 1981).

Plant Species and Communities

At least 694 species, subspecies, and varieties of plants have been identified in Garry oak and associated ecosystems in British Columbia (Table 1). Garry oak ecosystems are home to more plant species than any other terrestrial ecosystem in coastal British Columbia (Ward *et al.* 1998). Many of the species are "peripheral" species, reaching the northern limits of their range in southern British Columbia (Pojar 1980, Ceska 1993). Because many of the species are found nowhere else in British Columbia, Garry oak and associated ecosystems contribute disproportionately to the floral biodiversity of the province relative to the land area occupied by the ecosystems. A diverse bryophyte and lichen flora takes advantage of the thick, moisture-holding bark of Garry oak trees (Ryan 1991, Ryan 1993). Overall, individual plant species have varied habitat associations. This reflects the broad ecological amplitude of Garry oaks as well as the complex disturbance history of Garry oak and associated ecosystems. Consequently, plant community composition varies considerably. A number of research, inventory and classification projects have contributed to our understanding of plant community distribution as well as factors influencing community structure. This report summarizes work conducted in British Columbia. Floristic analyses have also been conducted in Garry oak and associated prairie ecosystems in the United States (*e.g.* Thilenius 1968, del Moral and Deardorff 1976, Fonda and Bernardi 1976, Saenz and Sawyer 1986, Sugihara

Table 1. Plant taxa of Garry oak and associated ecosystems in British Columbia[1]. Associated ecosystems include maritime meadows, coastal bluffs, vernal pools, grasslands, rock outcrops, and mixed transitional forests. * designates introduced taxon. [e] designates extirpated taxon. Compiled by W.R. Erickson and F.M. Spencer[2].

Bryophyte & Lichen Layer
Alectoria sp.
Amphidium lapponicum
Anacolia menziesii
Antitrichia californica
Antitrichia curtipendula
Aulacomnium androgynum
Bacidia declinis
Bacidia naegelii
Bacidia rubella
Bartramia stricta
Brachythecium albicans
Bryoria sp.
Bryum capillare
Bryum miniatum
Calicium spp.
Caloplaca citrina
Caloplaca holocarpa
Calypogeia muelleriana
Catillaria globulosa
Cetraria chlorophylla
Cetraria orbata
Cetraria pinastri
Chaenotheca subroscida
Claopodium bolanderi
Claopodium crispifolium
Cladina portentosa
Cladina rangiferina
Cladonia cariosa
Cladonia chiorophaea
Cladonia fimbriata
Cladonia furcata
Cladonia pocillum
Cladonia spp.
Claopodium crispifolium
Collema flaccidum
Collema nigrescens
Dendroalsia abietina
Dicranum fuscescens
Dicranum scoparium
Dicranum tauricum
Dicranoweisia sp.
Didymodon vinealis
Diploschistes scruposus
Drepanocladus uncinatus
Evernia mesomorpha
Evernia prunastri
Frullania bolander
Grimmia torquata

Table 1 cont'd

Hedwigia ciliata
Homalothecium aeneum
Homalothecium fulgescens
Homalothecium megaptilum
Homalothecium nevadense
Homalothecium nuttallii
Hylocomnium splendens
Hypnum circinale
Hypnum subimponens
Hypogymnia imshaugii
Hypogymnia physodes
Isothecium cristatum
Isothecium myosuroides
Isothecium stoloniferum
Kindbergia oregana (= *Eurhynchium oregonum*)
Lecanora impudens
Lecanora pacifica
Lecanora varia
Lecidea lurida
Lepraria chlorina
Leptogium furfuraceum
Leptogium saturninum
Lobaria oregana
Lobaria pulmonaria
Lobaria scrobiculata
Melanelia fuliginosa
Metaneckera menziesii
Micarea prasina
Nephroma helveticum var. *sipeanum*
Nephroma laevigatum
Nephroma resupinatum
Normandina pulchella
Ochrolechia parella
Opegrapha ochrocheila
Opegrapha varia
Orthotrichum lyellii
Pannaria leucosticta
Pannaria rubiginosa
Parmelia glabratula
Parmelia saxatilis
Parmelia sulcata
Parmeliella mediterranea
Peltigera britannica
Peltigera collina
Peltigera horizontalis
Peltigera leucophlebia
Peltigera neopolydactyla
Peltigera polydactyla
Pertusaria amara
Pertusaria ambigens
Pertusaria borealis
Pertusaria leucostoma
Pertusaria multipuncta

Table 1 cont'd

Phaeroceros hallii
Phlyctis argena
Physcia adscendens
Physcia grisea
Physconia enteroxantha
Physconia perisidiosa
Plagiomnium insigne
Plagiomnium venustum
Plagiothecium piliferum
Platismatia glauca
Platismatia herrei
Pleurozium schreberi
Pohlia cruda
Pohlia nutans
Polytrichum juniperinum
Polytrichum piliferum
Porella cordeana
Porella roellii
Porella navicularis
Pseudotaxiphyllum elegans
Ramalina farinacea
Ramalina menziesii
Racomitrium canescens
Racomitrium elongatum
Racomitrium heterostichum
Racomitrium lanuginosum
Rhytidiadelphus loreus
Rhytidiadelphus triquetrus
Rhizocarpon distinctum
Rhizocarpon geographicum
Rhizocarpon grande
Scapania bolanderi
Scleropodium cespitans
Schistidium sp.
Sphaerocarpos texanus
Stereocaulon alpinum
Sticta fuliginosa
Syntrichia laevipila
Thelotrema lepadinum
Tortula laevipila var. *meridionalis*
Tortula princeps
Tortula ruralis
Tortula cf. virescens
Usnea cavernosa
Usnea occidentalis
Xanthoparmelia cumberlandia
Zygodon viridissimus
Tree Layer
Abies grandis
Acer glabrum
Acer macrophyllum

Table 1 cont'd

Arbutus menziesii
Betula papyrifera
Cornus nuttallii
Fraxinus latifolia
Pinus contorta var*. contorta*
Picea sitchensis
*Pinus ponderosa**
Populus tremuloides ssp.*vancouveriana*
Populus balsamifera ssp. trichocarpa
*Prunus avium**
*Prunus domestica**
*Prunus pissardii**
Prunus emarginata
Pseudotsuga menziesii
Quercus garryana
Rhamnus purshiana
Thuja plicata
Shrub Layer
Acer circinatum
Amelanchier alnifolia
Arctostaphylos columbiana
Betula occidentalis
Cornus stolonifera (= *C. sericea*)
Corylus cornuta var*. california*
*Cotoneaster horizontalis**
Crataegus douglasii
*Crataegus monogyna**
*Cytisus scoparius**
*Daphne laureola**
Gaultheria shallon
Gaultheria ovatifolia
*Hedera helix**
Holodiscus discolor
*Ilex aquifolium**
*Ilex europea**
Juniperus communis
Juniperus scopulorum
*Ligustrum vulgare**
Lonicera ciliosa
Lonicera hispidula
Lycium barbarum (= *L. halimifolium**)
Mahonia aquifolium
Mahonia nervosa
Malus fusca
Oemleria cerasiformis
Pachystima myrsinites
Philadelphus lewisii
Physocarpus capitatus
Prunus virginiana
Ribes divaricatum
Ribes lobbii

Table 1 cont'd

Ribes sanguineum
*Rosa eglanteria**
Rosa gymnocarpa
Rosa nutkana
Rosa pisocarpa
*Rubus procerus** (= *R. discolor*, R. armeniacus**)
*Rubus laciniatus **
Rubus leucodermis
Rubus parviflorus
Rubus ursinus
Salix hookeriana
Salix scouleriana
Salix scouleriana
Sambucus caerulea
Sambucus racemosa
Shepherdia canadensis
Sorbus sitchensis
Spirea douglasii
Symphoricarpos albus
Symphoricarpos mollis
Taxus brevifolia
Toxicodendron diversilobum (= *Rhus diversiloba*)
Vaccinium ovatum
*Vinca minor**
*Vinca major**
*Ulex europaeus **
Herb Layer
Achillea millefolium
Adenocaulon bicolor
Agoseris glauca
Agoseris grandiflora
Agoseris heterophylla
*Agrostis capillaris** (= *A. tenuis*)
Agrostis exarata
*Agrostis gigantea** (= *A. alba**, in part)
Agrostis microphylla
Agrostis pallens (= *A. diegoensis*)
Agrostis scabra
*Agrostis stolonifera** (= *A. alba**, in part)
*Aira caryophyllea**
*Aira praecox**
*Alliaria petiolata** (= *Alliaria officinalis**)
Allium acuminatum
Allium amplectens
Allium cernuum
Allium geyeri
*Allium vineale**
Alopecurus aequalis
Alopecurus carolinianus
*Alopecurus geniculatus**
*Alopecurus prateneis**

Table 1 cont'd

*Amsinckia menziesii**
*Anagallis arvensis**
Anagallis minima (= *Centunculus minimus*)
Anemone lyallii (= *Pulsatilla lyallii*)
Anemone multifida (= *Pulsatilla multifida*)
Antennaria microphylla
Antennaria neglecta
*Anthoxanthum odoratum**
*Anthoxanthum puellii** (= *A. aristatum**)
*Aphanes arvensis** (= *Alchemilla occidentalis**)
*Aphanes microcarpa**
Apocynum androsaemifolium
*Arabidopsis thaliana**
Arabis drummondii
Arabis glabra
Arabis hirsuta
Arabis holboellii ssp. *secunda*
Arabis holboellii ssp. *retrofracta**
Arctostaphylos uva-ursi
Arenaria capillaris ssp. *americana*
*Arrhenatherum elatius**
*Artemisia absinthium**
Artemisia lindleyana
Asarum caudatum
Aspidotis densa
Asplenium trichomanes
Aster chilensis
Aster curtus
Aster eatonii
Aster ericoides ssp. pansus
Aster foliaceus
Aster occidentalis
Aster radulinus
Aster subspicatus
Athysanus pusillus
Balsamorhiza deltoidea
Barbarea orthoceras
*Barbarea vulgaris**
*Bellis perennis**
Bidens amplissima
Bidens cernua
Botrychium simplex
*Brassica campestris**
*Briza minor**
Brodiaea coronaria
Bromus carinatus
*Bromus commutatus**
*Bromus hordeaceus** (= *B. mollis**)
*Bromus inermis**
Bromus pacificus
*Bromus racemosus**
*Bromus rigidus**
Bromus sitchensis

Table 1 cont'd

*Bromus sterilis**
*Bromus tectorum**
Bromus vulgaris
Calandrinia ciliata
Callitriche marginata
Calypso bulbosa
Camassia leichtlinii
Camassia quamash
Campanula scouleri
*Capsella bursa-pastoris**
Cardamine nuttallii var. *nuttallii* (= *C. pulcherrima* var. *tenella**)
Cardamine oligosperma
Carex brevicaulis
Carex deweyana
Carex feta
Carex inops
Carex obnupta
Carex praticola
Carex rossii
Carex saximontana
Carex scirpoidea var. *stenochlaema*
Carex tracyi
Carex tumulicola
Carex unilateralis
Castilleja ambigua
Castilleja attenuata (= *Orthocarpus attenuatus*)
Castilleja bracteosa
Castilleja hispida
Castilleja levisecta
Caucalis microcarpa
*Centaurea biebersteinii** (= *C. maculosa**)
*Centaurea cyanus**
*Centaurea melitensis**
*Centaurea nigrescens**
*Centaurea paniculata**
*Centaurium erythraea** (= *C. umbellatum**)
Centaurium muehlenbergii
Cerastium arvense
*Cerastium semidecandrum**
*Cerastium viscosum**
*Cerastium vulgatum**
Cheilanthes gracillima
*Chenopodium album**
Chimaphila umbellata
*Chrysanthemum leucanthemum**
*Cichorium intybus**
*Cirsium arvense**
Cirsium brevistylum
*Cirsium vulgare**
Clarkia amoena
Clarkia purpurea ssp. *viminea*
Claytonia exigua (= *Montia spathulata*)
Claytonia parviflora (= *Montia perfoliata* var. *parviflora*)

Table 1 cont'd

Claytonia perfoliata (= *Montia perfoliata*)
Claytonia rubra (= *Montia parviflora* ssp. *depressa*)
Claytonia sibirica (= *Montia siberica*)
Clintonia uniflora
Clinopodium douglasii (= *Satureja douglasii*)
Collinsia grandiflora
Collinsia parviflora
Collomia grandifolia
Collomia heterophylla
Collomia linearis
Comandra umbellata var. *californica*
Conioselinum gmelinii (= *C. pacificum*)
*Conium maculatum**
*Conyza canadensis**
Corralorhiza sp.
Corydalis sempirvirens
Crassula aquatica
Crassula connata var. *connata*
Crassula erecta
*Crepis capillaris**
Crepis elegans
Crocidium multicaule
Cryptantha affinus
Cryptogramma crispa
*Cynosurus cristatus**
*Cynosurus echinatus**
Cystopteris fragilis
*Dactylis glomerata**
Danthonia californica
Danthonia intermedia
Danthonia spicata
*Daucus carota**
Daucus pusillus
Delphinum menziesii
Deschampsia cespitosa
Deschampsia danthonioides
Dicentra formosa
*Digitalis purpurea**
Disporum hookeri
Dodecatheon hendersonii
Dodecatheon pulchellum
*Draba verna**
Dryopteris arguta
Elymus glaucus
Elymus hirsutus
Elymus mollis
*Elymus repens** (= *Agropyron repens**)
Epilobium brachycarpum (= *E. paniculatum*)
Epilobium ciliatum
Epilobium densiflorum
Epilobium foliosum
Epilobium minutum
Epilobium torreyi

Table 1 cont'd

Erigeron philadelphicus
Erigeron strigosus
Eriophyllum lanatum
Erodium cicutarium*
Erythronium oregonum
Erythronium revolutum
Festuca idahoensis (= _F. idahoensis_ var. _roemeri_)
Festuca occidentalis
Festuca trachyphylla* (= _F. ovina*_)
Festuca rubra(*)[3]
Festuca saximontana
Fragaria chiloensis
Fragaria vesca
Fragaria virginiana
Fritillaria affinis (= _F. lanceolata_)
Gaillardia aristata
Galium aparine
Galium boreale
Geranium bicknellii
Geranium carolinianum
Geranium dissectum*
Geranium molle*
Geranium robertianum*
Gilia capitata var. _capitata_
Githopsis specularioides
Gnaphalium microcephalum
Gnaphalium purpureum*
Gnaphalium uliginosum* (= _G. vulgare*_)
Goodyera oblongifolia
Grindelia integrifolia
Helenium autumnale var. _grandiflorum_
Heterocodon rariflorum
Heuchera micrantha
Hieracium albiflorum
Holcus lanatus*
Hordeum brachyantherum
Hordeum murinum*
Hyacinthoides hispanicus (= _Endymion non-scripta_)
Hydrophyllum fendleri
Hypericum scouleri* (= _H. formosum*_)
Hypericum perforatum*
Hypochaeris glabra*
Hypochaeris radicata*
Idahoa scapigera
Isoetes nuttallii
Juncus acuminatus
Juncus arcticus
Juncus balticus
Juncus bufonius
Juncus effusus
Juncus kelloggii
Koeleria macrantha
Lactuca biennis

Table 1 cont'd

Lactuca muralis
*Lamium amplexicaule**
*Lamium purpureum**
*Lapsana communis**
Lathyrus japonicus
*Lathyrus latifolius**
Lathyrus nevadensis
*Lathyrus sphaericus**
*Leontodon taraxacoides** (= *L. nudicaulis**)
*Lepidium densiflorum**
Lepidium virginicum
Lilium columbianum
Limnanthes macounii
Linanthus bicolor
Linaria canadensis var. *texana*
*Linaria dalmatica**
Listera cordata
Lithophragma glabrum (= *L. bulbifera*)
Lithophragma parviflorum
*Lolium multiflorum** (= *L. persicum**)
*Lolium perenne**
Lomatium dissectum
Lomatium grayi
Lomatium martindalei
Lomatium nudicaule
Lomatium triternatum
Lomatium utriculatum
*Lotus corniculatus**
Lotus denticulatus
Lotus formosissimus
Lotus micranthus
*Lotus tenuis**
Lotus unifoliolatus var. *unifoliolatus* (= *L. purshianus*)
Luina hypoleuca
Lupinus bicolor ssp. *bicolor* (= *L. micranthus* var. *bicolor*)
Lupinus densiflorus var. *densiflorus*
Lupinus lepidus
Luzula multiflora ssp. *comosa*
Luzula multiflora ssp. *multiflora**
*Lychnis coronaria**
Madia exigua
Madia glomerata
Madia gracilis
Madia madioides
Madia minima
*Madia sativa**
Maianthemum canadense
Marah oreganus
*Marrubium vulgare**
*Matricaria matricarioides**
Meconella oregana
*Medicago lupulina**
*Medicago sativa**

Table 1 cont'd

Melica harfordii
Melica subulata
*Melilotus albus**
Microseris bigelovii
Microseris lindleyi
Mimulus alsinoides
Mimulus guttatus
Minuartia pusilla
Moehringia macrophylla (= *Arenaria macrophylla*)
Monotropa uniflora
Montia dichotoma
Montia fontana
Montia howellii
Montia linearis
Montia parvifolia
Muhlenberia filiformis
*Muscari botryoides**
*Myosotis discolor**
Myosotis laxa
Myosurus apetalus var. *borealis*
Myosurus minimus
*Narcissus pseudonarcissus**
Navarretia intertexta
Navarretia squarosa
Nemophila breviflora
Nemophila parviflora
Nemophila pedunculata
Olsynium douglasii (= *Sisyrinchium douglasii*)
Opuntia fragilis
Orobanche californica ssp. *californica*
Orobanche fasciculata
Orobanche pinorum
Orobanche uniflora
Orthocarpus bracteosus
Orthocarpus tenuifolius
Osmorhiza chilensis
Panicum occidentale
Panicum oligosanthes var. *scribnerianum*
Penstemon davidsonii
Penstemon serrulatus
Pentagramma triangularis (= *Pityrogramma triangularis*)
Perideridia gairdneri
Phacelia linearis
*Phleum pratense**
Phlox gracilis (= *Microsteris gracilis*)
Piperia candida
Piperia elegans (= *Platanthera unalescensis* ssp. *elata*)
Piperia unalascensis (= *Platanthera unalescensis*)
Plagiobothrys figuratus
Plagiobothrys scouleri
Plagiobothrys tenellus
Plantago elongata
*Plantago lanceolata**

Table 1 cont'd

*Plantago major**
*Plantago media**
Plectritis brachystemon
Plectritis congesta
Plectritis macrocera
*Poa annua**
*Poa bulbosa**
*Poa compressa**
Poa howellii
*Poa pratensis**
Poa secunda (= *P. sandbergii, P. canbyi, P. scabrella, P. rupicola*)
*Polygonum arenastrum**
Polygonum douglasii ssp. *spergulariaeforme*
Polypodium hesperium
Polypodium glycyrrhiza
*Polypogon monospeliensis**
Polystichum imbricans
Polystichum munitum
Potentilla glandulosa
*Prunella vulgaris**
Psilocarphus elatior
Psilocarphus tenellus var. *tenellus*
Pteridium aquilinum
Pyrola asarifolia
Ranunculus alismaefolius var. *alismaefolius*
Ranunculus californicus
Ranunculus lobbii[e]
Ranunculus occidentalis
Ranunculus orthorhynchus
*Ranunculus repens**
Rhinanthus minor (= *R. crista-galli*)
Rorippa palustris (= *R. islandica*)
*Rorippa sylvestris**
*Rumex acetosella**
Rupertia physodes (= *Psoralea physodes*)
Sagina decumbens ssp. *occidentalis*
Sanicula arctopoides
Sanicula bipinnatifida
Sanicula crassicaulis
Sanicula crassicaulis var. *tripartita*
Sanicula graveolens
Saxifraga caespitosa
Saxifraga ferruginea
Saxifraga integrifolia
Saxifraga rufidula (= *S. occidentalis*)
*Saxifraga tridactylites**
*Scirpus setaceous**
*Sedum acre**
Sedum lanceolatum
Sedum oreganum
Sedum spathulifolium
Selaginella wallacei
Senecio macounii

