TERRESTRIAL INVERTEBRATE PREDATORS OF THE COLUMBIA RIVER BASIN: AN ASSESSMENT

A Report to the U.S. Forest Service/Bureau of Land Management -- Eastside Ecosystem Management Project

by

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General Introduction

The terrestrial invertebrate predators of the Columbia River Basin are a diverse group of arthropods (primarily arachnids and insects), whose various species occur in every major habitat (Appendix 1). This report will cover primarily the spiders (Arachnida: Araneae) and the major insect groups, principally the true bugs (Heteroptera), the lacewings (Neuroptera), the beetles (Coleoptera), the ants (Hymenoptera: Formicidae) and the social wasps (Hymenoptera: Vespidae).

The report begins with some general-comments on the ecological function of invertebrate predators and their importance in forest protection, and discusses some of'the critical factors affecting their abundance and distribution; A second section describes some of the key habitat types for invertebrate predators within the Columbia River Basin, and a third section concentrates on the predaceous beetles, probably the most diverse group of Invertebrate predators of the CRB, and the only group of predators within which sensitive species have been listed. The report represents the collaborative effort of a coleopterist (James Labonte), an arachnologist (Rodney Crawford), and an insect ecologist (James McIver).

Caveat. Any assessment of such a large diverse group is likely to be superficial, for at least two reasons: 1) an assessment of a group such as the spiders would require information on well over 1000 species, the majority of which are poorly known; 2)even the available information is widely dispersed; and would require a substantial committment of time to excavate from the literature. Hence this report attempts to provide a basic view of the diversity of this functional group of invertebrates, their ecological function, and factors that are thought to affect their abundance and distribution.

Terrestrial Invertebrate Predator Diversity within the CRB

A list of the principal families of terrestrial arthropod predators found In the Columbia River Basin is provided in Appendix 1. This list covers those families that are predominantly predaceous, and a few (especially coleoptera) where primarily non-predaceous families contain species that are thought to be important predators. A total of 112 families are listed, assigned to 15 orders and 3 classes of the Phylum Arthropoda. Contained within these families are between 3544 and 6636 species known to occur within the CRB analysis area. The wide range in-this estimate is due to uncertainty from at least three sources: 1) unknown geographic distributions for many species: 2) incomplete examination of the literature; and 3) incomplete examination of museum records. A thorough examination Of literature and museum records would improve the accuracy of this estimate considerably.

Despite the inaccuracy of the species number estimate, it is clear from examination of this list'that arthropod predators occur in great diversity throughout the analysis area, in every major habitat type, and prey upon virtually every conceivable type of arthropod species. As a group, arthropod predators are a fundamental part of any functioning ecosystem, with the function simply being provided by a different species composition in each major habitat type. Some major taxa such as the spiders, true bugs and beetles, themselves contain representative species sprinkled throughout the analysis area; while others, such as the scorpions and pseudoscorpions tend to occur in dryland and moist microhabitat types respectively.

In terms of abundance, spiders and ants dominate the, terrestrial arthropod fauna associated with vegetation in the CRB, with beetles, ants and spiders more. prevalant on the ground. With respect to diversity, beetles are represented by over 1300 species, spiders at least 980 species, and predaceous Hymenoptera with at least soo species. Other major predaceous arthropod orders are the true bugs (Heteroptera) and the true flies (Diptera).

There are just 8 listed "special concern" species of arthropod predators (all beetles), and panel species Information is provided for each of these species. In addition, this report provides more detailed information on 14 additional "exemplar" species, chosen to represent not'only the taxonomic diversity of this functional group, but ecological function as well. These exemplar species include 5 species of beetles, 2 species of ants, 1 species of social wasp, and 6 species of spiders.

Invertebrate Predators and Ecological Function

Probably the most obvious and compelling evidence for the primacy of predation as an ecological force is the ubiquity of defensive adaptations against predators among the arthropods (Edmunds 1975). In a longterm study of the lupine arthropod community in the northern Great Basin Desert, I have documented the behavioral effects of mimicry and aposematism on lupine predators (McIver 1987; McIver 1989; McIver & Lattin 1990), and provided evidence of their ecological effects, mediated through these predator behavioral responses. Mimicry and aposematism are just two of the many defensive adaptations used by lupine herbivores: of the top 8 herbivore species of lupine (representing-90% of total herbivore abundance), 1 species is a mimic, 1 species is aposematlc, 2 species are hard-bodied, 2 species use convulsive escape behavior, 1 species is protected by ant attendance, and 1 species hops when disturbed.

. The ubiquity of defensive adaptations suggests that predation has been a powerful organizing force in natural communities since the terrestrial arthropods evolved some 100 million years ago. Predation is no less fundamental in managed ecosystems. In managed forest ecosystems, predation is thought to be responsible in large part for regulating arthropod populations, including pest populations under endemic conditions (Mason et al. 1983). A preliminary evaluation of. the "HUSSI" database (initiated by Hopkins and made available by Mel. McKnight), provides insight into the diversity of arthropods that have been observed to prey upon other organisms in the Columbia River Basin analysis area (Table 1). Of 24,392 collection records in the database, 5959 contain information on predator-prey or parasitoid-host relationships among the arthropods. The majority (92.7%) of these are parasitoid-host relations,. primarily involving pest insects. The prodominance of parasitoid-host records is not surprising, since observations of parasitoid-host relations require only that the collected host organism be reared in the lab. A total of 432 are observed predator-prey links, involving at least 93 predator species, 68 genera, 34 families, 5 orders and 2 classes. The occurrence of this many observed predator-prey links is notable, since it is extremely. rare to actually observe a predation event- in the field. For example, 'a similar sample size of lupine arthropods in the Great Basin Desert (10 year study; James McIver: 45,000 samples) has yielded.368 observations of predation (0.8% of samples); compared to the HUSSI database, in which 1.8% of records contain reference to predation.

The HUSSI database suggests that predation is an ecological process that is a fundamental part of any healthy managed ecosystem. The challenge for managers, however, is in maintaining this process for the longterm, such that arthropod population fluctuations are contained within some desirable range of boundaries., In some cases, maintaining predatory function may be as simple as maintaining structures on the landscape that predators are known to require (Camponotus modoc and down wood: Torgersen pers comm). Down wood, snags, special habitat features (hydrological function of a bog or spring), forbs, shrubs and trees of various species and sizes--these are the features on the landscape that predaceous arthropods will respond to, in much the same manner as the vertebrates (Thomas 1979). But unlike the vertebrates, virtually nothing is known about how particular human management practices influence the species composition, abundance and distribution of predatory arthropods. Yet habitat is fundamental: in a study of litter spiders of western Oregon coniferous forests, McIver et al. (1992) show that the characteristic oldgrowth litter spider assemblage is completely replaced upon clearcutting, with a guild shift from trapdoor/web spinning spiders on the oldgrowth forest floor to the wandering spiders (e.g. wolf spiders) dominant in clearcuts. The question is what effect this guild shift has on ecological function. Certainly, predation as a function is very much intact in the clearcut, with about the same diversity a&nearly-double the abundance of spiders when compared to the oldgrowth forest. The relevant difference that species composition makes in terms of ecological function is prey choice: trapdoor spiders eat very different things than woif spiders. So a landscape composed of a balanced mosaic of habitat types will likely have a concommittant balanced mosaic in the quality of ecological function. What is important is saving all the habitat parts, such that a source pool of colonists is available somewhere on the landscape when a disturbance occurs. Probably *one* of the effective ways to do this for arthropods is to manage vegetation in a variety Of different ways at a variety of different scales, and gradually come to understand in general terms how these different ways and scales may influence ecological function. From the perspective of the arthropod predator, settling-on one type of management style at one scale would narrow the predator species pool and the function it provides for the ecosystem.

Arthropod Predators and Pest Insects

Predation has long been regarded as a **potent** force In suppressing forest insect pest populations (Morris 1963). Predators have.been implicated as primary suppressive agents of several pest species, including Dendroctonus species (Furniss **&** **Carolin 1977), Ips** species (Jennings **&** Pase **1975),** pine tip moths (Bosworth et al. **1971),** and the two principal defoliator species of western coniferous forests, western spruce **budworm** (Choristoneura occidentalis: Campbell et al. 1983; Torgersen et al. 1990) and Douglas-fir **tussock moth (Orgyia pseudotsugata: Dahlsten et** al. 1977; Torgersen et al. 1983; Mason et al. 1983; Mason **&** Torgersen 1983; Mason **&** Paul 1988).

Studies on mortality of western spruce **budworm** populations have pointed toward bird and ant predation as primary **factors (Torgersen et** al. 1990). In whole ***tree*** **exclosure** experiments, several species of passerine birds were identified as most influential in the upper third of the canopy and ants (primarily **Camponotus** modoc) more effective in the lower third. Pupal stocking studies have also implicated thatch ants (Formica haemorrhoidalis) as significant mortality **factors of western** spruce **budworm.** Spiders **may** also play a role in suppressing' **budworm** populations, particularly when caterpillars are in the earlier stages of development. A key point established by these studies is that predation on spruce budworm'comes from **a diverse** ensemble of predators, including birds, ants, spiders, and other arthropods. Management techniques that enhance the role of these predators throughout the **budworm** population cycle will be likely to pay off in terms of decreased economic loss of green trees. An example illustrating the intricacy of predation effects is the central importance of down wood,. Because **Camponotus** modoc nests only in large diameter down wood, maintenance of adequate levels of wood will favor larger populations of this **important spruce budworm** predator. Further, since Camnonotus modoc is also the primary prey of pileated woodpeckers, and **since** these woodpeckers **excavate** cavities used by **a variety** of insectivorous birds, management of down wood can provide substantial benefit, by encouraging the maintenance of larger populations of **budworm** predators, principally ants and birds (Torgersen **pers. comm.).**

Numerous studies have implicated predation as **a primary** cause of mortality **in** Douglas-fir-tussock moth populations, including stocking experiments (Mason **&** Torgersen 1983; Mason **&** Paul 1988) and key-factor analysis (Mason et al. 1983; Mason **&** Torgersen 1987). Primary predators identified as mortality **factors** include the jumping spider **Metaphidippus** aeneolus, **philodromid** hunting spiders, web-spinning spiders, heteropteran predators, **predaceous** ants and birds **(Wickman** 1977; Mason **&** **Torgersen** 1987; Mason **&** Paul 1988). It is important to note however, that although predation may contribute well over half the total mortality of tussock moth larvae and pupae during outbreak conditions, it is thought that even this level of suppression is inadequate to deflect the outbreak population trajectory (Mason & Wickman 1988). Hence predation is typically thought to exert most of its influence during non-outbreak (or endemic) phases of the moths' population cycle (Mason 1987). Management activities that improve the impact of predation during these endemic conditions are therefore most likely to either defer or decrease subsequent population levels during the outbreak phase. For example, in the northeastern United States, spider populations on spruce are significantly higher. than on balsam fir, and thus altering the relative abundance of these tree species may influence the total suppressive effect of arthropod predation on populations of the spruce budworm Choristoneura fumiferana (Jennings et al. 1990).

The HUSSI database also Identifies some of the major predators of several insect pest species, including pine tip moths, tussock moths, budworms, sawflies, tent caterpillars, and bark beetles. A total of 71 predator species have been observed' to attack these pest insect species,' 33 for Dendroctonus species alone. These figures are almost certainly gross underestimates of the actual diversity of predators that attack pest insects--for example, the HUSSI database provides only one record of a spider preying upon an arthropod, and spiders have been demonstrated to be important predators of forest insect pests (Warren et al. 1967; Jennings & Pase 1975; Wickman 1977; Mason & Paul 1988). Nevertheless, the HUSSI database suggests that a diverse complex of predator species may act to cause substantial mortality of forest insect pests, and may play a significant regulatory role by suppressing pest population buildup, especially in defoliator species. (Mason et al 1983).

Critical Factors Affecting Arthropod Predators

The Importance of Habitat. Probably the only way to meaningfully manage most arthropod species is by managing habitat. It is assumed in this report that it is desirable to manage lands containing critical arthropod habitats in such a way that the value of those habitats for the constituent fauna are preserved. A discussion of'habitat types that are key to arthropod species is provided in this report by Rod Crawford.

A variety of factors, both natural and-human-induced, are likely to influence the distribution 'and abundance of arthropod predators. These can be broken into two basic categories: inherent features of the environmental, and disturbances.

Inherent Environmental Features; The architecture of the physical environment upon which predators depend to hunt and nest is of primary importance for almost every predator species. The natural, systematic variability in spider abundance among sites suggests that spider populations can be encouraged by management (Mason 1992). Plant architecture (size, number and arrangement of leaves, needles, branches) is known to influence canopy spiders (Stratton et al. 1979; Gunnarsson 1988). Plant species composition has been shown to influence-spider abundance as well: Jennings et al.(1990) have consistently recorded a significantly greater number of spiders in spruce as opposed to hemlock in forests of the northeastern United States. Physical structures like down logs can provide nesting, foraging, or hiding habitat for important predator species, such as ants (Formica species, Camponotus modoc; Torgersen pers comm), beetles, and spiders. A number of predator species are associated with specific habitat types (as discussed in LaBonte's section of this report), suggesting that special attention be paid to management of these features. In fact, since habitat can be considered the template for ecological interactions, a management approach that focuses on habitats of various scales is most likely to maintain a biodiversity of predator species.

Disturbances. In the most basic sense, any disturbance that affects habitat will affect the species that depend on that habitat. For example, the short fire return intervals of the cheatgrass dominated rangelands in southern Idaho will very likely eliminate dominate predator species such as the thatch ant Formica obscuripes. Although thatch ant colonies can survive fire by maintaining the queen and brood below ground, post-fire survival is challenged by lack of resource, since the sagebrush-feeding Homoptera that the ants depend upon for honeydew energy are typically eliminated. Hence colonies are generally reduced by fire to less than *20%* original size, and fires returning every few years will likely drive these challenged colonies to extinction. A general rule of thumb for thatch ants in the northern Great Basin: remove sagebrush and other shrubs upon which thatch ants tend Homoptera, and the ant will go with it. Systems with short fire-return intervals (cheatgrass dominated) will tend to favor "weedy" ant species with different ecological functions. In general, because current conditions in many of our ecosystems have been modified so significantly through fire suppression, grazing, and the introduction of exotic species, a simple reversal of fire management (using prescribed burning) may not accomplish an objective of returning the land to its previous condition. Hence it is recommended that prescribed burning be used with extreme caution, always with native species in mind.

