VI. LITERATURE ANALYSIS & RECOMMENDATIONS (TASK 5)

Task 5 involves identifying major information gaps without which land managers in the southern range of the northern spotted owl will be unable to effectively protect the ecological functions of forest understory and canopy gap herbivores. The Agencies need taxa and habitats prioritized for future study, and the rationale for strategic surveys that may help to fill the identified information gaps.

VI-1. Introduction

The forests of western Washington, Oregon, and California are part of a larger Western Coniferous Forest Biome that extends along the Pacific Coast from Alaska to Northern California. The largest part of this biome is dominated by large, long-lived Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and western redcedar (*Thuja plicata* Donn). The present Western Coniferous Forest flora has essentially been established for 1.5 million years (Waring and Franklin 1979). Before that, deciduous hardwoods dominated the region for 18 to 28 million years (Chaney 1948, Axelrod 1958, Wolfe 1978). The shift to coniferous dominance was probably due to a shift to climatic conditions similar to those that exist today (Waring and Franklin 1979).

Photo by Pacific Analytics

Figure VI-1. Old-growth coniferous forest in the Cascades range of western Oregon.

Coniferous forests dominate all Pacific Northwest physiographic regions, including four which occur within the southern range of the northern spotted owl; the Oregon Klamath, California Klamath, California and southern Oregon Cascades, and California Coastal Redwood physiographic regions (Hitchcock and Cronquist 1973.

The Cascades physiographic region has the greatest temperate zone accumulation of biomass in the world (Waring and Franklin 1979). In undisturbed areas, conifers reach 50 to 80 m (164 to 263 feet) high and occur in dense stands with some trees more than 500 years old (Fujimori 1971). Although several hardwood taxa are also present in the understory and canopy gaps of these forests (e.g. *Acer* L., *Alnus* Mill., *Castanopsis* (D. Don) Spach, *Lithocarpus* Blume, *Populus* L., *Quercus* L., and *Salix* L.), conifers represent the dominant tree type.

Photo by Pacific Analytics

Figure VI-2. Riparian hardwood forest in the H.J. Andrews Experimental Forest, Oregon.

Along the Oregon-California border, the Klamath physiographic region (also known as the Klamath-Siskiyou region) supports a diverse mixture of drought-resistant conifers and hardwoods, and has been called one of the most biologically diverse areas in the world (DellaSala et al. 1999). Over 3,500 plant species, including 281 endemic taxa occur here (Sawyer 1996). The difference in vegetation from the Cascade region is largely the result of highly variable topography and soil types, and lower precipitation.

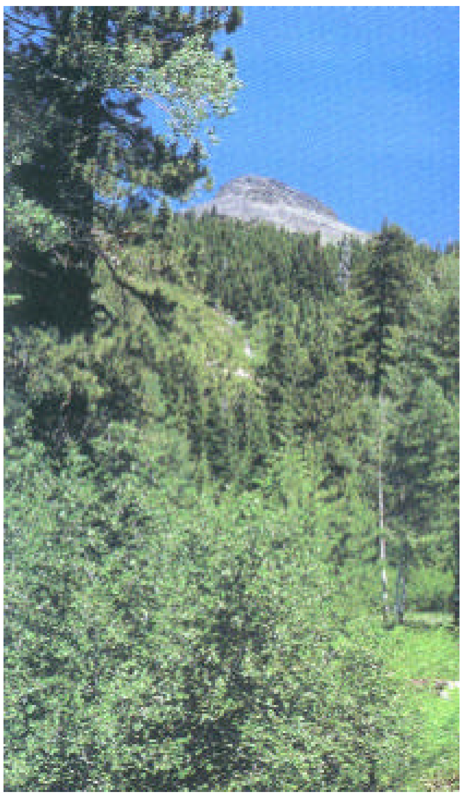

Photo courtesy of Dan Cheatham

Figure VI-3. Conifer forests in northern California are composed of firs, pines, and junipers, with a rich diversity of understory and gap species.