Table 1 cont'd

*Senecio vulgaris**
*Sherardia arvensis**
*Silene anthirrhina**
*Silene gallica**
Silene latifolia ssp. *alba** (= *Lychnis alba**)
Silene scouleri ssp*. grandis*
Sisyrinchium idahoense var*. macounii*
Smilacina racemosa
Smilacina stellata
*Solanum dulamara**
*Soliva sessilis**
*Sonchus arvensis**
*Sonchus asper**
Spiranthes romanzoffiana
*Stellaria media**
Stellaria nitens
Stipa lemmonnii
Streptopus amplexifolius
*Tanacetum vulgare**
*Taraxacum laevigatum**
*Taraxacum officinale**
*Teesdalia nudicaulis**
Tellima grandiflora
Thalictrum occidentale
Thelypteris nevadensis
*Thlaspi arvense**
Thysanocarpus curvipes
Tonella tenella
*Tragopogon porrifolius**
Trientalis borealis (= *T. borealis* ssp*. latifolia*)
*Trifolium campestre** (= *T. procumbens**)
Trifolium cyathiferum
Trifolium depauperatum
Trifolium dichotomum (= *T. macraei* var*. dichotomum*)
*Trifolium dubium**
*Trifolium hybridum**
Trifolium microcephalum
Trifolium microdon
Trifolium oliganthum
*Trifolium repens**
*Trifolium subterraneum**
Trifolium variegatum
Trifolium willdenowii (= *T. tridentatum*)
Trifolium wormskjoldii
Trillium ovatum
Triodanis perfoliata var*. perfoliata*
Triphysaria pusilla (= *Orthocarpus pusillus*)
Triphysaria versicolor ssp. *versicolor*
Trisetum cernuum var*. cernuum*
Trisetum cernuum var*. canescens = T. canescens*
*Triticum aestivum**
Triteleia howellii (= *Brodiaea howellii*)
Triteleia hyacinthina

Table 1 cont'd

Vaccinium caespitosum
*Veronica arvensis**
Veronica serpyllifolia var. *humifusa*
Veronica serpyllifolia var. *serpyllifolia**
*Veronica officinalis**
Vicia americana
*Vicia cracca**
*Vicia hirsuta**
Vicia nigricans ssp. *gigantea*
*Vicia sativa**
*Vicia tetrasperma**
Viola adunca
Viola howellii
*Viola odorata**
Viola praemorsa ssp. praemorsa
*Vulpia bromoides**[4]
Vulpia microstachys
Vulpia myuros var. *hirsuta* (= *V. megalura*)
Vulpia myuros var. *myuros**
Zygadenus venenosus

[1]Follows taxonomy of Douglas *et al.* 1994, Douglas *et al.* 1998a, Douglas *et al.* 1998b, Douglas *et al.* 1999a, Douglas *et al.* 1999b, and Douglas *et al.* 2000b.

[2]Compiled from Roemer 1972, Szczawinski and Harrison 1972, Bird and Bird 1973, Pojar 1980, Janszen 1981, Pattison and Karanka 1981, Ryan 1991, Roemer 1993, Douglas et al. 1994, Goward 1995, Erickson 1996, Pojar and MacKinnon 1996, Douglas *et al.* 1998a, Douglas *et al.* 1998b, Ryan 1996, Penn 1998, Douglas *et al*. 1999a, Douglas *et al*. 1999b, BC Conservation Data Centre 2000a, BC Conservation Data Centre 2000b, Chapman 2000, Douglas *et al.* 2000b, Biospherics 2001, Chislett *et al.* no date, A. Ceska pers. comm., T. Fleming pers. comm, J. Kirkby pers. comm, C. Maslovat pers. comm., H. Roemer pers. comm., W.R. Erickson pers. obs., W.R. Erickson unpublished data, H. Roemer unpubl. data.

[3]Includes both native and introduced forms

[4]Genus formerly known as *Festuca*

and Reed 1987b, Salstrom 1989, Riegel *et al.* 1992). These are not discussed in this report.

Approaches to inventory and classification of Garry oak and associated plant communities in British Columbia have varied widely. Extensive sampling has been conducted by Roemer (1972), Erickson (1996), the BC Conservation Data Centre (CDC), and others, but many sites have yet to be fully inventoried or mapped. A number of site-specific plant inventories have been conducted by governmental and non-governmental agencies, First Nations, individual naturalists, and others (Garry Oak Ecosystems Recovery Team 2000). These are more or less comprehensive, depending upon skills, resources, and objectives of those conducting the inventories. Some of this information is housed with the CDC, but much of it resides with various agencies and has not been integrated into a central repository. A comprehensive, standardized classification system for Garry oak and associated ecosystems has not been adopted by provincial and other agencies. Hence, many ecosystem inventory and mapping projects employ *ad hoc* approaches, using more or less generalized ecosystem designations (*e.g.* Janszen 1981, Searle and Associates 1990, Ussery 1992, Cousens and Lee 1998, T. Fleming pers. comm.). A few recent projects have used detailed provincial methodologies and derived classifications for units not currently defined by the provincial Ministry of Forests or Conservation Data Centre (see below) (Fleming 1999, Fleming 2000).

Following is a summary of 5 of the major classification systems that have been used in Garry oak and associated ecosystems in British Columbia. Objectives, methodologies, and scope vary among the different initiatives. Approaches and findings of the different initiatives are briefly described. Some of the schemes are more applicable to Garry oak ecosystems than others. Other than indicating extent of applicability, no attempt is made in this report to evaluate their relative merits.

Roemer (1972) conducted the first detailed vegetation study of Garry oak ecosystems in British Columbia. His hierarchical classification, based upon vegetation sampling at relatively undisturbed sites on the Saanich Peninsula, defined a *Quercus-Bromus* (*Q-B*) Alliance. The Alliance is comprised of 2 associations, the *Quercus-Geranium* (*Q-G*) association and the *Quercus-Erythronium* (*Q-E*) association, and a number of subassociations and variants within them. The Alliance is characterized by the presence of California brome (*Bromus carinatus*), yarrow (*Achillea millefolium*), Scotch broom (*Cytisus scoparius*; introduced), common vetch (*Vicia sativa*; introduced), field chickweed (*Cerastium arvense*), and Kentucky bluegrass (*Poa pratensis*; most or all forms introduced). The 2 associations share many species in common, but species composition of the *Q-E* association, in contrast with the *Q-G* association, overlaps considerably with that of conifer forests. The *Q-G* association occupies the driest core Garry oak area and the *Q-E* association is found in peripheral areas with higher annual precipitation. The *Arbutus-Pseudotsuga* (*A-P*) association, within the *Pseudotsuga* Alliance, also has a frequent presence of Garry oak, and is the most closely related of all other plant associations in the study area with the Garry oak communities. The *A-P* occupies sites with slightly cooler exposures than those occupied by *Q-B* communities. Roemer concluded that moisture relations are the dominant determinants of plant distributions. He also suggested that fire history accounts for disclimax occurrences of *Q-G* on deeper soils where conifer forest would otherwise occur. He noted that the prevalence of invasive species, in combination with changes in the fire regime and densities of grazing and browsing animals, obscures the elucidation of community structure and composition that was present prior to European settlement.

The BC Ministry of Forest's Biogeoclimatic Ecosystem Classification (BEC) system interprets vegetation communities as the product primarily of climate, local environmental factors, and time (Meidinger and Pojar 1991, Green and Klinka 1994). The influence of local environmental factors is expressed as the soil moisture regime and the soil nutrient regime. The most widely used application of the BEC system is site classification, known as site series. Sites are classified in terms of climatic zone and the potential climax vegetation that is either growing or predicted to grow at the site.

Although the BEC system comprises the foundation for most ecosystem analysis and interpretation in British Columbia, it is of limited applicability in Garry oak and associated ecosystems. The Ministry of Forest's focus has traditionally been forested systems, particularly systems dominated by commercially important tree species. Garry oak, grassland, and open ecosystems have not, for the most part, been classified within the BEC system. Site series that include a Garry oak component are Douglas-fir – Oniongrass (coded as 03) and, to a lesser extent, Douglas-fir – Lodgepole pine – Arbutus (coded 02), both within the Coastal Douglas-fir moist maritime (CDFmm) climatic subzone (Green and Klinka 1994). Both site series indicate very dry soil moisture regimes. Site series 03 indicates a rich to very rich soil nutrient regime, in contrast to 02, which indicates a very poor to medium one. Dominant plants in the 02 site series are Douglas-fir, arbutus, dull Oregon grape (*Mahonia nervosa*), oceanspray (*Holodiscus discolor*), electrified cat's-tail moss (*Rhytidiadelphus triquetrus*), and Oregon beaked moss (*Kindbergia oregana*). Dominant plants in the 03 site series are Douglas-fir, Garry oak, Alaska oniongrass (*Melica subulata*), purple sanicle (*Sanicula crassicaulis*), and electrified cat's-tail moss. No site series designations are available that pertain to sites with other Garry oak or associated plant communities in the CDFmm, nor to any such sites in the adjacent Coastal Western Hemlock xeric maritime (CWHxm) or dry submaritime (CWHds) subzones. The Ministry of Forests will soon be classifying grassland plant communities (BC Conservation Data Centre 2000c). If this includes remnant grasslands of southeastern Vancouver Island, more site series designations will be available for application in Garry oak and associated ecosystems.

The BC Conservation Data Centre identifies, locates, and tracks rare plant communities in British Columbia (BC Conservation Data Centre 2000c, Flynn 2000). Similar to the BEC approach, late-successional communities are the focus of the CDC classification scheme. Highly disturbed and early successional communities are not included in the CDC scheme. In contrast with the BEC approach, the CDC classifies actual vegetation communities rather than sites and their potential vegetation. Community types are defined from vegetation data collected from various sources. Rarity ranks are then derived from the number of occurrences of vegetation communities, area, range, trend, protected status, and threats. The CDC currently tracks 8 relevant communities within the range of Garry oaks (Table 2). These include 1 grassland community, 1 vernal pool community, 2 conifer-dominated communities that sometimes include an oak component, 1 mixed forest with a characteristic oak component, and 4 communities with Garry oak as a dominant or co-dominant tree species. All are ranked as critically imperilled, imperilled or imperilled/vulnerable. The classification is dependent upon data availability and therefore may not represent the full diversity of rare plant

Table 2. Rare plant communities of Garry oak and associated ecosystems in British Columbia tracked by the BC Conservation Data Centre[1]. Associated ecosystems include maritime meadows, coastal bluffs, vernal pools, grasslands, rock outcrops, and mixed transitional forests.

Scientific name **Common name**	**Provincial Rank[2]**	**BC Listing[2]**
Festuca idahoensis - Koelaria macrantha Idaho fescue - Junegrass	S1	Red
Myosurus minimus - Montia spp. - *Limnanthes macounii* Tiny mousetail – Montia spp. – Macoun's meadowfoam	S1	Red
Pseudotsuga menziesii - Arbutus menziesii[3] Douglas-fir - Arbutus	S2Q	Interim Red
Pseudotsuga menziesii - Pinus contorta - Arbutus menziesii[3] Douglas-fir - Lodgepole pine - Arbutus	S2S3Q	Interim Blue
Pseudotsuga menziesii - Quercus garryana / Melica subulata Douglas-fir - Garry oak / Alaska oniongrass	S1	Red
Quercus garryana - Acer macrophyllum - Prunus Garry oak - Big leaf maple - Wild cherry	S1	Red
Quercus garryana - Arbutus menziesii Garry oak - Arbutus	S1	Red
Quercus garryana / Bromus carinatus Garry oak / California brome	S1	Red
Quercus garryana / Holodiscus discolor Garry oak / Oceanspray	S1	Red

[1]Source: BC Conservation Data Centre 2000c.

[2]See Table 4 for an explanation of ranks and listings.

[3]Some occurrences include an oak component (S. Flynn pers. comm.).

communities (S. Flynn pers. comm.). A joint planning project involving the CDC, The Nature Conservancy (US) and the Nature Conservancy of Canada is currently in progress. The project is expected to provide additional plant communities from Garry oak ecosystems to be added to the CDC tracking list (J. Kirkby pers. comm.).

Erickson (1996) developed a detailed classification system for Garry oak ecosystems in British Columbia. His non-hierarchical system was based on sampling throughout the range of Garry oak ecosystems in British Columbia, and addressed only sites with oak occurrences. His approach differed from previous efforts in a number of ways. Sampling was conducted on a finer scale (approximately 70-300 m^2) than most other approaches (usually 400 m^2). Erickson distinguished early season plant (early April to mid-May) communities from late season (mid-May to early July) plant communities. He also included successional and disturbed communities in his classification scheme, in contrast to other initiatives. He suggested seasonal and successional relationships among the plant communities. Erickson concluded that vegetation communities are structured by climatic influences, local moisture regime, and disturbance history, particularly the fire regime, grazing history, and the introductions of exotic species.

Forty-three plant communities were defined by Erickson (Table 3). Six communities are restricted to bedrock outcrops. Twenty-six of the communities are dominated by native plants and 17 are dominated by introduced plants. Two types of disturbed plant communities were discerned. Erickson suggests that these 2 types of communities reflect a sequence of vegetation change that has occurred with the introductions of exotic species. Categories of native plant communities are named to reflect this sequence. Second-order communities are those dominated by Scotch broom in contrast with first-order communities, in which broom cover is sparse. All 7 early-season communities are included within the native plant category.

The Sensitive Ecosystems Inventory (SEI) is a joint initiative of the federal Canadian Wildlife Service, the BC Ministry of Environment, Lands and Parks Vancouver Island Regional Office, and the BC Conservation Data Centre (Ward *et al.* 1998). This project identified and mapped relatively unmodified remnants of select ecosystems in the Gulf Islands and southeastern Vancouver Island. Ecologically valuable modified ecosystems were also mapped. Mapping was based upon air photo interpretation, with some ground truthing for verification, and hence inventory scale differs considerably from that of the projects described above.

Ecosystems in the SEI are classified in terms of vegetation cover. Four of the 9 ecosystem types defined for the project include plant communities relevant to this report. These are woodland, coastal bluff, terrestrial herbaceous and, to a lesser extent, sparsely vegetated. In addition, older second-growth forest and older forest may be relevant if they contain oak cover and represent transitional forests. Garry oak ecosystems are not explicitly delineated, although they can be located by examining ground-truthing data where available. Minimum sizes for mapping is 0.5 ha for most ecosystems, except for forests for which larger minimum sizes are used. Consequently, smaller remnants of Garry oak and associated ecosystems are not included within the SEI.

Results of the SEI indicate that 92 % of the landscape has been significantly modified by human activities. Percentages of land area occupied by ecosystems that are potentially relevant to this report are as follows: coastal bluff: 0.3 %; terrestrial herbaceous: 1.0 %; woodland: 0.6 %; older forest: 2.6 %; and older second growth: 10.9 %. Garry oak

Table 3. Plant communities of Garry oak ecosystems defined by Erickson (1996).

Early Season Plant Communities
Oak – *Camassia quamash*: Typic subcommunity
Oak – *Camassia quamash – Erythronium oregonum* subcommunity
Oak – *Camassia quamash – Dodecatheon hendersonii* subcommunity
Oak – *Camassia quamash – Ranunculus occidentalis* subcommunity
Oak – *Camassia leichtlinii*
Oak – *Montia perfoliata*
Oak – *Dicranum scoparium – Plectritis congesta* subcommunity (also in additional grouping below)
Native Plant Communities of Bedrock Outcrops
Oak – *Dicranum scoparium – Plectritis congesta* subcommunity (also in additional grouping above)
Oak – *Dicranum scoparium – Montia parvifolia* subcommunity
Oak – *Dicranum scoparium – Sedum spathulifolium* subcommunity
Oak – *Dicranum scoparium*: Typic subcommunity
Oak – (FD) – Rhacomitrium canescens – Selaginella wallacei subcommunity
Other Native Plant Communities
Oak – *Mahonia aquifolium*
Oak – *Lonicera hispidula*
Oak – *Festuca idahoensis*: Typic subcommunity
Oak – *Festuca idahoensis – Cerastium arvense* subcommunity
Oak – *Festuca idahoensis – Trifolium microcephalum* subcommunity
Krummholz Oak – *Festuca idahoensis – Vicia americana* subcommunity (sea-edge)
Oak – *Elymus glaucus*
Oak – *Lathyrus nevadensis*
Oak – *Bromus carinatus*
Oak – *Carex inops*
Oak – *Melica subulata*
Oak – *Holodiscus discolor – Symphoricarpos albus – Polypodium glycyrrhiza*
Oak – (Fd) – *Holodiscus discolor – Symphoricarpos albus – Rhytidiadelphus triquetris*
Oak – *Symphoricarpos albus – Rosa nutkana – Lonicera ciliosa* subcommunity (thickets)
Oak – *Symphoricarpos albus – Rosa nutkana – Oemleria cerasiformis* subcommunity (thickets)
First-Order Disturbance Plant Communities
Oak – *Rhacomitrium canescens – Festuca bromoides* subcommunity
Oak – *Cynosurus echinatus* (late season)
Oak – *Bromus sterilis*
Oak – *Anthoxanthum odoratum*
Oak – *Poa pratensis – Vicia sativa*
Oak – *Dactylis glomerata*: Typic subcommunity
Oak – *Dactylis glomerata – Bromus carinatus* subcommunity
Oak – *Dactylis glomerata – Arrhenatherum elatius* subcommunity
Oak – *Dactylis glomerata – Agrostis stolonifera* subcommunity

Table 3 cont'd

Second-Order Disturbance Plant Communities of Bedrock Outcrops
Oak – Broom – *Rhacomitrium canescens* – *Festuca bromoides* – *Aira* subcommunity
Oak – Broom – *Rhacomitrium canescens*: Typic subcommunity
Oak – Broom – *Rhacomitrium canescens* – *Bromus tectorum* subcommunity
Other Second-Order Disturbance Communities
Oak - Broom - *Cynosurus echinatus* (late season)
Oak - Broom - *Anthoxanthum odoratum*
Oak - Broom - *Elymus glaucus*
Oak - Broom - *Poa pratensis*
Oak - Broom - *Dactylis glomerata*

dominates almost half of the ground-truthed woodland sites, especially in the southern portion of the study area. Woodlands are severely fragmented, and are frequently associated with terrestrial herbaceous and coastal bluff ecosystems. Invasions of exotic species and other disturbances are common features.

Plant Taxa at Risk

Fifty-nine taxa of vascular plants and 2 mosses from Garry oak and associated ecosystems are at risk in British Columbia (Table 4). This comprises approximately 10 % and 1 % respectively of such taxa that are at risk in British Columbia (BC Conservation Data Centre 2000e, BC Conservation Data Centre 2000f). Eleven of them are also at risk on a national scale and have vulnerable (special concern), threatened, or endangered designations from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2000). However, the majority of species at risk associated with Garry oak ecosystems have not yet been assessed by COSEWIC. Twelve of the plants are at risk on a global scale, including golden paintbrush (*Castilleja levisecta*), sulphur lupine (*Lupinus oreganus* var. *kincaidii*), and white meconella (*Meconella oregana*), which are globally imperilled or critically imperilled. Almost all the plants at risk in Garry oak and associated ecosystems reach the northern limits of their range in British Columbia. Many are more common in Washington and Oregon than they are in British Columbia. Some are common in California but rare in Washington as well as British Columbia. These include winged water-starwort (*Callitriche marginata*), Howell's montia (*Montia howellii*), coast microseris (*Microseris bigelovii*), California buttercup (*Ranunculus californicus*), and dense-flowered lupine (*Lupinus densiflorus*) (Ceska 1993).