Silvacultural practices can have profound effects on predator species composition. In coniferous forests of western Oregon, clearcutting causes a complete replacement of forest-dwelling litter spider species with species adapted to sunny open places (McIver et al. 1992). Selective cutting more typical of eastside *forests* is *not* likely to have such a profound effect, but more work needs to be done to determine the connection between silvaculture, predator species composition, and the quality and quantity of ecological service these species provide. The following recommendations would go a long way to insuring the health of habitat-specific forest predator populations: 1) Low elevation oldgrowth forests, because they represent such a low percentage of habitat types, should be managed cautiously, since the microhabitats they provide (through deep thick bark, and amelioration of environmental conditions on the forest floor) are favored by a number of predaceous species; 2) Bogs and wetlands, including lake-edge and stream-edge grassland, should have an uncut buffer zone: 3) Sand, gravel, canyon, waterfall, spring and cave habitats should also have an uncut buffer, as they all harbor unique predator species.

Development, including residential and dam building, can eliminate all native species. We recommend that development not be considered in areas where critical habitats are known.

Overgrazing of shrub-steppe, prairie, Savannah, or mountain meadows can eliminate arthropod species through conversion of perennial grasses to introduced annuals. It is recommended that range managers have as a primary objective the maintenance of native plant populations, since these favor native arthropod species.

Recreation can damage arthropod habitat, through trampling or road building. Probably the most critical habitat in this category is caves, within which live some of the more unusual arthropod fauna. Excessive traffic within caves (which could result from directed recreational use) can cause deterioration in numerous ways (see the Washington Department of Wildlife's forthcoming document).

Wildlife can in some cases damage critical habitat: sphagnum bogs can be drowned by beavers. Where bogs are to be preserved, beaver removal should be considered.

Exotic species can have profound effects on arthropod fauna. For example, natural-appearing habitat tracts in the suburbs of Seattle have as many as 30% introduced species in their spider fauna. Natural resource management agencies should consider developing stringent weed control policies; in concert with local governments and interest groups.

The taking of arthropod species for scientific study is general not a factor in the decline of species, simply because the population sizes of even rare, habitat-specific species are usually large enough to support moderate collection. If scientific study can help prevent destruction of a rare habitat, the effect of collecting will be beneficial, despite removal of a few individuals.

Research recommendations

As indicated in the panel information reports, basic knowledge on the ecological function, habitat needs, dispersal capabilities, and response to management activities are lacking in all but a very terrestrial invertebrate predator species. For example, we have relevant information on how management may effect only one species, Camponotus modoc, and this is because a concentrated effort has been made to study this species for several years, within a management context.

Future research should focus on obtaining basic information on the distribution and biology of a few species, selected on the basis of commonness, presumed ecological importance, or sensitivity to particular management activities. These species should be studied within the context of management experiments so as to assess how human activities influence their abundance and distribution.

Effort should also be placed on understanding how management influences the process of predation, through a continuing inquiry on predator-prey relationships. Despite the difficulty in obtaining information on predator-prey links, there is no other way to understand how predation as a process functions than to perform exclusion experiments coupled with predator gut content analysis. Exclusion experiments, guided by the type of information in the HUSSI database, and supported by real-time documentation of what each excluded predator is actually eating, **are** essential for a comprehensive understanding of how predation functions within the context of management activities.

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Table 1. List of observed predator-pray interactions in HUSSI database (prepared by Mel McKnight), with number of prey species observed and presence of pest species in predators' diet.

			PEST SPECIES						
PREDATOR GENUS/SPECIES	**PREDATOR FAMILY**	**#SPP**	**RH**	**OR**	**NE**	**MA**	**IP**	**DE**	**C**
ARANEAE Alicus sp.	ARANEIDAE	1							
HETEROPTERA Anthocorus musculus	ANTHOCORIDAE	1							
Lyctocoris stalii	ANTHOCORIDAE	1						X	
Aradus abbas	ARADIDAE	1						X	
Ligyrocoris latimarginatus	LYGAEIDAE	1							
Ceratocapsus pilosulus	MIRIDAE	1			X				
Deraeocoris barberi	MIRIDAE	1							X
Deraeocoris incertus	MIRIDAE	1							X
Phytocoris sp.	MIRIDAE	1							X
Plagiognathus sp.	MIRIDAE	1							X
Nabis rufusculus	NABIDAE	1							
Apateticus bracteatus	PENTATOMIDAE	1			X				
Chlorochroa ligata	PENTATOMIDAE	1				X			
Podisus maculiventris	PENTATOMIDAE	1			X				
Podisus placidus	PENTATOMIDAE	1			X				
Podisus serieventris	PENTATOMIDAE	4			X				
Apiomerus sp.	REDUVIIDAE	1							
COLEOPTERA Calasoma calidum	CARABIDAE	2							

PREDATOR GENUS/SPECIES	PREDATOR FAMILY	#SPP	RH	OR	NE	MA	IP	DE	CI
Scaphinotus angusticollis	CARABIDAE	1							
Scaphinotus sp.	CARABIDAE	1							
Enoclerus moestus	CLERIDAE	1							
Enoclerus sphegeus	CLERIDAE	2						X	
Hydnocera pubsescens	CLERIDAE	1	X						
Hydnocera sp.	CLERIDAE	1				X			
Phyllobaenus sp.	CLERIDAE	1							
Phyllobaenus subfasciatus	CLERIDAE	1							X
Thanasimus dubius	CLERIDAE	1						X	
Thanasimus undatulus	CLERIDAE	2						X	
Anatis mali	COCCINELLIDAE	1							
Anatis ocellata	COCCINELLIDAE	1							
Anatis rathvoni	COCCINELLIDAE	1				X			
Coccinella transversogutata	COCCINELLIDAE	1							
Hippodamia 5-signata	COCCINELLIDAE	1							
Neomysia sp.	COCCINELLIDAE	1							
Neomysia subvittata	COCCINELLIDAE	1		X					
Lasconotus complex	COLYDIIDAE	1						X	
Lasconotus subcostulatus	COLYDIIDAE	1						X	
Cucujus clavipes	CUCUJIDAE	1						X	
Athous sp.	ELATERIDAE	1	X						
Ctenicera glacus	ELATERIDAE	1			X				

PREDATOR GENUS/SPECIES	PREDATOR FAMILY	#SPP	RH	OR	NE	MA	IP	DE	CH
Dalopius nevadensis	ELATERIDAE	1						X	
Melanotus sp.	ELATERIDAE	1	X						
Paromalus mancus	HISTERIDAE	1							
Platysoma punctigerum	HISTERIDAE	1					X	X	
Plegaderus nitidus	HISTERIDAE	1					X		
Xylita laevigata	MELANDRYIDAE	1						X	
Rhizophagus scalpturatus	RHIZOPHAGIDAE	1						X	
Rhizophagus sp.	RHIZOPHAGIDAE	1						X	
Bryoporus refescens	STAPHYLINIDAE	1						X	
Hesperolinus parcus	STAPHYLINIDAE	1						X	
Nudobius cephalicus	STAPHYLINIDAE	1						X	
Phloeonomus lapponicus	STAPHYLINIDAE	1						X	
Bius estriatus	TENEBRIONIDAE	1						X	
Corticeus sp.	TENEBRIONIDAE	1						X	
DIPTERA *Hylemya* sp.	ANTHOMYIIDAE	2						X	
Scoloposcelis flavicornis	ANTHOMYIIDAE	1					X		
Dioctria sackeni	ASILIDAE	1							
Forcipomyia sp.	CERATOPOGONIDAE	1							
Leucopis sp.	CHAMAEMYIIDAE	1							
Medetera aldrichii	DOLICOPODIDAE	3					X	X	
Medetera sp.	DOLICOPODIDAE	3					X	X	

PREDATOR GENUS/SPECIES	PREDATOR FAMILY	#SPP	RH	OR	NE	MA	IP	DE	C
Lamproscatella quadrisetosa	EPHYDRIDAE	1						X	
Suillia Sp.	HELEOMYZIDAE	1						X	
Lonchaea corticis	LONCHAEIDAE	1						X	
Lonchaea hirticeps	LONCHAEIDAE	1					X		
Lonchaea sp.	LONCHAEIDAE	1					X		
Lonchaea watsoni	LONCHAEIDAE	1						X	
Megaselia sp.	PHORIDAE	1						X	
Mycetaulus nigritellus	PIOPHILIDAE	1						X	
Bradysia sp.	SCIARIDAE	1						X	
Epidapus sp.	SCIARIDAE	1						X	
Beris annulifera	STRATIOMYIIDAE	1	X						
Zabrachia polita	STRATIOMYIIDAE	2					X	X	
Zabrachia sp.	STRATIOMYIIDAE	1					X		
Baccha sp.	SYRPHIDAE	1							
Carposcalis stegna	SYRPHIDAE	1	X						
Chrysotoxum integre	SYRPHIDAE	1	X						
Didea fasciata	SYRPHIDAE	1							
Didea sp.	SYRPHIDAE	1							
Metasyrphus lapponicus	SYRPHIDAE	3				X			
Metasyrphus venablesi	SYRPHIDAE	1							
Syrphus torvus	SYRPHIDAE	1							
Xylophagus adbominalis	XYLOPHAGIDAE	1						X	

PREDATOR GENUS/SPECIES	PREDATOR FAMILY	#SPP	RH	OR	NE	MA	IP	DE	CI
Xylophagus sp.	XYLOPHAGIDAE	1						X	
HYMENOPTERA Camponotus laevigatus	FORMICIDAE	1	X						
Camponotus modoc	FORMICIDAE	2		X					X
Formica densiventris	FORMICIDAE	1	X						
Formica fusca	FORMICIDAE	1	X						
Formica subnuda	FORMICIDAE	1							
Liometopum apiculatum	FORMICIDAE	1	X						
Liometopum luctuosum	FORMICIDAE	1	X						
Monomorium peninsulatum	FORMICIDAE	1	X						
Podalonia occidentalis	SPHECIDAE	1				X			

	RH	OR	NE	MA	IP	DE	(
TOTAL PREDATOR SPECIES ATTACKING EACH PEST SPP:	12	2	6	5	9	33	

TOTAL PREDATOR SPECIES = 93
TOTAL PREDATOR SPECIES ATTACKING PESTS = 71

Pest species codes: RH: Rhyacionia spp., OR: Orgyia pseudotsugata, NE: Neodiprion spp., MA: Malacosoma s
IP: Ips spp., DE: Dendroctonus spp., CH: Choristoneura spp.

CRITICAL ARTHROPOD HABITATS

by Rod Crawford, Burke Museum, University of Washington, Seattle

The following notes list some of the most important habitat types for rare arthropods, which could potentially become threatened species or subspecies if most. occurrences of their habitat were destroyed. 'In general, the potential of an arthropod species to become threatened is directly correlated with how closely that species is tied to a rare, vulnerable habitat. Other factors, such as pollution, may also play a part in declining populations of rare arthropods, but habitat destruction is by far the most important, and the only major factor that needs to be considered by land managers. (Be it noted that collecting of specimens by entomologists plays no part at all in species declines of arthropods.) Since prevention of habitat destruction is so important, it follows that listing rare habitats which support 'numerous rare species, and managing these habitats as such, is a far more, practical procedure. than listing individuai rare species and attempting the impossible task of constructing' separate management plans for thousands of species.

The notes below are not a complete listing of all potentially important arthropod habitat types. They include habitat types for which the following factors apply:

1) those most likely to be found on federal lands in the assessment area;

2) those which I consider most readily identifiable;

3) those which are relatively uncommon and vulnerable to degradation or destruction;

4) those which are known to support at least one habitat-limited (endemic) species, generally several, and which in my judgement would be found to support many such species if a complete study were done.

The species listed include many which could potentially become 'threatened (in a biological sense) in all. or part of the assessment area if the listed habitats were destroyed. Few have been proposed for legal 'Threatened' or 'Endangered" status. In my view it is impossible to. do this 'for all the invertebrates which may deserve it; they outnumber the vertebrates by 20 to 1, and who would do all the management plans? The only solution is to manage by habitat, not by species.

The primary basis for this listing is my information on the habitat associations of spider species, some other arachnids (pseudoscorpions, harvestmen), and centipedes in Washington. , The species listed under each habitat are only examples; there has not been time to attempt a complete listing, even of. what is now known. Only species which have been found in the listed habitats within the assessment area are included; some may not have been found yet on federal land..

There are a number of varying classifications of habitat types available,' largely based on vegetation. Among the most important or relevant are those of Franklin and Dymess (1973), Daubenmire (1968, 1988) and the Washington state Natural Heritage Plan (DNR 1991). A partial list of habitats is also found in the Washington state Priority Habitats document (WDW 1993). Inevitably,' some habitat types which are important. for arthropods do not reliably correspond to. any specific type in any of the above classifications, though they can be easily described and identified. These will be noted as they occur. GIS-type land cover classifications also do, not correspond reliably to critical arthropod habitats, though a few (e.g., oak woodland) can be thus identified.

I have listed, where possible, one or. more high-quality specific site. examples on federal land in the assessment area for each habitat type, as well as which environmental zone(s) [of the Washington possibilities 4, 9, 10, 11, 15] have potential for occurrence of this habitat type, and some notes on the effects of expected. management activities: A number of other specific sites, especially of steppe habitats, are listed by Daubenmire (1975).

Management problems are much the same for a variety of rare habitats, i.e. the same human activities. impact a variety of habitats. Therefore these are discussed in a separate section at the end, and not individually for each habitat.

1. FORESTED HABITATS

A. Montane Old Growth Conifer Forest. Conifer forests in the Cascades and Selkirks at elevations of over 2000' (i.e. in the Douglas-fir, true fir, or mountain hemlock zones), with a substantial number Of conifers (any species) over 200 'years old and/or with large DBH; also with standard old growth characteristics (multilayered canopy, standing dead trees, large amount of dead wood on ground). The key operative factors for specialized invertebrates are: *large trees with very thick bark (providing habitat in bark furrows, epiphytes, and accumulated dead wood); numerous Jogs in all stages of decay; freedom from the soil desiccation associated with removal of tree canopy by clearcutting.* Structural category: Old Forest, Multi Strata. Avery precise definition of old growth is provided by WDW (1993).
Federal examples: I have seen typical examples in Salmo-Priest Wilderness, Colville National Forest; William 0. Douglas Wilderness, Wenatchee National Forest.
Potential in environmental zones: 4, 9, 11, 15.