This geologically complex region of about 30,560 sq. km (12,000 sq miles) in northwestern California and southwestern Oregon contains several mountain ranges including the Trinity, Scott, Scott Bar, South Fork, Salmon, Trinity Alps, Marble, and Siskiyou mountains. The mountains display dramatic evidence of Pleistocene glaciation, and substantial edaphic diversity. Three major rock types, metamorphics, granitics, and serpentines occur in a mosaic pattern and largely determine the local soil and vegetation development.

The montane Mediterranean type climate of the Klamath region is drier than that of the Cascade region, and is influenced by westerly winds from the Pacific Ocean. Local weather is modified by proximity to the ocean or the interior deserts of eastern California and Oregon.

Physical characteristics of the Klamath / Siskiyou region have been major factors influencing the evolution of the species rich, and highly endemic biota found in this region. The location and topography has contributed to a wide-range of climatic conditions, including steep climatic gradients (Englebrecht 1955, Whittaker 1960). A series of mountain-building and erosion events during the Mesozoic Era (248 – 65 mya) left this region with a wide-ranging topography, and significant edaphic diversity (Diller 1902, Whittaker 1960). The flora has a high degree of botanical relictualism and endemism reflecting these diverse topographic and edaphic conditions (Whittaker 1960, Smith and Sawyer 1988). Because of its central geographic location on the West Coast of North America, the region was a meeting ground for biotas broadly termed "Northwestern" and "Californian" (Whittaker 1960), and a species rich biota evolved in the Klamath/Siskiyou region during the Miocene Epoch about 25 mya (Whittaker 1960). During subsequent glaciation events, the region served as a refugium of Tertiary plants that has contributed to high endemism (Wolfe 1969, Axelrod 1976, Smith and Sawyer 1988).

The Klamath physiographic region is under continuous pressure to further develop mining and recreational operations, and to harvest remaining old-growth forests. A recent Conference on Siskiyou Ecology met to discuss the pressures for development and a wide range of resource management issues (Beigel, et al. 1997).

Forests in the Coastal Redwood physiographic region are largely composed of coast redwoods (*Sequoia sempervirens*). Average mature trees are several hundred years old, and average 200 to 240 feet tall with diameters up to 10 to 15 feet. Some of these trees have reached more than 360 feet and have lived more than two thousand years.

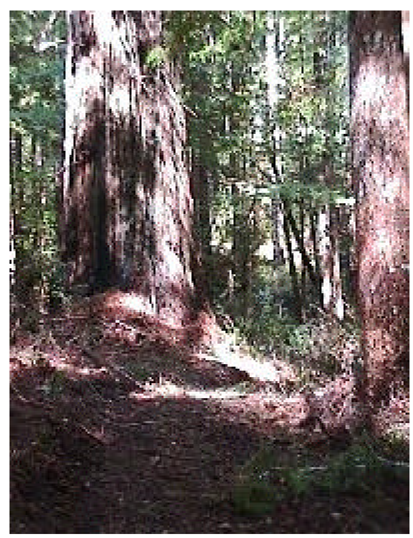

Photo by USDA, Forest Service

Figure VI-4. Large redwoods dominate the forests along the northern coast of California.

In some areas coast redwoods form almost pure stands in some areas with a rich understory of Pacific rhododendrons (*Rhododendron macrophyllum*), western azaleas (*Rhododendron occidentale*), and a variety of ferns. Mixed evergreen forests in this region contain Douglas-fir, western hemlock, grand fir, and Sitka spruce. On drier slopes tanoak (*Lithocarpus densiflorus*), madrone (*Arbutus menziesii*), maple (*Acer* spp.), and California bay laurel (*Umbellularia californica*) grow along with the evergreens. Other understory plants include poison oak (*Rhus diversiloba*), huckleberry (*Vaccinium* spp.), hazel (*Corylus cornuta* var. *californica*), salal (*Gaultheria shallon*), and many flowering herbs. Many ferns and flowers grow in the cool shade, such as western sword fern (*Polystichum munitum*) and redwood sorrel (*Oxalis oregana*).

