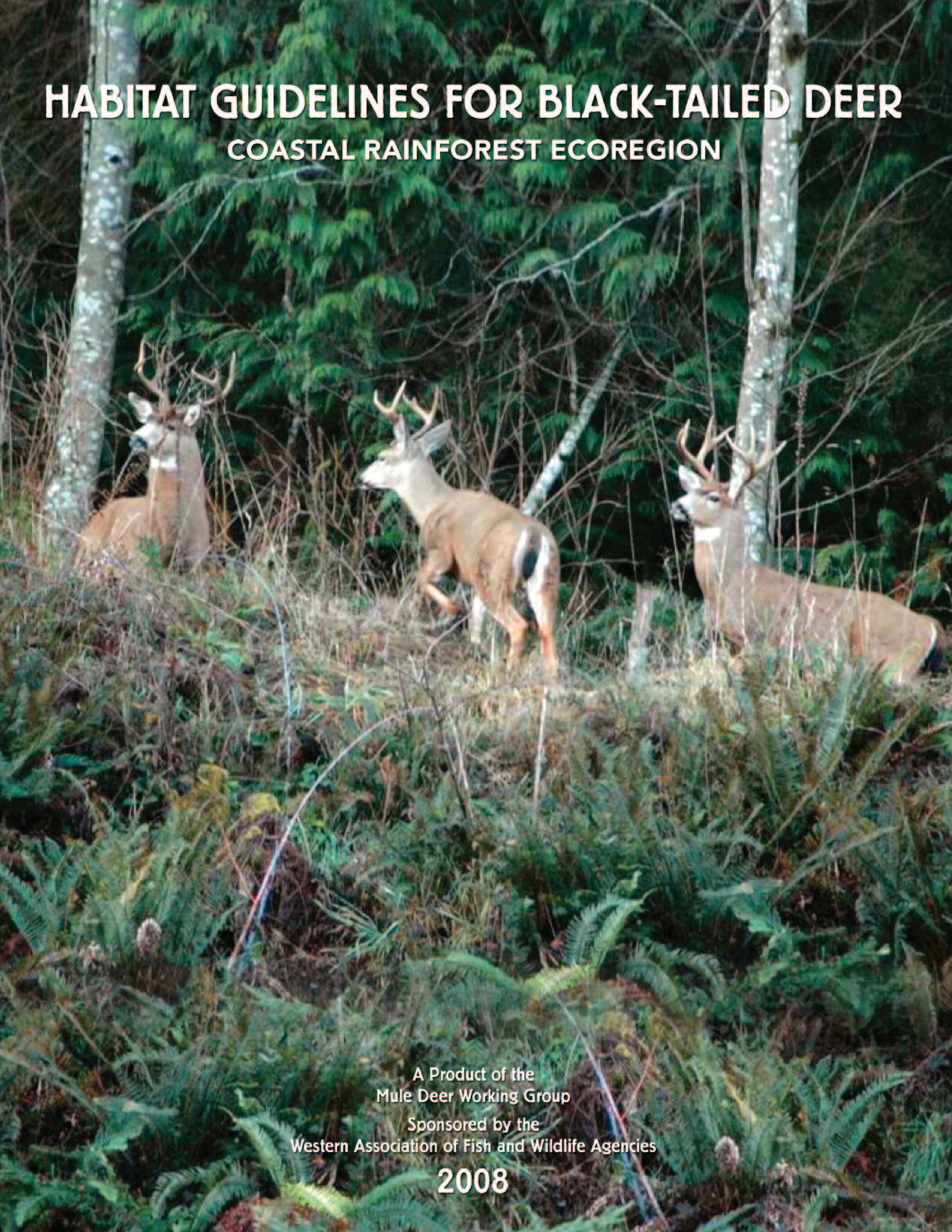
HABITAT GUIDELINES FOR BLACK-TAILED DEER

COASTAL RAINFOREST ECOREGION



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INTRODUCTION

Columbian black-tailed deer (*Odocoileus hemionus columbianus)* and Sitka black-tailed deer (O. h. sitkensis) are icons of the Pacific Northwest (Fig. 1). Because of their popularity and wide distribution, deer are one of the most economically and socially important big game animals in western North America. A survey of outdoor activities by the U.S. Fish and Wildlife Service (USFWS 2001) showed that over 4 million people hunted in the 18 western states. In 2001 alone, those hunters were afield for almost 50 million days and spent over $7 billion. Each hunter spent an average of $1,581 in local communities across the West on lodging, gas, and hunting-related equipment.

In 2006, hunters in Alaska, Washington, Oregon, and California numbered 780,000 participants and accounted for $1.57 billion in expenditures (US Fish and Wildlife Service 2007). Many of those hunters pursued black-tailed deer. Blacktail harvest is roughly 12,000 in Alaska (Straugh and Rice 2002, Alaska Dept. of Fish and Game 2004); 3,000 in British Columbia (British Columbia Fish and Wildlife Branch 2003); 14,000 in Washington (Washington Dept. Fish and Wildlife 2006a); 20,000 in Oregon (Oregon Dept. Fish and Wildlife 2007); and 12,000 in California (California Fish and Game, Deer Program 2007). Both Columbian black-tailed deer and Sitka black-tailed deer are also an important subsistence and cultural resource for coastal native peoples throughout the ecoregion. Because black-tailed deer are closely tied to the history, development, and future of the Pacific Northwest, this species has become one of the true barometers of environmental conditions in western North America.

Black-tailed deer and mule deer (*O. hemionus*) are distributed throughout western North America from the coastal islands of Alaska, down the west coast to southern Baja Mexico and from the northern border of the Mexican state of Zacatecas, up through the Great Plains to the Canadian provinces of Saskatchewan, Alberta, British Columbia, and the southern Yukon Territory. With this wide latitudinal and geographic range comes a great diversity of different climatic regimes and vegetation associations. Within this range of habitats mule deer have developed an incredibly diverse array of behavioral and ecological adaptations that have allowed the species to succeed amid such diversity.

These diverse environmental and climatic conditions result in a myriad of dynamic relationships between black-tailed deer and their habitat. Within this geographic distribution, however, areas can be grouped together into "ecoregions" within which deer populations share certain similarities regarding the issues and challenges that land managers must face. Within these guidelines we have designated 7 separate ecoregions (deVos et al. 2003): 1) California Woodland Chaparral, 2) Colorado Plateau Shrubland and Forest, 3) Southwest Deserts, 4) Great Plains, 5) Intermountain West, 6) Northern Forest, and 7) Coastal Rainforest. This document addresses the Coastal Rainforest Ecoregion.

The diversity among the aforementioned ecoregions presents different challenges to deer managers and guidelines for managing habitat must address these differences (Heffelfinger et al. 2003). Forest management practices can have an enormous impact on black-tailed deer populations. In many ecoregions, like the Coastal Rainforest, water availability is not a major limiting habitat factor. However, in more arid ecoregions (Southwest Desert), water can be important. Another factor affecting deer population fluctuations in some ecoregions is severe winterkill (Intermountain West, Northern Forest, Colorado Plateau). In other ecoregions, drought and domestic livestock grazing may have greater impacts on deer populations.

An intact forest canopy is important in some northern areas of the Coastal Rainforest Ecoregion. In that region, the forest canopy intercepts snow, which in turn impacts black-tailed deer survival. Natural processes that create openings (windthrow) or increase available forage (litterfall) are important ecological events for black-tailed deer, especially in the north. In contrast, many forested areas in the southern portion of the ecoregion are lacking the natural fire regime that once opened the canopy and provided for growth of important deer browse plants. Throughout the Coastal Rainforest Ecoregion, silvicultural practices that include chemically treating understory plants on commercial timberlands can also drastically reduce or eliminate high quality forage for black-tailed deer. The habitat and climate diversity within the Coastal Rainforest Ecoregion require site-specific prescriptions when managing for improved black-tailed deer habitat.

Across the 7 different mule deer/black-tailed deer ecoregions, the core components of deer habitat are consistent: water, food, and cover. An important aspect of good black-tailed deer habitat is the juxtaposition of these components; they must be interspersed in such a way that a population can derive necessary nutrition and cover to survive and reproduce. Over time we have learned much about deer foods and cover, but more remains to be learned. For example, we have learned that "cover" is complex and provides an array of habitat values. Weather effects can be ameliorated by vegetation and topography under highly variable weather conditions. Cover can also provide security, which affects survival. Available forage does not always equate to adequate forage. Adequate food supplies for deer must be abundant but also of high enough quality to meet the nutritional requirements of survival, reproduction, and recruitment. Black-tailed deer have basic life history requirements that weave a common thread throughout many issues facing deer management.

Black-tailed deer are primarily browsers, with a majority of their diet comprised of leaves, twigs, and buds of woody shrubs. But deer also eat lichens, some grasses, and seasonal forbs. Deer digestive tracts differ from cattle (*Bos taurus*) and elk (*Cervus elaphus*) in that they have a smaller rumen in relation to their body size so they must be more selective in their feeding. Instead of eating large quantities of low quality forage like grass, deer must select the most nutritious plants and parts of plants. Because of this, deer have more specific forage requirements than larger ruminants.

The presence and condition of the woody-browse component is an underlying commonality found throughout different ecoregions and is important to many factors affecting black-tailed deer populations. Shrubs are typically abundant in early successional habitats; that is, those recently disturbed and going through the natural processes of maturing to a climax state. This means disturbance is a key element to maintaining high quality deer habitat. In the past, fire cycles, wind-throw, landslides, and floods created disturbance in old growth forest that benefited black-tailed deer possibly allowing for more deer than seen under present conditions. More recently, human disturbance such as logging resulted in higher deer abundance than we see today, as long as the deer habitat was not completely eliminated in the process. For black-tailed deer, many of the closed-canopy, second-growth forests that are available today resulted from clear-cut logging that took place in the first seven decades of the 20th century. Given this context, although weather patterns, especially precipitation, drive deer populations in the short-term, only landscape-scale habitat improvement will make long-term gains in deer abundance in many areas of the Costal Rainforest Ecoregion.

Black-tailed deer can be characterized as a "K-selected" species (McCullough 1979). In theory K-selected populations will increase until the location's biological carrying capacity is met. If deer populations remain at or beyond carrying capacity they begin to negatively impact the habitat. The wildlife manager must also remember that in addition to impacts on habitat by deer, other long-term impacts on the ecosystem like vegetation succession and drought conditions can substantially lower the carrying capacity for deer. Even if habitat conditions improve, the overall capacity of the habitat to support deer may be lower

Figure 1. Mid-summer black-tailed deer buck with nearly full-grown velvet antlers in the Olympic Mountains of Washington (Photo by Scott McCorquodale/WDFW)

than it might have been 20 or 50 years earlier. This may well be the situation in many deer habitats in the west, and if so, the manager must be cognizant of this factor.

Because of the vast blocks of public land and private industrial timberland in western North America, the choice to manage habitat to benefit deer, throughout most of the geographic range of black-tailed deer, lies primarily with federal, state, and provincial land management agencies and private timber companies. Black-tailed deer habitat is facing unprecedented threats from a wide variety of human-related developments. If deer habitat is to be conserved, it is imperative that state, federal, and provincial agencies and private conservation organizations are aware of key habitat needs of black-tailed deer and participate fully in habitat management. Decades of habitat protection and enhancement under the principles of game management benefited countless other non-game species. A shift away from single-species management toward an ecosystem approach to the management of landscapes has been positive overall; however, some economically and socially important species such as black-tailed deer, are now de-emphasized or neglected in land use decisions. Deer, including black-tailed deer, have been the central pillar of the North American conservation paradigm and thus are directly responsible for supporting a wide variety of conservation activities that North Americans value.

Habitat conservation will mean active habitat manipulation or conscious management of other land uses. An obvious question to habitat managers will be–at what scale do I apply such habitat manipulations or treatments? This is a legitimate question and obviously a difficult question to answer. Treated areas must be sufficiently large to produce a treatment effect. There is no one “cookbook” rule for scale of treatment. However, the manager should realize the effect of habitat manipulation applied properly is larger than the actual number of acres treated because deer are mobile and will move in and out of the treatments and thus a larger area of habitat will benefit. In general, a number of smaller treatments in a mosaic or patchy pattern are more beneficial than 1 large treatment. Determining the appropriate scale for a proposed treatment should be a primary concern of the manager. Treatments to improve deer habitat should be planned to work as parts of an overall strategy. For example, treatments should begin in an area where the benefit will be greatest and then subsequent habitat improvement activities can be linked to this core area.

The status of black-tailed deer populations now and in the future relies on the condition of deer habitat. Habitat requirements of black-tailed deer must be incorporated into land management plans so improvements to deer habitat can be made on a landscape scale as the rule rather than the exception. The North American Mule Deer Conservation Plan (NAMDCP, Mule Deer Working Group 2004) provides a broad framework for managing black-tailed and mule deer and their habitat. These habitat management guidelines stem from that plan and provide specific actions for its implementation. The photographs and guidelines herein are intended to communicate important components of black-tailed deer habitat across the range of the species and suggest management strategies. This will enable public and private land managers to execute appropriate and effective decisions to maintain and enhance deer habitat.

Description

The Western States Mule Deer Working Group (Heffelfinger et al. 2003) defined the Coastal Rainforest Ecoregion as that part of coastal North America occupied by Columbian black-tailed deer and Sitka black-tailed deer. As such, it includes northern California from San Francisco Bay through Oregon and Washington west of the crest of the Cascade Range north through western British Columbia across the southwest tip of the Yukon Territory and into southeast, coastal Alaska and its islands as far north as Prince William Sound and as far west as Kodiak Island. Spanning latitudes from approximately 38°N to 60°N, this ecoregion provides a tremendous range of habitat diversity along this 2,100-mile strip of coastal lowlands, foothills, mountains, and forest (Fig. 2).