Species: **Spiders**
Microhexura idahoana
Lepthyphantes rainieri .
Wubana suprema
Scotinotylus **sp. #6 (undescribed)**
Tachygyna exilis
Pseudidius **sp. #1 (undescribed)** .
Sitticus finschii

Pseudoscorpion:
Pseudogarypus hesperus

B. Old growth Ponderosa pine. It is not necessary for an entire ponderosa pine stand to be old growth in character, for it to support characteristic rare species. It may be sufficient for even a few very large, old trees to be present. The key operative factors for rare invertebrates are *'characteristics of the bark of these large trees, including the deep fissures between bark polygons and the spaces between laminar bark scales.* **See Daubenmire (1968).**
Federal examples: Cottonwood Campground, Naches River, Wenatchee National Forest (both species noted below occur at this site). .
Potential in environmental zones: 9, 11, 15.
Species: **Spiders**
Zygiella carpenteri
Marchena minuta

C. Oregon white oak woodland. Good quality examples have been free from livestock grazing and hot wildfires, have at least a few standing dead trees, and an essentially undisturbed litter layer. Small oak clumps in grassland and savanna have essentially the same arthropod faunas as continuous oak woodland, but oaks isolated in conifer forest may not. Oak woodland sites which have been burned or heavily grazed have; in my experience, poor arthropod faunas. The key operative factors for-specialized invertebrates are: *habitat under bark on dead trees and dead portions of living trees; undisturbed oak leaf litter on the ground, at least some of which is relatively deep; living oak leaves for oak feeder insects.* **Considered a Priority Habitat by WDW (1993).**
Federal examples: probably exist, but I have not visited any in Washington. A high-quality example in Oregon is Mill Creek Research Natural Area, Mt. Hood National Forest (Daubenmire 1975: 56).
Potential in environmental zones: 9.
Species: **Spiders**

Antrodiaetus pugnax
Zanomys kaiba
Zanomys aquilonia
Agyneta **sp. #5 (undescribed)**
Tachygyna **sp. #2 (undescribed)**
Zora hespera
Orodrassus assimiiis
Clubiona mimula
Xysticus gosiutus
Ozyp tila conspurca ta

D. Douglas maple (*Acer glabrum* var. *douglasii*) riparian woodland. Found by me only in certain canyons in Chelan County (Washington), riparian woodland containing at least a moderate number of Douglas Maple trees and associated leaf litter seems to support several specialized invertebrates. A complete definition of 'riparian habitat is given by WDW (1993).
Federal examples: None have been identified.
Potential in environmental zones: 4, 9, possibly 15.
Species: Spiders
Orchestina' **sp. #1 (undescribed)**

E. Canyon-bottom willow swamps. Three localities in Kittitas and Yakima counties (Washington) with swampy willow stands in canyon bottoms surrounded by hills with typical shrub-steppe and pine grove vegetation, have yielded very unusual spiders.
Federal examples: None known, but should be searched for.
Potential in environmental zones: border of zones 9 and 10.
Species: Spiders
Enoplognatha wyuta **(other habitats outside area)**
Diplocephalus subrostratus **(other habitats outside area)**
Ceratinella **sp. #3 (undescribed)**
Scotinotylus **sp. #8 (undescribed)**
Disembolus torquatus
Walckenaeria communis **(other habitats outside area)**
Wubana utahana
Ebo iviei **(other habitats outside area)**
Metaphidippus **sp. #2 (undescribed)**
Neon ellamae

F. Forested/shaded talus. This habitat is found where exposed talus consisting of moderate-sized to large stones, with or without shrub vegetation but with few herbaceous plants, is sufficiently

interspersed with medium to large trees that it is in the shade most of the time. Very unusual species occur in this. habitat on the east slope of the Cascades, where the shade allows the under-rock situation to afford greater protection from 'desiccation for its arthropod inhabitants than would normally be the case.. Talus is considered a Priority Habitat by WDW (1993).

Federal examples: adjacent to Taneum Campground, Wenatchee National Forest (Kittitas Co., Wash.); Finley Canyon, 48.331 °N 119.952°W, Okanogan National Forest.

Potential in environmental zones: 4, 9, 11, 15

Species: Spiders

Zelotes josephine (also in ultramafic habitat)
Zelotes exiguoides
Scotinella sp. #2
Porrhomma convexum (not rare, talus assoc.)
Euophrys monadnock

G. Natural riparian woodland in shrub-steppe zone. Woodland of black cottonwood, aspen, and/or willow along free-flowing streams or rivers surrounded by shrub-steppe and not heavily impacted by cattle grazing. The key operative factors for specialized arthropods are: *presence of moist leaf litter, logs, bark, lush herb layer, and water in an otherwise xeric region.*

Federal examples: there must be some, but I have not specifically identified any.

Potential in environmental zones: 10, and others at edge of 10.

Species: Spiders

Dictyna minuta
Dictyna sp. #4 (undescribed)
Eulaira schediana
Tachygyna sp. #2 (undescribed)
Agyneta sp. #3 (undescribed)
Spirembolus demonologicus
Spirembolus selma
Ceratinella tigana
Walckenaeria exigua
Bathyphantes waneta
Agroeca pratensis
Micaria riggsi
Haplodrassus eunis
Sitticus sylvestris
Metaphidippus watonus

Subalpine and alpine habitats within forested zones have distinctive spider faunas, but are under little pressure from management activities, and so are not separately treated here.'

2. SPHAGNUM BOGS

Sphagnum bogs comprise wetlands of otherwise diverse types where the main ground cover on all or part consists of *Sphagnum* spp. and other mosses, such as *Hypnum*. The abundant presence of living sphagnum and, to a lesser extent, sphagnum-associated plants such as Labrador Tea, are the leading characteristics of these bogs for arthropods. I suspect that the moisture-retention qualities of sphagnum (lending safety from desiccation) and the fact that sphagnum bogs tend to be in topographic 'cold pockets" has led to the isolation of numerous relictual species in these sites. Many species are common to many or most sphagnum bogs, while others are found in only a few. Each bog of high quality has some peculiarities to its own fauna: thus, preserving as many bogs as possible would be desirable. There are several distinctive subtypes:

-Floating sphagnum mats, often at the edge or middle of open water
-Very wet bogs, mostly' open water, sphagnum largely at shrub bases
-Bogs (mostly wet) where *Spiraea* replaces the usual bog shrubs
--Grassy-sedgy fenlike or, meadowlike bogs with sphagnum on surface
-Late successional bogs with little or no open water, many young. trees
-Forested bogs with large trees but sphagnum-covered, swampy ground

I have not yet correlated these and other diverse types with individual faunal differences, but such correlations undoubtedly can be made.

Sphagnum bogs are the number one rare arthropod habitat. The many sphagnum endemic species are among the least likely to be found in other habitats; a high proportion of our bogs, formerly numerous, have been destroyed or degraded.

Federal examples: Fish Lake Bog, Chelan Co., Wash., 47.825°N 120.720°W (outside boundaries of Wenatchee National Forest, but sign on site indicates Forest Service management); Lost Creek Bog, 48.681°N 117.518°W, Colville National Forest (Pend Oreille Co., Wash.). Lost Creek Bog is an exceptionally fine example which should be protected. Rigg (1958) gives a detailed description of both these sites. Another site worth protecting is Huff Pond, Colville National Forest, described by Daubenmire (1975: 48-49).

Potential in environmental zones: 4, 15.

Species: **Spiders**

Caiiiopius wabritaskus
Theonoe striduia

Hybauchenidium cymbadentatum
Hybauchenidium gibbosum
Dicymbium elongatum
Oedothorax triioba tus
Scirites pectina tus
Baryphyma trifrons
Sa tiia tlas gen tiiis
C e r a t i c e i u s b u i b o s u s
Ceratinella **sp. #4 (undescribed)**
Sciastes **sp. #3 (undescribed)**
Fioricomus rostratus
Fioricomus **sp. #1 (undescribed)**
Scironis tarsaiis
fboria **sp. #1 (undescribed)**
S c i a s t e s e x t r e m u s
Sciastes **sp. #2 (undescribed)**
Giyphesis scopuiifera
Wabasso cacuminatus
Tunagyna debiiis
Antistea b r u n n e a
Pira ta insuia ris
A r c t o s a raptor
Ozyptiia gertschi
Sitticus stria tus

3. OTHER WETLAND TYPES

A. Low elevation marshy ponds in forest. Small ponds with shaded shorelines which have not been completely clearcut, which have not been disturbed by development, pollution, or excessive boating, and which contain shallow water with emergent vegetation, support a number of unusual spiders and'probably other species. Some sphagnum bogs are included in the definition and. these species may also occur at appropriate bogs. The primary species restricted to exactly the habitat described is the fishing spider *Doiomedes triton. The* **others listed, while rare, may occur in other types of wetlands occasionally.**
Federal examples: none of the high quality examples I have visited around the Columbia Basin are on federal land, but some must exist.
Potential in environmental zones: 4, 15, possibly 9 & 11.
Species: Spiders
Dictyna **sp. #7 (undescribed)**
Microiinyphia impigra

Tetragnatha shoshone
Tetragnatha vermiformis
Tetragnatha dearmata
Doiomedes triton
Xysticus chippewa

B. Fen-type bogs in Okanogan Highlands. A fen is a wetland with significant peat accumulation, which differs from a true bog in. that the main ground cover is grasses, sedges, and. rushes rather than moss. Several fens within forested portions of Okanogan, Ferry, and Stevens counties, Washington, have been investigated and found to support rare spider species. The best known examples are described by Rigg (1958). At some sites, fens grade into. sphagnum bogs. The key operative factors for specialized arthropods are: *densely packed plant bases with perennial moisture availability which has been uninterrupted for long enough to support relictual species populations.* **In this respect fens differ from marshes which usually are much younger and also tend to have too much standing water to support any but true wetland spiders. Federal examples: Bonaparte Lake Campground, Okanogan National Forest (a narrow strip of fen exists south of the campground in Federal ownership, but most of this fen appears to be private land).**
Potential in environmental zones: 15.

Species: **Spiders**
Antrodiaetus cerberus **(fen edge)**
Pachygnatha cierckii
Ceraticeius agathus
Pardosa fuscuia
Pardosa distincta
Agroeca **sp. #1 (undescribed)**
Ozyptiia gertschi
Xysticus chippewa
Metaphidippus fiavipedes
Phidippus borealis

See also: Canyon bottom willow swamp, above in forested habitats. A wetland which appears to be of a unique type is Moxee Bog in Yakima Co., Washington (Nature Conservancy). I know. of no other bogs of this type so it is not treated in detail here, but it contains some unique spider species. Other distinct wetland sites in the Columbia Basin which I am not yet able to characterize as habitat types of multiple occurrence, include a closed depression with small, temporary wetland at Boylston, Kittitas Co., Washington (supports a population of the spider

Antrodiaetus hageni); and a patchwork habitat of mud flats, grass, and willow on the Yakima River at Schaake Road, 'also in Kittitas Co., where a unique, undescribed species of the wolf spider genus *Pardosa* was found.

4; GRASSLAND

A. Mountain meadows (as defined by Franklin and Dyrness 1973), situated within mesic forests at moderate to high elevations in the Cascades, are an important habitat but undisturbed examples are very rare. Mountain meadow is included in Priority Habitat grassland by WDW (1985).
Federal examples: Deadhorse Meadow, 46.023°N 121.661°W, in Mt. Adams Ranger District of Gifford Pinchot National Forest, is an excellent undisturbed example if it has not been clearcut since I visited it in 1985.
Potential in environmental zones: 4, 9 (presence in 11, 15 unconfirmed).
Species: Spiders
Araneus gemma
Dictyna brevitarsus
Pityohyphantes sp. #3 (undescribed)
Nodocion voiuntarius

B.. Parks in Ponderosa pine forest. This habitat is described by Daubenmire (1968: 50; 1988: 73-74). Only examples at relatively low elevations are included as considered here; relatively flat grassy meadows or 'prairies" completely surrounded by forest within the Ponderosa pine zone on the east slope of the Cascades (in some cases, Ponderosa pine is not the main tree species present). The key operative factors for specialized invertebrates are: *grassland vegetation; lack of shade; logs for shelter; geographic location and climate.* Parks would be included in Priority Habitat grasslands by ,WDW (1993).
Federal examples: Peterson Prairie, 45.972°N 121.662°W, and South Peterson Prairies, 45.964°N 121.654°W, both near Peterson Campground in Gifford Pinchot National Forest. .
Potential in environmental zones: 4, 9, 11, 15.
Species: Spiders
Habronattus kubai
Habronattus jucundus

C. Grassland-oak savanna. Savanna conditions, as defined by Franklin and Dyrness (1973), exist when trees are well separated so as

to permit, grassland vegetation between them. Oak woodland often, grades into savanna, both in the Puget Trough area and on the east slope of the Cascades. In these circumstances there may be a mix of the grassland arthropods with those found in denser oak stands. Oak savanna is listed as a Priority Habitat by WDW (1993).
Federal examples: Probably exist, but I have not visited any.
Potential in environmental zones: 9.
Species: In eastern WA, combination of oak woodland species, some meadow steppe species, and some additional

Spiders (such as:)

Frontineiia ***communis*** **(also found Selkirk Mtns.)**
Theridion sp. #1 (undescnbed)
Tmarus anguiatus (also found Blue Mtns.)

D. Undisturbed meadow steppe (edge of Cascades). Between the lowest Ponderosa pine on the east slope of the Cascades and the sagebrush-dominated shrub-steppe is a discontinuous band of grassland termed 'meadow steppe" by Franklin' and Dymess (1973). Several types are described by Daubenmire (1988), but I am not yet able to differentiate the faunas of the different types. In one major type found in the northern part of the area, the shrub *Purshia tridentata* also occurs, but the habitat is still called meadow steppe rather than shrub-steppe. Some of the subtypes are relatively widespread, but most examples I have seen are seriously degraded by overgrazing and/or ORV use. The key operative factors for specialized invertebrates are: *Diverse, relatively dense grassland vegetation; soil generally not rocky; ciima te somewhat moister than Artemisia shrub-steppe.* Meadow steppe would be included in Priority Habitat grassland by WDW (1993).
Federal examples: probably exist, but I have not visited. any.
Potential, in environmental zones:4, 9.
Species: Spiders

Maiios ***niveus***
Dipoena sp. #1 (undescribed)
Caiiiiepis eremeiia
Peiienes shoshoneus
Habronattus sansoni
Habronattus sp. #3
Synageies ***occiden*** *taiis*

E. Undisturbed meadow steppe (Palouse Hills). The spider fauna of. this complex of habitat types, found in southeastern Washington to the north of the Blue Mountains, is essentially unknown. When it is sampled, unusual spider species are to be expected. As with other steppe types, undisturbed examples are rare; most have been overgrazed or converted to farmland. Full descriptions of Palouse meadow steppe types were given by Daubenmire (1988); some specific undisturbed sites were cited by Daubenmire (1975).

Federal examples: no high-quality, examples on federal land are known to me in Washington, but some might exist; they might be looked for at the edge of Umatilla National Forest, on sites that have been isolated from grazing for some reason.

Potential in environmental zones: 10, 11.

Species: Spiders

Tmarus anguia tus

F. Undisturbed shrub-steppe at pine forest edge. There is not always a zone of meadow steppe between the pine forest edge and Artemisia shrub-steppe. Typical shrub-steppe is better represented within the Columbia Basin proper. But there are a few species found only where this habitat is in relatively protected situations next to the pine forests. As with meadow steppe in this area, overgrazing has taken its toll and undisturbed examples. are hard to find. The key operative factors for specialized invertebrates are: *Shrub-steppe habitat. relatively protected from climatic extremes by location among pine groves or in pine-forested canyons.* Shrub-steppe is considered a Priority Habitat by WDW (1993).