The Coastal Redwood physiographic region is a narrow 450-mile strip along the Pacific Ocean from central California to southern Oregon. In the redwood belt, temperatures are moderate year-round, and heavy winter rains and dense summer fog provide the trees with necessary moisture. The natural forests here are perfect recycling systems. The soil (like that in many high-rainfall climates) contains fewer nutrients. Most of the organic matter and essential nutrients are locked in the trees themselves, living and dead, and in other plants and animals. Consequently, when trees are removed from the forest instead of being allowed to die and decay naturally, many nutrients are permanently lost from the system.

Western coniferous forests encompass a diversity of ecosystems that vary in their composition, structure, and productivity (Franklin et al. 1981). Major disturbance factors such as fire, wind, diseases, insects, landslides, and wind throws create a mosaic of terrestrial environments and habitats across the landscape (Lattin 1990, 1993a, Swanson et al. 1990, Wallin et al. 1996).

Plant diversity is high in western forests. Hitchcock and Cronquist (1973) list

3,280 species of flowering plants in 127 families known from the Pacific Northwest. Furthermore, more than 400 species of birds, fish, mammals, and reptiles breed or forage within mature forests in the Pacific Northwest (USDA 1988).

Photo courtesy of Essig Museum

Figure VI-5. Occurring along the coast in northern California and Oregon, the Oregon Silverspot (*Speyeria zerene hippolyta*) requires a meadow species of violet (*Viola adunca*) to complete its development.

The greatest diversity in the coniferous forests lies with arthropods. A square meter of forest floor can contain tens of thousands of individual mites, beetles, centipedes, pseudoscorpions, springtails and spiders, many of which are undescribed (Evans and Murdoch 1968, Moldenke 1990). The actual number of arthropod species in Pacific Northwest forests is difficult to estimate because of the lack of adequate surveys. Danks and Foottit (1989) estimate that about 22,000 species of insects inhabit Canada’s boreal forests. In the Pacific Northwest, over 3,800 species of arthropods are known from a single 6,400 ha late-successional forest site (Parsons et al. 1991, Lattin 1993a, Lattin personal

communication[1]). Arthropod species represent almost 85 percent of all species of organisms known to occur at that site (Asquith et al. 1990).
The richness of arthropod species in western coniferous forests suggests their tight coupling with a large number of ecological processes. Arthropods are the basic consumers in the forest where they ingest and process massive amounts of vegetation, and organic litter and debris. Studies have found up to five times more species and twice as many functional groups of arthropods in old, undisturbed forests compared to regenerating Douglas fir stands (Schowalter 1989, 1995). Yet the ecological roles of many of these species remain to be discovered.

Over the last 50 years, harvest on public forestland in the Pacific Northwest has used a dispersed-cutting system, scattering 10-40 ha clearcut units across the forest landscape (Spies et al. 1994, Wallin et al. 1994). Consequently, coniferous forests have been broken into a mosaic of young plantations, mature forests, and non-forested lands.

While the intent of dispersed-cutting management systems was to mimic natural disturbance regimes, encourage forest regeneration from adjacent stands, facilitate fire management, create early-seral habitats, and dissipate hydrologic and sediment production effects of clear cut areas (Smith 1985, Wallin et al. 1994), the result has been a loss of habitat for some species and reduced quality of habitat for others (Harris 1984, Lovejoy et al. 1984, Franklin and Forman 1987, Simberloff 1993a). Intensively managed young stands lack old-growth legacy components such as large snags, logs, and a diversity of understory vegetation that provide habitat for many species and were part of natural post-disturbance systems. Simberloff (1993b) called fragmentation of forest ecosystems the major environmental change occurring today, and one of

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the most likely to reduce biological diversity and disrupt ecological processes in the near future. Concerns about the health of forest ecosystems have made forest fragmentation a high-priority research topic (Lubchenco et al. 1991, Soulé 1991).