Although it is beyond the scope of this report to summarize the range of published information pertaining to the species in Table 4, it is evident that information regarding ecology and population biology of various species is exceedingly deficient. Notable exceptions are white-top aster (*Aster curtus*) (Clampitt 1984, Clampitt 1987, Giblin 1997a, Giblin 1997b, Giblin and Hamilton 1999) and golden paintbrush (Wentworth 1994, Wentworth 1997, Dunwiddie *et al.* 2000, Gamon *et al.* 2000). Monitoring has recently been initiated for populations of 7 of the species in British Columbia (Westland Resource Group 1999). Habitat associations for many of the species are also poorly known (Douglas *et al.* 1998). A preliminary review of the literature indicates a wide range of habitat associations (Table 4). Some of the taxa are associated with very specialized habitats. For example, 2 species occupy seepage sites at least some of the time, and 25 % of the species always or sometimes occur in vernal pools. More than half of the species are found primarily in moist to wet conditions during the growing season.

Threats have not yet been assessed for most of the species. Many species tend to be naturally rare at the northern edge of their ranges (Douglas *et al.* 1998). However, habitat loss can be a threat to peripheral and non-peripheral species alike. Habitat loss, primarily from agricultural and urban development, has been cited for all but 2 of the species that either have status reports or other status assessments. Encroachment of woody species as a consequence of fire suppression and invasion of exotic species also threaten the majority of species with known risks. Hydrological changes are a risk factor,

Table 4. Status, distributions, habitats of, and threats to plant taxa at risk in Garry oak and associated ecosystems in British Columbia[1]. Associated ecosystems include maritime meadows, coastal bluffs, vernal pools, grasslands, rock outcrops, and mixed transitional forests. Habitats are for occurrences in British Columbia only.

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
				Bryophytes					
Bartramia stricta	apple moss	Endangered	G?	S1	Red	Mediterranean, Australia and Tasmania, SW BC, N CA.	E Vancouver Island (2 sites: Nanoose Hill and Metchosin)	exposed soil, crevices and ledges on rock outcrops, possibly seepage sites	habitat loss, invasive exotics
Tortula laevipila var. *meridionalis*	twisted moss sp.		G?T?	S1	Red				
				Vascular Plants					
Agrostis pallens	dune bentgrass		G4G5	S2S3	Blue	WC BC, S to CA	S Vancouver Island and WC BC	seasonally wet depressions on rocky hilltops on shallow soils at open sites	invasive exotics
Alopecurus carolinianus	Carolina meadow foxtail		G5	S2	Red	SW BC, E to S SK and CT, S to FL, TX, NM, and CA	Vancouver Island and lower Fraser Valley, E to Saskatchewan	vernal pools	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Aster curtus	white-top aster	Threatened	G3	S2	Red	SW BC, S to SW Oregon (only 83 sites)	S Vancouver Island and the Gulf Islands (between 9 and 18 sites; 6 of 18 historic sites likely extirpated)	grass/woodland interface	habitat loss, woody encroachment, invasive exotics, trampling
Balsamorhiza deltoidea	deltoid balsamroot	Endangered	G5	S2	Red	SW BC, S to CA	SE Vancouver Island (5-9 sites; at least 5 historic sites extirpated)	grass/woodland interface	habitat loss, woody encroachment, invasive exotics
Callitriche marginata	winged water-starwort		G4	S2S3	Blue	S BC, S to CA and MX	S Vancouver Island	vernal pools	
Carex feta	greensheathed sedge		G5	S2S3	Blue	S BC, S to CA	S BC	vernal pools, seasonally wet depressions and wet meadows	
Carex tumulicola	foothill sedge		G4	S1	Red	S BC, S to CA	SE Vancouver Island	open slopes and dry meadows	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Castilleja ambigua	paintbrush owl-clover		G4	S2	Red	SW BC, S to CA	S Vancouver Island	seasonally wet depressions in rock on shallow soils, often in the spray zone	
Castilleja levisecta	golden paintbrush	Endangered	G1	S1	Red	SW BC, S to OR (11 sites)	Islands adjacent to SE Vancouver Island (3 sites); historically known from 9 sites on SE Vancouver Island and adjacent islands	maritime meadows on dry, gravelly soils	habitat loss, woody encroachment, invasive exotics, trampling, herbivory

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Centaurium muehlenbergii	Muhlenberg's centaury		G5?	S1	Red	SW BC, S to NV and CA	SE Vancouver Island (2 sites: Uplands Park and Chatham Island) and until recently adjacent mainland	vernal pools, salt marshes	
Cheilanthes gracillima	lace fern		G4G5	S2S3	Blue	S BC, S to ID, MT, UT, and CA	extreme S BC	cliff crevices, often on igneous rock	
Clarkia purpurea ssp. *viminea*	purple godetia		G3?T4?	S1	Red	SW BC, S to S CA	SE Vancouver Island (1 site: Mount Tzuhalem)	grassy bluffs	
Crassula connata var. *connata*	erect pigmyweed		G5T?	S2	Red	SW BC, S to AZ, CA, and MX; Chile	S Vancouver Island and Gulf Islands	seasonally wet, shallow, eroding soils on rock ledges	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Dryopteris arguta	coastal wood fern	Special Concern	G5	S2S3	Blue	SW BC, S to Baja California, disjunct in AZ	SE Vancouver Island and adjacent Gulf Islands (16 sites)	coastal bluffs, and coastal woodlands	habitat loss, trampling, exposure, erosion
Epilobium densiflorum	dense spike-primrose		G5	S2	Red	SW BC, S to MX, E to AB, MT, ID, and NV	S. Vancouver Island, AB	wet meadows, vernal pools	
Epilobium torreyi	brook spike-primrose		G5	S1	Red	SW BC, S to CA, E to ID and NV	S Vancouver Island (Victoria area only)	wet meadows, vernal pools	
Gilia capitata var. *capitata*	globe gilia		G5T5	SH	Red	BC, S to N ID and CA	BC (S. Vancouver Island, Peace region, scattered elsewhere in S BC)	dry sites	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Helenium autumnale var. *grandiflorum*	mountain sneezeweed		G5T?	S2S3	Blue	S BC, E to PQ, N to NT, S to FL, TX, and AZ	S BC, E to PQ, N to NT	seasonally wet meadows	
Idahoa scapigera	scalepod		G5	S2	Red	S BC, S to ID and CA	SW and SE BC	seasonally moist rock ledges	
Juncus kelloggii	Kellogg's rush		G3	S1	Red	SW BC, S to CA	SE Vancouver Island (1 site: Uplands Park, Victoria)	vernal pool in seasonally wet meadow	habitat loss, hydrological changes
Limnanthes macounii	Macoun's meadow-foam	Special Concern	G3	S3	Blue	SW BC and perhaps CA.	SE Vancouver Island and adjacent islands (East Sooke Park to Victoria, and Trial, Chatham and Saltspring Island), and Yellow Point	vernal pools and seepages at forest openings and open sites	habitat loss, invasive exotics, hydrological changes

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Lomatium grayi	Gray's desert-parsley		G5	S1	Red	SW BC, S to WY, CO, NV, and OR	Galiano and Saltspring Islands	crevices, rocky cliffs	
Lotus formosissimus	seaside birds-foot trefoil	Endangered	G5	S1	Red	SW BC, S to CA	SE Vancouver Island and adjacent islands (5 sites)	vernal pools in maritime meadows	habitat loss, fire exclusion, invasive exotics, herbivory
Lotus unifoliolatus var. *unifoliolatus*	Spanish-clover		G5T5	S2S3	Blue	SW BC, S to MN, MO, and N MX	SE Vancouver Island and Gulf Islands	moist to wet meadows	
Lupinus densiflorus var. *densiflorus*	dense-flowered lupine		G5T4	S1	Red	SW BC, S to NW WA	SE Vancouver Island (Victoria area only)	dry eroding banks	invasive exotics, lawn mowing
Lupinus lepidus var. *lepidus*	prairie lupine	Endangered	G5T5	S1	Red	SW BC, S to NW OR	SE Vancouver Island (maximum of 5 extant sites, 2 extirpated)	dry grassland and rock outcrops	habitat loss, fire exclusion, invasive exotics

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Lupinus oreganus var. *kincaidii*	sulphur lupine		G5T2	SX	Red	SW BC, S to CA	SE Vancouver Island (Victoria area only)	dry sites	habitat loss, woody encroachment, herbicide
Marah oreganus	manroot		G5	S2S3	Blue	SW BC, S to N CA	S Vancouver Island and Gulf Islands	dry grasslands, open woodlands	
Meconella oregana	white meconella		G2	S2	Red	S BC, S to CA	S and C Vancouver Island and SC BC	seasonally wet rock ledges	habitat loss, woody encroachment, hydrological changes, invasive exotics, trampling
Microseris bigelovii	coast microseris		G4	S2	Red	SW BC, S to CA	SE Vancouver Island	vernal pools, seasonally wet depressions	
Microseris lindleyi	Lindley's microseris		G5	S1	Red	SW BC, S to ID, AZ, NM, and CA	Gulf Islands	seasonally wet rock ledges	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Minuartia pusilla	dwarf sandwort		G5	S1	Red	SW BC, S to AZ and NW CA	SE Vancouver Island (1 site: Church Hill at Rocky Point)	seasonally wet depressions in maritime meadows	
Montia howellii	Howell's montia		G3	S3	Blue	SW BC, S to NW CA	SE Vancouver Island and adjacent islands	depressions in exposed shallow soils	
Myosurus apetalus var. *borealis*	mousetail		G5T?	S2	Red	S BC, S to MT, WY, UT, and CA	S Vancouver Island and SC BC	vernal pools	
Navarretia intertexta	needle-leaved navarretia		G5?	S2	Red	S BC, E to SK, S to CO, AZ, and CA	SE Vancouver Island, lower Fraser Valley, and Thompson Plateau, E to SK	vernal pools, wet meadows, sometimes in drawdown wetland margins	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Orobanche pinorum	pine broomrape		G4	SH	Red	SW BC, S to N ID and NW CA	S Vancouver Island (1 site: Cowichan River in Duncan)	parasite on *Holodiscus*, open dry forest or woodland	
Orthocarpus bracteosus	rosy owl-clover		G3?	S2	Red	SW BC, S to N CA	Trial Island off Victoria (formerly also a number of Victoria locations but not collected since 1954)	seasonally wet depressions and meadows	hydrological changes
Piperia candida	white lip rein orchid		G3G4	S2	Red	S AK, S to CA	N coast BC and SE Vancouver Island	dry forests and forest margins	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Plagiobothrys figuratus	fragrant popcorn-flower		G4	S1	Red	SW BC, N to SW AK, S to OR	SE Vancouver Island and Gulf Islands (only 1 site recently: Whaling Station Bay, Hornby Island)	seasonally wet depressions	
Plagiobothrys tenellus	slender popcorn-flower		G4G5	S2	Red	SW BC, S to ID, UT, and Baja California	SE Vancouver Island and Gulf Islands	sparse grassland with some open mineral soil	
Psilocarphus elatior	tall woolly-heads		G4Q	S1	Red	SW BC, SE AB, SE SK, S to N CA and S to ID	S Vancouver Island, E AB, SK	vernal pools, wet meadows, sometimes in drawdown wetland margins	habitat loss, park development, trampling, hydrological changes

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Psilocarphus tenellus var. *tenellus*	slender woolly-heads	Not at Risk	G4T4	S2	Red	SW BC, S to ID, WA, OR, CA, and Baja California	extreme S Vancouver Island; 11 extant sites, up to 7 historic populations extirpated	open, exposed sites with compacted soil	habitat loss, trampling
Ranunculus alismifolius var. *alismifolius*	water-plantain buttercup	Endangered	G4T5	S1	Red	SW BC, S to MT, ID, and NE CA; perhaps WY	SE Vancouver Island (recently only 1 site: Uplands Park, Victoria; 2 other historic sites) and Ballenas Island	wet meadows, vernal pools	habitat loss, park developments, fire exclusion, invasive exotics, trampling, lawn mowing
Ranunculus californicus	California buttercup		G5	S2	Red	SW BC, S to CA	SE Vancouver Island and adjacent islands	maritime meadows	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Ranunculus lobbii	Lobb's water-buttercup		G4	SX	Red	SW BC, S to CA	SE Vancouver Island (Victoria area only); probably extirpated as last collected in 1948	shallow water and muddy sites	
Rupertia physodes	California-tea		G4	S2S3	Blue	SW BC, S to CA	SE Vancouver Island	grass-woodland interface	
Sagina decumbens ssp. *occidentalis*[6]	western pearlwort		G5T?	S2S3	Blue	SW BC, S to CA	SW BC	vernal pools, dry grasslands, rock outcrops, woodlands	
Sanicula arctopoides	snake-root		G5	S1	Red	SW BC, S to CA	SE Vancouver Island and adjacent islands	maritime meadows, vernal seeps on gravelly or rocky outcrops	habitat loss, invasive exotics, landscaping
Sanicula bipinnatifida	purple sanicle		G5	S2	Red	SW BC, S to CA and MX	SW Vancouver Island	meadow openings in open forests, woodlands, eroding banks on seashore cliffs	Habitat loss, park developments, invasive exotics

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Senecio macounii	Macoun's groundsel		G5	S2S3	Blue	SW BC, S to OR	S Vancouver Island, Texada Island and adjacent mainland	montane open woodlands	
Silene scouleri ssp. *grandis*	Scouler's campion		G5T?Q	S1	Red	SW BC, S to CA	SE Vancouver Island and Gulf Islands	maritime meadows and open woodlands	
Tonella tenella	small-flowered tonella		G5	S2S3	Blue	SW BC, N OR to CA	Saltspring Island	rock outcrops	
Toxicodendron diversilobum	poison oak		G5?	S2S3	Blue	SW BC, S to MX	S Vancouver Island, Gulf Islands, adjacent islands in Strait of Georgia	open woodlands	
Trifolium cyathiferum	cup clover		G4	S1	Red	S BC, S to ID and CA	S BC	seasonally wet open sites	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Trifolium dichotomum	Macrae's clover		G3G4	S2S3	Blue	SW BC, S to C CA	SE Vancouver Island and adjacent Gulf Islands	seasonally wet open bluffs	
Triphysaria versicolor ssp. *versicolor*	bearded owl-clover	Endangered	G5T5	S1	Red	SW BC, S OR to CA	SE Vancouver Island (8 extant sites in the Victoria area and 1 historic site on adjacent island)	seasonally wet open sites with shallow soils on rock outcrops along shoreline, some seepage sites	habitat loss, introduced exotics, hydrological changes, trampling
Triteleia howellii	Howell's triteleia		G4?	S1	Red	SW BC, S to OR	SE Vancouver Island and Gulf Islands (recently only 1 site: Witty's Lagoon, Victoria)	grassy coastal bluffs and open woodlands	

Table 4 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[3]	Provincial Rank[4]	BC Listing[5]	Global Distribution	Canadian Distribution	Habitat	Threats
Viola howellii	Howell's violet		G4	S2S3	Blue	SW BC, S to OR	S Vancouver Island and adjacent mainland	woodlands	
Viola praemorsa ssp. *praemorsa*	yellow montane violet	Threatened	G5T3	S2	Red	SW BC, S to CA (subspecies *praemorsa*)	SE Vancouver Island and Saltspring Island (subspecies *praemorsa*)	open oak woodlands	habitat loss, woody encroachment, invasive exotics, trampling

[1] Compiled from Hitchcock and Cronquist 1973, Ceska and Ceska 1988, Brayshaw 1991, Ryan and Douglas 1995a, Ryan and Douglas 1995b, Douglas and Illingworth 1996, Illingworth and Douglas 1996a, Illingworth and Douglas 1996b, Penny *et al*. 1996, Ryan and Douglas 1996a, Ryan and Douglas 1996b, Ryan and Douglas 1996c, Belland 1997a, Belland 1997b, Ceska and Ceska 1997, Douglas *et al.* 1998, Jamison and Douglas 1998, Ceska and Ceska 1999, Douglas and Illingworth 1999, Illingworth and Douglas 1999, Penny and Douglas 1999, Ryan and Douglas 1999a, Ryan and Douglas 1999b, BC Conservation Data Centre 2000e, BC Conservation Data Centre 2000f, COSEWIC 2000, Donovan and Douglas 2000, Douglas *et al.* 2000a, Penny and Douglas 2000, US Fish and Wildlife Service 2000a, US Fish and Wildlife Service 2000b, Washington Department of Natural Resources, Washington Natural Heritage Program, and USDI Bureau of Land Management 2000, A. Ceska pers. comm, B. Costanzo pers. comm., G. Douglas pers. comm., M. Fairbarns pers comm., D. Fraser pers. comm., J. Penny pers. comm., and H. Roemer pers comm.

[2] Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status:

Extinct: no longer exists
Extirpated: no longer exists in the wild in Canada, but exists elsewhere in the wild.
Endangered: facing imminent extirpation or extinction.
Threatened: likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation or extinction.
Special concern (vulnerable): particularly sensitive to human activities or natural events, but not including extirpated, endangered, or threatened species.
Not at risk: evaluated and found to be not at risk.
Data deficient (indeterminant): insufficient scientific information to support status designation.

Table 4 cont'd

[3]BC Conservation Data Centre global ranks reflect the conservation status of species from a global (ie rangewide) perspective, characterizing the relative rarity or imperilment of the species.

Basic global ranks:

GX = Presumed Extinct: believed to be extinct throughout its range. Not located despite intensive searches and virtually no likelihood that it will be rediscovered.

GH = Possibly Extinct: known only from historical occurrences. Still some hope of rediscovery.

G1 = Critically Imperilled: critically imperilled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000).

G2 = Imperilled: imperilled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).

G3 = Vulnerable: vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations) , or because of other factors making it vulnerable to extinction. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals

G4 = Apparently Secure: uncommon but not rare, and usually widespread. Possibly cause for longterm concern. Typically more than 100 occurrences globally or more than 10,000 individuals.

G5 = Secure: Common, typically widespread and abundant.

Variant global ranks:

G#G# = Range rank: a numeric range rank (e.g., G2G3) is used to indicate uncertainty about the exact status of a taxon

GU = Unrankable: currently unrankable due to lack of available information about status or trends

G? = Unranked: global rank not yet assessed.

HYB = Hybrid

Rank qualifiers

? = Inexact numeric rank: denotes inexact numeric rank.

Q = Questionable taxonomy: taxonomic status is questionable; numeric rank may change with taxonomy.

C = Captive or cultivated only: taxon at present is extant only in captivity or cultivation, or as a reintroduced population not yet established.

[4]BC Conservation Data Centre provincial ranks reflect the conservation status of species from a local perspective, characterizing the relative rarity or imperilment of the species within the province of British Columbia.

Basic provincial ranks:

SX = Presumed Extirpated: believed to be extirpated. Not located despite intensive searches and virtually no likelihood that it will be rediscovered.

SH = Possibly Extirpated: known only from historical occurrences. Still some hope of rediscovery.

S1 = Critically Imperilled: critically imperilled provincially because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000).

S2 = Imperilled: imperilled provincially because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).

Table 4 cont'd

S3 = Vulnerable: vulnerable provincially either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals
S4 = Apparently Secure: uncommon but not rare, and usually widespread. Possibly cause for longterm concern. Typically more than 100 occurrences provincially or more than 10,000 individuals.
S5 = Secure: common, typically widespread and abundant.

Variant provincial ranks:
S#S# = Range Rank: a numeric range rank (e.g., S2S3) is used to indicate uncertainty about the exact status of a taxon.
SU = Unrankable: currently unrankable due to lack of available information about status or trends.
S? = Unranked: provincial rank not yet assessed.
HYB = Hybrid

Rank qualifiers:
? = Inexact numeric rank: denotes inexact numeric rank.
Q = Questionable taxonomy: taxonomic status is questionable; numeric rank may change with taxonomy.
C = Captive or cultivated only: taxon at present is extant only in captivity or cultivation, or as a reintroduced population not yet established.
B = Breeding: the associated rank refers to breeding occurrences of mobile animals.
N = Non-breeding: the associated rank refers to non-breeding occurrences of mobile animals.
Z = Moving: occurs in the province, but as a diffuse, usually moving population; difficult or impossible to map static occurrences.