Federal examples: I have not visited any specific Federal examples, but some undoubtedly exist along the edges of Wenatchee National Forest.

Potential in environmental zones: edge of 10 with other zones.

Species: Spiders

Chrysso peiyx

Chrysso nordica

Dictyna piratica

G. . Undisturbed shrub-steppe in Columbia Basin.. Grassland with *Artemisia* shrubs, found in and around the edges of the Columbia Basin. Various types exist, classified by Daubenmire (1988). As with meadow steppe in this area, overgrazing has 'taken its toll and, though a common enough habitat type, undisturbed examples are hard to find. The overgrazed tracts where native grasses have been replaced by *Bromus* and oth'er annuals, are 'unsuitable for rare long-grass spiders such as *Tibeiius chamberiini,* The key operative factors for specialized invertebrates are: *Relatively xeric steppe land with Artemisia spp., largely native grasses, and little grazing damage. Arthropod' diversity is also aided by presence of north-facing cliffs, talus, or adjacent* *riparian habitats.* **Shrub-steppe is considered a Priority Habitat by WDW (1993). Daubenmire (1975) discussed at length the rarity of completely natural, shrub-steppe, and described. a number of specific sites that existed at that: time.**

Federal examples:, Arid Land Ecology Reserve, AEC Hanford Reservation, Washington.' . .

Potential in environmental zones: 10.

Species: **Spiders**

Piectreurys tris tis
Uioborus ***diversus*** *.*
Dictyna shoshonea
Dictyna artemisia
. Dictyna piratica
Trichoiathys **sp. #2 (undescribed)**
Acuiepeira, **undescribed species**
Steatoda washona
Steatoda. fuiva'
Enopiognatha joshua
Disemboius **sp. #5 (undescribed)**
Satiiatias **sp. #2 (undescribed)**
Mimetus hesperus
Schizocosa **sp. #2 (undescribed)**
Caiiiena umatiiia
Zeiotes *hentzi*
Zeiotes tuobus
Tibeilus chamberiini
Misumenops ceier ceier
Habronattus ***amicus***
Peiienes **sp. #1 (undescribed)**

H. Sand dune- steppe, with or without juniper. The only undisturbed example I have visited is in the Juniper Dunes Wilderness.. The unusual spiders found at this site appeared to be associated more with- the grassy, open habitats than with the juniper savanna (the latter, however, harbors an endemic butterfly species and could contain rare spiders not yet found by me). The key operative factors for specialized invertebrate predators are: ***Xeric*** *climate, unstable sand substrate, grassy and sparse* ***herbaceous*** *vegetation. Shade provided by junipers could also be a factor for some species.*

Federal examples: Juniper Dunes Wilderness (BLM), Franklin Co., Wash (Daubenmire 1975: 49-50); Hanford Dunes (AEC), Benton Co., Wash. (Daubenmire 1975: 46).

Potential in environmental zones: 10.

Species: **Spiders**
Schizocosa **sp. #2 (undescribed)**
Ebo parabolis
Tibellus chamberiini
Habronattus amicus

5. OTHER UNFORESTED HABITATS

A. Alkaline lake shores. This habitat appears to be comparatively independent of the surrounding vegetation. The only example I have investigated thoroughly is Soap Lake, Grant Co., Washington. The key operative factors for specialized invertebrates are: *proximity of water whose alkalinity is relatively high, with water and alkalinity levels not undergoing major fluctuation; availability of stones, sand, and other natural cover.*
Federal examples: I have not visited any in Washington, but some may exist.
Potential in environmental zones: 10; also 12 in Oregon.
Species: Spiders (Washington):
Argenna obesa
Arctosa littoralis
Castianeira walsinghami
Ebo evansae
Sitticus dorsatus **(also** *some* **freshwater shorelines)**
others in Oregon

B. Caves. A cave is defined as 'a natural subterranean cavity, penetrable to man, with some portion in essentially total darkness.' Short "caves" (actually rockshelters or natural bridges) with no total darkness have none of the specialized fauna of true caves and should not be considered 'as such. I differ in this respect from the Priority Habitat definition offered by the WDW (1993). The key operative factors for specialized invertebrates are: *total darkness; constant high humidity; relatively constant temperature; few predators; food-poor environment; import ecosystem with food webs based on organic matter from outside.* **These conditions are remarkably easy to upset by human interference. Correct management of caves is a large and complex subject, fully addressed in the cave management document forthcoming from the Washington Dept. of Wildlife, so I will not go into it more fully here. In addition to invertebrates, caves are essential to the state and federal candidate species Townsend's Big-eared Bat; at least one cave contains critical habitat for Van Dyke and Larch Mountain salamanders.**

Federal examples: Most of the following listed species are found in caves on the Mt. Adams Ranger District of Gifford Pinchot National Forest, such as Deadhorse Cave, the Fallen Arches Cave System, and others. Numerous significant caves exist in that area, and a few in the Colville National Forest of Washington. Many important caves are on BLM land in the Snake River Plain of Idaho and various areas in eastern Oregon.

Potential in environmental zones: all (few' caves are in zone 10 except around its edges).

Species: (the following are known ONLY from caves)

Spiders

Anacornia microps

Harvestmen

Speleonychia sengeri

Speleomaster lexi

Cyptobunus, several species

Pseudoscorpions

Microcreagris columbiana

Predatory Mites

Elliotta howarthi

other *Elliotta* spp. and other mites, undescribed

Insects: campodeids

Haplocampa spp., 2, undescribed

Insects: grylloblattids

several undescribed *Grylloblatta* spp.

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TERRESTRIAL PREDACEOUS BEETLES (COLEOPTERA) OF THE COLUMBIA RIVER BASIN

James R. LaBonte

Introduction and Methodology

This report considers the terrestrial predaceous beetles (Coleoptera) known to occur in the Columbia River Basin (CRB) as defined by the funding agencies. I interpreted "terrestrial" to include any species not dependent upon partial or complete submersion in water for life cycle completion or prey capture. Families or taxa of predominantly non-predatory families were determined to be predaceous based upon the following references: Arnett (1968), Balduf (1935), Crowson (1981), Hatch (1953-1971) and Stehr (1991). Additional information regarding predaceous larvae of Elateridae was provided by Paul Johnson, Associate Professor, Department of Plant Science, South Dakota State University, Brookings, South Dakota.

Determination of whether a species is present in the CRB region was primarily derived from Melville H. Hatch's fine and invaluable books, "The Beetles of the Pacific Northwest" (1953, 1957, 1961, 1965, 1971), which fortuitously covered the vast bulk of the CRB region. Species he recorded as being present in Idaho, eastern Oregon or Washington, on both sides of the Cascade Crest. in Oregon or Washington, or in western Montana were considered as present in the CRB. Species he recorded only- from western Oregon or Washington and those he regarded as questionable records were not counted, unless I knew of other documentation or records substantiating their presence in the CRB. Additional distributional information for Carabidae was acquired from Bousquet (1993), from which I included only species recorded from Idaho unless I knew from other sources that a' species was definitely present in the CRB.

This was a very conservative approach and additional species could certainly be recorded for the area if exhaustive literature searches or examinations of museum collections could be mounted. Such a project would certainly yield much valuable information, but would require much more time than available for this phase of the CRB project. Systematic surveys would certainly add yet more species to the list as much of the CRB has received inadequate attention from entomologists. I would not be surprised if a minimum of several hundred additional species could be added. This would certainly include species new to science.

General information about CRB predatory beetle habitats or prey was primarily based upon Arnett (1968), Balduf (1935), Crowson (1981), Fumiss and Carolin (1977) and Stehr (199 1). Data on Carabidae was provided by' Lindroth (1961-1969) and Thiele (1977), as well as my personal knowledge. Information on Coccinellidae was extracted from Hodek (1973). Specific information on the biology of special concern species and exemplar species was predominantly derived from the literature cited in the detailed reports for each species (these citations are also included in the general literature citations). Special concern species. were derived from. the list provided to me.

This functional group has great species diversity (see below and Appendix). Combined with our general paucity of knowledge regarding all but a few species, it is effectively impossible to treat each species individually while 'still presenting a 'coherent picture of the significance of CRB terrestrial predaceous beetles. Consequently, I have provided detailed reports only for those species listed as being of special concern and "exemplar" -species of functional/habitat subgroups. The exemplar approach allows more detailed examination of key environmental factors, avoiding the broad generalizations necessary to embrace all species in a particular subgroup. Such generalizations will be addressed in the text of this report.

Many of the species discussed are carabid beetles and rove beetles. This is primarily a function of the disproportionate contributions of these two families to the species diversity (together they include over 55% of the total species of CRB terrestrial predatory beetles), the breadth of predatory behaviors and functions they 'exhibit, their ubiquity throughout the region and enormous variety of habitats in which they are found, and their often great abundance in those habitats. I am also most familiar with carabids, since they are my' speciality.

Diversity of Terrestrial Predaceous Beetles of the Columbia River Basin

Based upon the above methodology, slightly more than 1,300 species of terrestrial predaceous beetles from 28 families are known from this geographic area (Appendix 1). It should be noted that even the conventionally "purely predatory" families include at least a few non-predatory species, or those which are only facultatively predaceous. A familiar example is the Mexican bean beetle, *Epilachna varivestis* Mulsant, an important agricultural pest. It is a member of the Coccinellidae, famed predators of aphids and scales. The, converse is also true - many traditionally non-predaceous families often contain predators. For instance, the Derodontidae are believed to primarily subsist upon wood-decaying fungi, yet species of the genus *Laricobius* Rosen. are predators of wooly aphids (Fumiss. & Carolin 1977,' Hatch 1961, Stehr 1991). Furthermore, some predaceous families such as the rove beetles have received so little attention from ecologists that the trophic roles of many members are as yet unknown.

These caveats aside, the taxonomic diversity above is reflected.. in an enormous range of behaviors, ecological interactions, and habitats. Prey selection runs the gamut from monophagy to that of generalists attacking and eating any invertebrate (or life stage thereof) which can be overpowered. Habitat requirements include those of highly stenotopic species existing only within narrow environmental windows as well as those of eurytopic species found in a wide variety of habitats. Distributions range from species known only from single mountains to those found throughout the region.As will be discussed below, this variability poses complex problems for land and resource managers.

This taxonomic and ecological diversity can be overwhelming. Consequently, I suggest readers of this report first examine the panel species reports I've prepared on special-concern species and exemplars of ecological subgroups (see Table 1). This information will provide a base to which my broader discussions of 'habitat and trophic categories (below) can more readily appiy . An analysis of the implications of the biological diversity of CRB terrestrial predatory beetles for management strategies will follow the habitat/trophic category discussion.

TABLE 2

Special Concern and Exemplar Species for Which Panel Reports Have Been Prepared:

Special Concern Species	Family
Cicindela arenicola Rumpp	Cicindelidae
Cicindela coiumbica Hatch	Cicindelidae
****Glacicavicola bathyscoides*** Westcott	Leiodidae
Nebria gebleri fragariae Kavanaugh	Carabidae
Nebria gyllenhali lassensis Kavanaugh	Carabidae
Nebria paradisi Darlington	Carabidae
Nebria vandykei wyeast Kavanaugh	Carabidae

*Although initially believed to be a predator, literature review reveals this species to probably feed upon bacterial slimes and/or dead invertebrates.

Exemplar Species	Family
Cicindela willistoni echo Casey Exemplar of "alkaline lake margin predators".	Cicindelidae
Enoclerus sphegeus Fabricius Exemplar of "subcortical predators".	Cleridae
Epicauta normalis Werner Exemplar of "rangeland predators".	Meloidae
Hyperaspis lateralis Mulsant Exemplar of "arboreal predators".	Coccinellidae
Pterostichus protractus LeConte Exemplar of "forest floor predators".	Carabidae

Functional and Habitat Subgroups of Terrestrial Predaceous Beetles of the Columbia River Basin

The following groupings are not definitive, exhaustive or exclusive, but are merely one means of conveniently categorizing very diverse organisms. Other grouping methods are feasible and may be equally justifiable (see. Oligophagous Predatory Beetles). It is equally true that any of these groups can be further subdivided, which will be briefly alluded to within the discussion of each subgroup. Since any individual species has unique ecological roles and interactions, this process can conceivably be extended ad infinitum. Furthermore, a given species may be a valid member of more than one of these subgroups, depending upon the emphasis placed upon particular aspects of behavior, functional role or habitat. This is a pitfall inherent in the categorization process.

I perceived the focus of this project to be upon habitat and landscape issues, hence I have designed my categories to reflect this organizational theme.

Alpine Nival Predatory Beetles

These beetles forage on alpine ice and snow fields, as well as in talus fields and alpine riparian areas which are hydric and thermal refugia during the summer. Their prey primarily consists of wind-deposited insects originating from lower altitudes ("aeolian fallout", Edwards 1987), as well as any small indigenous invertebrates present on the snow or habitats in which they are present. My observations of alpine nival carabids in the Wallowa Mountains of northeastern Oregon suggest at feast some niche partitioning may occur, with some species "gleaning" the moribund aeolian "drift" while others prey upon some "gleaners".. Chronological partitioning is also apparent, with a contingent of diurnal species and a complementary crepuscular/nocturnal species group. Some of these beetles (*e.g. Nebria vandykei wyeast*) are probably the top invertebrate predators in their alpine nival foodwebs.

In addition to their predatory (and hence nutrient cycling) roles, CRB alpine nival predatory beetles (including non-adult stages) are prey for invertebrate or vertebrate insectivores which are either permanent alpine residents or transients, such as some birds and mammals.

Alpine nival predatory beetles, particularly the nocturnal species, are highly adapted to their habitat. Most are flightless and require high humidity, and cold temperatures. These physiological constraints necessitate the utilization of talus slopes and alpine riparian areas as hydric and thermic refuges during the seasonal retreat of ice and snow. fields. Such physiological limits restrict, these species to altitudinal islands. Consequently, these beetles have fragmented and often very restricted distributions, as lowland conditions have often been inimical during interglacial periods (as is now the case) and flight is, impossible. Endemism is particularly, rife among the isolated Great Basin mountain ranges, with two species known only from Steens Mountain in southeastern Oregon and several more known only from the Wallowa Mountains. Since alpine nival habitats are rarely used for agricultural purposes and are often very distant from urban centers, the majority of alpine nival habitats are contained within federal public lands.

Human impact upon alpine nival predatory beetles has probably been very limited to this point. Construction and maintenance of high altitude recreation areas (e.g. ski lodges) aimost certainly drastically reduces populations in the immediate vicinity of such activities, but these effects are probably very localized. Pesticide applications at the margins of alpine zones (or throughout grasshopper-susceptible alpine areas used for cattle or sheep range, i.e. Steens Mountain) are certainly of concern. A. greater potential threat is pesticide or pollutant contamination of the “aeolian fallout”. Most of this material originates from valleys and basins distant from the alpine “target” areas (Papp 1978) and is thus potentiaily exposed to pesticides and pollutants, rearing the specters of bioaccumulation and biomagnification as well as direct poisoning. Probably the greatest threat. is regional or global climatic warming, which could eliminate all or most current alpine nival predatory beetle habitats.