The changing demography and fragmentation of Pacific Northwest forests has led to concerns about the species that inhabit late successional forests. The great amount of attention given to the status and ecological needs of the northern spotted owl (*Strix occidentalis*) led to the 1993 Forest Conference in Portland, Oregon. The resulting Record of Decision (ROD) adopted an ecosystem approach to forest management in northern spotted owl habitat (USDA 1994).

The ROD provides standards and guidelines for managing natural resources within the range of the northern spotted owl from Northern California to the Canadian border, and from the coast to the Cascades Range. This decision creates a network of land allocations made of 4 components; 1) Late successional reserves to protect and enhance habitat for species associated with late successional and old-growth forests, 2) Riparian reserves designed to protect the integrity of riparian and aquatic habitats, 3) Adaptive management areas designed to support research on alternative management methods, and 4) Matrix lands that would support timber production and other resource uses.

The standards and guidelines of the ROD provide directions for managing timber harvests with the goal of protecting remnant populations of plant and animal species associated with late-successional and old-growth forests and accelerating development of old-growth conditions in younger stands. The standards and guidelines lay out an aquatics conservation strategy that includes management of upslope land use activities and maintenance of riparian buffers to minimize disturbance to riparian and aquatic ecosystems. Part of this strategy includes watershed analysis to identify key ecosystem processes, unstable slopes, and other hazards. The standards and guidelines also include various levels of survey efforts, management considerations, and habitat protection for special interest species, including an extensive list of specifically designated "Survey and Manage" species.

Many ecosystem processes and components in the southern range of the northern spotted owl are poorly understood and many Northwest Forest Plan prescriptions are based on limited empirical data (FEMAT 1993). There is an enormous amount of literature on the northern spotted owl, predating the rise in the interest in this species from the inception of the Northwest Forest Plan (NWFP). Extensive (and expensive) surveys have been conducted (and still are being made) to document the presence, number and survival possibilities of this bird. From these extensive studies have come conservation plans to protect the remaining birds and their immediate environment. The U.S. Fish and Wildlife Service now list the northern spotted owl as threatened, giving it broad protection resulting from this status. This bird species is widely, but sparsely, distributed in the southern part of its range, following the distribution patterns of its prey and the mosaic forests in which they are found. Throughout its range, the food web of the northern spotted owl is based in part on insects and other arthropods (Lattin personal communication[2]).

Photo by Pacific Analytics

Figure VII-6. Many species of wildlife can be found in the Pacific Northwest forested ecosystems

Determining how to achieve effective ecosystem management and follow the NWFP will require considerable research and innovation. One of the

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main difficulties of managing the complex ecosystems that fall under the NWFP jurisdiction is ensuring that there is sufficient useful information for managers to protect and conserve the plants and animals that inhabit this region.

Insects are the most numerous and diverse animals in forest ecosystems, both in numbers of species and in numbers of individuals (Asquith et al 1990). Their diverse functions as herbivores, predators, omnivores, pollinators, and detritivores make them a key component of virtually all food webs. Thus, it is imperative to include information about arthropod species in forest management decisions.

In spite of the dominance and importance of arthropods in forest ecosystems, other groups of organisms have been given more attention. High costs of study and low levels of knowledge resolution have been cited as primary reasons for ignoring arthropods. This simply is not true. The economic cost of studies of vertebrates and a handful of plant species is high when compared to the cost of studies of arthropods. As the attention shifts to a greater emphasis on forest ecosystem management, a much higher level of knowledge of all parts of the system including arthropods will be required. Formerly considered by many as just pests, we now know that arthropods are far more important and play more crucial roles in the functions of the forest than previously suspected.