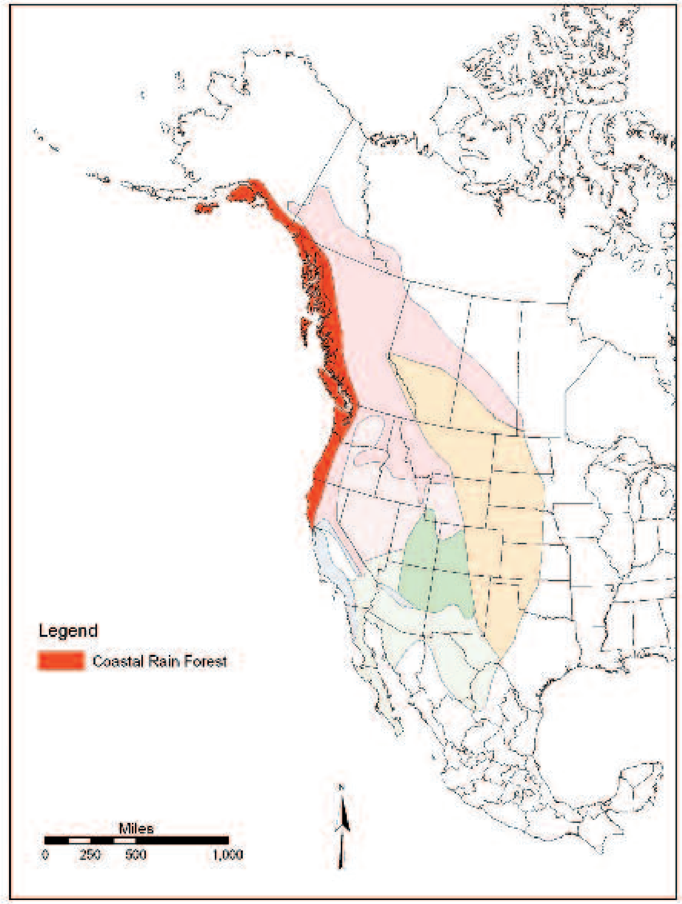

Figure 2. The Coastal Rainforest Ecoregion.

Johnson and O'Neil (2001) noted 19 habitat types just in Oregon and Washington associated with black-tailed deer. These habitat types ranged in elevation and structure from coastal dunes and beaches to Westside grasslands, Westside lowland conifer-hardwood forest, oak and dry Douglas-fir (*Pseudotsuga menziesii*) forest, true temperate conifer rain forest, and alpine grasslands.

The climate is cool with a strong maritime influence. Precipitation ranges from 30 to 200 inches annually. In general, soils are acidic and often depleted of nitrogen and other essential nutrients as a result of leaching from high precipitation levels.

The ecoregion is greatly impacted by human disturbance, more so in California, Oregon, and Washington than in British Columbia and Alaska. Increasing suburban and rural development and the infrastructure that supports it is steadily reducing black-tailed deer habitat. Black-tailed deer seem to be more adaptable to human encroachment than mule deer, but this adaptability often leads to human-wildlife conflicts.

Private industrial forests are intensively managed for commercial wood products (Fig. 3). Public forests have been less intensively managed for timber production in the southern portion of the ecoregion since the late 1970s when retention of old growth forest and late successional reserves (LSRs) were established as management objectives for state, and federal forest managers (Fig. 4). Timber production is a higher priority for public forest managers in Alaska and British Columbia. Smaller family woodlots and farms have traditionally been somewhat deer-friendly, but they too are disappearing in areas of increasing human population due to economic incentives associated with housing development.

Coastal forests of northern California, Oregon, and Washington are typically dominated by Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*) (Franklin and Dyrness 1973). These forests also often support stands of Douglas-fir, grand fir (*Abies grandis*), and Pacific silver fir (*Abies amabilis*). Localized areas dominated by coast redwood (*Sequoia sempervirens*) are also found in coastal Oregon and northern California. Deciduous trees such as vine maple (*Acer circinatum*), big-leaf maple (*Acer macrophyllum*), and red alder (*Alnus rubra*), and shrubs such as salmonberry (*Rubus spectabilis*), devil's club (*Oplopanax horridum*), and Pacific rhododendron (*Rhododendron macrophyllum*) are common understory components. Red alder is a particularly important early sere dominant following disturbance. Common understory components include huckleberry (*Vaccinium* spp.), sword fern (*Polystichum munitum*), salal (*Gaultheria shallon*), Oregon oxalis (*Oxalis oregana*), lady-fern (*Athyrium filix-femina*), and violets (*Viola* spp.). For a complete treatise on site-specific variability, habitat type descriptions, and habitat zones we refer the reader to Franklin and Dryness (1973) and Chappell et al. (2001).

Small-scale natural disturbances (windthrow, landslide, flood) and larger-scale disturbances resulting from forest management and wildfire are instrumental in creating and

Figure 3. Intensively managed second-growth forest on private industrial timberland of Western Washington (Photo by Scott McCorquodale/WDFW).

Figure 4. Open, park-like subalpine forest habitat in the Washington Cascade Range (Photo by Scott McCorquodale/WDFW).

maintaining black-tailed deer habitat in coniferous-forest-dominated habitat mosaics typical of the Coastal Rainforest Ecoregion.

Coastal forests of Alaska and British Columbia support a lower diversity of overstory species than forests of coastal Washington, Oregon, and California (Harris and Farr 1979). Productive old-growth forests in most of Southeast Alaska and coastal British Columbia consist of mature uneven-aged stands dominated by western hemlock and Sitka spruce (Alaback 1982). Wetter and less productive stands include western red cedar in the southern portion of the region and Alaska yellow cedar (*Chamaecyparis nootkatensis*) further north. Understory vegetation important to deer includes huckleberry and blueberry shrubs, half-shrubs such as bunchberry (*Cornus canadensis*), and herbaceous forbs such as five-leaved bramble (R*ubus pedatus*), spleenwort-leaved goldthread (*Coptis asplenifolia*), and foamflower (*Tiarella trifoliata*). Under shady conditions, most of these forage species are evergreen during winter.

The patterns of forest succession are well described by Alaback (1982, 1984) and Kramer et al. (2001). The predominant natural process is a "gap-phase" dynamic wherein small-scale blow down occurs, creating small gaps in the forest canopy. These gaps allow sunlight to reach the soil and detritus layer and understory plants, and the fallen decaying trees provide a rich substrate that enhances seedling development. The process occurs at small scales (<1 ha), but with high frequency, creating the fine-grained, uneven-aged forest structure characteristic of old-growth stands. Alternatively, large-scale windstorm events occur

that blow over many trees, creating large gaps, occasionally >100 ha, in contiguous forest stands. These events are rare, occurring only once or twice in a century and tend only to affect stands exposed to prevailing winds. Although initial successional stages following large windthrow events provide abundant forage for deer, older stages tend to produce even-aged or discrete cohort forest stands. In such stands, forest canopies are thick, with few gaps and little penetrating sunlight. Consequently, those stands commonly have depauperate understory vegetation (Alaback 1982).

Ecoregion-specific deer ecology

Distribution
Coastal areas of northern California, Oregon, Washington, and southern British Columbia are inhabited by Columbian blacktails, whereas coastal areas of northern British Columbia and southeastern Alaska support the Sitka blacktail subspecies (Wallmo 1981). Sitka blacktails also inhabit islands from Calvert Island, British Columbia in the south to Icy Strait, Alaska in the north and were introduced to the Kodiak Archipelago (Smith 1979), islands of Prince William Sound (Reynolds 1979), Afognak and Yakutat in Alaska, and the Queen Charlotte (Haida Gwaii) Islands (Golumbia 2000) of British Columbia. These 2 subspecies are the smallest of the mule deer subspecies (Bandy 1970, Anderson 1981). Sitka black-tailed deer range represents the northern and western extent of mule deer distribution.

Climate
Coastal blacktails inhabit an environment that is much wetter than those occupied by other mule and black-tailed deer populations of western North America. In coastal rainforests of California, Oregon, and Washington, annual precipitation of 50-80 inches is common. British Columbia and southeastern Alaska's Sitka blacktail habitats may receive the moisture equivalent of 200 inches of rainfall each year. This wet climate supports high primary production, but at higher latitudes of black-tailed deer range, reduced solar radiation constrains the effective growing season, despite high precipitation (Harris and Farr 1979).

On higher latitude black-tailed deer ranges, such as northern British Columbia and southeastern Alaska, winter severity is considerably greater than that typical of lowland Washington, Oregon, and California coastal deer habitats. Higher elevations of more northerly deer ranges may receive considerable winter snowfall and sustain persistent deep snow (Klein 1979, Hanley et al. 1989). Such conditions may dramatically impact deer energetics, and deer use is typically precluded by deep snow (Klein 1979, Parker et al. 1996, 1999). Under conditions where winter precipitation is principally snow, old-growth stands serve as essential elements of quality winter habitat mosaics for coastal blacktails (Wallmo and Schoen 1980, Longhurst and Robinette 1981, Fagen 1988, Hanley et al. 1989). These older stands offer a high degree of canopy closure that intercepts the frequent snowfalls (Hanley and Rose 1987, Kirchhoff and Schoen 1987). Despite the generalization that canopy closure limits understory development, old growth stands are structurally heterogeneous and small canopy gaps support important forage patches exploited by Sitka blacktails (Klein 1979, Kirchhoff et al. 1983, Hanley et al 1989, Schoen and Kirchoff 1990, Parker et al. 1999).

Plant Communities
Climax plant communities in the Coastal Rainforest Ecoregion are typically dominated by closed- and coarse-canopy coniferous forest (Franklin and Dyrness 1973, Schoen and Wallmo 1979). Ecosystem dynamics, influenced strongly by a maritime climate, have given temperate rainforests considerable economic value. This is particularly so for fast-growing, high volume, lower elevation stands. Intensive logging has changed historical disturbance regimes of temperate rainforests from one of high frequency and low magnitude to low frequency and high magnitude disturbances (Hanley et al. 1989), with variable implications for black-tailed deer habitat and populations across the ecoregion.

Old-growth conifer forests were, and sometimes still are, a prominent feature of coastal black-tailed deer range and have played a dominant role in conceptual models of deer habitat quality (Brown 1961, Klein 1979, Taber and Hanley 1979, Hanley et al. 1989). The typical generalization regarding overstory-understory dynamics suggests ungulate forage is limited in closed canopy habitats (Taber and Hanley 1979). Early seral stages on forested landscapes usually produce higher shrub and forb biomass than older stands and are commonly characterized as better foraging settings for large herbivores such as deer. Such a conceptual model has been supported by observations of strongly cyclic black-tailed deer populations in western Oregon and Washington (Brown 1961; Crouch 1964, 1981a). In these classical examples, extensive logging (Brown 1961) and large-scale wildfires (Hines 1975) created an abundance of early seral stage forest, which increased forage production, and subsequently, deer nutrition, growth, reproductive success, and density. Subsequent forest succession to dense second-growth stands was associated with declining deer populations.

Movement
Coastal black-tailed deer populations may be exclusively migratory or resident, depending on local environments (McCorquodale 1999b). On lower elevation ranges where climate and topography combine to provide large areas of

suitable year-round habitat, many coastal blacktails may be lowland residents (Brown 1961). Where deer summer range occurs at elevations or latitudes that are not snow-free during winter, most coastal black-tails migrate to lower elevation winter ranges (McCullough 1964, Klein 1979, Schoen and Kirchhoff 1985). Some island deer may make changes in elevation between summer and winter ranges that are separated by small distances (Bunnell 1979). Many coastal blacktail populations consist of both resident and migratory segments within the same total population (Loft et al. 1984, McNay and Voller 1995).

Figure 5. Mature black-tailed deer doe in summer pelage, Olympic Mountains, Washington (Photo by Scott McCorquodale/WDFW).

Figure 6. Black-tailed deer fawn (Photo by Scott McCorquodale/WDFW).

Survival Strategies

Black-tailed deer are selective foragers, reflecting energetic constraints imposed by relatively high metabolic demands and passage rate requirements (Hanley 1984a, Leslie and Starkey 1985, Spalinger et al. 1988). Coastal blacktails are habitat generalists that exploit a variety of vegetation types and forest seral stages (Miller 1968, Taber and Hanley 1979, Wallmo and Schoen 1980, 1981, Yeo and Peek 1992). Some research has demonstrated a preference for ecotone habitats by Columbian black-tailed deer (Hanley 1983, Loft and Menke 1984); Sitka blacktails have affinity for forest edge habitats in some settings (Chang et al. 1995), but not others (Kirchhoff et al. 1983), depending on local conditions and the scale of habitat patchiness (Kremsater and Bunnell 1992). Traditionally, black-tailed deer diets have been characterized as dominated by browse during most seasons (Brown 1961; Crouch 1979, 1981a; Leslie et al. 1984). However, analytic methods employed have often underestimated the dietary contribution of highly digestible forage, such as forbs (Hanley et al. 1989, Parker et al. 1999), which may be seasonally important to black-tailed deer. Conversely less digestible forage with low nutritional value like salal (Perez 2006), may be overestimated. In addition low evergreen shrubs, trailing blackberry, and lichens can also be important forage for deer depending on their seasonal

availability. The generality that deer are only browsers is fraught with exceptions depending on the season and location.

Foraging energetics of black-tailed deer are affected by the nutritional quality of forage consumed, not just biomass dynamics. Although forage production may be enhanced by forest overstory removal, it has been demonstrated that the nutritional value of forage in clearcuts may often be reduced relative to forage quality beneath the canopy (Billings and Wheeler 1979, Hanley et al. 1989, Happe et al. 1990). Forage quality may be higher in shaded habitats than clearcuts due to greater availability of succulent leaves, higher crude protein, and lower tannin astringency, which affects protein digestion. Shrubs and forbs growing in shade often retain leaves throughout much of the winter, whereas leaves of plants growing in full sunlight usually senesce in early autumn.

Both protein and energy availability may critically limit coastal deer habitat quality at various seasons. In Alaska, digestible protein during summer appears to be potentially limiting to deer carrying capacity and productivity in clearcuts, but less so in shaded habitats (Hanley et al. 1989). Digestible energy may be limiting in forage within closed canopy stands during summer and appears to be limiting in all habitats during winter (Parker et al. 1999). In one study of Sitka blacktails, energy intake was 2.5 times greater than expenditure during summer and 0.7 times less than expenditure in winter, and energy intake was 4-fold greater in summer than winter (Parker et al. 1996). Winter nutritional limitations to coastal black-tailed deer associated with seasonal forage quality declines are compounded by reductions of winter forage availability (Hanley et al. 1989) and increases in energy expenditures (Parker et al. 1999) due to snowfall. Survival and successful reproduction appears to be predicated on the accumulation of adequate energy reserves before winter's onset (Parker et al. 1999), implicating the importance of quality summer habitat in the annual strategy of coastal black-tailed deer (Parker et al. 1996).

Nutrition is known to strongly affect reproductive performance in deer (Short 1981, Parker et al. 1993). Recruitment success in black-tailed deer has been positively correlated with forage availability and negatively with deer density, both factors mediating a nutritional effect (Gilbert and Raedeke 2004). Reproductive success in black-tailed deer reflects the considerable nutritional constraints imposed by the interactions of soils, photosynthetic dynamics, climate, and forest succession characteristic of coastal rainforest habitats. Further evidence of this was demonstrated by the results of experimental fertilization of managed forests in western Washington. Sewage-sludge fertilizer applications supplemented soil nitrogen and substantially raised both crude protein content of black-tailed deer forage and reproductive success in treatment areas compared to unfertilized areas (Anderson 1983).