Infraspecific taxon ranks:
T = Infraspecific Taxon (trinomial): The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' provincial rank. Rules for assigning T ranks follow the same principles outlined above. For example, the provincial rank of a critically imperilled subspecies of an otherwise widespread and common species would be G5T1.
Z = Moving: occurs in the province, but as a diffuse, usually moving population; difficult or impossible to map static occurrences.

[5]BC Listing:
Red List = indigenous species or subspecies (taxa) considered to be extirpated, endangered, or threatened in British Columbia. Extirpated taxa no longer exist in the wild in British Columbia, but do occur elsewhere. Endangered taxa are facing imminent extirpation or extinction. Threatened taxa are likely to become endangered if limiting factors are not reversed. Red-listed taxa include those that have been, or are being, evaluated for these designations.
Blue List = indigenous species or subspecies (taxa) considered to be vulnerable in British Columbia. Vulnerable taxa are of special concern because of characteristics that make them particularly sensitive to human activities or natural events. Blue-listed taxa are at risk, but are not extirpated, endangered or threatened.

[6]Taxonomy uncertain

especially for species dependent on pockets of moist to wet habitats during the growing season. Other risks include trampling, exposure, erosion, herbivory, herbicides, and park developments.

Animal Species of Garry Oak and Associated Ecosystems

Vertebrate Species and Communities

One hundred and fifty one species of vertebrates have been identified in Garry oak and associated ecosystems in British Columbia (Table 5). This total is comprised of 7 species of amphibians, 7 reptiles, 104 birds, and 33 mammals. The vast majority of the species are not specialized associates of these ecosystems. Most of them are also found in forested, wetland, riparian, or other ecosystems of the Garry oak landscape (Orchard 1993, Ward *et al.* 1998). The few exceptions are all rare or extirpated, and are discussed later in this report.

Because of the generalized habitat use of most of the vertebrate fauna, Garry oak and associated ecosystems do not contribute considerably to the overall vertebrate diversity of British Columbia in terms of numbers of species that rely primarily or exclusively upon them. Nonetheless, the ecosystems do play an important role in other ways. Many resident bird species, such as the Cooper's hawk (*Accipiter cooperi*), western screech-owl (*Otus kennicottii saturatus*), downy woodpecker (*Picoides pubescens*), chestnut-backed chickadee (*Parus rufescens*), and brown creeper (*Parus rufescens*) commonly use oak habitats (T. Chatwin pers. comm.). Oak and rock outcrop ecosystems atop hilltops provide critical refuges for migratory songbirds during stormy weather (T. Chatwin pers. comm.). Oak and prairie habitats also provide important habitat for many neotropical migrant songbirds. Neotropical songbirds are of general conservation concern due to general declines of a number of the species. Among the declining species that use Garry oak and associated ecosystems in British Columbia are the band-tailed pigeon (*Columba fasciata*), rufous hummingbird (*Selasphorus rufus*), barn swallow (*Hirundo rustica*), Cassin's vireo (*Vireo cassinii*), orange-crowned warbler (*Vermivora celata*), yellow warbler (*Dendroica petechia*), Wilson's warbler (*Wilsonia pusilla*), and chipping sparrow (*Spizella passerina*) (Andelman and Stock 1994, Rogers *et al.* 1997). In addition, bird diversity has been found to be higher in Garry oak woodlands than in conifer forests in British Columbia (Shepard (M.G.) 1998; but see Feldman 2000) and Oregon (Anderson 1972), indicating that the Garry oak landscape may be important for avian diversity on a regional scale. Furthermore, Garry oak patches in the Victoria area were found support at least 2 species of breeding birds, the spotted towhee (*Pipilo maculatus*) and orange-crowned warbler, that were absent from adjacent urban areas (Feldman 2000). Finally, a number of habitat elements, discussed further below, provide valuable feeding, nesting, and roosting resources and may support relatively high populations of many vertebrate species.

Very little information is available pertaining to faunal distribution or abundance in Garry oak and associated ecosystems in British Columbia or in the United States. A limited number of inventories have been conducted in British Columbia, but almost all of them are of an *ad hoc* nature and make no attempt to employ systematic methodologies

Table 5. Vertebrate species of Garry oak and associated ecosystems in British Columbia and use of select habitat elements[1]. Associated ecosystems include maritime meadows, coastal bluffs, vernal pools, grasslands, rock outcrops, and mixed transitional forests. Sorted taxonomically. * designates introduced taxon. [e]designates extirpated taxon. "DW" designates species that use standing or downed dead wood for breeding, roosting, foraging, perching, thermal cover, or security cover. "A" designates species that consume acorns.

Latin Name	Common name	Habitat Elements
	Amphibians	
Ambystoma macrodactylum	long-toed salamander	DW
Taricha granulosa	northern rough-skinned newt	DW
Plethodon vehiculum	western red-backed salamander	DW
Ensatina eschscholtzii	Oregon ensatina	DW
Aneides ferreus	clouded salamander	DW
Bufo boreas	western toad	DW
Hyla regilla	Pacific treefrog	DW
	Reptiles	
Thamnophis sirtalis	common garter snake	DW
Thamnophis ordinoides	northwestern garter snake	DW
Thamnophis elegans	western terrestrial garter snake	DW
Elgaria coerulea	northern alligator lizard	DW
*Podarcis muralis**	European wall lizard	
Contia tenuis	sharp-tailed snake	DW
Pituophis catenifer[e]	gopher snake	DW
	Birds	
Ardea herodias	great blue heron	
Butorides virescens	green heron	
Anas platyrhynchos	mallard	
Cathartes aura	turkey vulture	DW
Pandion haliaetus	osprey	DW
Haliaeetus leucocephalus	bald eagle	DW
Accipiter striatus	sharp-shinned hawk	DW
Accipiter cooperii	Cooper's hawk	DW
Buteo jamaicensis	red-tailed hawk	DW
Falco sparverius	American kestrel	DW
Falco columbarius	merlin	DW
*Phasianus colchicus**	ring-necked pheasant	
*Callipepla californica**	California quail	A
Charadrius vociferus	killdeer	
*Columba livia**	rock dove	
Columba fasciata	band-tailed pigeon	DW, A
Zenaida macroura	mourning dove	
Coccyzus americanus[e]	yellow-billed cuckoo	
Tringa melanoleuca	greater yellowlegs	

Table 5 cont'd

Larus glaucescens	glaucus-winged gull	
Tyto alba	barn owl	DW
Otus kennicottii	western screech-owl	DW
Strix varia	barred owl	DW
Bubo virginianus	great horned owl	DW
Chaetura vauxi	Vaux’s swift	DW
Calypte anna	Anna's hummingbird	
Selasphorus rufus	rufous hummingbird	
Ceryle alcyon	belted kingfisher	DW
Melanerpes lewis[e]	Lewis' woodpecker	DW, A
Sphyrapicus ruber	red-breasted sapsucker	DW
Picoides pubescens	downy woodpecker	DW, A
Picoides villosus	hairy woodpecker	DW, A
Colaptes auratus	northern flicker	DW, A
Dryocopus pileatus	pileated woodpecker	DW, A
Contopus borealis	olive-sided flycatcher	DW
Tyrannus verticalis	western kingbird	
Contopus sordidulas	western wood-peewee	DW
Empidonax hammondii	Hammond's flycatcher	
Empidonax difficilis	Pacific-slope flycatcher	
Empidonax traillii	willow flycatcher	
Empidonax minimus	least flycatcher	
Vireo cassinii	Cassin's vireo	
Vireo gilvus	warbling vireo	
Vireo huttoni	Hutton's vireo	
Cyanocitta stelleri	Steller's jay	A
Corvus caurinus	northwestern crow	A
Corvus corax	common raven	A
*Alauda arvensis**	skylark	
Eremophila alpestris[e]	horned lark	
Progne subis	purple martin	DW
Petrochelidon pyrrhonota	cliff swallow	
Tachycineta bicolor	tree swallow	DW
Tachycineta thalassina	violet-green swallow	DW
Hirundo rustica	barn swallow	
Parus rufescens	chestnut-backed chickadee	DW, A
Psaltriparus minimus	bushtit	
Sitta canadensis	red-breasted nuthatch	DW, A
Certhia americana	brown creeper	DW
Thryomanes bewickii	Bewick's wren	DW
Troglodytes aedon	house wren	DW
Troglodytes troglodytes	winter wren	DW
Regulus satrapa	golden-crowned kinglet	
Regulus calendula	ruby-crowned kinglet	
Sialia mexicana[e]	western bluebird	DW

Table 5 cont’d

Sialia currucoides	mountain bluebird	DW
Myadestes townsendi	Townsend's solitaire	

Catharus ustulatus	Swainson's thrush	
Catharus guttatus	hermit thrush	
Turdus migratorius	American robin	
Ixoreus naevius	varied thrush	
*Sturnus vulgaris**	European starling	DW, A
Bombycilla cedrorum	cedar waxwing	
Vermivora celata	orange-crowned warbler	
Dendroica coronata	yellow-rumped warbler	
Dendroica townsendi	Townsend's warbler	
Dendroica petechia	yellow warbler	
Dendroica nigrescens	black-throated gray warbler	
Wilsonia pusilla	Wilson’s warbler	
Oporornis tolmiei	MacGillvray's warbler	
Geothlypis trichas	common yellowthroat	
Piranga ludoviciana	western tanager	
Pipilo maculatus	spotted towhee	
Spizella passerina	chipping sparrow	
Pooecetes gramineus	vesper sparrow	
Passerculus sandwichensis	savannah sparrow	
Passerella iliaca	fox sparrow	
Melospiza melodia	song sparrow	
Melospiza lincolnii	Lincoln’s sparrow	
Zonotrichia leucophrys	white-crowned sparrow	
Zonotrichia atricapilla	golden-crowned sparrow	
Junco hyemalis	dark-eyed junco	
Pheucticus melanocephalus	black-headed grosbeak	
Agelaius phoeniceus	red-winged blackbird	
Sturnella neglecta	western meadowlark	
Euphagus cyanocephalus	Brewer's blackbird	
Molothrus ater	brown-headed cowbird	
Pinicola enucleator	pine grosbeak	
Carpodacus purpureus	purple finch	
Carpodacus mexicanus	house finch	
Loxia curvirostra	red crossbill	
Carduelis pinus	pine siskin	
Carduelis tristis	American goldfinch	
Coccothraustes vespertinus	evening grosbeak	
*Passer domesticus**	house sparrow	DW
	Mammals	
*Didelphis virgiana**	Virginia opossum	DW, A
Sorex monticolus	dusky shrew	

Table 5 cont’d

Sorex vagrans	vagrant shrew	
Scapanus townsendii	Townsend's mole	
Eptesicus fuscus	big brown bat	DW
Lasionycteris noctivagans	silver-haired bat	DW
Lasiurus cinereus	hoary bat	DW

Myotis californicus	California myotis	DW
Myotis evotis	western long-eared myotis	DW
Myotis lucifugus	little brown myotis	DW
Myotis volans	long-legged myotis	DW
Myotis yumanensis	Yuma myotis	DW
Corynorhinus townsendii	Townsend's big-eared bat	DW
*Oryctolagus cuniculus**	European rabbit	
*Sylvilagus floridanus**	eastern cottontail	A
Microtus townsendii	Townsend's vole	A
Castor canadensis	beaver	
Peromyscus maniculatus	deer mouse	DW, A
*Mus musculus**	house mouse	DW
*Rattus norvegicus**	Norway rat	
*Rattus rattus**	black rat	
*Sciurus carolinensis**	eastern gray squirrel	DW, A
Tamiasciurus hudsonicus	red squirrel	DW, A
Canis lupus	gray wolf	DW
Felis concolor	cougar	DW
Lontra canadensis	river otter	DW
Mustela erminea	ermine	DW
Martes americana	marten	DW
Mustela vison	mink	
Procyon lotor	raccoon	DW, A
Ursus americanus	black bear	DW, A
Cervus elaphus	Roosevelt elk	
Odocoileus hemionus	black-tailed deer	A

[1] Compiled from McTaggart Cowan and Guiguet 1965, Burt and Grossenheider 1980, Gregory and Campbell 1984, Chatwin 1993, Erickson 1993b, Nagorsen and Brigham 1993, Orchard 1993, Campbell *et al.* 1997a, Campbell *et al.* 1997b, Bunnell *et al.* 1998, Fuchs 1998, Nagorsen 1998, Shepard 1998, Cannings *et al.* 1999, Fraser *et al.* 1999, Gonzales 1999, Ovaska and Sopuck 1999, Balke 2000, Feldman 2000, Nature Conservancy of Canada unpubl. data, T. Chatwin pers. comm., T. Gillespie pers. comm.

or test hypotheses (Garry Oak Ecosystems Recovery Team 2000). They provide general information about species distributions but do not investigate the factors that influence distributions or abundances and structure vertebrate communities.

Following is a discussion of habitat attributes and characteristics associated with faunal occupancy and diversity. Much of the discussion relies upon studies conducted in oak ecosystems outside of British Columbia. This discussion is general in nature. Detailed, species-specific descriptions are beyond the scope of this report. A large body of literature describes habitat associations of many of the species. Some of this information has been compiled by Erickson (1993b). The following discussion addresses aspects of vegetation structure as well as specific food resources that are associated with vertebrates in these ecosystems. Species-specific information is summarized here for only 2 habitat attributes, standing dead and downed wood and the acorn resource (Table 5).

Trees, shrubs, and open herbaceous areas provide different resources and are used by different vertebrate species. Large Garry oak and other woodland trees provide nesting opportunities for a number of species. For example, red-tailed hawks (*Buteo jamaicensis*) preferentially select large trees for nesting in oak woodlands (Tietje *et al*. 1997a), and large arbutus trees are a critical component of mixed forests in California for cavity-nesting species (Raphael 1987, Raphael 1995). The complex branching of Garry oak trees can also provide perching sites for species such as hawks, owls, and flycatchers as well as nesting sites for a number of bird species, such as Cooper's hawks which frequently nest in the oaks (Chatwin 1993, Larsen 1997, T. Chatwin pers. comm).

A critical contribution of trees to vertebrate diversity is the provision of cavities, standing dead wood, and downed wood. One hundred percent of the amphibians, 86 % of reptiles, 35 % of birds, and 64 % of mammals of Garry oak and associated ecosystems in British Columbia use standing dead or downed wood for breeding, roosting, foraging, perching, thermal cover, or security cover (Table 5). Cavities that are used for breeding and roosting are created in 2 different ways. Cavities are excavated directly by primary cavity nesters, primarily woodpeckers. Some primary cavity nesters prefer to excavate in live trees and others prefer trees in different stages of decomposition, usually trees killed slowly over time by root fungus. In addition, different species select trees of different diameters, although large diameter trees represent a particularly valued resource for a number of species. Secondary cavity nesters, who are unable to excavate their own cavities, rely upon natural cavities formed from broken and rotting branches and boles as well as those created by primary cavity nesters. Large old oaks, with their many twisting and dead limbs, are a rich source of such cavities. Garry oak may be a favoured species for cavity excavation by birds. A study in California found that Garry oak was used in much greater proportion for cavity excavation than other species of oaks at the site (Wilson *et al.* 1991). Overall, a range of tree sizes and trees in various stages of decomposition provide nesting opportunities for a range of primary and secondary cavity nesters (Barrett 1980, Wilson *et al.* 1991, Chatwin 1993, Erickson 1993b, Larsen 1997, Bunnell *et al.* 1998). Over time, standing dead wood falls to the forest floor and becomes downed wood. Standing dead and downed wood provide essential foraging substrate for a number of vertebrate species. In addition, downed wood provides a modified microclimate, of particular importance to amphibians that cannot tolerate temperature extremes. Many birds and mammals use downed wood opportunistically, but some species such as winter wrens are highly dependent on downed wood for breeding sites

(Larsen 1997, Bunnell *et al.* 1998). Presence of standing dead and downed wood is among the most significant predictors of vertebrate abundance in oak woodlands in California (Garrison and Standiford 1997, Tietje and Vreeland 1997, Tietje *et al.* 1997b).

Shrub cover is also an important habitat element to a number of vertebrate species. Shrubs provide thermal and security cover, breeding sites, and foraging substrate for insectivorous animals (Landres and MacMahon 1983, Block and Morrison 1990, Chatwin 1993, Erickson 1993b, Garrison and Standiford 1997, Tietje and Vreeland 1997, Tietje *et al.* 1997b, Block and Morrison 1998, Ward *et al.* 1998). In contrast, absence of shrub and/or tree cover is essential for some species, particularly aerial insectivores and some of the rare and extirpated grassland species that are discussed later in this report. Roosevelt elk (*Cervus elaphus roosevelti*) feed in meadows and many elk may have relied in the past on meadows associated with Garry oak ecosystems (T. Chatwin pers. comm.). Snakes and lizards are commonly associated with the rock outcrops in these ecosystems (Erickson 1993b, T. Chatwin pers. comm.). Some species are associated with the juxtaposition of patches of vegetation of contrasting structure. For example, Steller's jays frequent edges between closed and open patches of vegetation (Fuchs 1998). Lewis' woodpeckers (*Melanerpes lewis*), formerly found in Garry oak stands in British Columbia, sometimes nest in dense wooded areas adjacent to open areas (Fraser *et al.* 1999), and some animals of Washington's South Puget prairie landscape require upland prairie adjacent to woodlands, wetlands, and riparian areas (Leonard and Hallock 1997, Dunn 1998).

Garry oak and associated ecosystems provide a variety of food resources for vertebrates. Deep furrows in oak bark and standing dead and downed wood are rich habitats for invertebrates; these invertebrates in turn comprise an abundant food source for insectivores such as brown creepers (*Certhia americana*), red-breasted nuthatches (*Sitta canadensis*), and chestnut-backed chickadees (*Parus rufescens*). Herb, shrub, and tree foliage also support a diverse insect fauna consumed by insectivorous vertebrates. Shrews depend upon invertebrates found in rich, deep soils and thick litter. Arbutus, rose (*Rosa* spp.), and other fruits are important to frugivorous species such as American robins (*Turdus migratorius*), varied thrush (*Ixoreus naevius*) and band-tailed pigeons, especially in the fall (Anderson 1970, Landres and MacMahon 1983, Block *et al.* 1990, Block and Morrison 1991, Chatwin 1993, Erickson 1993b, Larsen 1997, Bunnell *et al.* 1998, T. Chatwin pers. comm.). Herbivores including voles and deer graze and browse upon forbs, grasses, shrubs, and trees. Oaks, with protein content approaching that of alfalfa, provide exceedingly nutritious browse for deer (Larsen 1997). Seeds of numerous plants are consumed by a variety of vertebrate species. Raptors and carnivorous mammals prey upon herbivores, omnivores, and other carnivores.

Acorns are among the most critical resources available to vertebrates in Garry oak ecosystems. Across North America, more vertebrate species may rely upon *Quercus* fruits than on those of any other genus except *Rubus* (Larsen 1997). Thirteen percent of the bird species and 27 % of the mammals of Garry oak ecosystems in British Columbia consume acorns (Table 5). However, the proportions of species underrepresent the overall importance of the resource. Acorns dominate the diet of a number of species when they are available. For example, acorns comprised 9-93 % and 11-76 % of the stomach contents of black-tailed deer in Oregon and California respectively (Coblentz 1980, Potter and Johnston 1980). Similarly, Steller's jays depended on acorns for 43 % of their annual diet and 99 % of their January food in California (Van Dersal 1940). Rodent populations, particularly *Peromyscus* spp., fluctuate in accordance with variations in the acorn crop in Maine and Virginia (McCracken *et al.* 1999, McShea 2000), and could be expected to show similar patterns in relation to Garry oak acorns in British Columbia.