CRB alpine nival predatory beetles are comprised almost exclusively of Carabidae and Staphylinidae. CRB alpine nival Carabidae are most often represented by species of the genera ***Bembidion*** Latreille and ***Nebria*** Latreille, including ***B. farrarae*** Hatch, ***B. incertum*** Motschulsky, ***N: jeffreyi*** Kavanaugh, ***N: labontei*** Kavanaugh, ***N: steensensis*** Kavanaugh, and ***N: wallowae*** Kavanaugh. CRB alpine nival Staphylinidae often include species of ***Phlaeopterus*** Motschulsky, ***e.g. P. loganensis*** Hatch and ***P. longipalpus*** Casey.

No exemplar species was chosen to represent alpine nival predators because several of the special concern species belong to this category, e.g. *Nebria paradisi* and *N. vandykei wyeast.*

Edwards (1987) and Mann et al. (1980) give very useful accounts of the adaptations, behaviors and habitats of alpine nival insects.

Arboreal Predator-v Beetles

Arboreal predatory beetles are those which live and. predate in vegetation such as grasses, forbs, shrubs and trees. Some of the most familiar terrestrial predatory beetles are found within this category, e.g. Coccinellidae. Other families represented include Cantharidae, Carabidae, Derodontidae (species of *Laricobius*) and Melyridae. Larvae may be found on the vegetation (e.g. Coccinellidae) or elsewhere (e.g. sandy soils in Melyridae). The breadth of prey varies greatly, with many coccinellids exhibiting relatively great prey specificity, while some carabids and melyrids may take a' broad range of prey. Homoptera (e.g. Aphidae and Coccidae) appear to be particularly favored. Specialist arboreal predators (e.g. coccinellids) may have profound impacts. upon prey abundance, as may those generalists with locally high population densities. Such effects upon their prey may well substantially affect the survival and reproduction of the plants upon which the prey feed.

The influence of arboreal predatory beetles on food webs and nutrient cycles outside those of their immediate arboreal environment may be quite substantial. Most adults fly to the plants where predation occurs, often passing through other habitats enroute and providing food to invertebrate and vertebrate insectivores and detritivores in those habitats. An extreme example is provided by the well known seasonal elevational migrations of certain coccinellids from the lowlands to alpine winter refugia (Hodek 1973). Of course, arboreal predatory beetles also contribute to the food webs and nutrient cycles in plant canopies.

It appears that the primary factors controlling the distribution and abundance of arboreal predatory beetles are the presence of prey, particularly with oligophagous predators such as most coccinellids (Hodek 1973). Given that each individual plant represents a moderately isolated biological "island", especially to the generally less vagile predator larvae, this seems quite reasonable. However, given, the paucity of information on non-coccinellid arboreal predatory beetles, this may be too broad a generalization.

Perhaps as a consequence of biotic factors primarily controlling their distribution and their relatively great dispersal capabilities, most CRB arboreal predatory- beetles appear to have rather broad and extensive distributions throughout much or essentially all of the region. This is especially true of Coccinellidae. Consequently, the ranges of CRB arboreal predatory beetles generally encompass a patchwork of private, state and federal lands.

Human impacts upon CRB arboreal predatory beetles have probably been quite dynamic on localized scales, depending upon the effects of these activities upon the host plants of their prey. Destruction and disruption of extensive areas of indigenous rangeland plant communities has probably had detrimental effects upon those beetles dependent upon herbivores of those plants. The introduction of vast areas of crop plants with their attendant pests may have countered, at least to some extent, these effects, depending upon the prey specificity of the predators. Intentionally introduced biocontrol agents, especially coccinellids, may compete or interfere with indigenous CRB predators. Certainly pesticide applications on crops and their margins, as well as those applied more extensively to range- and timber-lands, will reduce predator populations, at least in the short-term. Land management strategies causing changes in species and age structure in plant communities will also affect predator populations to varying degrees. However, given the distributions and presumably good dispersal capabilities of most CRB arboreal predatory beetles, re-establishment of populations should be possible if sites are within dispersal range and conditions return to acceptable parameters.

The familial composition of CRB arboreal predatory beetles was mentioned above. Some representatives include: ***Cantharis alticola*** LeConte and ***Podabrus pruinosus diversipes*** 'Fall (Cantharidae); ***Calleida viridis horni*** Chaudoir and ***Lebia vittata*** Fabricius (Carabidae); ***Coccinella 9-notata degener*** Casey and ***Hippodamia convergens*** Guer. (Coccinellidae); ***Laricobius laticollis*** Fall (Derondontidae); ***Anthocomus horni*** Fall and ***Collops hirtellus*** LeConte (Melyridae). ***Hyperaspis lateralis*** (Coccinellidae) was chosen as an exemplar species because of its distribution throughout the CRB region and its rangeland shrub habitat.

Balduf (1935) gives a good, if somewhat dated, treatment 'of all families of CRB arboreal predatory beetles, while Hodek (1973) provides an excellent account of the biology of the Coccinellidae.

Forest Floor Predator-v Beetles

This highly diverse category of predaceous beetles represents those preying upon the invertebrate fauna of the forest floor, including -the litter. and upper layers of the soil, as well as that found within downed logs and at the bases of snags. Thus, this group intergrades to some extent with the categories of "pure" endogean, litter, and subcortical predaceous beetles. Although many of these beetles are regarded as archetypal generalist predators, their ranks include many oligophagous species (see Oligophagous Predatory Beetles below). Further niche partitioning occurs via distinct diurnal versus crepuscular/noctumal activity patterns (as with Carabidae in Thiele 1977), although many of the crepuscular/noctumal species are active on heavily overcast days (personal observation).

Predatory beetles can be amongst the most abundant temperate zone forest floor invertebrates of modest-to-large size (personal observations) and are thus certainly important in forest nutrient cycling and trophic webs. Their impact upon prey populations must also be substantial. Several of these supposed predators may be more properly classified as omnivores, as laboratory evidence suggests their congeners may readily feed upon conifer seeds (Johnson, Lawrence & Ellis 1966). Forest floor carabids are known to be important food sources for other invertebrate and vertebrate forest predators, including many birds and mammals (Thiele 1977). This is presumably true to varying degrees of the other families of forest floor predaceous beetles. Furthermore, their ecological effects go beyond the forest floor habitat *per se* by the extension of their activities into ecotonal or non-forested areas, as well as the other habitats mentioned above.

Many forest floor predaceous. beetles show adaptations to the forest habitat such as dark colors, activity 'in cool temperatures and preference for humid environments. A substantial number (primarily carabids) have also lost the capacity for flight. Most species do not appear confined to forests or stands consisting of specific tree species, suggesting that conditions resulting from forest structure may be more critical to their distribution and abundance (Niemela, Langor & Spence 1993). These factors include available cover, humidity, light, soil moisture, temperature regimes, etc. This generalization may not be as applicable to oligophagous species.

The distribution patterns of forest floor predaceous beetles. are highly variable and not always a reflection of a given species' dispersal capabilities. Some flightless species like ***Pterostichus protractus*** and ***Scaphinotus marginatus*** Fischer (Carabidae) may have very broad ranges extending throughout much or all of the CRB region's forests, whereas others have very modest ranges, i.e. ***Scaphinotus manni*** **Wickham,** which is restricted to southeastern Washington. Most full-winged species for which there is good distribution data appear to have generally broad ranges, ***e.g. Notiophilus directus*** Casey. (Carabidae) with records throughout the .CRB region. Owing to this group's association with forested habitats,. the ranges of the member species encompass private, state, and federal lands, especially national forests.

Human impacts upon CRB forest floor predatory beetles have almost certainly been substantial. Not surprising, logging and other forest management practices are the major perturbations affecting this habitat group. The effects of these activities are highly species-specific, depending upon the ranges, and habitat requirements of the affected species. The net effects upon eurytopic and broadly distributed species, i.e. ***Pterostichus protractus,*** may be relatively benign. The impact upon stenotopic species and those with 'smaller or more fragmentary ranges may be much greater (Niemela, Larson and Spence 1993). Without entering into a lengthy discussion of this issue, suffice it to say that logging (including eradication of forest stands), changes in the availability of downed woody debris, changes in forest stand age and structure, forest fragmentation, roads and road-building, and pesticide applications almost certainly have profound effects on all forest floor predatory beetles. The exact nature and consequences of these effects are just beginning to be examined.

CRB forest floor predaceous beetle families include Carabidae, Lampyridae, Pselaphidae, Scydmaenidae, Silphidae and Staphylinidae, with the bulk of the. species diversity associated with carabids and staphylinids, Carabid examples have been provided above. Some representatives of the other families are: ***Ellychnia facula*** LeConte and ***Pyropyga fenestralis*** Melsh. (Lampyridae); ***Pselaptrichus curiosus*** Park (Pselaphidae); ***Connophron oregonense*** Casey (Scydmaenidae); ***Pteroloma tenuicorne*** LeConte (Silphidae); ***Ocypus tarsalis*** Mannerheim and ***Quedius lanei*** Hatch (Staphylinidae). ***Pterostichus protractus*** (Carabidae) was chosen as an exemplar species because of its distribution throughout the forested areas of the CRB region.

I am unaware of any comprehensive treatment of this habitat group. A substantial amount of ecological and physiological information is available on forest floor carabids, particularly those with holarctic distributions and European congeners. 'Relatively little data, other than taxonomic, is available for the other families.

<u>Lacustrine/Palustrine/Riparian Predatorv Beetles</u>

These beetles are 'often enormously abundant within this broadly defined. habitat category of the terrestrial/aquatic ecotone and also represent a significant proportion of the overall CRB terrestrial predaceous beetle species diversity. However, this group has received remarkably little attention from ecologists, as exemplified by its aimost total absence or cursory treatment' in considerations of wetland restoration. Presumably these beetles are generalist predators of any invertebrates (or stages thereof) which they. can capture. Among a few notable exceptions are species of the staphylinid genus ***Stenus,*** which have been reported to specialize upon springtails (Crowson 1981, Klausnitzer 1981). Diurnal and crepuscular/noctumal activity dichotomies are one. means of partitioning these often largely homogeneous (by human standards) habitats (Thiele 1977). The implicit paradigm is that most resource partitioning occurs via microhabitat selection and phenological differences (Andersen, 1969, Landry 1994). Substrate composition, size of water body and water flow rate appear to be key defining characteristics of microhabitat suitability (Andersen 1969).

The sheer numbers of these predatory beetles suggest they are important components in the terrestrial/aquatic ecotonal nutrient cycles and trophic webs, both as predators and prey. This ecotonal habitat enables these species to contribute to. aquatic and the non-ecotonal terrestrial ecological processes as well as 'those within their. habitat. For instance, these. beetles must fall into the water **relatively** frequently, -providing food for fish and aquatic amphibians., **Terrestrial** forest reptiles, birds. and mammals active on river banks can take advantage of this potentially:. rich insect resource.

Most predaceous beetles of this **category are** fully-winged and presumably have relatively great dispersal capabilities. Many readily fly when disturbed by potential predators..,, Consequently, except 'for the inherent discontinuities of water sources, the vast majority of these species have very broad ranges, often **seemingly** ubiquitous 'wherever suitable conditions exist. A good example: is ***Cicindela oregona*** **LeConte** (Cicindelidae),. which is present almost anywhere that water and lightly vegetated or -barren land meet. Exceptions to this general rule are those predaceous beetles **adapted** to **very** specific terrestrial/aquatic ecotonal habitats, such as -those associated with hot springs,' seeps and waterfalls. These species tend" to have quite rest&ted **and** often fragmented distributions. The dependence of this group of beetles upon open water leads to a very large proportion of their habitat under federal control, although smaller proportions are within private and state ownership.

The effect of human activities upon this group is highly variable, depending upon the extent, frequency, nature, permanence and timing of the perturbance. Erosional siltation, resulting from **upslope** logging or urban development, dams **and** flood control, drainage projects, irrigation, water pollution, pesticide applications for mosquito abatement and, trampling of. terrestrial/aquatic ecotonal habitat by humans and livestock all have different impacts. Different subgroups of this category (see below) will **vary in** their responses to these events. Widespread species existing in a **variety** of terrestrial/aquatic ecoton'es may experience little more than point population losses or declines. 'Widespread and **eurytopic** species are also the most likely beneficiaries of impoundment and wetland restoration projects. Predictably, more drastic actions such **as** damming and drainage which dramatically change or completely eradicate wetlands have the most, profound effects upon terrestrial/aquatic ecotonal predaceous . beetles..

Predaceous beetle families with terrestrial/aquatic ecotonal species include Carabidae, Cicindelidae, Histeridae and Staphylinidae. Table 2 lists more-or-less distinct faunas associated with the categories of terrestrial/ecotonal habitats. Several' examples of associated species are provided for each habitat. '*Cicindela willistoni* echo was selected as an exemplar species because of its prevalence in a habitat typical of the CRB, alkaline lake margins. It is worth noting that the primary habitats of two special concern species, *Cicindela columbica* and *Nebria gebleri fragariae*, are riparian. Alpine riparian habitat also serves as a seasonal hydric and thermic refuge for two other special concern species, *Nebria paradisi* and *N. vandykei wyeast.*

I am unaware of any comprehensive treatment of this habitat group. A substantial amount of ecological and physiological information is available on terrestrial/aquatic ecotonal carabids, particularly those with holarctic distributions and European congeners. Relatively little data, other than taxonomic, is available for the other families.

Rangeland . Predatorv Beetles

This category includes those predaceous beetles present in rangeland (grass and/or shrub communities) not directly associated with aquatic features or vegetation. While many rangeland predatory beetles are believed to be generalists accepting any invertebrate prey (or life stage thereof) they can capture, several families (e.g. Meloidae and Rhipiphoridae) are specialized to -varying degrees upon insects which are particularly abundant in the rangeland habitat, such as grasshoppers and solitary bees. As with other categories of predaceous beetles, rangeland predators also' partition resources with diurnal and crepuscular/nocturnal activity patterns as well as phenological differences.

In. addition to their ecological role as predators, rangeland predaceous beetles function as prey for other invertebrate and vertebrate predators and parasites within and passing through rangeland, as well as providing nutrients for detritivores.