One perspective that illustrates the function of arthropods in forest ecosystems is the trophic level approach. Arthropods interact with other organisms in three general ways, as providers, eliminators, and facilitators (Miller 1993). Arthropods act as food for other animals and as hosts to parasites. Many birds, rodents, and amphibians that occur in the Pacific Northwest feed on arthropods (Pimentel 1963, Nehls 1981). Arthropods also provide byproducts, such as honeydew, frass, and cadavers that sustain other organisms.

As eliminators, arthropods remove waste products and dead organisms from ecosystems. In this capacity, arthropods help recycle plant and animal material and the nutrients they contain, and facilitate tree and plant growth (Setälä and Huhta 1991). Food items passing through herbivorous arthropods form aggregates that increase soil nutrient and water storage capacity and reduce erosibility (Hendrix et al. 1990, Eldridge 1994, Schowalter 2000) Arthropods act as facilitators when they carry or vector other predaceous or decomposer organisms through forests. Arthropods also aid in pollination and seed dispersal, and help to maintain favorable microhabitat conditions (Miller 1993). The functions of arthropods are complex and important. Pollinators, for example, play a critical role in forest ecosystems because a vast majority of higher plants depend on insect-mediated pollination (Buchmann and Nablan 1996, Spira 2001). Rare and endangered plant species may be especially vulnerable to disrupted pollination systems (Spira 2001). Pollinators face a variety of threats, including habitat fragmentation, invasion by non-indigenous species, and direct mortality due to pesticides (Bond 1994).

From a conservation point of view, it is crucial to know how a plant population responds to a disruption in the population of its pollinator. Most plants rely on several arthropod species for pollination. Those that depend upon a small number of pollinator species are at a greater risk when habitat is altered or disturbed. Small populations and sparse floral displays may cause rare and endangered plant species to attract fewer pollinators (Spira 2001). Habitat alteration may decrease pollinator populations and lead to a lower frequency of pollinator visits to threatened plants.

As forests are fragmented, pollinator populations are likely to decline, resulting in a decrease in plant diversity and abundance and less pollination for the remaining plant taxa (Rathcke and Jules 1993). Nearly 25% of the vascular plants in the world face extinction in the next 50 years, and 22% of the vascular plants in the United States are currently of conservation concern (Raven 1987, Falk 1992). A key to slowing the rate of species loss and maintaining natural pollination systems is habitat preservation (Spira 2001). Management plans for rare plants should consider factors that influence natural pollinators. Although nearly 50% of the 728 federally listed threatened or endangered species are plants, few pollinators are even considered for listing (U.S. Fish and Wildlife Service 1992, Spira 2001).

Pesticides applied to crops and trees can cause high mortality of non-target organisms (Johansen 1977, Miller 1990). Native bees foraging on crops can passively collect insecticide dust on their bodies or in pollen that can cause significant larval and adult mortality (Johansen 1977). Solitary bees are particularly vulnerable to pesticides because their low fecundity slows population recovery (Tepedino 1979). Non-target indigenous moth populations in Pacific Northwest forests decline after *Bacillus thuringiensis* Berliner var. *kurstaki* (Btk) is applied to control pest species (Miller 1990). These moths may be the only pollinators of some native plant species.

Many exotic species of arthropods have been introduced into forest habitats. The most widespread is the honeybee (*Apis mellifera* L.). Although widely considered beneficial, honeybees can displace native pollinators and disrupt native-plant pollination systems. Studies have shown that while honeybees can remove up to 90% of the floral resources in an area, they are often poor pollinators of wild plants (O'Toole 1993). The decrease in food supply may also be correlated with a decrease in the number of native pollinator species (Ginsburg 1983, Pyke and Balzer 1985, Roubik et al. 1986, Paton 1993, Buchmann 1996). The disruption of natural pollination systems reduces seed production and may threaten the long-term survival of some plant species (Paton 1993, Spira 2001)

Exotic ants may also disrupt pollination systems. In Texas, fire ants (*Solenopsis* spp.) reduced diversity and abundance of native arthropods (Porter and Savignano 1990). It is possible that this and other ant species will prey on native bee larvae and caterpillars and reduce the abundance and diversity of indigenous pollinators.