Overall, habitat heterogeneity is essential for providing habitat for species with different habitat needs, including species that require adjacent patches of contrasting habitat. Furthermore, seasonal usage patterns also vary within and among species, so diverse habitats are important for sustaining species throughout the year (Anderson 1970, Roberts 1987, Block and Morrison 1990, Block *et al.* 1990, Block and Morrison 1991, Wilson *et al.* 1991, Chatwin 1993, Erickson 1993b). The importance of habitat elements, and hence habitat diversity, functions at a variety of spatial scales, ranging from microhabitats which are important for herpetiles (Block and Morrison 1990) to within-patch or -site vegetation (*e.g.* Steller's jays), to between-patch diversity (*e.g.* Lewis' woodpeckers), to provision of habitat for wide-ranging animals with different seasonal ranges (*e.g.* Roosevelt elk; Cannings *et al.* 1999). Given the diversity of habitat requirements of the different species, Hanna and Dunn (1996) suggest that conservation and restoration efforts in Garry oak ecosystems must set priorities based upon clear, value-driven objectives. No single habitat type is best for all species.

Invertebrate Species and Communities

With the exception of a few taxa, very little is known about invertebrate populations in Garry oak and associated ecosystems in British Columbia. Research effort has been devoted to 2 invertebrate acorn predators, the filbert weevil and filbertworm (Rohlfs 1999), and to a few introduced insect pests and their parasitoid and predator complexes. Some information has also been compiled about rare butterflies. These subjects are discussed elsewhere in this report. Evans (1985) compiled a list of more than 800 insect and mite species associated with Garry oak trees in British Columbia. The species comprise 16 orders. Included are species that feed on oak, prey upon species that feed on oak, scavenge upon oak trees, or seek shelter on oak trees. The list does not include species found in oak ecosystems that are not associated with the trees themselves. Such information has yet to be compiled. One study sampling canopy and forest floor invertebrates is currently underway, but results are not yet available (Cannings 1996).

Varied habitats provide food, cover, and suitable microclimates for a range of invertebrates. These habitats include rich soil litter, deep-furrowed bark of Garry oak trees, standing dead and downed wood in various stages of decay, warm open expanses for flying insects, and leaves of herbs, shrubs, and trees (Chatwin 1993, Larsen 1997). Approximately 140 species of insects are known to feed on Garry oaks themselves in British Columbia (R. Duncan pers. comm.). Among these are 48 obligate feeders on the oaks, including the rare propertius dusky wing (*Erynnis propertius*). Many butterflies depend upon open, sunny habitats, including savannahs, grasslands and coastal bluffs (Ward *et al.* 1998, Baron and Backhouse 1999), but some also require plant communities such as forests and disturbed habitats in addition to open grasslands (Dunn and Fleckenstein 1997). Some insects are generalist feeders, but many species are highly dependent on specialized food sources (*e.g.* Table 6 later in this report). Food sources also vary within species as they reach different life stages. As with vertebrate species, habitat heterogeneity provides a variety of resources for a diverse assemblage of species as well as for varying seasonal needs within species. Habitat diversity on a fine scale can also be critical for the ability of invertebrates to respond to unpredictable weather events. For example, the survival of rare Bay checkerspot (*Euphydryas editha bayensis*) butterflies in California grasslands depends upon synchronicity of larval emergence with the availability of host plants before the plants senesce with summer drought. Timing of larval development and host plant senescence varies with weather conditions and these frequently become uncoupled. Topographic diversity on a scale of tens of metres allows for variation in plant phenology and is a critical factor in the persistence of butterfly populations (Dobkin *et al.* 1987, Weiss *et al.* 1988).

Animal Taxa at Risk

One earthworm, 10 butterflies, and 7 other insects from Garry oak and associated ecosystems are listed as being at risk in British Columbia (Table 6). This earthworm (*Arctiostrotus perrieri*) is the only earthworm species known to be at risk in British Columbia. The butterflies and other insects comprise approximately 8 % and 14 % respectively of such taxa that are at risk in the province (BC Conservation Data Centre 2000a, BC Conservation Data Centre 2000d). Vertebrates at risk are 2 reptiles (18 % of such taxa that are at risk in British Columbia), 9 birds (10 %) and 3 mammals (5 %) (BC Conservation Data Centre 2000g). To date, 4 butterflies (1 threatened, 2 endangered, and 1 extirpated), 1 reptile (endangered), and 2 birds (2 special concern) have designated “at risk” status on a national scale from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2000). However, the majority of the species in Table 6 have yet to be assessed by COSEWIC. All but 2 of the butterflies are at risk on a global scale, including 1 that is possibly extinct and 2 critically imperilled taxa. Two of the other insects, both leaf bugs, are likely critically imperilled on a global scale. Two bird taxa are globally at risk, including one, the streaked horned lark (*Eremophila alpestris strigata*) that is globally imperilled.

Little status or distribution information is available about any of the invertebrates except the butterflies. Global status is uncertain for 5 of the non-butterfly species, and provincial status itself is uncertain for *Arctiostrotus perrieri* (Table 6). Distributions and status of butterfly and vertebrate taxa are better known. All but a few of these taxa either reach the northern limits of their ranges in British Columbia or else represent subspecies found at the northern limits of the range of the species as a whole.

Type and quantity of published literature about these species vary widely. Virtually nothing has been published about any of the invertebrates except the butterflies. A number of butterfly taxa of the same species, but different subspecies, as some of those at risk in British Columbia have been studied in other localities. For example, 4 decades of research have produced an enormous literature about the Bay checkerspot butterfly in California (summarized in US Fish and Wildlife Service 1998a). This research has provided fundamental insights into butterfly biology and ecology. Other taxa that have received various degrees of attention in the United States include Mission and Fender’s blue (*Icaricia icarioides missionensis* (= *Plebejus icarioides missionensis*) and *I. i. fenderi*), Myrtle’s and Oregon silverspot (*Speyeria zerene myrtleae* and *S. z. hyppolyta*), and San Bruno elfin (*Incisalia mossi bayensis* (= *Callophrys mossi bayensis*)) butterflies

Table 6. Status, distributions, habitats of, and threats to animal taxa at risk in Garry oak and associated ecosystems in British Columbia[1]. Associated ecosystems include maritime meadows, coastal bluffs, vernal pools, grasslands, rock outcrops, and mixed transitional forests. Sorted taxonomically.

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
Earthworms											
Haplotaxida: Megascloecidae											
Arctiostrotus perrieri	earthworm		G?	S3?	Blue	BC, S to OR	Queen Charlotte Islands, Islets of Kyoquot Sound, Vancouver Island	mineral soil in dry *Pseudotsuga* forests			
Insects											
Orthoptera: Lygaeidae											
Scolopostethus tropicus	seed bug		G5	S1	Red	S BC, CA, ID, OR, Guatemala	S Vancouver Island at Goldstream				
Orthoptera: Miridae											
Clivenema fusca	leaf bug		G1?	S1	Red	S BC	S BC at Saanich				

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
Ceratocapsus downesi	leaf bug		G1?	S1	Red	S BC	S Vancouver Island at Royal Oak, Saanich, and Victoria				
						Orthoptera: Rhopalidae					
Harmostes dorsalis	scentless plant bug		G5	S1	Red	S BC, OR, CA, AZ, TX, MX to Argentina and Peru	S Vancouver Island at Goldstream, Langford, Royal Oak, and Victoria				
						Orthoptera: Scutelleridae					
Camirus porosus	shield-backed bug		G5	S1	Red	S BC, CA, CO, FL, NC, TX, VA, MX S to Columbia	SE Vancouver Island, Galiano Island, formerly Vancouver				

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
						Diptera: Asilidae					
Nicocles rufus	robber fly		G?	S1	Red	S BC, S to CA	S Vancouver Island at Saanich and Victoria	open oak/Douglas-fir woodland	habitat loss		
Scleropogon bradleyi	robber fly		G?	S2	Red	S BC, CA	S Vancouver Island and Gulf Islands	oak meadows, especially open rock outcrops	habitat loss		
						Butterflies					
						Lepidoptera: Hesperidae					
Erynnis propertius	propertius dusky wing		G5	S3	Blue	SW BC, S to CA	SE Vancouver Island and adjacent islands, SW mainland	hillsides, woodland clearings, open meadows, always near oaks		*Quercus garryana, Q. agrifolia*	various, including *Camassia*, *Vicia*, *Allium*

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
Euphyes vestris vestris	dun skipper	Threatened	G5T3	S2	Red	SW BC S to CA (subspecies *vestris*)	SW BC (subspecies *vestris*)	various, moist areas near deciduous woods including meadows, seeps, swamp edges, streams, roadside ditches, also dry sites with permanent springs or spring floods	habitat loss, invasive exotic plants, hydrological changes	*Carex*, *Cyperus eshulentus*, possibly grasses	white, pink, and purple flowers
						Lepidoptera: Pieridae					
Euchloe ausonides undescribed subspecies	Island marble	Extirpated	G5T1	SX	Red	S BC N to AK, YK and NWT, E to ON and MN; S to CA and CO (entire species); S Vancouver Island and Gabriola Island (extirpated), also N WA, perhaps small islands in Strait of Georgia (undescribed subspecies)	S Vancouver Island and Gabriola Island (extirpated), perhaps small islands in Strait of Georgia (undescribed subspecies)	open grassland in Garry oak woodland and lower southern slopes with open habitat	habitat loss, invasive exotic plants, sheep grazing	*Arabis* (likely *A. hirsuta*), *Sisymbrium*, introduced Brassicaceae	

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
						Lepidoptera: Lycaenidae					
Incisalia mossi mossi	Moss' elfin, subspecies *mossi*		G4T4	S3	Blue	S BC, S to C CA (entire species); S BC, S to OR (subspecies *mossi*)	SE Vancouver Island, Gulf Islands, possibly Burns Bog on mainland (subspecies *mossi*)	rocky knolls and cliffs	habitat loss, invasive exotic plants, deer grazing	*Sedum spathulifolium*	*Sedum spathuli-folium*
Plebejus saepiolus insulanus	Island blue	Endangered	G5TH	SH	Red	SW BC, N to AK, YK and NWT, E to NS, S CA and AZ (entire species); SW BC (subspecies *insulanus*)	SE Vancouver Island; probably extinct (subspecies *insulanus*)	open areas including moist meadows, bog edges, prairies, streamsides, roadsides and other moist disturbed sites, near host plants	invasive exotic plants	*Trifolium* spp., including *T. wormskjolkii*	
Icaricia icarioides blackmorei	Blackmore's blue		G5T3	S3	Blue	BC, S to CA, E to S SK (entire species); E Vancouver Island (subspecies *blackmorei*)	E Vancouver Island at Mt. Green near Nanaimo; formerly Goldstream (subspecies *blackmorei*)	prairie, sagebrush, woodland clearings, subalpine	habitat loss, invasive exotic plants, woody encroachment	*Lupinus* spp., possibly *Trifolium* spp.	*Allium, Calachortus, Camassia, Eriophyllum, Sidalcea* (subspecies *fenderi* in OR)

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
					Lepidoptera: Nymphalidae						
Speyeria zerene bremnerii	Bremner's silverspot		G5T3T4	S3	Blue	??; extirpated in OR, San Juan Islands (subspecies *bremnerii*)	S Vancouver Island, mainland coast (subspecies *bremnerii*)	mountains, foothills, prairies		*Viola* spp. especially *V. adunca*.	various, especially Asteraceae, including *Aster curtus*
Euphydryas chalcedona perdiccas	perdiccas checkerspot				provincial population secure, Garry oak populations extirpated	BC S to MX and N to AK, W to AB and AK (entire species)		sagebrush flats, chaparral, desert hills, high prairie, open forest, alpine tundra (entire species)		*Penstemon*	
Euphydryas editha taylori	Taylor's checkerspot	Endangered	G5T1	S1	Red	SW BC, S to OR (subspecies *taylori*)	historic: S Vancouver Island and Hornby Island; current: 3 sites on Hornby Island, (subspecies *taylori*)	various, including coastal chaparral, meadows, fields, foothills, open woods, alpine meadows (entire species)	habitat loss, invasive exotic plants, woody encroachment	*Plantago maritima, P. lanceolata,* perhaps *P. major*, *Orthocarpus* or other Scrophulariaceae	*Lomatium utriculatum, Fragaria*

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
Coenonympha california insulana	Vancouver Island ringlet		G5T3T4	S2S3	Blue		SE Vancouver Island (subspecies *insulana*)	various grassy habitats, including roadsides, woodland edges and clearings, prairies, bogs, arctic and alpine taiga and tundra (entire species)		Grasses including *Poa pratensis* and *Stipa* spp.	
					Reptiles						
					Squamata: Colubridae						
Contia tenuis	sharp-tailed snake	Endangered	G5	S1	Red	SW BC, S to CA	SE Vancouver Island, Gulf Islands, perhaps McGillvray Lake near Chase, BC	open forests and woodlands, especially near edges, meadows with cover objects (rocks, downed wood); concentrations along south-facing rocky slopes	habitat loss, shortage of downed wood, perhaps domestic cats		
Pituophis catenifer catenifer	gopher snake, subspecies *catenifer*		G5T5	SX	Red	SW BE to S CA, but extirpated from BC and WA (subspecies *catenifer*)	formerly Galiano Island and Can/US border near Sumas, WA (subspecies *catenifer*)	various, forested to open, nest in abandoned burrows and spaces under logs	habitat loss, invasive exotic plants, persecution		

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
					Birds						
					Cuculiformes: Cuculidae						
Coccyzus americanus	yellow-billed cuckoo		G5	SXB, SAN	Red	breeding: E N America, CA, UT, CO, TX, S to Caribb. and MX; extirpated from BC, WA, OR; non-breeding: Central and S America	Historically lower Fraser Valley and SE Vancouver Island near Victoria	deciduous thickets, riparian, open woodland, orchards; nest in hardwoods including oak	habitat loss, drought, loss of prey from pesticide use, perhaps shortage of large nesting trees		
					Strigiformes: Tytonidae						
Tyto alba	barn owl	Special Concern (western population)	G5	S3	Blue	all continents except Antarctica	breeding: SE Vancouver Island, Saltspring Island, lower mainland, possibly S interior BC, S ON, possibly PQ; casual along most of S Cdn border	open country, especially agricultural lands, also meadows, marshes, urban; nest mostly in farm buildings.	habitat loss, severe winters, possibly pesticide and rodenticide poisoning, road traffic mortality		

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
						Strigiformes: Strigidae					
Otus kennicottii saturatus	western screech-owl, subspecies *saturatus*		G5T3T4 Q	S3	Blue	SE Vancouver Island, Gulf Islands, and San Juan Islands (subspecies *saturatus*)	SE Vancouver Island and Gulf Islands (subspecies *saturatus*)	open mixed forests, riparian; sometimes winter in orchards and urban areas	habitat loss, habitat fragmentation, possibly competition with *Strix varia*, predation by *Bubo virginianus*		
						Piciformes: Picidae					
Melanerpes lewis	Lewis' woodpecker	Special Concern (entire species)	G5T?Q	SXB, SZN	Red (Georgia Depression population)	breeding: S BC, E to SW AB, S to AZ and NM; also CA E to CO; non-breeding: S BC, S to MX	breeding: SW BC E to SW AB; historically SE Vancouver Island, lower Fraser Valley; non-breeding: S interior BC	open forests and woodlands, with large standing dead trees and open areas, including logged and burned forest; winter in woodlands, orchards, other open areas	habitat loss, shortage of large standing dead and dying trees, fire suppression, competition with *Sturnus vulgaris*, acorn shortage from loss of Garry oak habitat		

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
					Passeriformes: Alaudidae						
Eremophila alpestris strigata	streaked horned lark		G5T2	SH	Red	resident: SW BC, S to WA and OR (subspecies *strigata*)	current: lower Fraser Valley; historically also SE Vancouver Island (subspecies *strigata*)	open grassland with sparse vegetation	habitat loss, habitat fragmentation, invasive exotic plants		
					Passeriformes: Hirundinidae						
Progne subis	purple martin		G5	S2B	Red	breeding: SW BC, E to NS, S throughout US to MX; non-breeding: S America	breeding: SE Vancouver Island, lower Fraser Valley, E to NS	patches of dead trees adjacent to open areas including sheltered harbours, ponds, farmland	shortage of dead trees		
					Passeriformes: Muscicapidae						
Sialia mexicana	western bluebird		G5T?Q	SHB,SZN	Red (Georgia Depression population)	S BC, MT, and CO S to MX	S BC; extirpated from Vancouver Island and the Gulf Islands	Habitats with interspersed trees and openings including woodlands, sparsely forested slopes, hill summits, burned or logged forest, pastures			

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
					Passeriformes: Emberizidae						
Pooecetes gramineus affinis	vesper sparrow, subspecies *affinis*		G5T3	S1B	Red	breeding: SW BC, S to WA and OR; non-breeding: C CA, S to Baja California (subspecies *affinis*)	breeding: SE Vancouver Island; historically also lower mainland (subspecies *affinis*)	open grassland with sparse vegetation and scattered tall structures.	habitat loss, invasive exotic plants, inappropriate mowing schedules, fire suppression		
					Passeriformes: Icteridae						
Sturnella neglecta	western meadowlark		G5T?Q	SXB,SZN	Red (Georgia Depression population)	breeding: S BC, E to PQ, S to MX; non-breeding: S BC, E to S MB, S to MX	breeding: S BC, E to PQ; non-breeding: S BC, E to S MB; extirpated as a breeding population from Vancouver Island	open grassland and savannah with scattered tall structures			

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
						Mammals					
						Chiroptera: Vespertilionidae					
Corynorhinus townsendii	Townsend's big-eared bat		G4	S2S3	Blue	S BC S to MX, and a few isolated populations in C and E US	S Vancouver Island, Gulf Islands, Fraser Valley, S. Interior BC	various, must have caves and cave-like roosts; forage in riparian, wetlands, other moist places	human disturbance at hibernacula and nursery colonies.		
						Carnivora: Mustelidae					
Mustela erminea anguinae	ermine, subspecies *anguinae*		G5T3	S3	Blue	throughout N America and Eurasia (entire species); Vancouver Island and Saltspring Island (subspecies *anguinae*)	Vancouver Island and Saltspring Island (subspecies *anguinae*)	various, especially riparian, thick understorey	habitat loss and fragmentation, possibly forest practices, limitations of prey base		

Table 6 cont'd

Latin Name	Common Name	COSEWIC Status[2]	Global Rank[2]	Provincial Rank[2]	BC Listing[2]	Global Distribution	Canadian Distribution	Habitat	Threats	Larval Foodplant (butterflies only)	Adult Nectar Source (butterflies only)
						Artiodactyla: Cervidae					
Cervus elaphus roosevelti	Roosevelt elk		G5T4	S2S3	Blue	Historically from SW BC to C CA (subspecies *roosevelti*)	Vancouver Island, SW mainland; historically lower Fraser Valley, islands adjacent to Vancouver Island (subspecies *roosevelti*)	open coniferous or deciduous forest, wetlands, riparian; require cover and high quality forage in proximity; different seasonal ranges	habitat loss, overharvest, resource extraction activities, predation, harsh winters		

[1] Compiled from Campbell and Campbell 1984, Gregory and Campbell 1984, US Fish and Wildlife Service 1984, Godfrey 1986, Speirs *et al.* 1986, Borror *et al.* 1989, Spalding 1993, Guppy *et al*. 1994, Lanyon 1994, Scudder 1994, Brown 1997, Campbell *et al.* 1997a, Campbell *et al.* 1997b, Canadian Museum of Nature 1997, Tobalske 1997, Blood 1998, Cooper *et al.* 1998, Layberry *et al.* 1998, Ovaska and Engelstoft 1998, Shepard (J.H.) 1998, US Fish and Wildlife Service 1998b, Baron and Backhouse 1999, Cannings *et al.* 1999, Engelstoft and Ovaska 1999, Fraser *et al.* 1999, Hughes 1999, Kenner and Needham 1999, Kirk 1999, Sauer *et al.* 1999, US Fish and Wildlife Service 1999, Vellend and Connolly 1999, BC Conservation Data Centre 2000a, BC Conservation Data Centre 2000d, BC Conservation Data Centre 2000g, Finnish University and Research Network 2000, Guppy 2000, Northern Prairie Wildlife Research Center 2000, Shepard 2000a, Shepard 2000b, Shepard 2000c, Shepard 2000d, US Fish and Wildlife Service 2000a, R.A. Cannings pers. comm., D. Fraser pers. comm.