Rangeland predaceous beetles have considerable variability in dispersal capacities. Many species are fully winged and are presumably capable of dispersing over considerable differences (e.g. many meloids), while a number of species are incapable of flight, such as many carabids and some meloids. As a rule, most rangeland predaceous beetles have

TABLE 3

Lacustrine/Palustrine/Riparian Habitats and Associated Species of Terrestrial Predaceous Beetles

Habitat	Species	Family
Lacustrine:		
Alkaline lakes	***Cicindela willistoni echo***	Cicindelidae-
	Pogonistes planatus Horn	Carabidae
Fresh water lakes and ponds	***Bembidion bifossulatum*** LeC.	Carabidae
	Cicindela oregona	Cicindelidae
Palustrine:		
Bogs & Marshes	***Elaphrus clairvillei*** Kirby	Carabidae
	Stenus dissentiens Casey	Staphylinidae
Hot Springs	***Cicindela amargosae' nyensis*** Rumpp	Cicindelidae"
	Polyderis rufotestacea Hayw.	Carabidae
Seeps	***Pterostichus spathifer*** Bousquet	Carabidae
Riparian:		
Lowland	***Cicindela repanda repanda*** Dej.	Cicindelidae
	Hypocaccus estriatus LeConte	Histeridae
Montane	***Bembidion gebleri turbatum*** Casey	Carabidae
	Phlaeopterus frosti Hatch	Staphylinidae
Alpine	***Bembidion complanulum*** Mann.	Carabidae
	Nebria meanyi Van Dyke	Carabidae
Waterfalls	***Pterostichus johnsoni*** Ulke	Carabidae

rather extensive ranges throughout the CRB region. This phenomenon may in part be a function of the geographic contiguity of most rangelands. Some species with either limited dispersal capabilities or specialized habitats have more restricted or fragmented distributions. Plant community structure, especially the degree and nature of vegetation cover, may affect the abundance and distribution of rangeland predatory beetles on local scales.

Human impacts upon CRB rangeland predatory beetles are probably quite variable. Destruction and disruption of extensive areas of indigenous rangeland plant communities via grazing, irrigation, crop planting and "range improvement" have probably had significant effects upon the abundance and distribution of these beetles. However, whether these effects have been beneficial or detrimental is a function of species-specific responses. For instance, overgrazing favors grasshoppers adapted to disturbed environments, e.g. some species of *Melanoplus* (Orthoptera: Acrididae). Rangeland predatory beetles preying upon grasshoppers may experience population increases in overgrazed areas. Pesticide applications on crops and their margins, as well as those applied more extensively to rangelands, have a more consistent effect. The immediate non-target kill of rangeland predaceous beetles subsequent to pesticide applications for grasshopper control in eastern Oregon appeared quite significant (personal observation). The impact of such treatments will again be somewhat species-specific and is also dependent upon the pesticide used, means of application, time of application and other variables. Given the broad distributions and presumably good dispersal capabilities of many CRB rangeland predatory beetles, re-establishment of populations following perturbation should be readily accomplished, providing disrupted sites are within range of propagule sources.

Rangeland predatory beetles include Carabidae, Cicindelidae, Elateridae, Histeridae, Meloidae, Rhipiphoridae and Staphylinidae. A few examples are: *Calosoma tepidum* LeConte (Carabidae); *Cicindeia plutonica* Casey (Cicindelidae); *Meloe opacus* Leconte (Meloidae); *Macrosiagon cruentum* Germ. *Epicauta normalis* was selected as the exemplar for this group because of its distribution throughout much of the CRB area and because its larval prey of grasshopper eggs illustrates a close relationship with a key herbivore.

A subset of rangeland predatory beetles that deserves special mention are those predaceous beetles more-or-less restricted to sand dunes and sandy habitats. As adults, many of these species burrow into the sand during the. day, emerging. only at night. This behavior may enable them to both escape diurnal temperature extremes as well as day-active predators. Due to the patchy nature of their habitat, these beetles generally have somewhat fragmented distributions. A special concern species, ***Cicindela arenicola*, serves** as an exemplar of this set of rangeland predatory beetles. Other CRB members of this group include ***Geopinus incrassatus*** Dejean and ***Rhadine balesi*** Gray (both carabids).

Subcortical Predatorv Beetles

Subcortical predatory beetles are those whose predatory activities primarily take place under the bark of trees and shrubs. This category exhibits the greatest familial diversity of any CRB terrestrial predaceous beetle group, including within its ranks Carabidae, Cleridae, Colydiidae, Cucujidae, Elateridae, Histeridae, Melyridae, Nitidulidae, Ostomidae, Othniidae, Pselaphidae, Rhizophagidae, Salpingidae, Scydmaenidae and Staphylinidae. Not surprisingly, the predominant prey of these beetles are presumed to be xylophagous insects such as Buprestidae, Cerambycidae and Scolytidae (all Coleoptera) and several species are regarded as important in controlling outbreaks of pest xylophages. Many species certainly feed upon other subcortical predaceous beetles, as well as other invertebrates present in the subcortical and decaying wood habitats, such as worms, mites, Collembola, fungivorous beetles, Anisopodidae and Cecidomyiidae (Diptera), Formicidae (Hymenoptera), ***et. cetera.*** In turn, subcortical predatory beetles are prey to other subcortical predators, parasites and pathogens, as well as invertebrate and vertebrate predators (e.g. 'salamanders,. woodpeckers, shrews) present or transient in habitats supporting subcortical predatory beetles. Subcortical predatory beetles are often very abundant, certainly providing significant contributions to nutrient cycles with which they are associated. Resource partitioning probably occurs predominantly via prey specificity, age and stage of limb or log decay or phenological distinctions.

A common, though not universal, characteristic of subcortical predaceous beetles is dorso-ventral flattening of the body, an obvious adaptation to the limited vertical space under bark. Some of these beetles use the pheromones produced by their prey to locate prey populations, as with some clerids and their scolytid prey (Crowson 1981). The literature (e.g. Fumiss & Carolin 1977) and museum records reveal that many subcortical predatory beetles occur under the bark of many different trees, suggesting that the "host tree" species is relatively unimportant. Prey abundance and species, along with bark characteristics, decay stage, size of limb or tree, location of the' habitat within 'a stand and stand characteristics may instead be the factors determining whether these beetles are present. Almost all "strict" subcortical predaceous beetle adults are capable of flight, presumably indicative of relatively great dispersal capabilities. This generalization does not necessarily apply to facultative subcortical predators, e.g. ***Pterostichus protractus.*** Almost all CRB subcortical predaceous beetles have broad distributions extending throughout the forested areas of the region. This is probably a function of the relatively continuous nature of the habitat over space and time, as well as the presumably great dispersal capabilities of the majority of CRB subcortical predatory beetles.

There is no question that the human influences upon the distribution and abundance of CRB subcortical predaceous beetles have been profound. Forest management practices, in particular those affecting the age and structural characteristics of stands, have changed the distribution and abundance of many xylophagous insects, either directly or indirectly (the latter via such effects as spruce budworm outbreaks). Although "census figures" are unavailable, subcortical predaceous beetles have undoubtedly responded to such changes in prey availability. It seems very likely that many subcortical predatory beetles have become more abundant with the advent of human forest activities. However, this generalization is almost certainly not universally applicable to this category of CRB beetles. Those species (if any) dependent upon conditions or prey found in extensive stands comprised of large and old trees, or associated with tree species not favored by foresters are probably declining. Applications of pesticides will probably have species-specific variable effects, depending as always upon the particular pesticide, method and time of application, frequency of application, and so on. The broad distributions and good dispersal capabilities of most CRB subcortical predaceous beetles may well counter many deleterious effects- of human activities; at least in the long run.

Some specific examples of CRB subcortical predaceous beetles are ***Psydrus piceus*** LeConte (Carabidae), ***Deretaphrus oregonensis*** Horn (Colydiidae), ***Alaus melanops*** LeConte (Elateridae), ***Plegaderus nitidus*** Horn (Histeridae), ***Temnochila virescens chlorodia*** Mannerheim (Ostomidae), ***Tyrus corticinus*** Casey (Pselaphidae) and ***Nudobius cephalicus*** Say (Staphylinidae). ***Enoclerus sphegeus*** was chosen as an exemplar of this group because. of its extensive range throughout the CRB region and acknowledged significance in controlling scolytids.

As a result of their role. in potentially controlling the abundance of forest pests such as Scolytidae, the biology of a number of subcortical predaceous beetles is relatively well known. Balduf (1935) and Fumiss & Carolin (1977) provide useful treatments, while Crowson (198 1) supplies a discussion of the subcortical habitat.

Oligophagous Predatory Beetles

Oligophagous 'predatory beetles are those which specialize, to a greater or lesser degree, upon just a few species or groups of prey. This category of CRB terrestrial predatory beetles will be discussed only briefly, but not because its members are unimportant, for the key ecological interactions of many oligophagous species are. the reasons for considering this group. It is difficult to. coherently discuss many oligophagous predatory beetles within the' context of landscape issues because many of their habitats do not conveniently fall within conventional landscape habitat definitions. However, this is not always the case - several oligophagous species or taxa have already been discussed or alluded to under each of the previous habitat categories.

Table 3 summarizes some broad oligophagous predatory beetle subgroups based upon known or presumed prey preferences. A brief statement regarding the habitat association of each species is included.

The effects of human activities upon the distribution and abundance of oligophagous predatory beetles will not be discussed at length because of the enormous diversity in behavior, distribution patterns, and habitats exhibited by this group. Suffice it to say that, as with the habitat categories, response to any given perturbation will be species-specific to varying degrees. Like the previous groups, habitat destruction will

TABLE 4

Groups of CRB Oligophagous Terrestrial Predatory Beetles Based Upon Prey Preferrence

Prey	Beetle Species	Author	Family	Habitat
Coleoptera:				
Chrysomelidae	*Lebia vittata*	Fabricius	Carabidae	Arboreal
Hydrophilidae	*Brachinus fumans*	Fabricius	Carabidae	Lacustrine & Riparian
Collembola (springtails)	*Dianous nitidulus*	LeConte	Staphylinidae	Lacustrine & Palustrine
	Leistus ferruginosus	Mannerheim	Carabidae	Arboreal
	Loricera pilicornis	Fabricius	Carabidae	Moist forest
	Notiophilus nitens	LeConte	Carabidae	Xeric forest
Diptera (flies) eggs, larvae, & pupae	*Nicrophorus investigator*	Zetterstedt	Silphidae	Carrion & dung
	Ontholestes cingulatus	Gravenhorst	Staphylinidae	Carrion & dung
	Saprinus discoidalis	LeConte	Histeridae	Carrion & dung
	Silpha ramosa	Say	Silphidae	Carrion & dung
Hymenoptera				
Formicidae - ants	*Adranes taylori*	Wickham	Pselaphidae	Ant nests
	Cremastocheilus armatus	Walker	Scarabaeidae	Ant nests
	Hetaerius exiguus	Mannerheim	Histeridae	Ant nests
	Xenodusa cava	LeConte	Staphylinidae	Ant nests
Solitary Bees	*Meloe opacus*	LeConte	Meloidae	Rangeland, bee nests
Mollusca (slugs & snails)	*Cychrus hemphillii*	Horn	Carabidae	Forest
	Diplochella striatopunctat	LeConte	Carabidae	Lacustrine
	Photinus pyralis	Linnaeus	Lampyridae	Forest

probably. have the most drastic and permanent impacts (Erhlich 1988).

No exemplars of this category will be provided because suitable examples have already been provided in the context of several habitat categories: *Enoclerus sphegeus*, a scoly tid predator, for. subcortical beetles; *Epicauta normalis*, a predator of grasshopper eggs, for rangeland beetles; *Hyperaspis lateralis*, a predator of- mealybugs, -for arboreal beetles.

Conclusion

Columbia' River Basin terrestrial predaceous beetles · exhibit a bewildering degree of ecological and 'taxonomic diversity,. as has been demonstrated by the panel discussion data, Tables 2 and 3, and the preceding text. 'Nonetheless, some broad generalizations. useful in the context of land management strategies can be made about this critical group of organisms.-

Ecological Functions of Columbia River Basin Terrestrial Predaceous Beetles

By definition, a primary ecological role of .CRB terrestrial predatory beetles is predation. These beetles feed on a wide variety of invertebrates, including detritivores, herbivores,. pollinators, other predators and parasites, ***et cetera.*** The impact they have on prey abundance and distribution is in part a function of their own abundance (often substantial) and prey selectivity. Prey selectivity ranges from virtually nil in generalists (e.g.' ***Pterostichus protractus)*** to extreme oligophages with such narrow prey parameters that essentially parasitic relationships exist (e.g. ***Meloe opacus***). Other factors affecting the impact of these predators upon their Prey include prey abundance and distribution, abiotic 'conditions,. phenological aspects and vegetation structure.

CRB predatory beetles also function as food for other insectivorous predators; parasites, and pathogens. (Crowson 1981, Thieie 1977). A wide array of predatory and parasitic arthropods prey upon predaceous beetles, including centipedes, scorpions, mites, spiders, grylloblattids, true bugs, other predaceous beetles, robber flies, ants and wasps. The same is true of insectivorous "vertebrates (Crowson 1981, Thiele 1977), including fish, frogs, salamanders, lizards, snakes; songbirds,-. raptors, woodpeckers, rodents,. bats, and even carnivores such as foxes (Elias & Halfpenny 1991).

CRB predaceous beetles are host to a virtually unknown, but probably substantial, microbial and fungal community.

Such widespread and abundant organisms certainly contribute substantially to the detritus system, both via their .own bodies and waste products and the excrement and waste products of their predators and parasites. Food for detritivores and nutrients for plants are thus provided, as well as organic material comprising some soil layers.

, Some CRB predatory beetles even act as herbivores and pollenivores during some life stages. For instance, adult meloids ***(e.g. Epicauta normalis)*** are herbivorous and some adult carabids, such as species of ***Amara*** and ***Harpalus*, are** now felt to be predominantly seed eaters (Thiele 1977). Furthermore, many "predaceous" beetles. may be more properly classed as omnivores at least facultatively feeding 'upon plant components such as seeds (Johnson, Lawrence & Ellis 1966).

Arboreal predaceous beetles and those groups with herbivorous adults ***(e.g. Epicauta normalis)*** may even function as pollinators, since they are often active on flowers. The magnitude of this service is unknown,. although it seems unlikely that CRB predaceous beetles are significant poilinators.

Habitats of Columbia River Basin Terrestrial Predaceous Beetles

The preceding pages make it clear that the terrestrial predaceous beetles of the CRB exist in a wide array of habitats, rendering this group ubiquitous throughout the region.. These habitats can be defined to differing degrees by both abiotic and biotic factors. The abundance and distribution of some groups appears to be more tightly controlled by abiotic factors such as precipitation and temperature (e.g. alpine nival predators) while others seem to primarily respond to biotic factors such as prey presence (e.g. oligophagous arboreal predators). However, great emphasis should not be placed upon this apparent dichotomy as the interaction of both types of factors is necessary to provide suitable habitat.

CRB predatory beetle species range from those which are eurytopic and often widespread ***(e.g. Pterostichus protractus)*** to narrowly stenotopic species which often have very restricted or highly fragmented distributions (e.g. ***Cicindela arenicola).*** Habitat exploitation is often expanded by different foods for different life stages (e.g. ***Epicauta***

normalis). Habitat breadth in CRB predatory beetles can also be expressed via prey selectivity. Habitats are often further partitioned by differing daily activity rhythms and phenological patterns.