The recent infestation of European honeybees with predatory mites and subsequent decline in pollination services has lead to a greater awareness of conserving natural pollinators. In natural systems, pollinators play a key role, and keeping natural pollination systems functioning is an important step towards maintaining healthy ecosystems.

Herbivores are a critical component of forest ecosystems (Miller 1993). Plant intra- and inter-specific competition may be influenced by changing levels of herbivory resulting in changes the floral composition and microhabitat conditions in the forest (McEvoy et al. 1991). Furthermore, because herbivores are important food sources for other organisms, eliminating this group will inevitably reduce the food supply of many birds, rodents, spiders, and amphibians.

To summarize, there are several reasons for concern about the conservation of understory and canopy gap herbivorous arthropods in late-successional forests. First and foremost, the insects and their near relatives represent at least 85% of the biological diversity in these forests. Second, these arthropods serve key ecological functions, aiding in nutrient recycling, determining forest structure, providing pollinator services, and facilitating energy transfer within food webs. Third, endemicity is high in the region and some species may be found only in undisturbed forests. Fourth, a number of species are flightless and have limited dispersal capabilities, and may therefore be highly susceptible to changes in the conditions of their habitat. Fifth, the effects of disturbance like fire, drought, thinning and other management activities on these species are relatively unknown. Finally, recent work in the region has shown that there are a number of species that have not been described and are new to science (Lattin and Moldenke 1992).

One of the mitigation measures of the NWFP has been the Survey and Manage Standards and Guidelines for species that occur within the range of the northern spotted owl. The goal of Survey and Manage is to provide additional protection for species that, because of rarity, endemism, or lack of information, might not be adequately protected by the broad-scale ecosystem approach outlined in the NWFP. For arthropods, the objective is not to specifically protect any one species, but to ensure that their ecological functions persist.

To achieve the goal of Survey and Management for arthropod species in the NWFP it will be necessary to acquire more information on the community composition, abundance, and distribution of taxa, and to determine appropriate levels of protection for ecosystem processes and functions (U.S.D.A. 2000). Strategic surveys will be used to accumulate necessary information about arthropods. These strategic surveys will take a predominantly research-based experimental approach to examine the effects of disturbance on arthropod diversity and function (U.S.D.A. 2000). The key to long-term success of Survey and Manage actions is the evaluation of the latest information about taxa, and identifying gaps in that information. This ongoing process will ensure that Survey and Management standards and guidelines are applied efficiently to all taxa.

Effective forest management requires good scientific information about the systems of interest. Much information has been accumulated on a variety of forest species and the impacts of disturbance on these species. As mentioned previously, much of the past attention given to arthropods was largely focused on pest species, but this is changing. More information is needed on native arthropod species, their function in forest ecosystems, and the impacts of forest management on these taxa. Because Pacific Northwest forests contain thousands of arthropod species, it is difficult to prioritize what to study and where to begin. Managers need assistance in determining what information already exists, where the information gaps are, and what priority should be given to gathering the necessary information.

The first step in determining the gaps in information is to review the existing literature. In Tasks 1 through 3 above we gathered and classified bibliographic citations for literature pertinent to understory and canopy gap herbivorous arthropods in the southern range of the northern spotted owl. Analysis of these citations will help uncover some information gaps.

We grouped the information needs for implementing the NWFP into two broad categories: Taxa and Habitats. The information gaps at various taxonomic levels will be explored in the Taxa category. Under the Habitats category, information gaps about riparian reserves, late-successional forests, and other special habitats are discussed. The information needs pertaining to understory and canopy gap herbivores for each category are reviewed below and gaps in information as they appear in the bibliographic database are identified.