[2]See Table 4 for an explanation of ranks and listings.

(Schultz 1998, Schultz and Crone 1998, Schultz and Dlugosch 1999, and summaries in US Fish and Wildlife Service 1984, US Fish and Wildlife Service 1998b, US Fish and Wildlife Service 1999). Information from British Columbia includes status, range, and general biology (Guppy *et al.* 1994, Shepard (J.H.) 1998, Shepard 2000a, Shepard 2000b, Shepard 2000c, Shepard 2000d), but little to no focussed research about ecology or population biology appears to have been conducted to date. All of the taxa are associated with open habitats, ranging from woodland clearings to dry open grasslands, to moist meadows, seeps, and streamsides (Table 6). Because butterfly distributions are closely tied to those of their foodplants, habitat associations of butterflies are essentially equivalent to those of the foodplants. Invasive exotic plants have been cited as a threat to all butterflies for which status reports or other status evaluations have been done, and habitat loss has been cited for all but one of the invertebrates with cited threats. Other threats include habitat encroachment by woody species, hydrological changes, and grazing by sheep and deer.

Most of the vertebrate taxa at risk have received considerably more attention. Particularly well studied are the barn owl (*Tyto alba*) (summarized in Campbell and Campbell 1984, Kirk 1999) and Roosevelt elk (summarized in Nyberg and Janz 1990). Habitat associations and threats for most of these species are fairly well known, although, in general, use of Garry oak ecosystems has not been well described. Habitats vary widely and include open forests and woodlands, deciduous thickets, agricultural lands, meadows, and sparse, dry grasslands (Table 6). For some of the species (*e.g.* western screech-owl, ermine (*Mustela erminea anguinae*), Roosevelt elk), Garry oak and associated ecosystems comprise a relatively small proportion of their ranges. Notably, all of the species that historically relied exclusively upon grassland and open Garry oak ecosystems in the region (streaked horned lark (*Eremophila alpestris strigata*), vesper sparrow (*Pooecetes gramineus affinis*), western meadowlark (*Sturnella neglecta*), Lewis' woodpecker, and western bluebird (*Sialia mexicana*)) have been entirely or nearly extirpated. Habitat loss is cited as a threat for all but one of the species for which status information is available. Other threats vary. They include habitat fragmentation, shortage of large live trees or standing dead or downed wood, invasive exotic plants and animals, shortage of food sources, and other causes.

Essential Ecosystem Characteristics

Introduction

Effective conservation planning requires that consideration be given to all levels of biological organization, including genes, populations, species, communities, and ecosystems (Noss *et al.* 1997, Poiani *et al.* 2000). Associated with each of these levels of biological organization are elements, interactions, and spatial scales that influence the composition, structure and function of the corresponding level. At the broadest level, a conservation initiative concerned with ecosystem sustainability must identify ecosystem-level characteristics, especially those associated with ecosystem function, or the dynamic processes within ecosystems concerned with exchanges of energy and materials (Hebda *et al*. 2000). Identifying the critical characteristics of ecosystems can then provide strategic direction for research, planning, and implementation programs that will target the most important aspects of ecosystem conservation.

Following is a discussion of "essential ecosystem characteristics" for Garry oak ecosystems in British Columbia. They have been adapted from a list of generic characteristics developed by Harwell *et al.* (1999). The characteristics were selected by the members of the Garry Oak Ecosystems Recovery Team and as such are based upon expert opinion. Two different types of criteria are integrated into the selection process. First, the characteristics are critically associated with the composition, structure, and function of Garry oak ecosystems as discussed above. In addition, they are also characteristics deemed to be at significant risk within the modern context and hence incorporate an element of risk assessment. This dual nature of the characteristics underscores their importance for conservation planning.

Three primary characteristics are presented. The characteristics are:

1. Spatial integrity, in terms of the consequences of habitat fragmentation;
2. The role of fire as a natural disturbance agent; and
3. Biotic integrity, in terms of the presence and effects of exotic species.

Minimal research has been conducted in Garry oak ecosystems that addresses these ecological issues. Information from British Columbia is even more limited. Hence, this review relies largely upon a brief discussion of ecological theory as well as information pertaining to other ecosystems including oak and grassland ecosystems where possible. Because of the wide scope of the characteristics, this review considers each characteristic only briefly, and is largely general in nature.

A number of other essential ecosystem characteristics were also identified by the Garry Oak Ecosystems Recovery Team. They are:

1. Habitat quality, in terms of landscape, community, and habitat structural diversity;
2. Ecological processes, including succession, trophic interactions, seed dispersal, and pollination;
3. Hydrological characteristics and processes; and
4. Soil characteristics and processes, including nutrient relations, mycorrhizae, soil fauna, and the role of the microbiotic crust.

These characteristics fall into 2 general categories. Some of the characteristics, in particular some aspects of habitat quality and ecological succession, are directly related to 1 or more of the 3 primary characteristics. Ecological and conservation issues are closely tied to those of the primary characteristics, and as such are discussed in the following sections of this report. Many of the relevant issues are also discussed earlier in this report in relation to plant and animal species and communities. The other essential ecosystem characteristics are deemed to play critical roles in sustainability of Garry oak and associated ecosystems, but very little is known about them and how they function in these ecosystems. Hence, these topics represent knowledge gaps of significant importance in relation to Garry oak and associated ecosystems. The breadth of ecological issues that must be covered in even the most cursory discussion of these characteristics is immense. For this reason, such a discussion is beyond the scope of this report. They are mentioned here to flag their importance for future investigation.

Spatial Integrity and Habitat Fragmentation

The consequences of habitat loss are dependent not only upon the amount that is lost. The spatial patterning of the loss, or from the other perspective the spatial patterning of what remains, can also have important consequences. Habitat fragmentation has been defined as the process by which "a natural landscape is broken up into small parcels of ecosystems" (Hunter 1996:179). Small remnant parcels are vulnerable to additional risks beyond the risks associated with simple habitat loss. Two of the most important risks are related to issues of patch size and patch isolation.

The importance of patch size to the conservation of biodiversity is a cornerstone of the discipline of conservation biology. A voluminous literature concerns the many aspects of this relationship (see reviews in Shafer 1990, Bunnell *et al.* 1998). An overview of this literature is beyond the scope of this report. However, one effect of patch size with direct conservation applicability is the numbers of individuals of target species that patches of different sizes can support. The ability of larger patches to support larger populations is important for preventing local extinctions, because larger populations are buffered from the potential for environmental stresses (*e.g.* predation, disease, adverse weather), random demographic events (*e.g.* skewed sex ratio, unusually low birth rate or high death rate), and genetic stresses associated with small populations (*e.g.* inbreeding depression, loss of adaptive potential) to lead to extinctions. Patch size is a critical consideration for the conservation and recovery of rare and endangered species, for which losses of individual populations may represent significant reductions in the number of individuals comprising the entire species. One approach to deriving predictions about the potential of a patch of a given size to sustain individuals is a simple assessment of the density or territory sizes of target species. Vertebrate species, particularly birds and mammals, are usually used for these analyses because they are the most demanding in terms of habitat area (Meffe and Carroll 1994). Density information, coupled with Minimum Viable Population (MVP) analyses at best, or ballpark estimates of MVP sizes drawn from the literature at the least, can be used to predict the ability of patches of different sizes to support populations with high probabilities of persisting over time. For species that occupy and defend exclusive territories during the breeding season, home range and territory sizes are equivalent, and territory size can be directly translated into density. For other species, home ranges between individuals may overlap, so the data cannot be translated without an additional estimate of the degree of overlap.

Information about home range sizes or densities of fauna in Garry oak ecosystems in British Columbia is limited to 2 studies, 1 completed (Shepard 1998) and 1 in progress (Feldman 2000). These studies mapped territories of breeding birds in the Victoria area. Table 7 presents a small sample of densities, territory sizes, and home ranges for species that occur in Garry oak habitats in British Columbia as well as other ecosystems and other localities. Data are compiled from Shepard (1998), Feldman (2000), and a few other published studies conducted in a number of different regions. Much more such information is available in the scientific literature. Animal densities, territory sizes, and home range sizes exhibit enormous spatial and temporal variation. Much of the within-species variation is due to variation in habitat quality (Harestad and Bunnell 1979). Despite the great variation, some patterns among species are evident. In general, smaller animals require less space than larger animals. Trophic level is also an important factor.

Table 7. Sample densities, territory sizes, and home range sizes of a subset of bird and mammal species of Garry oak and associated ecosystems in British Columbia. Associated ecosystems include maritime meadows, coastal bluffs, vernal pools, grasslands, rock outcrops, and mixed transitional forests. Data are from studies conducted in a number of different locations in North America. Species within each taxonomic class are presented in order of generally increasing area demands.

Latin Name	Common Name	Density (pairs/ha) birds only	Territory size (ha)	Home Range Size (ha)	Location	Source
			Birds			
Pooecetes gramineus	vesper sparrow	6.90	*0.14*[1]		IA	Camp and Best 1994
		0.28-0.33	3.05-3.57		IA	Perritt and Best 1989
Regulus satrapa	golden-crowned kinglet	0.88	*1.14*		BC	Feldman 2000
Troglodytes troglodytes	winter wren	0.88	*1.14*		BC	Feldman 2000
Turdus migratorius	American robin	0.88	*1.14*		BC[2]	Feldman 2000
		0.88	*1.14*		BC	Feldman 2000
Parus rufescens	chestnut-backed chickadee	0.13	*0.80*		BC[2]	Feldman 2000
		0.75	*1.33*		BC	Feldman 2000
Zonotrichia leucophrys	white-crowned sparrow	0.40-0.80	*1.25-2.50*		BC[2]	Shepard 1998
Junco hyemalis	dark-eyed junco	0.30-1.40	*0.71-3.33*		BC[2]	Shepard 1998
		1.00	*1.00*		BC[2]	Feldman 2000
		0.61	*1.64*		CA	Tietje and Vreeland 1997
		0.24	*4.00*		BC	Feldman 2000
Melospiza melodia	song sparrow	2.90	*0.34*		IA	Camp and Best 1994
		0.38	*2.63*		BC	Feldman 2000
		0.20	*5.00*		IL	Kershner and Bollinger 1996

Table 7 cont'd

Latin Name	Common Name	Density (pairs/ha) birds only	Territory size (ha)	Home Range Size (ha)	Location	Source
Empidonax	Pacific-slope	0.50-0.70	*1.43-2.00*		BC[2]	Shepard 1998
difficilis	flycatcher	0.19	*5.26*		BC	Feldman 2000
Eremophila	horned lark	*0.71-3.33*	0.30-1.40		CO	Beason 1995
alpestris		*0.37-0.77*	1.30-2.70		?	Beason 1995
		0.63	1.60		Midwest US	Beason 1995
		0.29	3.50		?	Beason 1995
		0.20	*5.00*		IL	Kershner and Bollinger 1996
		0.02-0.06	*16.67-50*		SK	Pylypec 1991
Dendroica	Townsend's	0.38	*2.67*		BC[2]	Feldman 2000
townsendi	warbler	0.25	*4.00*		BC	Feldman 2000
Dendroica	yellow-	0.63	*1.60*		BC[2]	Feldman 2000
coronata	rumped	0.30	*3.33*		BC[2]	Shepard 1998
	warbler	0.13	*8.00*		BC	Feldman 2000
Sitta canadensis	red-breasted nuthatch	0.25	*4.00*		BC	Feldman 2000
Wilsonia pusilla	Wilson's warbler	0.25	*4.00*		BC	Feldman 2000
Sturnella	western	*0.16-0.83*	1.20-6.10		WI	Lanyon 1994
neglecta	meadowlark	*0.14*	7.00		MB	Lanyon 1994
Spizella	chipping	0.20-0.40	*2.50-5.00*		BC[2]	Shepard 1998
passerina	sparrow	0.38	*2.67*		BC[2]	Feldman 2000
		0.13	*8.00*		BC	Feldman 2000
Troglodytes	house wren	0.30-0.50	*2.00-3.33*		BC[2]	Shepard 1998
aedon		0.25	*4.00*		BC[2]	Feldman 2000
		0.16-0.22	*4.54-6.25*		CA	Verner *et al.* 1997
		0.04	*25.00*		CA	Tietje and Vreeland 1997

Table 7 cont'd

Latin Name	Common Name	Density (pairs/ha) birds only	Territory size (ha)	Home Range Size (ha)	Location	Source
Carpodacus mexicanus	house finch	0.22	*4.55*		CA	Tietje and Vreeland 1997
		0.16-0.18	*5.56-6.25*		CA	Verner *et al.* 1997
Coccyzus americanus	yellow-billed cuckoo	1.90	*0.53*		IN	Hughes 1999
		0.21-0.50	*2.02-4.88*		TX	Hughes 1999
		0.03-0.38	*2.67-40*		NM	Hughes 1999
Melanerpes lewis	Lewis' woodpecker	0.16	*6.25*		WA & OR	Tobalske 1997
Picoides villosus	hairy woodpecker	0.16-0.18	*5.56-6.25*		CA	Verner *et al.* 1997
		0.13	*8.00*		BC	Feldman 2000
Calypte anna	Anna's hummingbird	0.12-0.14	*7.14-8.33*		CA	Verner *et al.* 1997
		0.13	*8.00*		BC	Feldman 2000
Dendroica petechia	yellow warbler	0.13	*8.00*		BC[2]	Feldman 2000
Empidonax hammondii	Hammond's flycatcher	0.13	*8.00*		BC	Feldman 2000
Certhia americana	brown creeper	0.13	*8.00*		BC[2]	Feldman 2000
		0.13	*8.00*		BC	Feldman 2000
Contopus borealis	olive-sided flycatcher	0.13	*8.00*		BC[2]	Feldman 2000
Piranga ludoviciana	western tanager	0.13	*8.00*		BC[2]	Feldman 2000
Pipilo maculatus	spotted towhee	1.13	*0.89*		BC[2]	Feldman 2000
		0.38	*2.63*		BC	Feldman 2000
		0.10-0.80	*1.25-10.00*		BC[2]	Shepard 1998
		0.07	*14.29*		CA	Tietje and Vreeland 1997

Table 7 cont'd

Latin Name	Common Name	Density (pairs/ha) birds only	Territory size (ha)	Home Range Size (ha)	Location	Source
Psaltriparus	bushtit	0.25	*4.00*		CA	Verner *et al.* 1997
minimus		0.09	*11.11*		CA	Tietje and Vreeland 1997
Vireo huttoni	Hutton's	*0.34-1.43*	0.70-2.90		CA	Davis 1995
	vireo	0.12	*8.33*		CA	Tietje and Vreeland 1997
		0.03	*33.33*		CA	Verner *et al.* 1997
Thryomanes	Bewick's	0.20	*5.00*		BC[2]	Shepard 1998
bewickii	wren	0.17-0.22	*4.54-5.88*		CA	Verner *et al.* 1997
		0.13	*8*		BC	Feldman 2000
		0.07	*14.29*		CA	Tietje and Vreeland 1997
Vermivora	orange-	0.50	*2.00*		BC[2]	Feldman 2000
celata	crowned	0.50	*2.00*		BC	Feldman 2000
	warbler	0.10-0.40	*2.50-10.00*		BC[2]	Shepard 1998
		0.03	*33.33*		CA	Tietje and Vreeland 1997
Passerculus	savannah	0.06	*16.67*		IL	Kershner and Bollinger 1996
sandwichensis	sparrow					
Tachycineta	violet-green	0.03-0.11	*9.09-33.33*		CA	Verner *et al.* 1997
thalassina	swallow					
Sialia	western	0.09	*11.11*		CA	Tietje and Vreeland 1997
mexicana	bluebird	0.05-0.06	*16.67-20*		CA	Verner *et al.* 1997
Colaptes	northern	0.38	*2.67*			Feldman 2000
auratus	flicker	0.08-0.09	*11.11-12.5*		CA	Verner *et al.* 1997
		0.01	*100.00*		CA	Tietje and Vreeland 1997
Corvus	common	0.13	*8*		BC	Feldman 2000
corax	raven	<0.01	*>100*		CA	Verner *et al.* 1997
Dryocopus	pileated			53-160	MI	Bull and Holthausen 1993
pileatus	woodpecker			66-400	IA	Buck *et al*. 1996
				257-1056	OR	Bull and Holthausen 1993
				407-597	OR	Bull and Holthausen 1993
		<0.01	1428.00		OR	Bull and Holthausen 1993

Table 7 cont'd

Latin Name	Common Name	Density (pairs/ha) birds only	Territory size (ha)	Home Range Size (ha)	Location	Source
Bubo virginianus	great horned owl	0.01	*100.00*		CA	Verner *et al.* 1997
Accipiter cooperi	Cooper's hawk	<0.01 <0.01	*>100* *>100*		CA CA	Verner *et al.* 1997 Tietje and Vreeland 1997
Cathartes aura	turkey vulture	<0.01	*>100*		CA	Verner *et al.* 1997
Mammals						
Peromyscus maniculatus	deer mouse			0.81	?	Harestad and Bunnell 1979
Mustela erminea	ermine			1.00-87.40 20.64	PQ ?	Robitaille and Raymond 1995 Harestad and Bunnell 1979
Odocoileus hemionus columbianus	black-tailed deer			58.85	?	Harestad and Bunnell 1979
Ursus americanus	black bear			2413	?	Harestad and Bunnell 1979
Felis concolor	cougar			1400-17200 29733 9700-33400	BC ? AB	Spreadbury *et al.* 1996 Harestad and Bunnell 1979 Ross 1992

[1]Territory data in italics are calculated for comparison purposes from published density data, and vice versa, based upon the assumption that the species occupy discrete, non-overlapping territories and that territories are contiguous. Assumptions may not be valid; therefore such transformed data should be treated with caution. Apparent miscalculations are a result of rounding of numbers.

[2]Data from Garry oak ecosystems in British Columbia

Carnivores tend to require more space than omnivores of similar weight, who in turn require more space than herbivores (Harestad and Bunnell 1979, Meffe and Carroll 1994). Hence, small, isolated patches of natural habitat are unable to provide adequate resources for species that require larger amounts of space, and species losses in habitat fragments will likely be concentrated among animals of larger size and higher trophic levels. These changes, especially the disruption of the food web in such a skewed manner, may also have unpredictable, cascading effects throughout the ecosystem. The specific numbers in Table 7 from other localities and ecosystems cannot be applied directly to the situation in Garry oak habitats in British Columbia, and an analysis of the frequency distribution of patch sizes is not currently available. However, it is evident that Garry oak woodlands are very fragmented within the landscape of southern Vancouver Island (Ward *et al.* 1998). Unless the surrounding landscape can help support species populations, many of the remnant natural areas will most likely lose a large complement of the component species. This projection is especially sombre, given that estimates for MVP sizes generally range from the hundreds to the thousands of individuals (Noss *et al.* 1997).

Needless to say, the ability of the surrounding landscape to help support species depends upon the characteristics of the landscape. Feldman (2000) found that species composition of breeding bird communities in Garry oak fragments in British Columbia was influenced by the character of the surrounding landscape. Garry oak patches surrounded by highly developed habitat had reduced species richness compared to patches in less developed areas. Six species that were found in Garry oak patches in moderately and lightly developed landscapes were completely absent from the patches in the more urbanized areas. Feldman and Krannitz (in prep.) found that breeding populations of most oak-associated bird species (birds that use oaks, breed in grassland or open habitat, or eat acorns) have declined in the Victoria area since the 1970's but that wintering populations of most of the species have increased. They attribute the breeding trends to the loss and fragmentation of breeding habitat that has resulted from urban development. In contrast, they found increases in winter populations of many bird species. They suggest that wintering birds are limited by food availability rather than habitat area. Urban and suburban habitats, with their many bird feeders and planted shrubs, may offer enhanced food supplies. Hence, the functionality of landscape characteristics for helping to support species populations can vary seasonally as well as among wildlife species.