Distribution's of Columbia River Basin Terrestrial Predaceous Beetles

. Most CRB predaceous bketles are presumed to disperse primarily as adults by flight or extended walking. Since larvae are generally : restricted to walking as their means of locomotion and are often. assumed to have more narrow environmental tolerances,. the range of larval dispersal is generally regarded as strictly local. There are exceptions to. this generalization. For instance, first instar rhipiphorid larvae and some first instar meloid larvae "hitch" rides -to' the 'nests of their hosts (Balduf 1935, Crowson 1981). The relative contribution of active larval dispersal in species with flightless adults (e.g. ***Nebria vandykei wyeast***) may be equivalent or greater to that. of the adults.

, The dispersal capabilities of CRB predatory beetles are highly. variable, depending upon the species' or species group under consideration. Dispersal capabilities are not only dependent upon whether adults are capable of flight but also such factors as habitat fidelity, physiological limitations, phenology, population dynamics, prey abundance, habitat distribution and patchiness, geographical barriers, and weather conditions. Consequently,' it is probably safe to say that any given CRB predaceous beetle species has unique dispersal capabilities.

To further muddy the picture, the current distributions of CRB predaceous beetles are not just a function of their present dispersal capabilities but are the result of" past events, such as climatic changes, lava., flows and mountain building. The evolutionary history of these beetles must also be considered. This is also true of past events affecting prey distributions, particularly for oligophagous CRB. predatory beetles. It must also be' recognized that. our distribution knowledge for most species is inadequate "(see Research- Needs).

Although the net result of this plethora of events and phenomena is to yield distributions that are virtually unique for every species of CRB predaceous beetle, some rough generalizations appear possible, although exceptions abound. Most arboreal; lacustrine and riparian; rangeland, and subcortical species have broad and extensive distributions throughout the CRB region wherever suitable habitat exists. Surprisingly, presumably poor dispersal capability (i.e. flightlessness) does not in itself necessarily imply restricted or fragmented distributions, especially for eurytopic species such as ***Pterostichus protractus.*** Highly fragmented or localized distributions appear to be the rule for stenotopic species restricted to very patchy and isolated habitats such as alpine nival habitats, hot springs, waterfalls and sand dunes. One outstanding exception to the last "rule" is that ***Geopinus incrassatus*** has one of the broadest distributions of any North American carabid (Bousquet & Larochelle 1993).

Responses of Columbia River Basin Terrestrial Predaceous Beetles to Perturbation

A major obstacle to developing generalizations about the effects of perturbations, human-caused or otherwise, upon CRB terrestrial predaceous beetles is the diversity typifying this group of insects. Each species or species group will almost certainly respond to any given disturbance in a unique manner. The short- and long-term impacts will also vary depending upon the species or group under consideration. Compounding the problem is that no one perturbance is precisely identical to another - the effect of a particular disturbance upon CRB predatory beetles will depend upon its nature, extent, intensity, frequency, and magnitude. The effects upon organisms other than these beetles must also be considered, such as the response of prey species. .

Attempting to understand such complex phenomena given our current state of knowledge about insects in general and CRB terrestrial predatory beetles specifically (see Research Needs) guarantees facile and almost certainly erroneous generalizations. However, a few very broad statements can be made.

Large-scale habitat disruption and destruction will tend to have the greatest and most permanent effects upon CRB predatory beetles in general. Arboreal, lacustrine and riparian, rangeland and subcortical species will probably be least vulnerable since they often have extensive ranges and good dispersal capabilities. Alpine nival and restricted-distribution species are at greatest risk. Regional or global climate change, volcanic eruptions, dams and wholesale elimination of old forests are examples of such perturbations. *Cicindela columbica*, a highly stenotopic riparian species, is apparently. extinct throughout much of its former range due to inundation of its habitat by dams (Leffler 1979). Global "warming, if real, may result in very severe elevational habitat contractions 'for alpine nival species like ***Nebria vandykei wyeast.***

Spatially and temporally localized perturbations may have little overall effect upon eurytopic, widespread species with good dispersal capabilities or with nearby propagule sources. However, the tolerances of local populations may be exceeded, leading to local or temporary extinctions or aberrant ecological responses. Depending upon the previously mentioned disturbance variables, arboreal, lacustrine and ripariari, rangeland and subcortical species will probably be least affected. Again,'. 'alpine nival species and those from patchy and isolated habitats are most vulnerable.. Examples of such' localized disturbances are droughts, fires, floods, drought, logging of individual stands and pesticide applications. For instance, several populations of ***Cicindela arenicola*** may be declining because of livestock trampling and off-road-vehicle 'traffic (Baker' et al. 1994).

The introduction of non-indigenous species into the CRB region, whether intentional or otherwise, represents a particularly insidious form of disturbance. Once established in a region, non-indigenous species generally become permanent features, with ranges often expanding into other regions. The impact of exotic species upon indigenous species may be expressed indirectly through habitat-modifying effects or directly through predation/parasitism or 'competition. At least one population of ***Cicindela arenicofa*** is considered potentially at risk due to dune encroachment' by exotic weeds (Baker et al. 1994). A number of European carabid species have become established in the CRB region, for example *Elaphropus parvulus* Dejean and ***Trechus obtusus*** Erichson (LaBonte 1989). The eventual impact of such exotic species upon the indigenous. CRB carabids can only be conjectured,. but the possibility of at least localized competitive 'displacement cannot be discounted.

Research Needs

The current level of knowledge about' almost all species of insects is woefully limited. The situation is no different for CRB terrestrial predaceous beetles. This is clearly indicated in the attached panel reports by the plethora -of "unknown" responses. Our minimal understanding of the ecological roles and responses of this group of 'insects primarily rests upon studies of a few relatively well-known species and families which may not be particularly representative. examples. This lack of information . is particularly crippling when efforts are made to assess the 'complex potential effects of human or natural disturbances within a land management context. Consequently, numerous and often highly questionable extrapolations from the available data must be made to fill the gaps in our knowledge, when in truth we simply don't know how most species or species groups will respond, particularly in the long term.

Unfortunately; there is no substitute for data. Conjectures, extrapolations and guesstimates based upon. very limited information can only be taken so far, and probably shouldn't be taken as far as' is often the case. Fortunately, some of the most useful baseline data can be acquired with relative ease. However, in order to do so, a systematic, well-designed and carefully planned commitment of resources is necessary.

Distribution data is crucial to understanding biogeographic patterns and habitat limitations. The distributions of most species are poorly known, with many of the apparent limits the result of collecting artifacts, publication idiosyncrasies or simply lack of scientific attention. This is particularly true of small species and "unpopular" families such as the Staphyiinidae. Much of the information necessary to improve our knowledge of CRB terrestrial predaceous beetle distributions is quite accessible, residing in museums, private collections, or existing literature. These information sources simply need to be examined.

There are definite limits to the utility of literature searches and specimen label data. To gain true understanding of the ecology of CRB terrestrial predatory beetles, field studies are necessary. Initially, significant private, state and federal lands in the CRB region should be systematically surveyed. This approach will not only provide much additional distributional information but will yield vital baseline data. about the ecological parameters and habitats of CRB species and species groups. Furthermore, short- and long-term field and laboratory experiments examining the basic biology of CRB species are necessary. For instance, dispersal capabilities, habitat fidelity, and ranges of ecological parameters defining suitable habitat should be examined for a wide variety of CRB species and species groups. Only with such information will it be possible to adequately assess the impact of land management strategies upon CRB terrestrial predaceous beetles.

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Appendix 1. List of principal families of terrestrial arthropod predators found in the Columbia River Basin analysis area, with estimate of number of species, principal prey, and typical habitats. Species number of non-insects derived from Crawford (1988; pers obs), of beetles from Hatch (1953, 1957, 1962, 1965, 1971), and of other insects from (Danks 1978) and the list of invertebrates of the HJ Andrews Experimental Forest (Parsons 1991), assuming similar percentages of species found in each taxon. *NOTE: Estimates of species number represent preliminary examination of literature; accurate estimates would require thorough examination of primary literature, beyond the scope of this report.

FAMILY (Common Name)	#SPP	PRINCIPAL PREY: Immatures	PRINCIPAL PREY: Adults	HABITAT: Immatures	HABITAT: Adults
CLASS ARACHNIDA Spiders, scorpions, pseudoscorpions, harvestman (53 Families)	1156-2735				
ORDER ARANEAE: Spiders (32 Families)	983-2279	Immatures are small replicas of adults--prey will have same features, but will be smaller	As a group, spiders prey upon almost every type of terrestrial arthropod	As adults	Most commonly encountered terrestrial arthropod predator. Found in every major habitat, from litter to canopy, in all ecoregions
AGELENIDAE (Funnel-Web Spinners)	75-150		Medium to large hopping/running arthropods		Logs, litter, soil surface, tree trunks, caves; forest/range
AMAUROBIIDAE (White-Eyed Spiders)	20-60		Medium to large sized arthropods		Forest floor, on logs, trunks, under bark
ANTRODAETIDAE (Folding-Door Tarantulas)	8-20		Medium-sized ground surface arthropods		Forest floor

FAMILY (Common Name)	#SPP	PRINCIPAL PREY: Immatures	PRINCIPAL PREY: Adults	HABITAT: Immatures	HABITAT: Adults
ANYPHAENIDAE (sac spiders)	10-20		Varied insects		Trees, shrubs, under rocks; forest/range
ARANEIDAE (Orb-Weavers)	30-60		Flying insects		On shrubs, trees, rocks; forest/range
CLUBIONIDAE (Running Spiders)	30-100		Running arthropods		On ground, vegetation; forest/range
DICTYNIDAE (Hackled-Band Weavers)	50-100		Flying insects, hopping arthropods, esp. Diptera, Hymenoptera		Ubiquitous; Ground level to shrubs, trees; forest/range
GNAPHOSIDAE (Nocturnal Hunting Spiders)	75-150		Medium to large arthropods		On ground, under bark, tree trunks; forest/range
HAHNIIDAE (hahniid spiders)	12-25		Small insects		Varied, under objects on ground, logs, litter, webs on moist soil; forest
LINYPHIIDAE (Sheet-Web Weavers)	350-900		Samll to medium arthropods, flying insects		Ubiquitous; Ground level to shrubs, trees, less common in dry places; forest/range
LYCOSIDAE (Wolf Spiders)	60-120		Medium to large sized running and hopping arthropods		Ground level; forest/range

FAMILY (Common Name)	#SPP	PRINCIPAL PREY: Immatures	PRINCIPAL PREY: Adults	HABITAT: Immatures	HABITAT: Adults
OXYOPIDAE (Lynx Spiders)	2-5		Medium to large sized running and hopping arthropods, flying insects		On shrubs, trees; forest/range
PHOLCIDAE (Cellar Spiders)	5-15		Flying insects		Webs under rocks; forest/range
SALTICIDAE (Jumping Spiders)	80-160		Mostly small running, hopping, flying insects		Ubiquitous. On ground, shrubs, trees; forest/range.
TETRAGNATHIDAE (Long-bodied Orb-Weavers)	20-50		Weak-flying insects, terrestrial and aquatic		On shrubs, trees, esp. in riparian areas, forest/range
THERIDIIDAE (Comb-Foot Weavers)	60-110		Flying, hopping insects, ants, other spiders		Ubiquitous; ground level to shrubs, trees, forest/range
THOMISIDAE (Crab Spiders)	75-150		Running/hopping arthropods		Ubiquitous; ground level to shrubs, trees, on flowers; forest/range
15 ADDITIONAL FAMILIES OF ARANEAE	21-84				
ORDER SCORPIONIDAE: Scorpions (1 Family)	6-10	Immatures small replicas of adults, with similar feeding habits	Use substrate-born signals for prey detection; feed on running or hopping insects	Same as adults	Common on ground in desert habitats

FAMILY (Common Name)	#SPP	PRINCIPAL PREY: Immatures	PRINCIPAL PREY: Adults	HABITAT: Immatures	HABITAT: Adults
VEJOVIDAE	6-10		Crickets, nocturnal insects, arachnids		On ground, in burrows, under rocks; dry rangelands
ORDER OPILIONES: Harvestmen (10 Families)	83-186	Immatures have similar feeding habitats as adults, but prey is smaller	Widespread as group, probably more important as scavengers. Small mouthparts--small prey	Same as adults	Common on ground; primarily in forested areas
ISCHYROPSALIDIDAE	22-40		Small decomposer invertebrates		Under objects, litter, caves, on ground
PHALANGIDAE (Daddy-Longlegs)	10-25		Small-medium sized invertebrates		Vegetation, ground level, under rocks, logs; forest/range
NEMASTOMATIDAE	22-40		Small decomposer invertebrates		Litter in forest
TRIAENONOYCHIDAE	9-25		Small invertebrates		Logs, under wood on ground, litter; forest
6 ADDITIONAL FAMILIES OF OPILIONES	20-56				
ORDER SOLPUGIDA: Wind Scorpions (1 Family)	10-25	Immatures small replicas of adults	Running/hopping arthropods	Same as adults	Ground level; rangelands
EREMOBATIDAE	10-25		Ground-dwelling arthropods		Under objects, on ground; dry rangelands

FAMILY (Common Name)	#SPP	PRINCIPAL PREY: Immatures	PRINCIPAL PREY: Adults	HABITAT: Immatures	HABITAT: Adults
ORDER CHERNETIDA Pseudoscorpions (9 Families)	74-235	Immatures small replicas of adults	Small insects	Same as adults	Litter, caves, moss, mammal nests, caves
CHELIFERIDAE	15-50		Small flies, Psocoptera, insect larvae		Under rocks, litter, tree bark
CHERNETIDAE	15-40		Small flies, Psocoptera, insect larvae		Mammal nests, tree and log bark
CHTHONIIDAE	15-40		Collembola		Litter, soil, rotten wood, moss, caves, tree bark, mammal nests
NEOBISIIDAE	15-40		Collembola		Litter, moss
5 OTHER FAMILIES OF PSEUDOSCORPIONS	14-65				
CLASS CHILOPODA Centipedes (12 Families)	149-343	Immatures small replicas of adults	Soil invertebrates	Generally same as adults	Soil, litter, under rocks, logs; forest/range
ORDER LITHOBIOMORPHA (3 Families)	50-100				
LITHOBIIDAE	50-100		Small to medium sized arthropods		Litter, logs, under rocks
ORDER GEOPHILOMORPHA (3 Families)	70-145				
CHILENOPHILIDAE	30-60		Small soil invertebrates		Litter, soil
GEOPHILIDAE	15-30		Small soil invertebrates		Litter, soil