Reproduction

Black-tailed deer may breed from mid-October to early December, but conceptions usually peak in mid-November (Brown 1961). Gestation length is approximately 203 days, similar to other mule deer subspecies (Brown 1961, Thomas 1983, see also Anderson 1981). Female black-tailed deer rarely breed as fawns in the wild (Brown 1961, Connolly 1981, Thomas 1983). However, experience with hand-raised blacktails has demonstrated that fawns are capable of breeding in their first fall if nutrition is adequate (Mueller and Sadleir 1993). Body mass appears to be the primary determinant defining the age of first reproduction. In general, black-tailed deer appear to be less fecund than the larger mule deer subspecies (Brown 1961, Anderson 1981, Connolly 1981, Thomas 1983), as reflected by slower attainment of maximum fertility and smaller litter sizes. There is evidence that black-tailed deer rarely conceive during their first ovulation of the season, but frequently during their second (Thomas and McTaggart-Cowan 1975). There appear to be physiologic mechanisms that enhance the synchrony of the second ovulation across individual females (Fig. 5).

Single blacktail fawns typically outweigh fawns of the same gender within 2-fawn litters (Mueller and Sadleir 1980). Male fawns are usually larger than female fawns from similarly sized litters. Neonatal sex ratios appear to be slightly male-biased. Smaller fawns at birth often demonstrate compensatory growth, gaining weight at a faster rate than their heavier-born counterparts (Fig. 6, Mueller and Sadleir 1980).

MAJOR IMPACTS TO BLACK-TAILED DEER HABITAT IN THE COASTAL RAINFOREST

1. Forest succession and forest disturbance regimes have been altered
Mule deer habitat is completely lost or fragmented due to expansion of urban/suburban areas and other associated activities such as road building, vineyard establishment and motorized recreation. Related human activity can also displace mule deer from otherwise suitable habitat.

2. Forage quality is inadequate
Available browse is sub-par due to public and private forest management practices including understory vegetation control, fire suppression, commercial forest product objectives, and old-growth or late successional forest objectives.

3. Plant species composition and structure have been modified.

- Both increases and decreases in conifers and woody shrubs can decrease black-tailed deer habitat quality, depending on the age, species diversity, and spacing of plants. Decreases in conifers and woody shrubs may result in less security cover, thermal cover, and available winter browse. Increasing woody cover can decrease the amount and diversity of forage species.
- In some cases noxious or invasive plants have proliferated in native plant communities, reducing species richness.
- In other cases, less desirable species have become more abundant at the expense of more desirable plant species that are used by deer.

In general, complexity in both habitat structure and plant species composition will benefit deer.

4. Loss of usable habitat due to human encroachment and associated activities.
Black-tailed deer habitat is lost when urban and suburban areas expand and other associated infrastructure, such as roads, are constructed. Related human disturbance can also displace deer from otherwise suitable habitat.

Photo by Mike Middleton, Wildlife Biologist / Muckleshoot Indian Tribe

Forest Management

Background

Forest management activities have had a dramatic, ecosystem-altering effect on the habitats of Columbian and Sitka black-tailed deer within the Coastal Rainforest Ecoregion since European settlement (Brown and Curtis 1985, Williams 1989, Bolsinger and Waddell 1993, Chappell and Kagan 2001, Washington Department of Fish and Wildlife [WDFW] 2006). Timber harvest, historically dominated by clear-cutting, has been extensive throughout the ecoregion (Fig. 7, Beschta 2000). For example, as little as 3% of the historic, coastal old-growth forest within Washington and Oregon remains (Figs. 8, 9, 10, WDFW 2006). Spies et al. (1994) documented that closed-canopy coniferous forest cover in a western Oregon managed forest landscape declined from 71% to 58% due to logging between 1972 and 1988. By 1988, most large (>12,500 acres) patches of contiguous forest were restricted to public lands designated as reserve areas (e.g., federal wilderness or research natural areas, Spies et al. 1994). Similarly, Bolsinger and Waddell (1993) reported California coastal old-growth forest acreage as a small fraction of historic levels. Harvest of old-growth forests has been less complete in the British Columbian and Alaskan portions of coastal black-tailed deer range, but has affected a considerable acreage and continues on an ongoing basis (Longhurst and Robinette 1981, Nyberg et al. 1989, Hanley et al. 2005, Moola et al. 2004). In the very recent past, declines in rates of timber harvest on public land forests in the United States have occurred over large areas of the ecoregion to accommodate conservation of older forest conditions and associated species, with implications for habitat condition and trend for black-tailed deer. That decline has not been as dramatic in British Columbia.

The Coastal Rainforest Ecoregion is dominated by stands of very large coniferous trees including Sitka spruce, western red cedar, western hemlock, Douglas-fir, and redwood. These stands typically contain small but ubiquitous openings of one to three trees in size, as well as large but usually limited and often transitory forest openings and areas of early successional habitats. These openings are commonly produced by fire, windstorms, floods, landslides, and forest pathogens (Greene et al. 1992, Lertzman et al. 1996, Sinton et al. 2000, Snyder 2006), or are associated with naturally occurring openings, such as alpine areas, meadows, and stream courses. These breaks in the otherwise forested landscape occur in an irregular pattern over the landscape. In contrast, timber harvest and subsequent forest management activities have converted vast portions of this habitat into early and mid-successional forest (Nyberg et al. 1989). Although urbanization and conversion to agriculture continue to alter these forested habitats, timber harvest remains the single most dramatic influence on the habitat of coastal black-tailed deer.

Figure 7. Western Washington mosaic of clear-cuts and closed canopy forest habitats on Industrial timberland (Photo by Scott McCorquodale/WDFW).

Figure 8. Intensive timber management, such as characterized by this western Washington landscape, creates dramatic habitat edges. The large size of this clear-cut and the high road density created, likely limits the value to black-tailed deer despite the early successional habitat that has been created (Photo by Scott McCorquodale/WDFW).

Figure 9. Seed trees left after clear-cut (Photo by Scott McCorquodale/WDFW).

Forest succession patterns following disturbance control the dynamics of deer habitat attributes and quality through time. Disturbances such as logging, fire, or windthrow initiate secondary successional pathways from residual, post-disturbance vegetation. Much of the plant species composition characteristic of mature forests of the ecoregion is retained in post-disturbance seral stages (Dyrness 1973; Franklin and Dyrness 1973; Halpern 1989, 1995). However, the proportional representation and biomass of these species is dynamic across the complete sere (Halpern 1995). Invaders, including both native and exotic species, often colonize post-disturbance stands, typically where soil disturbance has occurred, on more xeric sites, or where abundant seed sources are present (Dyrness 1973, Halpern 1989, Halpern et al. 1999). In western Oregon and Washington, early seral stages commonly develop dense shrub communities dominated by salmonberry, huckleberry, salal, and vine maple; all highly-utilized black-tailed deer foods. A common alternative succession pathway on mesic to wet sites is characterized by a near complete dominance of the understory by dense stands of red alder (Franklin and Dyrness 1973). Fast-growing, red alder often overtops residual conifer regeneration, yielding a persistent alder forest. Conifers may eventually replace alder as the overstory dominant, but this occurs slowly. Red alder is a nitrogen-fixer, so its presence in the sere is thought to have important soil-building properties (Franklin and Dyrness 1973). Secondary succession in the ecoregion has been shown to have both a deterministic component determined by the pre-existing plant community, and a stochastic component reflecting the site's disturbance history (Halpern 1989).

Forest succession affects not only stand attributes such as species composition, understory diversity, and principal stand dominants, but also relative biomass across functional plant classes. This is largely responsible for variation in deer foraging habitat quality through time. Typically, understory biomass increases with the reinitiation of secondary successional seres (Brown 1961, Taber and Hanley 1979). Thus, disturbances such as logging, fire, and windthrow can stimulate forage production. In the absence of management, succession towards closed canopy forest leads to decreases in overall understory biomass, until gap-phase dynamics associated with old growth stands yields patchy increases in understory production within the canopy gaps. Heavy restocking of stands, as is typical of commercial timberlands, can drastically reduce the period of post-disturbance understory proliferation. Modeling of stand dynamics and forest succession at a landscape scale in western Washington suggested that ungulate forage production peaked in the 1960s and declined thereafter through the recent past (Jenkins and Starkey 1996). Topics of interest that need further exploration include the importance of lichens and litterfall to deer diets. Lichen use by deer, although important, is difficult to document (Kirchoff and Larsen 1998, Parker et al. 1999). Litterfall may also be very important depending on age of timber stands, and wind dynamics but deposition rates and deer use are also difficult to document. Both litterfall and lichens may add to the available deer forage in old-growth forest.

The removal of old-growth forest stands and establishment of industrial

Figure 10. Clear-cuts providing little value for deer due to size, location and topography (Photo by Scott McCorquodale/WDFW).

tree farms over much of the southern two-thirds of the Coastal Rainforest Ecoregion has converted large areas of uneven-aged mature forest to even-aged monoculture stands of fast-growing conifers. The simplification of complex forest communities that once featured multi-storied canopies, robust shrub components, a diverse array of overstory species, and small irregular openings, into short-rotation, monotypical stands with understories that are reduced or eliminated by intensive herbicide treatments, generally has not benefited deer.

In Alaska and British Columbia, industrial-scale logging began in the mid-1900s and targeted the most productive hemlock and spruce stands at lower elevations for harvest. Clear-cutting was, and still is, the dominant timber harvesting strategy throughout coastal Alaska and British Columbia (Harris 1974, Nyberg et al. 1989, Moola et al. 2004, Hanley 2005). Consequently, a large proportion of prime winter habitat for deer was clearcut in areas where intensive logging occurred, such as Prince of Wales and adjacent islands in Southeast Alaska. More recently, timber market conditions have shifted harvest toward red cedar and Alaska yellow cedar on less productive sites.

For 25-30 years following logging, the biomass of forage available to deer in clearcuts during snow free months is often substantially greater than the biomass available in productive old-growth forest stands prior to logging (Alaback 1982, 1984; Farmer 2002; Alaska Department of Fish and Game [ADFG], unpublished data). For example, the mean annual production of forage biomass measured in vegetation transects in clearcuts 0-30 years old on Prince of Wales and Heceta Islands was 3,160 lb/acre and 2,008 lb/acre (ADFG, unpublished data, Farmer 2002, Farmer and Kirchhoff 2007). The mean annual increment of forage biomass in productive old-growth forest was 1,503 lb/acre on Prince of Wales Island and 886 lb/acre on Heceta Islands. In winters with snow, however, approximately 75% of that biomass was still available to deer in old-growth stands, whereas in clearcuts <10% was available (Farmer 2002). Young clearcuts provide abundant food in snow free months, but much of the forage is low in digestible protein compared with the same forage species grown under shade. High forage biomass may compensate somewhat for lower quality, but this contention is still open for debate. Conifer regeneration is natural and even-aged seedlings eventually grow sufficiently tall to form a dense canopy that prevents sunlight from penetrating to the forest floor. This "stem exclusion" successional stage generally occurs 25-40 years post-logging depending on the productivity of the site (Alaback 1982, 1984). Forage biomass in clearcuts >40 years old on Heceta Island averaged 72 lb/acre, a 96% decline in biomass from peak production in younger clearcuts (Farmer 2002, Farmer and Kirchhoff 2007). Stem-exclusion seral forest represents very poor habitat for deer in all seasons, and those conditions may persist for >150 years before gap-phase dynamics recreate the uneven-age conditions characteristic of old-growth forest (Alaback 1982). In Southeast Alaska, the expected harvest rotation age for productive sites is approximately 100 years; therefore, stem-exclusion stands will persist for >60 years before subsequent timber harvest.

Issues and Concerns

For Sitka black-tailed deer at the northern extent of their range, winter weather is an important factor influencing population dynamics (Klein and Olson 1960). For example, 65% of radio-collared deer on Admiralty Island in Southeast Alaska died during a severe winter in 1982 (M. Kirchhoff, ADFG, personal communication). Forested habitats play a key role affecting survival of deer during winters with heavy snowfall (Longhurst and Robinette 1981, Fagen 1988). Where snowfall is deep (>20 in), deer typically select productive, coarse-canopy, old-growth forests on southerly aspects below 820 ft elevation during winter (Schoen and Kirchhoff 1990). In these stands, the forest canopy intercepts snow, but discontinuities in the canopy also allow sunlight to reach the forest floor, producing patches of abundant understory vegetation. Thus, deer are able to move and find forage during most winters with snow. In areas with lower snowfall and during snow-free months, deer are more general with respect to habitat selection. For example, deer use muskeg heaths, and less productive forests on hydric soils, during summers or mild winters on Prince of Wales Island in the southern portion of the region (ADFG, unpublished data). Some Sitka black-tailed deer migrate upward to lush alpine meadows during summer while others are non migratory and remain at low elevations all year. On Admiralty Island, 75% of radiocollared deer migrated to alpine habitat during summer (Schoen and Kirchhoff 1985). In contrast, only 4% of radiomarked deer on Heceta and Prince of Wales islands were migratory (Farmer et al. 2006; ADFG, unpublished data).

Schoen and Kirchhoff (1990) found that deer on Admiralty Island strongly selected productive old-growth forest on southern exposures during winters with snow. Admiralty Island is located in the northern portion of the Alexander Archipelago in Southeast Alaska and winters characteristically have persistent snow accumulating to depths >20 in. In southern coastal forests of Alaska, where snow cover is less or intermittent, deer select young clearcuts year round and may avoid productive old-growth stands during mild winters in favor of habitats with higher forage biomass (Yeo and Peek 1992; Farmer 2002; Doerr et al. 2005; ADFG, unpublished data). Nonetheless, Farmer et al. (2006) and Person (ADFG, unpublished data) examined correlations between habitat use and risks of death, and concluded that an increase of 10% in use of clearcuts

< 10 years old increased risk of predation by gray wolves (*Canis lupus*) by > 60%. Furthermore, an increase of 10% in use of clearcuts 10-30 years old increased risk of malnutrition of adult and yearling does 4-fold during winter and doubled their risk of death from hunting. In Southeast Alaska, selection by deer of young clearcuts may be contrary to maximizing fitness. Person (unpublished data) and Farmer et al. (2006) reported that deer avoided stem-exclusion second-growth forest, use of which also strongly increased risk of death from malnutrition. That relation was particularly strong for fawns. For deer on Heceta Island, a 10% increase in use of stem-exclusion forest by young deer increased risk of death by 50% (Farmer et al. 2006).

The importance of southern and southeastern aspects has been emphasized in most habitat management efforts in Southeast Alaska. Nonetheless, radiocollared deer on Heceta and Prince of Wales islands showed stronger preference for southwestern aspects than southeastern exposures (Farmer 2002; ADFG, unpublished data). Although southern and southeastern aspects generally have higher incident radiation, southwestern exposures experience higher daytime temperatures and heat load (McCune and Keon 2002). Consequently, snow depths and duration often may be less on southwestern slopes.