Closely related to issues of patch size are issues pertaining to patch isolation. Movements of organisms between patches of suitable habitat occur on a number of different temporal scales. Animals may obtain food, water, and cover in different locations. These resources may be located in separate patches, especially in fragmented landscapes, requiring movements among the patches on a daily basis. Resource requirements and availability can also shift on a seasonal basis, necessitating movements between different habitats at different times of year. For example Roosevelt elk use different habitats in different seasons, and thus require corridors of suitable habitat to move between them (Cannings *et al.* 1999). On the scale of once per generation is the dispersal of plant propagules (Howe and Smallwood 1982) and offspring of breeding animals (Sutherland *et al.* 2000) to suitable habitats. On a larger temporal scale, occasional dispersal of organisms is a fundamental component of the dynamics of metapopulations, in which smaller sub-populations are linked by the occasional migration of individuals between them. These migrations promote genetic exchange, thus reducing the probability of genetic bottlenecks and inbreeding depression. The movements also increase the probability that a given species will persist within a particular habitat patch over time, either by bolstering the sizes of subpopulations and thus reducing their vulnerability to extinction from environmental or demographic events, or by recolonizing areas after local extinctions occur. For example, Fahrig and Merriam (1994) conclude that annual extinction rates of 10-20 % of the local populations of habitat fragments are common. Ongoing occupancy of such fragments by the resident species largely depends upon continual recolonization events. Finally, the ability to shift range in response to environmental change, such as infrequent disturbance events or climate change, is necessary for the persistence of species over time. Recent analyses reinforce the notion that global warming will require many species in Canada to migrate at very high rates, such as more than 1,000 m/year, to avoid extinction as a result of climate change (Malcolm and Markham 2000). Migration barriers represented by urban and agricultural development can impede range shifts and thus decrease the probability that species will migrate at rates necessary for survival.

Functional connectivity between patches depends upon both the distance between the patches and the nature of the intervening landscape (Fahrig and Merriam 1994). These factors have meaning only in relation to the needs and abilities of the resident biota. Our ability to predict the effects of fragmentation, and hence develop effective conservation and restoration plans, depends upon our ability to detect and to apply information about how different species respond to these variables. Unfortunately, data are extremely limited, particularly in terms of travel distances, for most species in general, and virtually non-existent for species of Garry oak stands in British Columbia.

Distances between patches of suitable habitat must not exceed the distances that organisms are able to travel. Distances traveled by plant propagules are dependent upon the vectors that transport them. Fuchs (1998) investigated distances that Garry oak acorns are dispersed by Steller's jays, the primary vector for Garry oak acorns in British Columbia, and determined that movements of a few kilometres are not uncommon. No other information is available that is specific to Garry oak ecosystems in British Columbia. In contrast with most taxa, metapopulation dynamics for the Bay checkerspot butterfly in California, including dispersal distances, have been studied for decades and are extremely well-known. A number of other rare and endangered butterflies have also received attention. Some of the dispersal data for a few such taxa that are related to butterflies of Garry oak and associated ecosystems in British Columbia are summarized in Table 8. Long-distance movements are difficult to detect, but research suggests that, for a least some species, predominantly small distances punctuated by rare long-distance events are characteristic movement patterns.

For daily movements of vertebrates, distances are restricted largely by the amount of food energy the animals are able to consume. Estimates of distances for these types of movements might be derived from an examination of home range or territory sizes (Table 7). Sutherland *et al.* (2000) derived predictive equations for natal dispersal distances of birds and mammals by synthesizing data from the scientific literature. Data from this study that pertain to movements of birds and mammals that are found in Garry oak habitats in British Columbia are summarized in Table 9. Although maximum dispersal

Table 8. Dispersal distances traveled by butterflies related to butterflies of Garry oak and associated ecosystems in British Columbia. Associated ecosystems include maritime meadows, coastal bluffs, vernal pools, grasslands, rock outcrops, and mixed transitional forests. Data are from studies conducted in a number of different locations in western North America. Sorted taxonomically.

Taxon	Common Name	Distances traveled	Location	Source
Callophrys mossi bayensis	San Bruno elfin	mean total distance 45.9 - 53.4 m (males) and 40.2-51.7 m (females); maximum distance 250 m (males) and 224 m (females)	CA	US Fish and Wildlife Service 1984
		maximum total distance 800 m	CA	US Fish and Wildlife Service 1984
Plebejus (Icaricia) icarioides missionensis	Mission blue	mean total distance 28.7-40.2 m; maximum 154 m (males) and 162 m (females)	CA	US Fish and Wildlife Service 1984
		maximum adult distance 2,500 m, most < 600 m	CA	US Fish and Wildlife Service 1984
		barrier (industrial park) prevented any dispersal.	CA	US Fish and Wildlife Service 1984
Icaricia icarioides fenderi	Fender's blue	estimated lifetime movement within habitat with foodplants 1.0 km (male) and 0.4 km (female); within habitats without foodplants 2.4 km (male) and 1.7 km (female)	OR	Schultz 1998
Speyeria zerene myrtleae	Myrtle's silverspot	kilometres	CA	US Fish and Wildlife Service 1998b
Speyeria zerene hippolyta	Oregon silverspot	100's of metres	OR	US Fish and Wildlife Service 1999
Euphydryas editha bayensis	Bay checkerspot	mostly sedentary, rare long distance movements; maximum recorded 7.6 km	CA	US Fish and Wildlife Service 1998a

Table 9. Natal dispersal distances of a subset of native bird and mammal species of Garry oak and associated ecosystems in British Columbia. Associated ecosystems include maritime meadows, coastal bluffs, vernal pools, grasslands, rock outcrops, and mixed transitional forests. Data are from studies conducted in a number of different locations in North America and compiled by Sutherland *et al.* (2000). Species within each taxonomic class are presented in order of generally increasing dispersal distances.

Latin Name	Common Name	Median Distance (km)		Maximum Distance (km)	
		male	female	male	female
		Birds			
Passerculus sandwichensis	savannah sparrow	0.2	0.2	1.6	1.4
Zonotrichia leucophrys	white-crowned sparrow	0.3	0.4	2.6[1]	2.6[1]
Melospiza melodia	song sparrow	0.2	0.2	13.2	1.3
Zenaida macroura	mourning dove			4.8	4.8
Hirundo rustica	barn swallow	6.4[1]	6.4[1]	8.1[1]	8.1[1]
Dryocopus pileatus	pileated woodpecker			32.0[1]	32.0[1]
Falco sparverius	American kestrel	4.8	5.1	32.5	38.8
Accipiter cooperi	Cooper's hawk	9.2	14.4	35.2	
Molothrus ater	brown-headed cowbird			40.0[1]	40.0[1]
Progne subis	purple martin	40.0[1]	40.0[1]	336.0[1]	336.0[1]
Bubo virginianus	great horned owl			1305.0[1]	1305.0[1]
		Mammals			
Microtus townsendi	Townsend's vole	<0.1	<0.1	0.1	0.1
Peromyscus maniculatus	deer mouse	0.1	0.2	0.9	1.0
Tamiasciurus hudsonicus	red squirrel	0.5	0.2	0.6	0.6
Scapanus townsendii	Townsend's mole			0.7	0.9
Mustela erminea	ermine			5.6	1.0
Odocoileus hemionus	black-tailed deer	4.0	2.0	15.2	12.2
Ursus americanus	black bear			225.0	28.8
Procyon lotor	raccoon			265.5[1]	265.5[1]
Felis concolor	cougar			274.0	155.0
Canis lupus	gray wolf	125.0,225.0	75.0,125.0		

[1]Data from studies in which sexes were not differentiated.

distances are considerable for some species, they are uncommon, suggesting that recolonization of isolated habitat patches following local extinctions might experience considerable time lags. Some of the factors affecting dispersal distances are similar to those affecting area requirements, but show an inverse pattern. In general, larger animals and animals of higher trophic levels tend to disperse farther. This affords them the potential to bolster small populations with immigrants, and hence to buffer extinction processes in these small populations. It also increases the probability of recolonizing patches after local extinctions occur. Smaller animals, and animals of lower trophic levels, are less likely to experience extinctions due to area effects, but are also less likely to be rescued from extinction processes that do exist.

The nature of the intervening habitat will affect the likelihood that different species will move through it (Fahrig and Merriam 1994). The matrix landscape within which patches of natural or semi-natural habitat are embedded will be more or less permeable to movements of particular species. Permeability will depend on the responses of species to the specific attributes of the matrix. Corridors of natural or semi-natural habitat within developed landscapes can also ameliorate fragmentation effects if they are used by species to travel between isolated patches of habitat. As with the matrix, the functionality of corridors will depend on the responses of the various species to their attributes. Fuchs (1998) found that scattered trees facilitate movements of Steller's jays when they are transporting acorns across open meadows. No other information is available that deals directly with the question of how species move through the Garry oak and surrounding landscape in British Columbia. However, information about habitat associations of many of the component animal species, particularly vertebrates, is scattered throughout the literature. Erickson (1993b, 1996) synthesized some of the information pertaining to vertebrates and butterflies of Garry oak ecosystems in British Columbia and some general habitat associations for vertebrates and invertebrates are presented by Ward *et al.* (1998). Considerable data have also been collected in recent years regarding vertebrate use of corridors, particularly in forested and agricultural landscapes, in various locations (reviewed by Bunnell *et al.* 1998). Noticeably deficient is information about movements of species through urbanized landscapes. Such information would be critical for conservation efforts for the Garry oak and surrounding landscape in British Columbia. Urbanization can have devastating impacts upon species' movements. For example, an industrial park prevented migration of Mission blue butterflies between 2 suitable patches of habitat (US Fish and Wildlife Service 1984). Given the lack of local research, a thorough review of the literature, coupled with a spatial analysis of distances between Garry oak patches and attributes of intervening habitats, would enable some testable predictions to be made about the effects of patch isolation on the resident biota, and provide direction for local research, protection, and restoration efforts.

The Role of Fire as a Natural Disturbance Agent

The history of oak-prairie ecosystems throughout North America is inextricably linked with fire. Extensive research has addressed the role of fire in structuring, maintaining, and restoring oak and prairie ecosystems, which is summarized in numerous reviews (*e.g.* Daubenmire 1968, Agee 1993, McPherson 1997) and is a recurring theme in many conference and symposium proceedings (*e.g.* Plumb 1980, Lotan *et al.* 1985, Plumb and Pillsbury 1987, Standiford 1991, Loftis and McGee 1993, Hardy and Arno 1996, Dunn and Ewing 1997, Pillsbury *et al.* 1997). In general, evidence indicates a long history of relatively frequent, low-intensity fires in virtually all oak and prairie ecosystems. Over historical time, many fires originated with lightning, but landscape-management activities of the local First Peoples were responsible for much of the regularity and consistency of the fire regime across the continent. European settlement has disrupted the fire regime in virtually all locations that have been studied. The predominant post-settlement pattern has been one of fire suppression or complete fire exclusion. These changes in the disturbance regime have resulted in dramatic changes to the composition, structure, and function of oak and prairie ecosystems. As can be expected, the precise nature of the role of fire, and the changes that have accompanied fire exclusion, vary among vegetation types. For example, in the mesic hardwood woodlands of the central and eastern United States, fire has a strong influence on the relative composition of advance regeneration within forest stands (Loftis and McGee 1993). Without fire, fewer subcanopy oaks are available for release relative to other species, and over time the canopy composition includes fewer and fewer oaks. In drier oak and prairie ecosystems, fire inhibits the establishment of woody vegetation and thus plays a key role in determining vegetation structure. Without fire, many prairies convert to shrublands and savannahs, and savannahs convert to closed-canopy woodlands and forests.

Fire history, dynamics, and effects within Garry oak and associated prairie and mixed forest ecosystems have been studied in California (Reed and Sugihara 1987, Sugihara and Reed 1987a, Sugihara and Reed 1987b, Sugihara *et al.* 1987, Hastings *et al.* 1997, Hastings and Barry 1997), Oregon (Sprague and Hansen 1946, Smith 1949, Habeck 1961, Thilenius 1968, Johannessen *et al.* 1971, Cole 1977, Towle 1979, Boyd 1986, Riegel *et al.* 1992), and Washington (Moravets 1932, Lang 1961, Norton 1979, Agee and Dunwiddie 1984, Agee 1989, Salstrom 1989, Hanna and Dunn 1996, Dunwiddie 1997, Schuller 1997, Tveten 1997, Dunn 1998, Tveten and Fonda 1999), and to a lesser extent in British Columbia (Roemer 1972, Turner 1991, Lutz 1995, Erickson 1996, Turner 1999). These studies document the ubiquitous use of fire by First Nations prior to European settlement. The functions of these management activities varied from place to place, but for the most part were associated with directly enhancing important food resources or improving the ease of capture or collection (Agee 1993). The precise characteristics of the fires is largely unknown, but historical accounts and dendroecological analyses indicate that they were ignited in late summer and fall, that they burned frequently, perhaps annually in some places, and covered large expanses of the landscape. This regular fire regime prevented the buildup of fuels, and consequently fires were generally flashy and low intensity, carried quickly through the landscape by the dry herbaceous understorey.

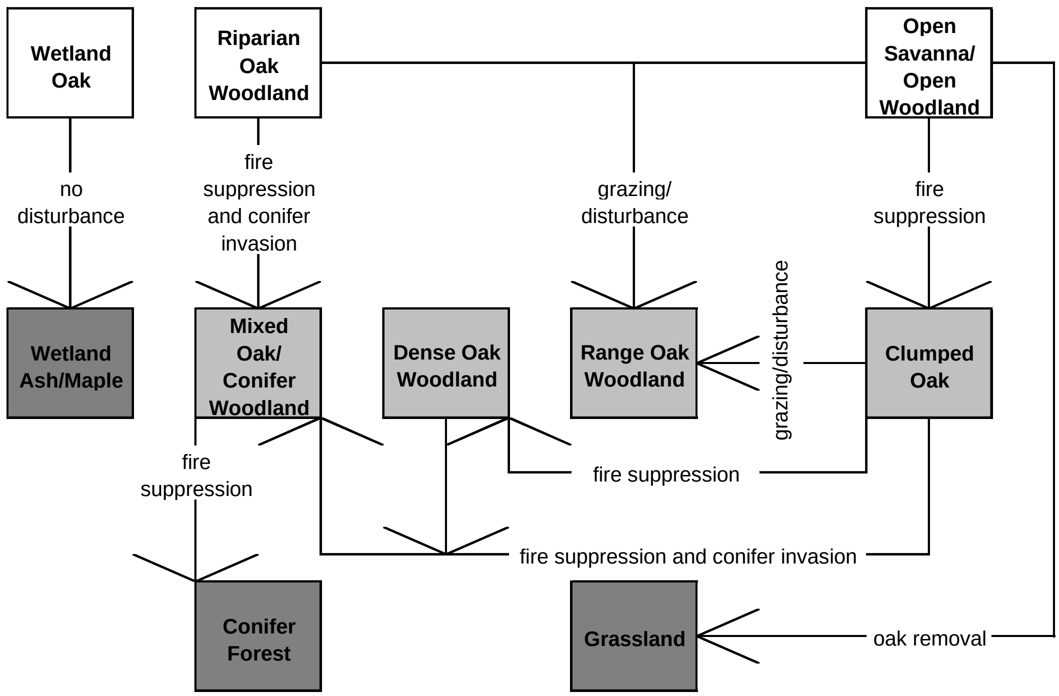
Seedlings of few species of woody plants can survive fire (McPherson 1997). Hence, shrubs and trees, such as Douglas-fir, are unable to establish under a regime of frequent fire. Garry oak seedlings, however, have deep taproots and the ability to resprout from buds at the root collar if the shoot is damaged or killed (Stein 1990, Hibbs and Yoder 1993, Fuchs 1998, Fuchs *et al.* 2000). Although some oak seedlings succumb to fire, these adaptations enable some to persist. In addition, mature Garry oaks are stimulated to sprout from the base or underground rhizomes by shoot damage from fire or other disturbances. Corky bark confers a high degree of fire tolerance to mature oaks. Consequently, oaks are able to establish and maintain themselves under a frequent fire regime, but seedling survival is also limited by fire.

Fire was instrumental in inhibiting shrub and tree, including oak, encroachment into open prairies. It also maintained the open vegetation structure of open oak savannahs and parklands. Hanna and Dunn (1996) present a stand-development model illustrating the impacts of post-European-settlement disturbance regimes, particularly fire suppression, upon different types of Garry oak stands of the South Puget Sound area of Washington (Fig. 3). In the absence of fire, conifers are able to directly invade moist sites such as riparian oak woodlands. Xeric conditions at other sites prevent the direct invasion of conifers. The progression in these locations is first to denser oak woodlands as a consequence of the increased survival of oak seedlings. As the canopy closes, understorey conditions are moderated and conifers are able to establish. Over time, faster-growing conifers overtop and shade out oak trees, oaks are unable to establish in the shady understorey, and stands ultimately convert to conifer forests. Hanna and Dunn (1996) observe that many of the oak stands in existence today are transitional in nature, and note that stem densities within oak stands are an order of magnitude higher than they were at the time of European settlement. Sugihara and Reed (1987a, 1987b) describe similar stand dynamics in the Bald Hills Oak Woodlands in Redwood National Park in California. They found that fire stimulates oak sprouting but causes high seedling mortality. In the absence of fire, oak density increases, conifers establish in the understorey, and oak stands convert to conifer forests.

Fire exclusion has been described as the most serious ecological problem facing remnant Garry oak stands that are protected from development (Sugihara and Reed 1987b, Agee 1993, Hanna and Dunn 1996). Large-scale conversions of prairie and oak savannah have been documented in California, Oregon and Washington (Habeck 1961, Thilenius 1968, Johannessen *et al.* 1971, Towle 1979, Sugihara and Reed 1987a, Sugihara and Reed 1987b, Agee 1993). Sugihara and Reed determined that the Garry oak - prairie complex in Redwood National Park had declined by 26 % over the last century as a result of conifer encroachment. Based upon an analysis of current stand composition and relative growth rates, they projected overall canopy dominance by Douglas-firs within 20-30 years in the absence of remedial action. Agee concluded in 1993 that up to 50 % of all Garry oak woodlands suitable for conifer establishment might be lost within 30 years.

Stand dynamics have not been described in any detail for Garry oak ecosystems in British Columbia. Stand types and site conditions in British Columbia differ from those in Washington (Hanna and Dunn 1996) and California (Sugihara and Reed 1987a, Sugihara and Reed 1987b), but similar patterns have been observed at some locations. Roemer (1972) concluded that anthropogenic fires were responsible for the persistence of the *Quercus-Geranium* plant association occupying sites suitable for conifer dominance, but that the spatial extent of open Garry oak stands had not significantly diminished since European settlement. Patches of conifer saplings under a Garry oak canopy comprised a habitat type identified by Fuchs (1998) at one site. Oak density at this site was approximately 300-450 stems per hectare (Fuchs 1998, Chatwin 1997). This density exceeds that of most sites described by Hanna and Dunn (1996), including those in which stand densities greatly exceed those that existed prior to European settlement. Ussery

Figure 3. Stand development model illustrating the impacts of different disturbance regimes, particularly fire suppression, upon different types of Garry oak woodland of the South Puget Sound area of Washington. Disturbance regimes are representative of those dominating the landscape since European settlement. Progression from white to light gray to dark grey boxes indicates a transition from historic oak to altered oak to non-oak habitats. Redrawn with permission from Hanna and Dunn (1996).



(1997) observed increased densities of Garry oak stems, conifer seedlings, and native understorey shrubs, particularly snowberry (*Symphoricarpos albus*), and suggested that these structural changes are the result of cessation of a frequent fire regime. Shrub encroachment resulting from fire exclusion has been identified as a threat to a number of rare plants of Garry oak and associated ecosystems in British Columbia (Table 4). Erickson (1996) assessed Garry oak vegetation communities with moderate to dense shrub cover as appropriate management units for prescribed fire. No analyses have been done about the rates or extent of encroachment of conifers or other woody species. Many extant oak stands are located on xeric sites such as rocky outcrops, where conifers may be excluded due to edaphic conditions and hence conifer encroachment may not be a threat.