FAMILY (Common Name)	#SPP	PRINCIPAL PREY: Immatures	PRINCIPAL PREY: Adults	HABITAT: Immatures	HABITAT: Adults
HIMANTARIIDAE	15-30		Small soil invertebrates		Litter, soil
SCHENDYLIDAE	10-25		Small soil invertebrates		Litter, soil
2 OTHER ORDERS AND 7 OTHER FAMILIES OF CENTIPEDES	29-98				
CLASS INSECTA (47 Families)	2239-3558				
ORDER THYSANOPTERA: Thrips (2 Families)	10-40	Immatures have similar feeding habits as adults, with prey size just smaller	Most are plant feeders, a few species prey upon small arthropods	Same as adults	On herbs, shrubs, trees, typically near or within flowers
AEOLOTHRIPIDAE (Broad-Winged Thrips)	5-20		Other thrips, aphids, mites, other small insects		Flowers
THRIPIDAE (Common Thrips)	5-20		Other thrips, mites		Flowers, foliage of herbs, shrubs
ORDER HETEROPTERA: True Bugs (6 Families)	184-550	Immatures small replicas of adults, with prey size smaller	Plant feeders, predators, scavengers, parasites	Same as adults	Ubiquitous--aside from the beetles, is the most important group of insect predators
ANTHOCORIDAE (Minute Pirate Bugs)	10-20		Small insects, insects eggs		On flowers, subcortical, in leaf litter, decaying fungi; forest/range
LYGAEIDAE (Seed Bugs)	40-160		Hopping/running arthropods		Ubiquitous, from ground to shrubs, trees; forest/range

FAMILY (Common Name)	#SPP	PRINCIPAL PREY: Immatures	PRINCIPAL PREY: Adults	HABITAT: Immatures	HABITAT: Adults
MIRIDAE (Plant Bugs)	100-250		Hopping/running arthropods, flying insects		Ubiquitous, from ground to herbs, shrubs, trees; forest/ range
NABIDAE (Damsel Bugs)	5-20		Hopping/running arthropods, aphids, caterpillars		On herbs, shrubs, trees; forest/range
PENTATOMIDAE (Stink Bugs)	20-80		Running arthropods, caterpillars		On herbs, shrubs, trees; forest/range
REDUVIIDAE (Assassin Bugs)	5-20		Wide variety of other insects, spiders		Ubiquitous, ground to shrubs, trees; forest/range
ORDER NEUROPTERA (Lacewings, Owlflies) (4 Families)	17-60	Mostly predaceous	Predaceous: relatively weak prey	Arboreal, arbuscular	Aerial: weak fliers
CHRYSOPIDAE (Green Lacewings)	5-20	Aphids, scales	Aphids, scales	Arboreal, arbuscular	Aerial
HEMEROBIIDAE (Brown Lacewings)	5-20	Aphids, scales		Arboreal, arbuscular	Aerial
MYRMELIONTIDAE (Antlions)	5-10	Ground-dwelling insects		Ground surface, dry places	Aerial
RAPHIDIIDAE (Snakeflies)	2-10	Aphids	Aphids	Arboreal, arbuscular	Arboreal, arbuscular

APPENDIX

TERRESTRIAL PREDACEOUS COLEOPTERA OF THE COLUMBIA BASIN

FAMILY (Common Name)	# OF SPECIES	PRINCIPLE PREY: Larvae	Adults	HABITAT: Larvae	Adults
Cantharidae (Soldier Beetles)	47	Invertebrates, all stages.	Small soft-bodied insects, e.g. aphids.	Epigean, litter.	Flowers & foliage.
Carabidae (Carabid Beetles)	420	Invertebrates, all stages. Some mono- or oligo-phagous (e.g. molluscs), some omnivorous.	Invertebrates, all stages. Many mono- or oligophag-ous (e.g. collembola, millipedes, molluscs), some omnivorous.	Ubiquitous (see adults). Generally endo- and epigean, litter, sub-cortical.	Ubiquitous, especially epigean. Prominant in alpine nival, burn, endogean, forest, lacustrine, riparian, and sand dune habitats.
Cicindelidae (Tiger Beetles)	18	Epigean invertebrates, larvae & adults.	Invertebrates, larvae & adults.	Generally in open areas, some in forests. Endogean, with burrows opening onto soil surface.	Epigean, generally in open areas, some in forests. Prominant in lacustrine, riparian and sand dune habitats.
Cleridae (Checkered Beetles)	21	Xylophagous insects in wood, galls, cones, esp. subcortical beetles (e.g. Buprestidae, Cerambyc-idae, Scolytidae). Some prey on grasshopper eggs, bee & wasp larvae.	Xylophagous insects, esp. adult Scolytidae.	Subcortical or within prey galleries & tunnels.	Flowers, foliage, tree limbs & trunks, subcortical.
Coccinellidae (Ladybird Beetles)	85	Same as adults.	Homoptera (e.g. aphids & coccids) & phytophagous mites. Some prey on eggs, young instars or small larvae, & pupae of Coleoptera, Diptera, Hymenoptera, Lepidoptera, Thysanoptera.	Same as adults.	Ubiquitous when prey present. Upon foliage, flowers, tree limbs & trunks.
Colydiidae (Cylindrical Bark Beetles)	7	Predators & parasites of xylophagous beetles, especially larvae (e.g. Buprestidae, Cerambyc-idae, Scolytidae).	Xylophagous beetles, esp. larvae (e.g. Buprestidae, Cerambycidae, Scolytidae).	Subcortical or within prey galleries & tunnels.	Subcortical or within prey galleries & tunnels.

APPENDIX

FAMILY (Common Name)	# OF SPECIES	PRINCIPLE PREY: Larvae	Adults	HABITAT: Larvae	Adults
Cucujidae (Flat Bark Beetles)	9	Subcortical insects, especially larval & adult beetles (e.g. Cerambycidae & Scolytidae).	Subcortical insects, especially larval & adult beetles (e.g. Cerambycidae & Scolytidae).	Subcortical.	Subcortical.
Elateridae (Click Beetles)	140	Endogean, subcortical & xylophagous invertebrates. Facultatively herbivorous.	Herbivorous or non-feeding.	Endogean, subcortical, decaying wood.	Foliage, flowers, tree limbs & trunks, some riparian under stones.
Histeridae (Hister Beetles)	46	Invertebrates, all stages, especially larvae of Coleoptera, Diptera, Lepidoptera. Several ant predators.	Invertebrates, all stages, especially larvae of Coleoptera, Diptera, Lepidoptera. Several ant predators.	Carrion, feces, decomposing plant material, lacustrine/riparian & sandy areas, under bark, ant nests.	Carrion, feces, decomposing plant material, lacustrine/riparian & sandy areas, under bark, ant nests.
Lampyridae (Firefly Beetles)	9	Earthworms, molluscs, insect larvae, millipedes.	Many believed herbivorous or non-feeding. Some females "cannibalistic" upon males of same and other species of Lampyridae. Some females larviform, feeding upon millipedes & molluscs.	Epigean, litter, under rocks in riparian areas.	Vegetation, especially near riparian areas. Also subcortical.
Leptinidae (Mammal Nest Beetles): *Platypsyllus castoris* Ritsema	1	Ectoparasitic upon beaver (epidermis & epidermal exudates).	Ectoparasitic upon beaver (epidermis & epidermal exudates).	On beaver.	On beaver.
Lycidae (Lycid Beetles)	8	Soft or fluid material in decaying wood.	Small soft-bodied insects?	Litter, subcortical, decaying wood.	Vegetation.
Meloidae (Blister Beetles)	41	Eggs of Orthoptera; eggs, larvae, & provisions of solitary bees.	Herbivorous.	Endogeous as Orthopteran egg predators. First instar larvae of solitary bee brood predators on flowers, in bee nests thereafter.	Flowers, foliage, epigean.

APPENDIX

FAMILY (Common Name)	# OF SPECIES	PRINCIPLE PREY: Larvae	Adults	HABITAT: Larvae	Adults
Melyridae (Soft-winged Flower Beetles)	63	Small invertebrates, all stages. Many are also scavengers.	Small invertebrates, all stages. Many herbivorous.	Subcortical, xylophagous insect galleries, litter, vegetation, decaying wood, fungi. Endo- and epigean, especially sandy soils.	Flowers, foliage, litter.
Ostomidae (Bark-Gnawing Beetles)	14	Subcortical/xylophagous invertebrates (especially Coleoptera, e.g. Scolytidae), stored grain & cereal product pests. Some are fungivorous.	Subcortical/xylophagous invertebrates (especially Coleoptera, e.g. Scolytidae), stored grain & cereal product pests. Some are fungivorous.	Subcortical, galleries of xylophagous insects, stored grains & cereal products.	Subcortical; galleries of xylophagous insects; limbs, trunks & foliage of conifers; stored grains & cereal products.
Othniidae (False Tiger Beetles)	1	Subcortical invertebrates, all stages.	Subcortical & xylophagous invertebrates, all stages.	Subcortical.	Subcortical; limbs, trunks & foliage of conifers.
Pselaphidae (Short-winged Mold Beetles)	16	Mites, all stages; eggs, larvae & pupae of ants; small invertebrates, e.g. collembolans, fly larvae.	Mites, all stages; eggs, larvae & pupae of ants; small invertebrates, e.g. collembolans, fly larvae.	Endogean, epigean, litter, subcortical, ant nests, mammal nests.	Endogean, epigean, litter, subcortical, ant nests, mammal nests.
Pyrochroidae (Fire Beetles)	2	Facultative predators of subcortical invertebrates?	Herbivorous or non-feeding?	Subcortical.	Subcortical, foliage.
Rhipiphoridae (Rhipiphorid Beetles)	6	Ecto- and endoparasites of wasps, solitary bees.	Pollen feeders.	Wasp and solitary bee nests.	Flowers.
Rhizophagidae (Root-eating Beetles): species of *Rhizophagus*	3	Subcortical/xylophagous insects (esp. Coleoptera, e.g. eggs & larvae of Scolytidae).	Subcortical & xylophagous insects (esp. Coleoptera, e.g. eggs & larvae of Scolytidae).	Subcortical.	Subcortical.
Salpingidae (Narrow-waisted Bark Beetles)	7	Subcortical/xylophagous invertebrates, especially Scolytidae.	Invertebrates, especially Scolytidae.	Subcortical, galleries of xylophagous insects.	Subcortical, litter, flowers & foliage.
Scydmaenidae (Ant-like Stone Beetles)	3	Mites, all stages; other small invertebrates.	Mites, all stages; other small invertebrates.	Litter, epi- & endogean, subcortical.	Litter, epi- & endogean, subcortical.

APPENDIX

FAMILY (Common Name)	# OF SPECIES	PRINCIPLE PREY: Larvae	PRINCIPLE PREY: Adults	HABITAT: Larvae	HABITAT: Adults
Silphidae (Carrion Beetles): species of *Nicrophorus*, *Pteroloma*	11	Larvae of Diptera, possibly larvae & adults of coprophagous Coleoptera (e.g. Scarabaeidae) - *Nicrophorus*. Small invertebrates - *Pteroloma*.	Larvae of Diptera - *Nicrophorus*. Small invertebrates - *Pteroloma*.	Carrion, decaying vegetation, feces - *Nicrophorus*. Litter, epigean - *Pteroloma*.	Carrion, decaying vegetation, feces - *Nicrophorus*. Litter, epigean - *Pteroloma*.
Staphylinidae (Rove Beetles)	300	Invertebrates, all stages. Subcortical/xylophagous invertebrates. Many mono- or oligophagous, e.g. preying upon fly larvae, all stages of ants, parasites of fly pupae. Many presumably detrivorous or fungivorous.	Invertebrates, all stages. Subcortical/xylophagous invertebrates. Many mono- or oligophagous, e.g. preying upon collembola, fly larvae, millipedes, mites, all stages of ants. Many presumably detrivorous or fungivorous.	Ubiquitous. Epi- and endogean, litter, lacustrine & riparian areas, subcortical, decaying wood and plant material, fungi, bird & mammal nests carrion, feces, ant nests, etc.	Ubiquitous. Epi- and endogean, litter, lacustrine & riparian areas, subcortical, decaying wood and plant material, fungi, bird & mammal nests, carrion, feces, ant nests, flowers, etc.
The following families are predominantly non-predaceous. Only the predaceous species are counted.					
Derodontidae (Tooth-necked fungus Beetles): species of *Laricobius*	3	All stages of Chermidae (Homoptera), e.g. *Adelges piceae* Ratzeburg.	All stages of Chermidae (Homoptera), e.g. *Adelges piceae* Ratzeburg.	Trunks, branches, & twigs of conifers.	Trunks, branches, & twigs of conifers.
Nitidulidae (Sap Beetles)	18	*Cybocephalus* on Coccidae (Homoptera); *Epuraea* on scolytid eggs & larvae; *Glischrochilus*, *Nitidula*, *Pityophagus* on Scolytidae.	Saprophagous, mycetophagous.	Subcortical.	Subcortical, flowers, tree wounds, fungi.
Scarabaeidae (Scarab Beetles): *Cremastochellus*	5	Ant larvae.	Ant larvae.	Ant nests.	Ant nests; under stones in fields, meadows, & pastures.
Tenebrionidae (Darkling Beetles): *Corticeus*	4	Larvae, pupae & teneral adults of Scolytidae.	Larvae, pupae & teneral adults of Scolytidae?	Subcortical.	Subcortical.
TOTAL SPECIES	**1308**				

FAMILY (Common Name)	#SPP	PRINCIPAL PREY: Immatures	PRINCIPAL PREY: Adults	HABITAT: Immatures	HABITAT: Adults
ORDER DIPTERA: True Flies (3 Families)	220-700	Larvae, adults eat different food.		Larvae, adults occur in different habitats.	
ASILIDAE (Robber Flies)	50-200	Invertebrates	Flying Insects	Down Wood	Aerial
CHAMAEMYIIDAE (Aphid Flies)	20-100	Aphids		Arboreal, arbuscular	Aerial
SYRPHIDAE (Hover Flies)	150-400	Aphids	Pollen, Nectar	Arboreal, arbuscular	Aerial
ORDER HYMENOPTERA: Bees, Ants, Wasps (4 Families)	500-900	Larvae are helpless, fed by adults	Social (ants, vespids) or solitary (mud-daubers, spider wasps)	Larvae are found within nests constructed by adults.	As a group, these insects are widespread, common, and ecologically important
FORMICIDAE (Ants)	150-200	Fed by workers	Almost entirely polyphagous		Ubiquitous
POMPILIDAE (Spider Wasps)	100-150	Fed by adult female	Spiders		Ubiquitous
SPHECIDAE (Mud Daubers)	200-400	Fed by adult female	Medium to large arthropods, esp. Lepidoptera		Ubiquitous
VESPIDAE (Paper Wasps, Hornets)	50-150	Fed by workers	Medium to large arthropods, esp. Lepidoptera		Ubiquitous

TOTALS: 3 CLASSES, 15 ORDERS, 112 FAMILIES, BETWEEN 3544 AND 6636 SPECIES