Distribution of habitats and topography are as important as habitat composition with respect to habitat selection and risks of mortality. Resource selection functions containing variables associated with habitat distribution and topography explained patterns of habitat use and mortality of deer substantially better than models representing habitat composition (ADFG, unpublished data). Deer on Prince of Wales and Heceta islands selected higher density of edge and fragmented habitat, however, both of those landscape attributes were positively correlated with wolf-caused mortality (Farmer et al. 2006; ADFG, unpublished data). For example, a 10% increase in density of edge within 500 yd buffers around telemetry locations of deer increased risk of death 98%. In contrast, deer selected steeper slopes, which strongly reduced risks of death from predation and malnutrition. Patch size of various habitats had important influence on selection and risks of death. For example, size of patches of muskeg heath was positively correlated with risk of death from malnutrition. A 10% increase in patch size within about 500 yd buffers around telemetry locations resulted in a greater than 5-fold increased risk of death (Farmer et al. 2006).

Management of habitat for Sitka black-tailed deer in Southeast Alaska and much of coastal British Columbia entails preserving sufficient old-growth forest habitat to enhance deer survival during severe winters, mitigating the effects of the legacy of stem-exclusion second-growth forest that has accumulated over the last 50-60 years. Implementing new timber harvesting strategies that retain understory vegetation for a longer period of time after logging is also important. Silvicultural treatments that increase the snow interception capability of developing stands should also be considered. Each of these tasks must consider more than simply enhancing or retaining forage plants. Topography and landscape contexts play important roles in determining where and when forage is available to deer, which affects deer survival and fitness. For example, small patches of productive old growth within clearcuts and muskegs may be isolated by deep snow. Although forage biomass may be high in the stand, the energetic cost to deer of obtaining it may severely reduce its value. Wolves prefer hunting flat terrain and take advantage of edges and fragmentation to detect and pursue deer (Kunkel and Pletscher 2001, Farmer et al. 2006, ADFG, unpublished data). Consequently, timber harvest or second-growth management practices that create fragmentation and edge on flat terrain increase risks to deer of predation by wolves (Farmer et al. 2006). Further, deer are attracted to landscapes dominated by young clearcuts during snow-free months (Yeo and Peek 1992, Farmer 2002, ADFG unpublished data). Hunters are also attracted to these areas because they are accessible by roads and deer are visible. Consequently, use of these landscapes by deer increases the risk of death from legal and illegal hunting (Farmer et al. 2006).

In contrast, in the southern portion of the Coastal Rainforest Ecoregion, timber harvest has often been assumed to oster habitat conditions beneficial to coastal black-tailed deer (Brown 1961, Wallmo and Schoen 1980, 1981, Jenkins and Starkey 1996). In this portion of the ecoregion, winters are typically wet, but relatively mild, with deep snow accumulating only at the highest elevations. Under these conditions, opening of the closed forest canopy can dramatically increase the biomass production of deer forage (Brown 1961, Scotter 1980, Witmer at al. 1985), enhancing deer nutrition, productivity, and supporting higher deer densities. However, the scale and pattern of openings created by logging can dramatically affect responses of black-tailed deer (Taber and Hanley 1979). Maintaining landscape-scale habitat quality through intensive forest management can be challenging in the face of forest succession patterns (Taber and Hanley 1979, Jenkins and Starkey 1996), policy constraints on forest management options on public lands, and reforestation practices on private timberlands. Nonetheless, compelling historical evidence shows that disturbances that create and maintain early seral forest conditions in the southern portion of the ecoregion are essential to maintaining landscape-level habitat quality for coastal black-tailed deer. Recent declines in black-tailed deer densities in Washington and Oregon likely are habitat mediated. Fire suppression, reduced timber harvest, and succession of large areas to relatively

Table 1. Impact of forest herbicides (range of % injury) on important black-tailed deer forage plants as identified by Brown (1961), Crouch (1981a), U.S. Forest Service (1987), and Rue (1997).

	Herbicide			
Species	**Glyphosate**	**2, 4-D**	**Picloram and 2, 4-D**	**Triclopyr**
Big leaf maple	60-90		25-60	90-100
Black oak		60-90	90-100	90-100
Cascara		60-90	90-100	90-100
Cherry (*Prunus* spp.)		60-90	90-100	90-100
Cottonwood		60-90		90-100
Elderberry (*Sambucus* spp.)	90-100	60-90	90-100	90-100
Evergreen blackberry	90-100		90-100	90-100
Forbs	90-100	90-100		
Grasses	90-100			
Hazelnut (*Corylus cornuta*)	60-90	60-90	60-90	60-90
Pacific madrone (*Arbutus menziesii*)		90-100		
Manzanita (*Arctostaphylos* spp.)				60-90
Red alder	60-90	90-100	90-100	90-100
Salal				60-90
Salmonberry	90-100	60-90	90-100	60-90
Thimbleberry (*Rubus parviflorus*)	90-100	60-90	60-90	60-90
Trailing blackberry (*Rubus ursinus*)	60-90			
Vine maple	90-100	60-90	60-90	60-90
Willow (*Salix* spp.)		90-100	90-100	90-100

Figure 11. Approximately 4 square miles of industrial forestland in the Willapa Hills of Washington State. In excess of 20 miles of roads have been constructed within the area (Aerial Photo Washington Department of Natural Resources).

unproductive second-growth forest are probably important contributing factors.

In spite of the potential advantages of forest canopy removal in some landscape contexts, certain modern forest management activities may have several detrimental impacts to deer habitat. These disadvantages are primarily a function of simplification and fragmentation of forested habitats. Forestlands used primarily for the production of wood fiber have many characteristics that more closely resemble agricultural lands with intensively managed, even-aged, monocultures and understory plant species that are controlled with herbicides, rather than unaltered forest habitats. Collectively, these characteristics come at the detriment of black-tailed deer in the Coastal Rainforest Ecoregion.

Roads
The harvest of forest products and the transport of these commodities to processing and marketing areas generally require construction of a vast system of forest roads. In

Figure 12. State-owned forest in various stages of stand development. Dense stands ready for harvest in the upper right. Approximately 6-year old stand on the left, and clear-cut following herbicide treatment in the foreground (Photo by Eric Holman/WDFW).

Figure 13. Old-growth forest, Olympic National Park, Washington (Photo by Scott McCorquodale/WDFW).

excess of 5 miles of road may be constructed within each square mile of industrial forestlands (Fig. 11). Additional areas are impacted by road-like features such as landings, rock pits, equipment storage areas, spoils disposal areas, etc. Road densities in more remote portions of the ecoregion may still average well below 1 mile of road/mile2 of forest (e.g., Tongass National Forest, Foster Wheeler Environmental Corporation 2003).

The impact of roads on distribution and resource use by deer and elk has been documented (Stewart et al. 2002, Wisdom et al. 2005, see also Gaines et al. 2003). Little research has been focused on black-tailed deer responses to road density and other road-mediated effects (Gaines et al. 2003). Research on mule deer has suggested that whereas elk predictably avoid areas near roads, mule deer responses may be modified by interference competition with other herbivores such as elk or livestock (Stewart et al. 2002, Wisdom et al. 2005). Roads may negatively impact coastal black-tailed deer via increased vulnerability of deer to legal and illegal harvest (Farmer et al. 2006), dispersal of undesirable plants, increased vulnerability to predation, fragmentation and isolation of habitats, and direct loss of habitat to road development.

Understory Management

Among the more detrimental aspects of common forest management activities is the use of herbicides following timber harvest. This practice is extensively conducted on both commercial and public forestland. The Society of American Foresters (2001) official position supports use of these chemicals. This position is not surprising given the additional wood fiber and, therefore, economic gain that may be achieved with use of such products (Wagner et al. 2004).

The study of the impact of herbicide application to wildlife has focused primarily on toxicity, which is thought to be negligible (Society of American Foresters 2001). Nonetheless, land managers post areas of pending herbicide applications to make the public aware of potential hazards related to these chemicals. The habitat altering effects of herbicide application is acknowledged to be a more serious impact (Society of American Foresters 2001, Wagner et al. 2004). However, quantification of the impact of this practice as it relates to diets of black-tailed deer has been little studied. Campbell et al. (1981) evaluated the effects of herbicide application on forage acceptance to black-tailed deer in experimental trials. Deer did appear to readily accept forage that was treated with most commercially available herbicides, including 2,4,5-T, 2,4-D, atrazine, fosamine, dalapon, and glyphosate. Deer did appear sensitive, as evidenced by reduced browsing, to glyphosate application, but researchers could not discriminate between direct effects of the herbicide and subsequent changes to Douglas-fir seedlings post-spraying. Nonetheless, some impact of herbicides is intuitive when various types of commonly used herbicides, their target species, and intended effects are compared to a partial list of plants comprising the diet of black-tailed deer (Table 1, Brown 1961, Crouch 1981a, U.S. Forest Service 1987, Rue 1997).

Timber Stocking Rates

An additional detrimental aspect of current forest management practices is the dense stocking rates used in forest plantations. Conifer seedlings are commonly replanted at rates >400 trees/acre on commercial and public forestlands (U.S. Forest Service 1987). These dense plantings achieve near complete canopy closure in just 10-12 years. This practice, often in combination with herbicide treatments, assures a tremendously reduced period of early successional habitat (Fig. 12). Furthermore, such forests develop little in the way of understory vegetation or desirable forage plants. In contrast, naturally regenerated stands may offer a >30-year period of vigorous understory vegetation and develop into multi-species communities including understory vegetation (Brown and Curtis 1985).

Preserving Productive Old-growth Forest
Stands of coarse-canopied productive old-growth forest from tree line to sea level have value for coastal black-tailed deer (Fig. 13). Conserving such habitat is particularly important in watersheds that have been heavily logged in the past, and in areas where snow accumulations typically exceed 20 inches. Protecting old growth near treeline will provide winter habitat for migratory deer that over winter at higher elevations than non-migratory deer. Although southern portions of the region usually have milder winters, they are still affected by occasional severe winter weather events (Parker 1988). Productive old-growth stands provide critical winter habitat that will enhance survival of deer under those conditions. Further, deer populations reduced by the lack of winter-abatement habitat have often been held at these lower levels for decades by wolf and bear (*Ursus* spp.) predation, retarding deer population recovery. Consequently, it is important to preserve winter habitat for deer where gray wolves or bears also occur. In severe winters, deer that inhabit areas near shorelines may migrate to open snow-free beaches to avoid deep snow (Fig. 14). Drifts of snow may trap deer on the beaches where they feed on kelp and along the forest edge. Preserving productive old-growth stands along beaches provides available forage for deer when deep snow prevents them from using interior forest habitat.

In extensively logged watersheds, productive old-growth forest stands that are deferred from logging often exist in small patches between clearcuts or bordering lakes and streams. Frequently, those patches are <100 yd wide and constitute a small fraction of deer home ranges. Deep snows may isolate deer in forest patches within clearcuts and muskeg heaths for long periods of time because mobility is restricted (McNay and Voller 1995). Consequently, in heavily logged watersheds, residual patches of productive old growth >175 acres should be given the highest priority for preservation. That area represented 50% of the average winter home range of radiocollared deer on Prince of Wales (ADFG unpublished data), Heceta (Farmer et al. 2006), and Admiralty islands (Schoen and Kirchhoff 1985). A circular area of that size would have a radius of approximately 545 yd. Smaller noncontiguous patches that have total areas >175 acres and are tightly clustered spatially should also be given a high priority for preservation.

Managing Existing Second-growth Forest
Efforts to manage existing second-growth forest for deer generally emphasize retaining understory forage biomass for as long as possible as stands progress toward a stem-exclusion successional stage. The primary method used in Southeast Alaska has been pre-commercial thinning of stands that are 10-30 years old. Various fixed and variable-spaced thinning prescriptions have been applied with mixed success (Doerr and Sandburg 1986, Deal and Farr 1994, DellaSala et al. 1994). For example, 30-year-old stands on Heceta Island that were thinned at 18-20 years produced an average of 1,376 lb/acre of forage for deer compared to 613 lb/acre for similarly aged, unthinned stands (Farmer 2002). At best, however, pre-commercially thinned stands retain understory forage 10-15 years longer than unthinned stands (DellaSala et al. 1994). Because of the expense ($200-400/acre at this writing), pre-commercial thinning usually is only applied to stands on the most productive sites, where the silvicultural benefits of rapid tree growth offer the greatest economic return. Unfortunately, after thinning those stands, productive sites transition to stem exclusion more rapidly than stands on less productive sites. Thus the positive effects of thinning for deer are shorter lived. Further, slash is rarely removed or treated during pre-commercial thinning

Figure 14. Sitka black-tailed deer doe isolated on a beach due to deep snow on Chichagof Island, Alaska. This photo was taken in April 2007 after an extremely severe winter in southeast Alaska (Photo by Phil Mooney/ADFG).

Figure 15. Clear-cuts in Alaska (Photo by Dave Person/ADFG).

Figure 16. Mixture of clear-cuts and retained clumps of trees that function well as travel and security cover, Nooksack, Washington (Photo by Scott McCorquodale/WDFW)

in Southeast Alaska. Accumulations of slash > 6.5 ft deep are common, creating obstacles to movement by deer. Such slash may persist 5-15 years depending on the age of the stand when thinned (Farmer et al. 2006). Treating slash by piling, windrowing, burning, chipping, or bucking may enhance the value of thinned stands as deer habitat, but the costs of those treatments are very high. A combination of light thinning and girdling may produce results similar to typical pre-commercial thinning, but will also reduce slash. In addition, greater spacing of residual trees after thinning will keep the forest canopy open longer. However, it may also promote thicker regeneration of conifer seedlings that out-compete understory forage plants. Due to the high costs, pre-commercial thinning is likely to have very limited application for maintaining habitat for deer within managed forest landscapes (Figs. 15, 16, 17).

Thinning seral stands >30 years old has not been attempted on an extensive basis in Southeast Alaska (Hanley 2005). Opening the canopy by clear-cutting small patches and narrow strips, selectively thinning at various intensities, and girdling trees have all been tried on small experimental plots. Forage plants typically respond positively to gaps in the canopy (Hanley 2005), but the duration of the effect is unknown. Rapid growth of dominant trees after thinning likely will result in canopy closure and a return to stem exclusion. Consequently, treatments would have to be applied several times during the harvest rotation. Further, the availability of forage in treated seral stands during winters with snow also is unknown. The U.S. Forest Service is currently conducting studies in the Tongass National Forest designed to evaluate some of these treatments with respect to timber management and habitat for deer. Results from those studies, however, will not be available for many years. Treatments in older seral stands are very expensive unless they are part of an economically viable commercial harvest. Consequently, extensive thinning or cutting of those stands likely will depend on the market demand for small diameter logs. No such market currently exists in Southeast Alaska.