Effects of fire on herbaceous vegetation are not limited to the inhibition of woody shrubs and trees. Different species of plants have differential responses to the changes in temperature, litter, soil moisture, soil chemistry, microclimate, and soil biota from fire, as well as varying levels of vulnerability to direct damage (Daubenmire 1968). Fire-adapted forbs and grasses that evolved and persisted in these ecosystems possess various structural adaptations (*e.g.* perennating tissues near or below the ground surface) and life history strategies (*e.g.* late summer die-back of above-ground parts) that enable them to tolerate frequent, low-intensity fires. Bulb and rhizome-forming species, and species with fire-adapted seed strategies, tend to be favoured by fire (Sugihara and Reed 1987b). Community responses to fire are complex due to competitive interactions among resident species as well as factors such as microhabitat, weather, seasonality and frequency of burning, fire intensity, and many other factors. A compilation of responses of numerous species to fire is available from The Fire Effects Information System (1996), and other information is available in the scientific literature. The complexity of the responses precludes inclusion of a summary of information pertaining to species of Garry oak ecosystems in this report.

Prescribed fire has been introduced as a restoration tool in Garry oak and associated prairie ecosystems at a number of locations in California and Washington (Sugihara and Reed 1987a, Sugihara and Reed 1987b, Agee 1993, Agee 1996, Hannah and Dunn 1996, Hastings and Barry 1997, Dunwiddie 1997, Schuller 1997, Tveten 1997, Hastings 1997, Hastings *et al.* 1997, Dunn 1998, Tveten and Fonda 1999). The technique, sometimes augmented with manual removal of larger Douglas-firs that exceed fire-sensitive size, has been effective in inhibiting woody encroachment into prairies and savannahs. However, the efficacy of fire as a restoration tool is equivocal due to the complexities associated with the invasion of exotic plant species, an issue discussed in more detail in the next section of this report. Some invasive species of Garry oak ecosystems in British Columbia tend to be favoured by fire, but spatial and temporal variation is considerable. Some factors associated with this variation have been determined, but the causes of much of the variation are a mystery. Fire can be an effective method for control of Scotch broom if repeated over a number of years (Agee 1996, Dunn 1998). In general, prescribed fire has tended to reduce cover of invasive herbs in Redwood National Park (Sugihara and Reed 1987b) and Annadel State Park (Hastings and Barry 1997) in California and has had mixed results at Fort Lewis (Tveten 1997, Tveten and Fonda 1999), Mima Mounds (Schuller 1997), and Yellow Island (Dunwiddie 1997) in Washington. These results underscore the need for caution in the application of prescribed fire. Potential sites must be carefully assessed and burning should be applied within an adaptive management framework, in which management actions are applied within an experimental framework, results are monitored, and management is refined according to the results.

Faunal response to fire has received considerably less explicit attention than has that of plants. The Fire Effects Information System (1996) presents information about responses of a number of vertebrate species, including some species found in Garry oak and associated ecosystems in British Columbia. Other information is available in the scientific literature. The responses of vertebrates to a fire regime are largely mediated by fire effects on vegetation structure. For example, animals associated with grasslands and other open ecosystems tend to benefit from a frequent fire regime. Such species in fact rely on fire or other disturbance agents for the maintenance of their habitats. However, some grassland species are favoured by conditions immediately following a burn while others favour conditions a few years hence (Clark and Kaufman 1990, Johnson 1997). Fire also promotes the genesis of standing dead and downed wood, which favours species that depend upon these habitat elements. Such species of Garry oak ecosystems in British Columbia are discussed elsewhere in this report. Temporal factors, such as the seasonality of burning, are also important in determining the effects of fire on animals. For example, direct mortality or disruption of breeding may occur if burning occurs during periods of critical activity (Cavitt 2000).

Similar to vertebrates, invertebrate species vary in their response to fire. Some are favoured by conditions immediately following a burn while others favour conditions a few years later. In contrast to highly mobile vertebrates, invertebrates are more vulnerable to direct fire-caused mortality (Nicolai 1991, Swengel 1996, Siemann *et al.* 1997). Because fire suppression has caused increased fuel loads in most places, fires tend to burn hotter than they did historically, thus increasing the mortality risk. Maintaining populations of invertebrates that are vulnerable to fire-caused mortality but depend on fire-maintained ecosystems requires a staggered strategy, such as rotating burns among portions of the habitat, in order to continually recruit new habitat patches but prevent local extinctions of invertebrate populations (US Fish and Wildlife Service 1984, Schultz and Crone 1998). Thus, management must incorporate not only the disturbance process itself, but variation in time and space to support a complex of species over time. Habitat patches in fragmented landscapes must be large enough to accommodate such complex disturbance regimes. The area required to support a disturbance regime that incorporates the natural spatial and temporal variation is called the minimum dynamic area (Shafer 1990).

Presence and Effects of Exotic Species

Biological invasions are among the most serious modern ecological problems (D'Antonio and Vitousek 1992, de Poorter 1999, National Invasive Species Council 2000, Haber no date). Invasions are 1 of the top 2 factors responsible for species extinctions worldwide, approaching habitat loss in importance (D'Antonio and Vitousek 1992). Because invasive species by definition are active colonizers of habitat, they freely cross the boundaries of reserves and protected areas. Direct impacts of a particular invasion may be restricted to the level of individual species, such as losses of one or more particular species within an area, or they may occur at the level of the biological community, such as when aggressive invaders alter the structure and composition of a suite of species. Most pernicious are ecosystem-level changes. These occur when invasive species alter ecosystem processes by changing resource supply (*e.g.* invasions of nitrogen-fixing plants into formerly nitrogen-limited sites), trophic structure (*e.g.* addition or removal of top predators) or disturbance regime (*e.g.* alterations by introduced plants to fire frequency or intensity) (D'Antonio and Vitousek 1992). Biological invasions are sometimes characterized by positive feedback loops, in which the invasive species change conditions such that the new conditions are more favourable to themselves, thus reinforcing the trajectory towards an invaded ecosystem.

The prevalence of invasive exotic plants in Garry oak and associated ecosystems in British Columbia has been documented in a number of studies. Roemer (1972) found that 25 % of the species within the core of the Garry oak range in British Columbia were introductions from the Mediterranean and other parts of Europe. He noted that these species are so fully integrated into the ecosystem that they comprise a part of the characteristic plant association. Subsequent sampling at different sites in 1995 revealed that 40-76 % of the herbaceous species in camas meadows of the core area were exotic, and that exotic species comprised 59-82 % of the herbaceous cover, suggesting an increased presence in exotic species over the 2 decades (Roemer 1995). Seventeen out of 42 Garry oak plant communities in Erickson's classification (1996) are defined as "introduced plant communities," of which 8 are "second order" communities interpreted as more degraded derivations of "first order" introduced plant communities. Various inventories throughout the region have also noted the large number of introduced plants (*e.g.* Radcliffe *et al.* 1994, Ryan *et al.* 1996, Swanson 1996, Cousens and Lee 1998, McPhee *et al.* 2000). An assessment of regional parks within the Capital Regional District concluded that 100 % of the parks are threatened by the invasion of non-native plant species, 36 % of them severely so (Fleming 1998). Out of 546 species of vascular plants of Garry oak and associated ecosystems (Table 1), 29 % of them are introduced. Shrub and tree strata, with 22 % and 20 % each respectively comprised of introduced species, are less invaded in terms of numbers of species than the herbaceous layer.

Although relatively fewer shrub species are introduced compared to the proportion of introduced herbaceous species, introduced shrubs pose some of the most serious threats to Garry oak ecosystems in British Columbia. Scotch broom, introduced to the region as a garden ornamental in 1850, has since become a dominant component of much of the Garry oak landscape, as indeed it has invaded other parts of British Columbia, Canada, North America, and the entire world (Hoshovsky 1986, Erickson 1996, Ussery 1997, Peterson and Prasad 1998, Ussery and Krannitz 1998). Scotch broom has dramatically altered the vegetation structure of these ecosystems by forming a dense shrub layer where shrubs were formerly absent, sparse, or at most patchy. This shrub layer shades out native understorey species adapted to open conditions. These changes can negatively affect habitat suitability for animal species, including many birds and butterflies, that require open vegetation structure. Furthermore, Scotch broom is a nitrogen-fixer, and thus has the potential to change ecosystem-wide resource supply. It also generates large amounts of woody fuel that can support high intensity fires and in this way alter the natural disturbance regime. Gorse (*Ulex europaeus*) shares similar characteristics and destructive potential with Scotch broom but to date is not as widespread in British Columbia (Hoshovsky 1989b, Clements *et al.* 2000). Other invasive shrubs of great concern include English ivy (*Hedera helix*), Himalayan blackberry (*Rubus armeniacus*), cut-leaved blackberry (*Rubus laciniatus*) and laurel-leaved daphne (*Daphne laureola*).

Exotic grasses are a ubiquitous presence in Garry oak ecosystems, and dominate the herbaceous flora at many if not most sites (Roemer 1972, Roemer 1993, Roemer 1995, Erickson 1996, Maslovat 2000). They include perennial grasses, primarily the result of past and current intentional seeding for livestock forage and erosion control, and annual grasses that were for the most part accidental introductions (D'Antonio and Vitousek 1992). Common species include orchardgrass (*Dactylis glomerata*), common velvet-grass (*Holcus lanatus*), Kentucky bluegrass, barren brome (*Bromus sterilis*), sweet vernalgrass (*Anthoxanthum odoratum*), hedgehog dogtail (*Cynosurus echinatus*), perennial ryegrass (*Lolium perenne*), and others. Many exotic grasses can directly outcompete native species by reducing light at the ground level and aggressively capturing water and nutrients. They also have the potential to alter ecosystem processes by producing nitrogen-enhanced litter, changing ground-level microclimates from extensive litter, altering fire regimes as a result of their high flammability and enhancement of soil moisture deficits, and other characteristics (D'Antonio and Vitousek 1992). The potential for these ecosystem-level changes is particularly great when exotic grasses invade ecosystems that were not previously grass-dominated. The historical composition of Garry oak plant communities in British Columbia, especially those from the core area, is largely unknown (Roemer 1972, Roemer 1993, Roemer 1995). Consequently, the previous relative abundance of grasses and forbs is not clear, and to what extent these grass invasions have caused ecosystem changes has not been directly investigated. Introduced forbs are also numerous in British Columbia, and include dovefoot geranium (*Geranium molle*), hairy vetch (*Vicia hirsuta*), common vetch, cleavers (*Galium aparine*), chickweed (*Stellaria media*), sheep sorrel (*Rumex acetosella*), and hairy cat's ear (*Hypochaeris radicata*) (Roemer 1993, Roemer 1995). Invasive forbs are not generally described as being as destructive as invasive grasses in Garry oak ecosystems.

Strategies for prevention and control of these invasions have entailed a variety of approaches in different locations. Suggested approaches for prevention include limiting or preventing livestock grazing, restricting recreational access into Garry oak ecosystems, and siting developments as far as possible from sensitive areas (McPhee *et al.* 2000). Livestock grazing has been implicated in the increased presence of exotic plants in Garry oak woodlands in California (Saenz and Sawyer 1986) and soil disturbance, such as that associated with roads, buildings, and the recreational use of natural areas, is a primary factor contributing to the introduction and establishment of exotic species in open oak and grassland ecosystems (Knops *et al.* 1995). A variety of management tools have been employed for control of different exotic species, with varying degrees of success. Methods include manual, mechanical, chemical, and biological controls, as well as the use of fire. Overall, efforts have been resource-intensive and success has been limited (Hoshovsky 1986, Pitcher and Russo 1988a, Pitcher and Russo 1988b, Hoshovsky, M. 1989a , Hoshovsky 1989b, Agee 1996, Erickson 1996, Sather 1996, Buschmann 1997, Dunwiddie 1997, Tveten 1997, Ussery 1997, Carpenter and Murray 1998, Dunn 1998, Peterson and Prasad 1998, Schuller 1998, Ussery and Krannitz 1998, Tveten and Fonda 1999, Morisawa 1999, Clements *et al.* 2000, Maslovat 2000). Efficacy of the different techniques has varied with identity, density and extent of the target species, location, season, overall species composition (exotic and native), life stage of the exotics, and other known and unknown factors. The apparent ability of some exotic species (*e.g.* some grasses) to impede invasion by other exotic species (*e.g.* Scotch broom) complicates the selection and evaluation of treatment options (Parker *et al.* 1997). Applicability of the different techniques has depended in part upon site sensitivity and agency resources.

Very little information pertaining to control of exotic plants originates from Garry oak ecosystems in British Columbia. One local study compared different approaches to manual removal of Scotch broom (Ussery 1997, Ussery and Krannitz 1998), and a few other studies currently in progress are examining ecosystem restoration including control of invasive plant species. No local research has investigated prevention methodologies. Given the variability of the results that are available, the need for local information is pressing. Adaptive management provides an appropriate framework for simultaneously implementing and testing approaches to prevention and control of invasive plants (Ussery 1997).

Numbers of introduced animal species are relatively lower than for plants (Tables 1 and 5) but the impacts from some of them are potentially severe. No introduced amphibians are found in Garry oak ecosystems. The European wall lizard (*Podarcis muralis*) is the only introduced reptile. To date it has only colonized a restricted area on the Saanich Peninsula, but numerical and geographical expansion is occurring (Orchard 1993, D. Fraser pers. comm.). Six percent of the birds of Garry oak and associated ecosystems are introduced. The European starling (*Sturnella vulgaris*) has been implicated in the decline of the Lewis' woodpecker, and perhaps other cavity nesting species including western bluebirds and purple martins (*Progne subis*), because it is an aggressive competitor for the limited supply of tree cavities (Verner *et al.* 1997, Ward *et al.* 1998, Fraser *et al.* 1999). Of all vertebrate classes, mammals include the largest proportion of invasive species. Twenty one percent of all mammal species are exotic. One study of small mammals in Uplands Park, a relatively large park in the Victoria metropolitan area, yielded only house mice (*Mus musculus*) and black rats (*Rattus rattus*) (Chatwin 1993). Of greatest current concern is the eastern gray squirrel (*Sciurus carolinensis*). The squirrel was introduced into the Victoria area in the 1960's (Bennett (B.) 1993). Squirrel numbers and range have increased dramatically since then, and they are currently distributed throughout most of the Vancouver Island range of Garry oaks (Bruemmer *et al* 2000). Gray squirrels consume acorns, and thus pose a threat as a competitor for this valued resource. Although they also cache acorns and hence may be dispersal vectors, limited acorn transport distances and their habit of biting out the apical meristem at the tip of the acorn prior to caching likely limits their role as dispersers (Fox 1982, Pigott *et al.* 1991, Fuchs 1998). Gray squirrels have been observed eating bulbs of native plant species, such as camas (D. Fraser pers. comm.), and are known to damage and sometimes kill oak and other hardwood trees in Europe by stripping bark (Bruemmer *et al* 2000). The gray squirrel may also be a great threat to the native red squirrel (*Tamiasciurus hudsonicus*). Large-scale extirpations of European red squirrels (*Sciurus vulgaris*) have followed gray squirrel introductions to Britain, Ireland, and Italy (Bruemmer *et al*. 2000). Introduced eastern gray squirrels are also considered a contributing factor to the decline of the native western gray squirrel (*Sciurus griseus*), closely associated with Garry oak ecosystems, in the United States (Ryan and Carey

1995). One study is currently examining the rate of spread of eastern gray squirrels in British Columbia (Gonzales 1999). A trapping program is attempting to reduce the population of the Virginia opossum (*Didelphis virgiana*) on Hornby Island (Balke 2000), the only locality of this introduced mammal within the Canadian range of Garry oak ecosystems. Other than localized rat and mouse control programs, no other research or control of invasive vertebrates has been initiated.

Four invasive insects have caused, or have the potential to cause, serious damage to Garry oak trees in British Columbia. Severe outbreaks of the winter moth (*Operophtera brumata*) in the 1970's and 1980's were effectively controlled by the release of a parasitic tachinid fly (*Cyzenis albicans*) and an ichneumon wasp (*Agrypon flaveolatum*) (Smith 1995). The jumping gall wasp and oak leaf phylloxeran are currently causing considerable damage (Bennett (R.G.) 1993, Duncan 1993, Maier 1993, Smith 1993, Smith 1995, Bennett 1997, Duncan 1997a, Duncan 1997b). Research suggests that parasitoids that attack the gall wasps are starting to control wasp populations, and that approximately 90 % of Garry oak trees are genetically resistant to the phylloxeran. In addition, predation by the introduced Asian lady beetle (*Harmonia axyridis*) appears to be controlling phylloxeran populations (R. Duncan pers. comm.). In contrast, the gypsy moth has the potential to devastate Garry oak populations in British Columbia (Miller *et al.* 1991, Humble and Stewart 1994). Oaks, including Garry oak, are among the preferred food of the gypsy moth. Infestations have defoliated vast expanses of oak forests in eastern North America and killed more than half of the trees in some of the outbreaks (Davidson *et al*. 1998). Aerial spraying of a microbial pest agent, *Bacillus thuringiensis* ssp. *kurstaki* (*Btk*), is the most commonly used control method. Concerns about broadcast spray programs on human health, insectivorous birds, and non-target Lepidoptera, especially rare species, illustrate the complexities of invasive species management (Miller 1990, Capital Health Region 1999, Ovaska and Sopuck 1999, Boulton *et al.* 2000).

Evidence for the potentially devastating impacts of introductions also exists in lesser-known taxonomic groups. In British Columbia, the majority of the earthworm species present are European introductions. This is especially true on southeastern Vancouver Island, where native earthworms are generally absent (Marshall and Fender 1998). Marshall and Fender (1998) do not indicate whether native species were always sparse or absent in this area, or if they have been displaced by the introduced earthworms. In either case, the transition to an introduced earthworm fauna may have profound effects on ecosystem function. Earthworms play pivotal roles in decomposition processes and in structuring and aerating layers of the forest floor (Speirs *et al.* 1986, Koss 1999). Changes in the nature or rate of earthworm activity that may accompany changes in earthworm abundance or species composition may alter nutrient regimes, ecosystem productivity, and other ecosystem functions. Herbivory from the introduced black slug *Arion ater* may be harming populations of native plant species including rare plants such as yellow montane violet (*Viola praemorsa* ssp. *praemorsa*) and deltoid balsamroot (*Balsamorhiza deltoidea*) (McPhee *et al*. 2000, D. Fraser pers. comm.). In California, an oak epidemic dubbed "Sudden Oak Death Syndrome" that has spread hundreds of miles in 5 years has been linked to a species of *Phytophthora*. This fungus appears to be spread by humans and was formerly unknown in California, suggesting that it may be an introduced exotic species (CAMFER 2000, Fimrite 2000).

Conclusion

Three major conclusions can be drawn from this review. First, the range of biological and cultural values vested in Garry oak and associated ecosystems confers great significance to ecosystem conservation. Protection and restoration of the ecosystems, and the essential ecosystem characteristics that sustain them, is a prerequisite for preserving their diverse elements and attributes. Secondly, the extent and rate of past, current, and potential future declines of the ecosystems and the associated species at risk imparts an urgency to the development and implementation of conservation initiatives. Continued, rapid declines are likely if not inevitable unless trends are reversed. Finally, significant knowledge gaps constrain our ability to assess ecosystem and species status and threats as well as our ability to develop effective conservation measures. Research is required to address these knowledge gaps. However, the urgency of the situation necessitates that conservation efforts cannot wait until the gaps are filled. Conservation actions must be applied in the meantime, based upon the best available knowledge. New information gleaned from adaptive management and research programs can be applied to conservation initiatives along the way, and thereby improve the efficiency and effectiveness of the initiatives.

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