Thinning in Douglas-fir stands typical of western Washington and Oregon has demonstrated its utility in promoting understory production (Figs. 18, 19, Thomas et al. 1999). Higher levels of thinning produced higher levels of understory biomass. Interestingly, stand fertilization in such stands negatively impacted understory

Figure 17. High-elevation summer range in the Olympic Mountains, Washington (Photo by Scott McCorquodale/WDFW).

production. Thinning also increased understory species richness, whereas fertilization decreased it (Thomas et al. 1999).

Timber Harvest Strategies that Maintain Habitat for Deer

Timber harvest strategies that mimic gap-phase forest dynamics have the most potential for retaining habitat for deer through all successional stages, at least in the northern one-third of the Coastal Rainforest Ecoregion. Kirchhoff and Thomson (1998) conducted a retrospective study of logged sites in southeast Alaska > 50 years old and concluded that removal of < 12 trees/acre distributed evenly within a stand and < 50% of the total basal area likely would retain understory biomass comparable to unlogged productive old growth throughout the harvest rotation. This contention was confirmed by Deal (2001), who demonstrated that partial cutting (< 50% basal area of the stand) maintained many of the understory attributes of unharvested stands of western hemlock-Sitka spruce. These studies focused on productive sites near sea level. Little is known about how stands on less productive sites would respond. Alternatives to clear-cutting have been examined, such as uniform partial harvests, clumped partial harvests, and combinations of those strategies (McClellan et al. 2000). However, evaluation of retention of understory biomass through rotations under these methods will not be possible for several years. Unfortunately, many residual clumps and trees succumb to windthrow following harvest unless retention is > 75% of the original stand. One promising approach may be to plant red alder following clear-cutting (Hanley 2005). Since the late 1990s, alder has consistently increased in commercial value. Alder keeps the forest canopy open, allowing retention of understory forage longer during the harvest rotation. Alder is also a nitrogen fixer that may enhance growth of understory vegetation. Stands of alder may persist for > 40 years, but the duration of their effect on delaying stem exclusion is unknown. Data regarding snow depths and deer use during winter in stands containing alder are not available.

Planning Tools

Several handbooks for land managers and foresters have been written for black-tailed and mule deer range in British Columbia and Alaska (Armleder et al. 1986; Nyberg et al. 1989; Dawson et al. 2006, 2007). These handbooks contain guidelines for identifying important deer habitat values, particularly on winter range, and provide guidance on planning and implementing stand treatments designed to protect critical deer habitat functions while fostering extraction of commercial forest products and attainment of forest management objectives.

Dawson et al. (2006, 2007) may contain useful information for managing habitat in the Coastal Ecoregion, however, they were written to guide management on interior

Figure 18. Second-growth state-owned forest in southwestern Washington prior to mechanical thinning (Photo by Eric Holman/WDFW)

Figure 19. Second-growth state-owned forest in southwestern Washington immediately after mechanical thinning from below with variable spacing. Although originally intended to benefit endangered species, this treatment will also benefit black-tailed deer as the understory responds over time (Photo by Eric Holman/WDFW)

Douglas-fir forests. Nyberg et al. (1989) describes habitat management guidelines that may be useful for partially mitigating the impacts of extensive logging on winter habitat for deer. These handbooks provide specific guidelines useful for the management of coastal watersheds in the northern portion of the ecoregion that have been extensively modified by timber harvesting, however, they were not developed to guide management of intact undeveloped watersheds where the range of opportunities for protecting important deer habitats are greater.

Another potentially useful tool for habitat management is a computer-based program designed to evaluate habitats called Forage Resource Evaluation System for Habitat (FRESH) developed by Hanley et al. (2006) and available online at http://cervid.uaa.alaska.edu/ . The program incorporates forage composition, forage quality, sex- and

Figure 20. Coarse-canopy, old-growth forest, Settler's Cove, Alaska (Photo by Dave Person/ADFG).).

Figure 21. Second-growth, stem exclusion forest providing little or no value to deer (Photo by Dave Person/ADFG).

Figure 22. Coarse-canopy, old-growth forest, Connell Lake, Alaska (Photo by Dave Person/ADFG).

age-specific energetic requirements for deer, and snow depth to estimate deer-days of use for any defined habitat patch or project area. The program provides extensive tables that include data concerning digestibility, protein content, and energy content of specific forages but users are able to input their own data values for their specific areas and species composition. In addition, users can easily substitute snow depth constraints appropriate from their own regions by modifying the snow depth component of the model. Outcomes from the program indicate maximum potential deer-days of use for a project area given constraints on availability due to snow depth. Deer days of use can be estimated for young, adults, males, and females. Pregnancy and lactation of does can also be factored into the analyses.

Effective planning designed to conserve deer habitat values emphasizes well-defined and geographically explicit objectives, detailed descriptions of analysis strategies, explicit silvicultural prescriptions, and measurable benchmarks and performance standards (Nyberg et al 1989).

Guidelines

Forest management activities in the Coastal Rainforest Ecoregion have tremendous effects on the habitats of the black-tailed deer that inhabit this area (Brown 1961, Longhurst and Robinette 1981, Nyberg et al. 1989). Furthermore, timber harvest and reforestation methods strongly influence the dynamics of black-tailed deer habitat quality (Hanley 1984a, Witmer et al. 1985, Armleder et al. 1986, Nyberg 1987, see also Franklin and Forman 1987). Landscape management offers the opportunity to manipulate habitat conditions following timber harvest or maintain existing high-quality habitats across time and space. Successful deer habitat management requires a considerable number of very detailed site-specific decisions, such as those embodied in the management handbooks described above. The detailed scale of actual management prescriptions required is not well suited for simple tabular summaries, but some general recommendations are outlined below.

A. Forest Management Planning

1. Designate specific black-tailed deer habitat management objectives in planning documents (e.g., Armleder et al. 1986).
2. Develop geographically and seasonally explicit deer habitat management strategies. Map critical winter range, summer range, riparian areas, proposed timber sales, proposed and existing road networks.
3. Define measurable benchmarks of success and plan compliance (see Nyberg et al. 1989; Dawson 2006, 2007).
4. Objectives and strategies should emphasize long-term maintenance of habitat values that account for

predictable successional trajectories and economically feasible stand rotations.
5. Work with state wildlife agencies to monitor black-tailed deer population responses to habitat management.

B. Road Management
1. Develop and implement a formal road management strategy prior to management prescriptions, as opposed to an ad hoc approach.
2. Avoid constructing roads within topographic or vegetative buffers to maintain security cover.
3. Avoid road construction within designated Old Growth Management or Emphasis Areas.
4. Minimize open road densities as much as possible. Although sometimes difficult to achieve, the ideal to strive for is less than 1 linear mile of road for every square mile of forest.
5. Implement road buffers to maintain deer security cover and reduce harassment along open roads.
6. Minimize “circle” or “loop” routes when establishing new road systems.
7. Minimize plowing of nonessential roads during winter.
8. Consider timber harvest methods that require relatively fewer roads where appropriate (e.g., lateral cable harvest systems, mobile yarding, or helicopter logging).
9. Decommission unneeded roads after management activities are completed.
10. Monitor road use.
11. Monitor and treat invasive plants along road systems.

C. Silviculture
1. Complex, uneven-aged timber stands are generally preferred over simpler, even-aged stands (Figs. 20, 21).
2. Light, selective harvesting in continuous forest that emphasizes removal of small groups of trees, should be used in zones of heavy snow accumulation or areas of high windthrow risk.
3. In cases of more aggressive timber harvest, retain connected “clumps” of trees rather than isolated individual trees in clear-cuts to provide effective thermal and security cover for deer.
4. Maintain small forest openings:
   - Less than 50 acres on summer range,
   - 10 to 48 acres on winter range that does not experience snow accumulation,
   - and 2.5 to 7.4 acres on deer winter range that experiences enough snow accumulation to restrict deer foraging and movement.
5. Maintain structural heterogeneity both within stands and between stands (Fig. 23).
6. Conifers typically have low forage value, but deer will use them in winter. For winter forage use, red cedar and yellow cedar should be favored as retention trees over those with lesser forage value such as Douglas-fir, hemlock, and spruce.

Figure 23. Coarse-canopy, old-growth forest, Lunch Creek, Alaska (Photo by Dave Person/ADFG).

Figure 24. Sitka black-tailed deer wintering in old growth forest. The snow interception benefits provided by mature forest are critical to winter survival in northern portions of the ecoregion (Photo by John Schoen).

7. Stand prescriptions should be tailored to specific environmental conditions such as soils, slope, aspect, elevation, latitude, climate, etc. (see Dawson et al. 2007).
8. Buffer important habitat features such as ridge tops, knolls, meadows, wetlands, and riparian areas.
9. In areas of high snow accumulation, use a "thin–from–below" strategy to maintain snow interception capacity of the overstory and promote understory forage production.

D. Post-entry Stand Maintenance

If a timber stand is to provide positive habitat value for deer, understory forage should be conserved.

1. Treat post-entry stands by means other than aerial herbicide applications such as ground-based spraying, mechanical or hand thinning of unwanted tree species, slash burning, etc. Minimize broadcast herbicide application.
2. Avoid broad slash piles or extensive slash fields that hinder or completely prevent deer use and travel. If economically feasible, burn or chip slash on site.
3. If reforestation occurs, plant <300 seedlings/acre. Promote plant species diversity and structural complexity.
4. Conduct pre-commercial thinning with variable spacing in young conifer stands in advance of canopy closure. Retain some alder and other lower commercial value species if possible.
5. Allow plant species that do not interfere with forestry efforts to proliferate. Identify those understory plants that provide deer forage but compete minimally with commercial timber.
6. Minimize soil scarification and other disturbance that promote invasive plant species colonization.

E. Old-Growth Forest

1. Emphasize retention of intact old-growth forest that has features characteristic of critical winter range, particularly in the northern half of the ecoregion (i.e., Southeast Alaska, British Columbia) (Figs. 22, 23, 24).
2. Designate and retain residual areas of old-growth within logged landscapes and along beach fringes.

Human Encroachment

Background

Human encroachment is occurring in the ecoregion. Urban and suburban perimeters are expanding and rural residential development continues. Development is not occurring evenly in the ecoregion as it is prohibited on most public lands and a variety of socio-economic factors affect development of private holdings regionally.

Impacts of development can be expected to be acute when little consideration is given to deer habitat within the land use planning process, when little public land or other lands where development is prohibited are available, and when property values are increasing dramatically. Development is most detrimental when it occurs on limiting habitat (e.g., critical deer winter range), when it hinders seasonal movements between deer ranges, or when it is so pervasive that large expanses of deer habitat are lost.

In the western United States, 14,288,000 new privately owned housing units have been built since 1968. Population increases from 1960 through 2000 within those portions of each state located in the Coastal Rainforest Ecoregion averaged 236% (U.S. Census Bureau 2006, Table 2). The projections for population increase by the year 2030 for the entirety of each state are depicted in Table 2 (U.S. Census Bureau 2006).

Interestingly, Washington, with the second highest rate of increase in human population and the highest projected rate of increase for the future, is also the state with the least amount of landscape area available of the listed states (U.S. Census Bureau 2006).

Issues and Concerns

Habitat Loss and Degradation

The primary impact on black-tailed deer habitat resulting from human encroachment is habitat loss. Habitat can be lost from conversion to a type that is less suitable or unsuitable, or it may be lost through exclusion. Exclusion can result from fencing, disturbance from human activity or domestic animals, busy roadways, or from dense development separating any of the key habitat components of food, water, and cover. The loss of habitat resulting from urban expansion is generally considered to be a permanent loss.

Given that habitat losses resulting from human encroachment are usually permanent, it is important that deer habitat conservation efforts be proactive and promote limits to conversion of deer habitat prior to their development. Participating in and influencing the land use planning process is critical. Participation in county and city general plan review may provide opportunities to influence land use zoning and establish habitat specific protection measures. Some states have enacted legislation that provides guidelines to county governments on how zoning and development might be conducted, such as Washington's Growth Management Act, which was adopted in 1990. Washington's Growth Management Act requires that city and county governments develop comprehensive plans for growth, and those plans must address all types of land use including agriculture, timber production, and open space, as well as the human population densities proposed for all land uses. It is through this planning process that wildlife managers will have the opportunity to influence

Table 2. Percentage of population increase from 1960 through 2000 and projected increase by 2030 within that portion of each state located in the Coastal Rainforest Ecoregion (U.S. Census Bureau 2006).

State	Increase 1960-2000	Projected Increase by 2030
California	201%	37%
Oregon	198%	41%
Washington	239%	46%
Alaska	305%	38%

the retention or enhancement of black-tailed deer habitat. The Act also establishes independent hearing boards to help resolve land use planning disputes (although county governments are not compelled by law to follow the recommendations of the hearing boards).

Using a similar, land-use planning process that considered impacts to deer habitat, Jackson County and Oregon Department of Fish and Wildlife (ODFW) have established protection measures for deer winter range in the Jackson County General Plan. These include 160-acre parcel size minimums in areas designated as especially sensitive deer winter range, 40-acre minimums in areas designated as sensitive deer winter range, and defaulting to existing land use zoning standards for areas designated as deer winter range. Also, primary building sites must be located within 300 feet of an existing road or driveway, and extra dwellings must be located within 200 feet of the primary or existing dwelling (D. Jackson, ODFW, personal communication). Other opportunities, such as the establishment of minimum riparian and wetland buffers, may also be available.

Opportunities may also exist to influence mitigation requirements at the level of individually proposed development projects. These opportunities exist in states that have adopted legislation that is equivalent to the federal National Environmental Policy Act (e.g., California Environmental Quality Act).

Deer habitat may be protected through land acquisition. This can be accomplished by public entities (e.g., state wildlife agencies, federal agencies, county or city government), or by private non-profit organizations. If fee-title acquisition is not appropriate, conservation easements may be purchased from private landowners using public funds (e.g., California Wildlife Conservation Board) or private sources (e.g., land trusts). Such agreements leave the land in private ownership, but require that the land be managed and maintained in the manner agreed upon in the easement, which may include prohibitions on development. A proactive approach in land acquisition and establishment of easements is advantageous because purchase prices increase dramatically as development accelerates in an area.

Programs exist that provide landowner incentives to maintain or enhance deer habitat. Various private lands hunting programs have been developed to provide for sport hunting or economic value (e.g., landowner tag programs, California's Private Lands Wildlife Habitat Enhancement and Management Area Program). Other programs that provide landowner incentives that may benefit deer indirectly include tax advantages for maintaining open space or lands in timber or agricultural production (e.g., Williamson Act, property tax reductions based on zoning, and lower property assessment values with conservation easements) and riparian and wetland protection and enhancement programs. Various public and private programs exist that provide grants for the protection or enhancement of wildlife habitat.

Encouraging the enactment of new legislation that directly or indirectly protects deer habitat from development may be an option. Such legislation may be designed to prohibit development, to better mitigate impacts to deer habitat resulting from development, or to provide incentives for not developing deer habitat.

Educational outreach can contribute to maintenance of deer habitat by increasing support for conservation efforts among the public and policy makers. Such efforts will be most successful when they provide information focused upon the geographical scale and audience most appropriate for the locale. Relevant topics include the economic and ecological value of deer, deer population and habitat trends, risks posed to deer habitat by development, and available strategies for preserving habitat or accommodating human growth with minimal impacts.

Depredation and Public Safety

Urban expansion, especially low-density suburban growth and rural residential development, can lead to an increase in nuisance and depredation complaints. Such complaints usually involve the consumption of cultivated ornamental and garden plants.

Public safety issues can result from deer and people living in close proximity to each other. Physical conflicts between deer and people can be serious when they occur and are typically the result of deer habituating to humans and human activity. Urban deer populations can also increase the likelihood of predators, such as mountain lions (*Puma concolor*) and coyotes (*Canis latrans*), frequenting areas of human activity. Although the risks to people from such predators are rare, there is a relatively high level of public concern regarding the potential for conflict.

Deer-vehicle collisions on roadways or on airport runways, may result in injuries to people and damage to property. Funds may be available from state and federal transportation agencies to address fencing and underpasses or overpasses to prevent wildlife-auto collisions. The Federal Aviation Administration, the Office of Homeland Security, and Transport Canada may be able to provide financial assistance to fence airports.

Providing public education regarding the value of deer in the ecosystem and to society, and strategies to effectively coexist with and control deer may be an important tool to address depredation and public safety concerns. Examples of such information sources published by the California Department of Fish and Game (CDFG) include Living with Deer, the Keep Me Wild series, and A Gardener's Guide to Preventing Deer Damage. Washington Department of Fish and Wildlife developed an extensive Living With Wildlife in the Pacific Northwest (Link 2004) publication. Other states and provinces have similar programs and publications.

Establishing and enforcing prohibitions on intentionally feeding deer also helps reduce nuisance complaints. In some cases of deer depredation, direct response may be warranted. Examples include modification of public hunting management strategies, issuance of special permits, authorization for the removal of animals, or the removal of animals by wildlife agency personnel.

Guidelines

Human encroachment into black-tailed deer habitat is having a dramatic impact in terms of habitat degradation and habitat loss. As human populations continue to grow as predicted within the Coastal Rainforest Ecoregion, a priori planning and economic considerations must be incorporated in a successful approach to retain or enhance black-tailed deer habitat.

1. Loss of black-tailed deer habitat resulting from human encroachment is usually permanent. A proactive approach to protect deer habitat prior to development is important.
2. Wildlife managers may influence land use policy for the benefit of deer habitat through participation in the legislative process, land use zoning review, and the evaluation of proposed development projects.
3. Privately owned deer habitat may be secured through purchase of property title or conservation easements. Cost effectiveness of such purchases increases when the economic incentives for development are low.
4. Economic incentives may be provided to private landowners for retaining deer habitat.
5. Limited resources available to protect deer habitat from human encroachment should be focused on critical habitats.
6. Support for the retention of deer habitat may be engendered through educational outreach regarding the economic, ecological, and esthetic value of deer; current deer population and habitat trends; development trends; and risks to deer and their habitat resulting from human encroachment.

Long-term Fire Suppression

Background

Purpose of Fire Suppression

Fire suppression in the Coastal Rainforest Ecoregion is undertaken primarily to protect human life and property, primarily residences and timber stands. Suppression is also used to maintain esthetic values and protect the environment. Natural fire regimes and active fire suppression are less of a factor in the wetter climates of British Columbia and Alaska. Environmental values include air, water, and special-status species and their habitats, such as marbled murrelet (*Brachyramphus marmoratus*) nesting habitat and habitat for anadromous fish. Fire suppression is expensive and involves risks to firefighting personnel. Suppression is widely viewed by the public as beneficial and necessary to protect public safety and private property and figures prominently in the media and political arena.

History of Fire Suppression

Agee (1993) related that the advent of modern forest fire management in the Douglas-fir region began after large-scale, high intensity fires in 1902. At that time, severe forest fires occurred in nearly every county west of the Cascades in Washington and Oregon. Most resulted from fires intentionally set to clear land and logging slash that burned out of control. The initiation of organized forest fire protection was driven by forest industry concerns about protection of virgin timber to supply its mills, along with other political and social pressures. Kozlowski and Ahlgren (1974) reported vigorous suppression of fire in the redwood zone being attempted since approximately 1915.

In Western Oregon in the 1930s, forest protection associations were under the control and jurisdiction of timber companies, which were interested primarily in protecting their own timberlands. Government foresters had less manpower, fewer firefighting resources, and fewer laws available to them to suppress wildfire than are available today (Lucia 1983). In approximately 1905, the U.S. Forest Service (USFS) adopted a policy of virtual fire exclusion on National Forest lands (Arno and Allison-Bunnell 2002). The California Division of Forestry adopted a similar policy in 1924 covering private lands (Kozlowski and Ahlgren 1974). Key (2000) noted that in the 1920s, the California Forestry Committee concluded that light burning was harmful to timber and not economical, and as a result policies calling for the complete suppression of fire became common practice. Fire suppression policies were not adopted without controversy. Arno and Allison-Bunnell (2002) reported great debate occurring in the early 1900s regarding the use of fire suppression versus light burning as a means of protecting and managing timber resources.

According to Wills (1991), fire suppression became effective across the landscape in the mid-1900s as a result of new firefighting technologies and increased access to remote areas. Prior to 1940, remote fires could not be effectively controlled, and fire suppression efforts focused on wildfires likely to cause injury to property or people. Arno and Allison-Bunnell (2002) agreed that no effective means to suppress forest fire existed until well after 1910. The USFS policy of virtual fire exclusion persisted until late in the twentieth century (Arno and Allison-Bunnell 2002). Over the last approximately 60 years, effective and aggressive fire suppression has been applied across much of the Coastal Rainforest Ecoregion.

Current State of Fire Suppression

Today, wildfire suppression activities are overseen and conducted almost exclusively by federal and state governments. The 2 most active federal agencies are the USFS and Bureau of Land Management. Federal, state, and local agencies cooperate to assign areas of primary responsibility, based on such factors as land ownership and the spatial allocation of firefighting resources among the agencies.

Agencies charged with fire suppression are relatively well funded and comprised of highly trained professional wildland firefighters supported by seasonal fire crews. Substantial research has been directed toward improving the effectiveness of fire suppression activities, and a greater number and variety of equipment and material resources are available than had been previously. In northwestern California, the vast majority of wildfires, especially those located on or adjacent to privately owned lands, are quickly suppressed (K. O'Neil, California Department of Forestry and Fire Protection, personal communication). Arno and Allison-Bunnell (2002) stated that only the most intense fires defy suppression efforts in the West.

Fire policy for federally owned lands has recently transitioned from fire exclusion to fire management. This entails fuels reduction using prescribed fire, limited suppression of some wildfires, and traditional suppression for others (Arno and Allison-Bunnell 2002). The goal of limited suppression, also known as the "let it burn" strategy or "prescribed natural fire", is not to minimize the spatial extent of wildfire, but rather allow fire to function where desired. Fire is only suppressed through containment at pre-designated boundaries beyond which it is not desired. This strategy is considered to be a low-cost method of returning fire to the landscape. Limited suppression is generally reserved for remote public lands where damage to private property or certain resource values are not anticipated. Aggressive suppression of wildfire remains the nearly exclusive management strategy on private lands. The goal there is to extinguish the fire as rapidly as possible to minimize its spatial extent and potential for destroying property.

Effects of Long-term Fire Suppression on Black-tailed Deer Habitat

Generally, long-term fire suppression adversely impacts black-tailed deer habitat through the loss of foraging and edge habitats. The effects of this are most pronounced in the southerly portion of the Coastal Rainforest Ecoregion. In the more northerly portion of the Coastal Rainforest Ecoregion, the effects of fire suppression may be minimal and may provide some benefit to black-tailed deer through the protection of late-seral habitat. Given the diversity of plant communities and conditions present in the large geographic area contained within the Coastal Rainforest Ecoregion and the wide variation in black-tailed deer foraging preferences, the effects of long-term fire suppression on black-tailed deer habitat is generalized here by discussing the effect that long-term fire suppression has on fire regimes. Discussion regarding chaparral communities has been omitted in this section. Chaparral communities comprise a far greater proportion of the California Woodland Chaparral Ecoregion and are covered in the Habitat Guidelines document specific to that region.

Wildfire occurrence in ecosystems can be broadly classified by fire regime. Low, mixed, and high severity fire regimes have been described based on the frequency of fire and effects on dominant vegetation (Agee 1993, Brown and Smith 2000, Arno and Allison-Bunnell 2002). Table 3 provides a summary of the occurrence of fire in select plant communities within the Coastal Rainforest Ecoregion.

A low severity fire regime is typified by frequently occurring underburns resulting in little removal of dominant

Table 2. Percentage of population increase from 1960 through 2000 and projected increase by 2030 within that portion of each state located in the Coastal Rainforest Ecoregion (U.S. Census Bureau 2006).

Plant Community	Fire Regime (severity)	Location	Fire Return Interval (yrs)
Sitka Spruce	High	Western Washington	1,146
		Northwestern Oregon	400
		Southwestern Oregon	200
Western hemlock	High	Generalized	<750
Silver fir	High	Moist sites	300 - 600
		Dry sites	100 - 300
Red fir	Mixed	Generalized	42 - 65
Subalpine forest	High	Olympic Mountains	1,000 - 1,500+
White fir	Low	Low elevation	9 - 18
	Mixed	High elevation	40
Redwood	Various	Northern sites	500 - 600
	Low	Southern inland sites	20+
	Low	Lowland valleys	5 - 25
Douglas-fir	High	Northwestern Oregon Western Washington Southwestern British Columbia	100 - 200
	Mixed	Southwestern Oregon Northwestern California Puget Sound Lowlands	7 - 61
Oak woodlands	Low	Generalized	<30

vegetation. Low severity fire regimes generally have a fire return frequency of <30 years. Plant communities associated with this regime include grasslands and open understory forests and woodlands composed of thick-barked, fire-resistant trees growing at medium to wide spacing (Agee 1993, Brown and Smith 2000, Arno and Allison-Bunnell 2002).

A high severity fire regime generally results from infrequent fires that remove most of the dominant vegetation, often resulting in stand replacement. High severity fire regimes typically have fire return intervals >100 years. Moist forests are commonly subject to this regime, as fuels seldom dry out enough to burn, allowing dead fuels, dense vegetation, and shade-tolerant, fire-sensitive species to occupy the site (Agee 1993, Brown and Smith 2000, Arno and Allison-Bunnell 2002).

A mixed severity fire regime is one in which fire frequency and severity exhibit greater variability than observed in the other fire regimes. This regime tends to result in a more complex mosaic of impacts on dominant vegetation, ranging from those exhibited in low severity regimes to those of high severity regimes. The mixed severity fire regime generally has fire return intervals ranging from 30 to 100 years with irregular frequency. The effects of a mixed severity fire regime on dominant vegetation range from underburns to stand replacement.

Low Severity Fire Regimes

Long-term fire suppression in plant communities within the Coastal Rainforest Ecoregion that traditionally exhibited a low severity fire regime has adversely affected black-tailed deer habitat. It has resulted in the reduction of forage through the loss of grasslands, oak woodlands, and open understories in some conifer forests.

Forage availability is low within forests with dense overstory canopies because the overstory blocks much of the light needed to grow forage on the forest floor (Taylor 1956, Brown 1961, Wallmo 1981). Deer numbers increase soon after wildfire with the opening of dense forest and accompanying increase in forage (Wallmo 1981). Such openings are ephemeral and are lost without regular disturbance. Maintenance of prairies and oak woodlands with a low severity fire regime provided stable long-term openings within the extensive conifer forests of the Coastal Rainforest Ecoregion. Taylor (1956) reported that in

California, the highest black-tailed deer densities occurred in mixed woodlands that were maintained in an early successional stage by frequent small burns.

Although low in overall total proportion of habitat in the Ecoregion, oak woodlands and prairies provide important seasonal foraging opportunities. Acorns are a highly nutritious food source that black-tailed deer exploit heavily in the fall (Taylor 1956, Wallmo 1981, Loft et al. 1988). Availability of such a rich food source prior to the onset of winter improves winter survival of black-tailed deer (Loomis et al. 1995, McCorquodale 1999a). Prairies and oak woodlands provide important foraging opportunities during their winter green-up of young nutritious forbs and grasses (Wallmo 1981).

A decrease in fire frequency in grasslands and oak woodlands can favor conifers (Kozlowski and Ahlgren 1974, Agee 1993, DeBano et al 1998, Boyd 1999, Key 2000, Arno and Allison-Bunnell 2002). Douglas-fir is invading prairie and oak woodland in the Coastal Rainforest Ecoregion due to the reduction of fire (Figs. 25, 26, Agee 1993, Barnhart et al. 1996, Boyd 1999, Key 2000, Hunter and Barbour 2001, Arno and Allison-Bunnell 2002, Lepofsky et al. 2003). Over time, Douglas-fir will overtop Oregon white oak (*Quercus garryana*) and the shade-intolerant mature oaks will die (Fig. 27 Agee 1993).

Agee (1993) warned that without prescriptive treatment, up to 50% of the threatened oak woodlands that occur in the Pacific Northwest, could be beyond a recoverable condition by the year 2010. Prairies with oak-dominated margins have declined by 26 percent in the Bald Hills of Redwood National Park (Agee 1993), and forest openings in the Klamath Mountains are becoming smaller and more fragmented due to effects of fire suppression (Key 2000). Arno and Allison-Bunnell (2002) stated that although California black oak (*Quercus kelloggii*) and Oregon white oak readily regenerate in forest openings caused by fire, competing conifers will eventually shade out both species in the absence of periodic fires or other disturbance (Figs 28, 29, 30).

In conifer-dominated forest stands that traditionally had low severity fire regimes, open young understories have been replaced with closing overstories and decadent understories due to fire suppression. This is disadvantageous for black-tailed deer due to the loss of forage. Brown and Smith (2000) reported that fire suppression in redwood forests resulted in a reduction of early seral species, including chaparral species. Greenlee (1975) found that herbaceous diversity increased in redwood forests following burning. Such diversity is an important component of black-tailed deer forage (Taylor 1956, Wallmo 1981). Also, young shrubs and younger portions of shrubs provide higher quality

Figure 25. Douglas-fir invasion of oak woodland and prairie on private ranchland in Humboldt County, California (Photo by David Lancaster/CDFG).

Figure 26. Douglas-fir invasion of oak woodland and prairie on USFS ownership in Humboldt County, California (Photo by David Lancaster/CDFG).

Figure 27. Douglas-fir becoming established under a white oak in Humboldt County, California (Photo by David Lancaster/CDFG).

Figure 28. Mechanical eradication of Douglas-fir in oak woodlands in California. Oak woodlands can be extremely valuable habitat for deer in the southern portion of the ecoregion (Photo by Leonel Arguello/Redwood National and State Parks).

Figure 29. Prescribed burn in oak woodland in California (Photo by Leonel Arguello/Redwood National and State Parks).

Figure 30. Prescribed fire working its way through understory in oak woodland (Photo by David Lancaster/CDFG).

forage than do older ones (Taylor 1956, Taber and Dasmann 1958). The loss of fire allows the shrub layer to increase in decadence and lose forage value. In addition, deer foraging height is limited in most situations to approximately 4-5 feet (Taylor 1956, Wallmo 1981). As fire suppression allows shrubs to grow in stature beyond the vertical foraging limit of black-tailed deer, an increasing proportion of their new growth becomes unavailable. Also, the reduction in fire leads to greater recruitment of conifer into the overstory and increasing closure of the overstory canopy.

Mixed Severity Fire Regimes

Fire suppression has adversely impacted black-tailed deer through habitat loss in plant communities subject to mixed severity fire regimes. Drier conifer forests in inland and southerly portions of the Coastal Rainforest Ecoregion are the habitat types primarily impacted. Inland Douglas-fir forests and some white fir (*Abies concolor*) forests are examples of this type.

The mixed severity fire regime is associated with highly diverse forests in both structure and species composition, including shrubs and herbaceous plants (Agee 1993, Arno and Allison-Bunnell 2002). Hanson (2002) related that the high variation in fire return interval and severity that previously occurred in Douglas-fir–hardwood forests in the Klamath Mountains contributed toward the maintenance of a patchy mosaic of community types in a variety of seral stages with extensive edge. These conditions are advantageous to black-tailed deer because deer are strongly associated with edge habitat due to the close juxtaposition of foraging and cover habitats (Einarsen 1946, CDFG et al. 1998). Also, the high level of plant diversity resulting from the mixed severity fire regime accommodates black-tailed deer preference for using a wide variety of forage species (Taylor 1956). Habitat diversity resulting from this fire regime allows black-tailed deer to exploit seasonal variation in forage availability and quality among plant communities and seral stages. This mixture of fire on the landscape also ensures that a young nutritious browse component used by black-tailed deer throughout the year is available (Reynolds and Sampson 1943, Taylor 1956, Brown 1961, Wallmo 1981, CDFG et al. 1998).

The habitat diversity and extensive edge maintained in a mixed severity fire regime results from localized variability in fire return interval and severity (Agee 1993, Arno and Allison-Bunnell 2002). Fuels and dominant vegetation of varying fire sensitivity accumulate unevenly across the landscape, resulting in a heterogeneous distribution of high severity burns with associated forest openings, low severity burns with young understories and intact but thinned overstories, and dense unburnt forest stands. Succession and a reduction in the variability of fire severity are the primary effects of long-term fire suppression causing the

reduction of habitat suitability for black-tailed deer. Early seral stages, which often constitute foraging habitat preferred by deer, are lost as larger portions of the landscape transition toward closed canopy later seral vegetation communities in the absence of disturbance by fire (Taylor 1956, Wallmo 1981, CDFG et al. 1998). Wills and Stuart (1994) reported that a high frequency of fire occurring in Douglas-fir–hardwood forests prior to fire suppression, contributed to the maintenance of a more complex mosaic of forest seral stages. In addition, the distribution of forest types is almost as important to deer as the stage of forest succession; diverse landscapes support a greater number of deer than do those dominated by large areas of uniform vegetation (Taylor 1956).

Fire suppression has led to an increase in fire severity where fire frequency has been reduced (Atzet and Wheeler 1982, Agee 1993, Key 2000, Arno and Allison-Bunnell 2002). The average fire return interval in white fir forests in the Six Rivers National Forest was 27 years prior to the advent of fire suppression, and 74 years for the period after suppression was implemented (Stuart and Salazar 2000). Agee (1993) and Key (2000) related that fire severity has increased in Douglas-fir–hardwood forests, as a result of fire suppression. The increasingly uniform occurrence of high severity fire results from successional changes in the plant community and increases in fuels caused by fire suppression.

Succession in the absence of fire disturbance contributes to the transition of the plant community toward shade tolerant species that are often more susceptible to fire mortality. Stand density in the Six Rivers National Forest of northwestern California has increased since the early 1960s due to an increase in shade tolerant species resulting from a longer fire return interval (Key 2000). Key (2000) also related that as fire suppression allows fuels to build up more evenly across the landscape, the patchy mosaic of seral distribution resulting from the uneven build up of fuels under the mixed severity fire regime is reduced.

High Severity Fire Regimes

Plant communities that naturally exhibit high severity fire regimes are primarily moist forest types such as Sitka spruce, western hemlock, silver fir, subalpine fir (*Abies lasiocarpa*), and certain coastal Douglas-fir forests. The impacts of long-term fire suppression on plant communities with natural, high severity fire regimes may be minimal for black-tailed deer. Due to the long fire return intervals (hundreds of years) observed in plant communities with high severity fire regimes and the relatively short time (approximately 60 years) in which fire suppression has been effective across the landscape, fire suppression may not have had an appreciable effect on these communities. In addition, timber management has become a more regular and widespread source of disturbance across much of the area containing plant communities with high severity fire regimes than wildfire had been prior to the advent of fire suppression (Arno and Allison-Bunnell 2002).

In those areas where late-seral conifer habitats constitute an important habitat component for black-tailed deer and are limiting, fire suppression may be advantageous by helping to retain such stands on the landscape. In southeastern Alaska and British Columbia, deer population performance is better when late seral forest habitat is available than when absent (Fennessy and Drew 1985, Nyberg et al. 1986, Fagen 1988), however wildfire frequency is low and less of a management issue in wetter climates.

Issues and concerns

There are substantial difficulties associated with returning wildfire to the landscape. Much of the impetus for protecting property, esthetic values, and the environment through fire suppression remains. In many plant communities, decades of fire suppression have resulted in an increase in fire severity over that which had previously occurred. Timber management has also led to an increase in fire severity (Key 2000; L. Salazar, U.S. Forest Service, personal communication; K. O'Neil, personal communication). As such, hazards associated with wildfire have increased, including a compromised ability to exclude wildfire where it is undesirable and overly severe effects where it is otherwise considered beneficial.

Expense and conflicts with other interests impede the implementation of vegetation management projects to redress the adverse effects of long-term fire suppression on black-tailed deer habitat. In terms of expense, the geographic area degraded by fire suppression greatly exceeds the acreage that habitat improvement projects can encompass with available funds. Also, perpetual maintenance will be required to retain target habitat conditions occurring in early seral stages where the occurrence of wildfire is not sufficient to do so. Some of the primary conflicting interests inhibiting the implementation of vegetation management projects include protection of private property, public safety, air and water quality, cultural resources, and special-status species and their habitats.

Guidelines

Implementation of the following guidelines may increase the likelihood of successfully reversing some of the adverse effects of long-term fire suppression on black-tailed deer habitat:

1. Where feasible, fire suppression policy should be established that discourages the suppression of those wildfires that contribute to the creation and maintenance

Table 4. Vegetation management techniques to address the effects of long-term fire suppression (Reynolds and Sampson 1943; Wagle 1981; DeBano et al. 1998; Brown and Smith 2000; Richardson et al. 2001; Vesely and Tucker 2004; Harrington and Devine 2006; T. LaBanca, CDFG, personal communication).

Technique	Advantages	Disadvantages
Prescribed Burning	➤ Efficient for long-term maintenance of oak woodlands and early seral understories ➤ Consumes fuels ➤ Provides ecosystem services such as nutrient cycling and seed scarification ➤ Effects on vegetation are usually uneven which promotes patchiness of habitat ➤ May be used to regenerate decadent shrub layers ➤ May be used to promote herbaceous diversity ➤ May be more cost-effective at larger scales	➤ Restrictions for the protection of air and water quality, public safety, private property, cultural resources, and special-status species ➤ Pretreatment of fuels with mechanical manipulation may be required to reduce fire severity to a desirable level ➤ Low to moderate control of effects on vegetation resulting in less predictable outcome relative to other techniques ➤ Expensive at smaller scales
Mechanical Manipulation	➤ High level of control regarding effects on vegetation ➤ May be more cost effective than prescribed burning for small scale projects ➤ Useful for pretreatment of fuels prior to reintroduction of fire ➤ Fewer impediments to use than exist for prescribed burning ➤ May be used to regenerate decadent shrub layers ➤ May be used to promote herbaceous diversity	➤ Restrictions for the protection of water quality, cultural resources, and special-status species ➤ Limited by topography, fire hazard, and saturated soils ➤ May produce slash or ground disturbance requiring treatment ➤ May encourage undesirable exotic vegetation ➤ Expensive, but costs may be reduced if associated with commercial timber or firewood harvesting
Livestock Grazing	➤ May slow succession ➤ Cost effective ➤ Moderate to high level of control regarding effects on vegetation	➤ Generally not sufficient on its own to maintain desired vegetation conditions over the long-term ➤ May produce ground disturbance requiring treatment ➤ Excessive grazing can reduce habitat value for black-tailed deer
Herbicide	➤ Herbicide is rarely used to address the effects of fire suppression but may be used to control exotic or shade tolerant vegetation that fire would have otherwise excluded ➤ High level of control regarding effects on vegetation.	➤ Restrictions for the protection of air and water quality and special-status species ➤ Creates standing dead vegetation that may need to be treated ➤ Broadcast applications may damage desirable vegetation ➤ Expensive
Out-planting	➤ Allows for the reestablishment of desirable vegetation lost due to the effects of fire suppression ➤ Moderate level of control over vegetation response	➤ Variable survival rates ➤ Generally not sufficient on its own to maintain desired vegetation conditions over the long-term ➤ Expensive, but costs may be substantially lowered if plant stock can be acquired non-commercially

of desirable habitat conditions for black-tailed deer.

2. Focus the resources available for vegetation management projects to address the adverse effects of fire suppression in key deer habitat.
   - Predictive habitat and population performance models may be useful for identifying focus areas.
   - Expending resources in plant communities that traditionally exhibited high severity fire regimes should be avoided, as the effects of fire suppression may be minimal.
   - Vegetation management projects may include eradicating conifer that is encroaching on oak woodlands and prairies or reducing fuels to a desirable level prior to the reintroduction of fire.
3. Attributes of the various techniques available for managing vegetation to address the effects of fire suppression should be understood and the techniques applied to their most effective use based on site-specific conditions (Table 4).

Non-native Invasive Plant Species

Background

The Coastal Rainforest Ecoregion has been highly altered during the past 2 centuries. Non-native plant species impact on wildlife habitat has been a growing concern especially during the past 2 decades. The Oregon Conservation Strategy (ODFW 2006) states that invasive species are considered one of the primary causes of species becoming threatened and endangered, second only to habitat conversion. Oregon has identified ≥39 documented invasive plant species in the Coastal Rainforest Ecoregion. Although some of these plants are likely of minimal negative impact on black-tailed deer, several are of major concern. The invasive plant species in this ecoregion that affect blacktail habitat are often toxic, or have low nutritional value. Several develop homogenous monocultures that eliminate more desirable native plant species. It is beyond the scope of these guidelines to provide a comprehensive treatise on the management of invasive plant species. For that, the authors suggest the final EIS developed by the Olympic National Forest (USFS 2008). The following invasive plant species are considered to be some of the most detrimental to black-tailed deer habitat.

Himalayan blackberry (*Rubus armeniacus*)
Himalayan blackberry (Figs. 31, 32) is a robust, perennial, sprawling shrub that is the most widespread and economically disruptive of all the noxious weeds in western Oregon. It aggressively displaces native plant species, dominates most riparian habitats, and has a negative economic impact. This species also invades forest edges, disturbed areas, meadows, and clear cuts. Himalayan blackberry is very competitive and shades out other plant species, limits movements of large wildlife, and can reduce the utility of small meadows (Soll 2004, ODA 2006a).

Scotch broom (*Cytisus scoparius*)
Scotch broom (Fig. 33) forms pure stands at the expense of desirable grasses and young trees and is reported in Europe to be toxic to livestock (PNW 1998). Large monoculture stands of Scotch broom reduce available black-tailed deer forage.

Knapweeds (*Centaurea* spp.)
Several species of knapweed occur within the coastal rainforest. They aggressively displace native species, and provide limited value as forage. Knapweed infestations decrease native plant diversity and increase erosion. Generally, they are allelopathic. Diffuse knapweed (*C. diffusa*) has been documented to cause up to 63% loss of grazing forage (WSDA 2003). Yellow star-thistle (*C. solstitialis*) is adapted to a wide range of habitats and environmental conditions in California, Washington and Oregon.

Gorse (*Ulex europaeus*)
This shrub is a stout, perennial evergreen with well-developed spines. Few invasive species dominate a site like gorse (Fig. 34) and it is considered the most unmanageable

Figure 31. Himalayan blackberry vines taking over fence line and abandoned livestock loading chute (Photo by Eric Holman/WDFW).

Figure 32. Himalayan blackberry vines covering an entire power line corridor. All other plants are being crowded out at this site and travel across or within the corridor is nearly impossible (Photo by Eric Holman/WDFW).

Figure 33. The foreground of this picture is covered in young Scotch broom plants. If left unchecked they will out compete the other plants and ultimately gain a height of 6 to 8 feet (Photo by Eric Holman/WDFW).

Figure 34. Gorse covering bluff along highway north of Florence, Oregon (Photo by Doug Cottam/ODFW).

Figure 35. Bull thistle (Photo by Doug Cottam/ODFW).

Figure 36. Tansy ragwort (Photo by Doug Cottam/ODFW).

exotic weed in California (Hoshovsky 1989, WSDA 2000). This species outcompetes native vegetation with seeds that are viable for 30 years. Gorse changes soil characteristics, which can permanently prevent re-establishment of native species without considerable treatment. Gorse stands can be considered useless to black-tailed deer.

Thistles: bull (*Cirsium vulgare*) (Fig. 35); Canada (*C. arvense*); Scotch (*Onopordum acanthium*)
These thistles can be found throughout or in limited areas of the coastal rainforest (ODA 2006b). They typically outcompete native vegetation and can be a barrier to livestock (and likely deer) movement due to their dense stands and large spines. Canada and Bull thistle often occupy clear cuts, thereby reducing native forage species in what otherwise would be considered important habitat.

Tansy ragwort (*Senecio jacobaea*) (Fig. 36) and common groundsel (*S. vulgaris*)
These 2 invasive species in the genus Senecio are toxic and occupy disturbed areas. Common goundsel can be found in Oregon and Washington (Aldrich-Markham 1994). Groundsel has been observed dominating in clear cuts in the mid-coast of Oregon. Tansy ragwort was once considered Western Oregon's most serious noxious weed; however, biological controls have reduced the severity of outbreaks below economic threshold levels (ODA 2006c).

Issues and Concerns

Invasive plant species are one of several major issues affecting black-tailed deer habitat in the coastal rainforest. Conditions in the ecoregion that allow coastal rainforests to thrive can also be very favorable for non-native, invasive plants.

In general, invasive plant species tend to thrive on disturbed sites. Non-native, invasive species can benefit from contemporary silvicultural practices as well as other forms of habitat disturbance. Some forest management practices, like chemical management of plant species in competition with conifer seedlings can lead to the decline in early seral native plant species. On federal lands, fire suppression and reduction in timber harvest also contribute to loss of native, early successional habitat types. Invasive plants can often establish and become a substantial problem under these conditions.

Black-tailed deer are often thought to be well-suited to dense, high-canopied conifer forests, but Brown (1961) and Hines (1973) suggested that early successional habitats created by logging or fire produce higher deer densities. In Washington and Oregon, the black-tailed deer's principal diet consists of trailing blackberry, red huckleberry (*Vaccinium parvifolium*), forbs, salal, grasses, acorns, lichens, and mushrooms (Brown 1961, Crouch 1966, Miller

1968, Maser et al. 1981). Hines (1973) demonstrated that the most preferred, nutritious, and digestible food source is trailing blackberry, and its leaves supplied half of the food supply at the onset of winter. Highly preferred huckleberry twigs and moderately preferred evergreen salal provide the residual winter food, although Perez (2006) found little nutritional value in salal. Invasive, non-native plant species that supplant native forage species are likely detrimental to the quantity and quality of black-tailed deer forage available.

Guidelines

Implementation of the following guidelines will help reduce the deleterious effects of non-native species of vegetation on black-tailed deer habitat.

1. Implement Best Management Practices to prevent weed establishment and spread as a part of regular land-management activities and planning. Plan activities prior to seed set, limit soil disturbance, reduce risk by closing roads to weed carrying vehicles, manage livestock operations to reduce weed infestation risk, clean vehicles after working in infested areas, etc.
2. Identify infestations of weeds and other undesirable or invasive plant species as a part of regular land-management activities before infestations become large and difficult to control. Control known infestations of weeds and other undesirable plant species on a regular basis prior to widespread infestation.
3. Monitor the effectiveness of control measures and adapt methods accordingly.
4. Coordinate invasive plant management activities with adjacent landowners.
5. Comply with weed-related regulations established by state and county authorities.
6. Establish desirable plant species on disturbed sites in advance of invasion by undesirable species.

Increased Herbivory

Background

Ungulate herbivores interact with their habitats in complex ways that can affect conspecifics, other herbivores, and community attributes (Hobbs 1996, Augustine and McNaughton 1998). For many deer populations, herbivory by domestic livestock and native ungulates is an important factor affecting deer habitat (see Mackie 1981, Fleischner 1994). In the Coastal Rainforest Ecoregion, livestock grazing plays a less substantial role in manipulating structure and plant species composition of habitats used by deer. This is principally because livestock grazing is a relatively limited land use in the closed canopy dominated communities of the coastal rainforest. However, some livestock grazing occurs within the ecoregion (Hatch et al. 1999), and herbivory associated with wild herbivores is a potentially important factor affecting coastal black-tailed deer habitats and land management.

Issues and Concerns

Domestic Livestock

Livestock grazing can dramatically influence plant communities, particularly in sensitive habitats such as riparian areas and meadows (Kauffman and Krueger 1984, Fleischner 1994, Belsky et al. 1999). In general, livestock grazing in the Coastal Rainforest Ecoregion principally occurs in lowlands and valley bottoms on small to mid-sized parcels of private land. Grazing on national and provincial forestlands is limited, compared to other ecoregions of the western U.S.

Grazing by domestic sheep has been proposed as a potential tool to manage undesired understory proliferation on managed Douglas-fir plantations (Rhodes and Sharrow 1990). Experimental summer-fall sheep grazing reduced fall shrub and forb biomass with limited effects on graminoid biomass, relative to ungrazed controls. Grazing also improved fall forage quality relative to ungrazed controls, but these effects were no longer detectable by the following spring. Sheep grazing as a silvicultural tool was inferred to be reasonably effective at achieving desired forest management outcomes. The authors inferred summer-fall sheep grazing had positive implications for deer and elk forage quality (Rhodes and Sharrow 1990), but the tradeoffs of enhanced forage quality and reduced forage biomass on elk and deer were not evaluated.

In a study of diet selection by black-tailed deer and cattle near the southern extent of the Coastal Rainforest Ecoregion, there were substantial differences in forages selected (Elliot and Barrett 1985). Cattle principally selected graminoids, whereas deer foraged primarily on forbs. Diet diversity was low for both herbivores, and diet overlap was minimal, especially during midwinter and summer months. Diet specialization appeared to reduce potential competition, but because the environment was relatively xeric compared to most of the ecoregion, implications may not be widely applicable to coastal blacktail range.

Wild Herbivore Interactions

Coastal blacktails are sympatric with other large, wild herbivores, most notably Roosevelt elk (*C. e. roosevelti*). Deer and elk are potential competitors for forage (Mackie 1981, Kingery et al. 1996), but widespread, long-term sympatry suggests the existence of mechanisms that commonly reduce direct competition. Such mechanisms would include diet specialization and scale-specific differences in habitat selection (Hanley 1984b, Leslie et al. 1987, Stewart et al. 2002). Habitat heterogeneity would tend to enhance opportunities for specialization, but coastal black-tailed deer range has been noted for relatively low

floristic diversity (Harris and Farr 1979, Regelin 1979, Kirchoff and Larsen 1998).

Studies of sympatric Roosevelt elk and coastal black-tailed deer have demonstrated potential for direct competition between the 2 species, based on diet similarity. In old growth forests of coastal Washington, elk and black-tailed deer diets were both comprised of relatively common old-growth understory species, and diet overlap was high (Leslie et al. 1984). Deer diet quality appeared superior to elk diet quality during some seasons (Leslie and Starkey 1985). Competition potential was presumed to be high based on diet composition. However, in managed forests of western Washington, deer and elk appeared to select different habitat patches and select different forages, reflecting nutritional constraints unique to each species (Hanley 1983, 1984b). Elk selected higher biomass settings and accepted lower quality forages than did deer in the managed forest setting. Logging may have increased habitat diversity in the managed forest relative to old growth forest in these 2 examples, increasing the potential for specialization and reducing direct competition.

Sitka black-tailed deer diets in southeast Alaska were similar to diets of introduced Roosevelt elk (Kirchhoff and Larsen 1998). The potential for diet specialization was apparently constrained by community forage diversity, which is relatively low in southeast Alaska (Harris and Farr 1979, Regelin 1979, Kirchhoff and Larsen 1998). Competition was presumed to be limited because of ungulate density, but considerable potential for forage competition appeared to exist if elk numbers increased. Diet overlap between elk and deer varied through time, but was substantial during a relatively mild winter. Elk did consume more grasses and sedges than deer, and deer ate more forbs and low-growing evergreens than elk. The potential for substantial competition was inferred to be greater under severe winter conditions when food availability would be reduced and both species would be utilizing the same forage, especially *Vaccinium* spp.

Black-tailed deer diets were seasonally dissimilar to diets of tule elk (*C. e. nannodes)* in coastal prairie scrub at the southern tip of the Coastal Rainforest Ecoregion (Gogan and Barrett 1995). Diet overlap was highest during dry summer months and lowest during wet winter periods. Deer diets appeared to generally be higher in quality, as judged by fecal nitrogen levels, than elk diets. Because forbs were prominent in deer diets most seasons, diet similarity between blacktails and elk appeared to principally reflect the degree to which elk seasonally consumed forbs. Cattle grazing had occurred just prior to the study, but cattle were not present during the actual timeframe elk and deer diets were quantified.

In Washington and Oregon, coastal blacktails are sympatric with Columbian white-tailed deer (*O. virginianus leucurus*). Little research had addressed potential interactions such as competition for forage and space between these 2 deer species. However, Smith (1987) presented data that suggested that Columbian black-tailed deer may avoid Columbian whitetails, using some habitats more in areas where whitetails were absent or few than where they were common.

Coastal black-tailed deer range overlaps geographically with the range of mountain sheep (*Ovis canadensis* and *Ovis dalli*). Although some subalpine summer range for coastal blacktails may also support wild sheep use, research addressing potential competitive relationships between sheep and deer has been rare. Presumably, habitat specialization, especially by sheep, has minimized substantial competition between coastal blacktails and wild sheep. Similarly, black-tailed deer share portions of their range with populations of mountain goats (*Oreamnos americanus*). Though interactions and competition between the deer and mountain goats has not been well studied, it is presumed to be minimal due to the restricted range of mountain goats and the habitat used by goats. Moose (*Alces alces*) occur in the northern half of the Coastal Rainforest Ecoregion and may occupy habitats also exploited by black-tailed deer (Darimont et al. 2005). Very little literature exists neither on potential competitive relationships between moose and coastal blacktails nor on impacts of moose herbivory to black-tailed deer habitat. Divergent foraging strategies based on much different morphological and energetic constraints likely serve to limit potential competition between moose and black-tailed deer.

Herbivory Effects On Coastal Deer Habitat

Herbivory by large ungulates has been demonstrated to dramatically influence long-term habitat structure, succession, and plant associations (Woodward et al. 1994, Hobbs 1996, Riggs et al. 2000, Rooney 2001, Côté et al. 2004). In a well-documented general example from northeastern Oregon, elk and mule deer herbivory strongly influenced understory succession, and biomass and nutrient accumulation (Riggs et al. 2000). The abundance and distribution of deciduous shrubs was strongly limited by deer and elk browsing, and species assemblages were dramatically influenced by selective foraging on preferred species. Studies on Haida Gwaii off the coast of British Columbia also demonstrated substantial effects of high levels of black-tailed deer browsing on forest structure, species diversity, and understory biomass (Stockton et al. 2005, Gaston et al. 2006). On this island, heavy browsing by deer predictably simplified forest communities. Similar effects were reported by Hanley (1987) in southeast Alaska especially in understory poor, young-growth forest on Admiralty Island, and heavily browsed old-growth forest on Coronation Island.

Herbivory has been characterized as a chronic disturbance that operates in concert with other episodic disturbances, such as fire, logging, and herbicide application to affect structure, composition, and succession of forested plant communities (Riggs et al. 2005). Effects of herbivory are strongly influenced by intensity, seasonality, and foraging style of the predominant large herbivores. Effects of wild ungulate foraging have been demonstrated to potentially affect all structural layers of northwestern forest communities (Woodward et al. 1994). Herbivory during the growing season often suppresses palatable herbaceous plant taxa, whereas dormant season browsing may enhance some herbaceous taxa (Riggs et al. 2005). Year-round browsing, or intense seasonal browsing by deer and elk may dramatically suppress shrub growth and alter successional outcomes (Hanley and Taber 1980, Riggs et al. 2000). Palatable plants preferred by ungulate herbivores tend to have lower concentrations of secondary metabolites that inhibit digestion, and fewer indigestible components (Riggs et al. 2005). Palatability and susceptibility to suppression by herbivory tend to be correlated among forage species.

Coastal blacktails forage on a diverse array of plant species (Crouch 1979, 1981a; Hanley et al. 1989, Regelin 1979). Deer herbivory effects on individual forage species and plant communities are not limited to herbaceous plants and deciduous shrubs commonly assumed to be preferred forages (Hanley and Taber 1980, Woodward et al. 1994, Riggs et al. 2000, 2005). Coastal blacktails will forage on evergreen shrubs and conifers (Hanley et al. 1989, Oh et al. 1999, Parker et al. 1999), which on other mule deer ranges are often forages of last resort. Conifers commonly browsed by black-tailed deer include western red cedar (Vourc'h et al. 2001), western hemlock (Hanley et al. 1989, Vila et al. 2003a), Douglas-fir (Brown 1961), and Sitka spruce (Hanley et al. 1989).

Plants have evolved a rich array of defenses to herbivory, including structural (e.g., thorns, fibrousness) and chemical defenses (e.g., phenolics) (Hanley 1984a, Hanley et al. 1992). Differences in evolutionary exposure to herbivory may yield divergent levels of defensive adaptations within the same species of plant. For example, forest communities of the islands of the Haida Gwaii archipelago (British Columbia) were free of large ungulates until approximately the 20th century, whereas nearby mainland forests evolved with long-term herbivory by Sitka black-tailed deer (Vourc'h et al. 2001, 2002a). Terpenes, a chemical with herbivory inhibiting properties, were demonstrated to be systematically lower in seedling and older red cedar tissues on islands with only recent exposure to deer herbivory, relative to mainland forests. Experimental offerings of island-grown and mainland-grown red cedar seedlings and older tree branches (i.e., trees that matured prior to exposure to herbivory) demonstrated that deer preferred the island forages with lower terpene concentrations (Vourc'h et al. 2001). Sapling red cedars from the islands tended to have relatively high terpene concentrations, suggesting a recent defensive response in red cedars to deer browsing. Deer fed indiscriminately when offered saplings from the mainland and island forests.

Black-tailed deer herbivory has been demonstrated to affect growth rates and modify morphology of conifers (Vila et al. 2001, 2003b). High levels of browsing can reduce radial growth (Vila et al. 2001, 2003a), potentially stagnating development. Heavily browsed trees also tend to have stunted forms with ramified branches in the browse zone (Vila et al. 2003a, 2003b). Browsing intensity may not be uniform across all trees in a stand, reflecting apparent differences in individual tree response to browsing damage and concentrations of secondary metabolites that inhibit browsing (Vourc'h et al. 2002a, 2002b). Although heavily browsed conifers typically grow slowly, they usually grow adequately to eventually reach a height above the reach of foraging deer (the so-called browse line). Portions of these trees, now released from browsing, tend to recover normal shape and growth patterns (Vila et al. 2001, 2002, 2003b). Uneven-aged stands browsed heavily by deer often consist of larger, older trees with evidence of previous browsing, and younger trees strongly modified by ongoing herbivory. Deer foraging may also suppress conifer recruitment (Hanley and Taber 1980, Woodward et al. 1994, Martin and Baltzinger 2002, Vila et al. 2003a).

Deer Herbivory As Damage

Damage, as an outcome of deer foraging, is context dependent. Deer browsing can strongly affect community attributes such as rates and outcomes of succession, species associations, nutrient cycling, and productivity (Riggs et al. 2000, 2005; Rooney 2001, Côté et al. 2004, McNeil and Cushman 2005, Stockton et al. 2005). Characterizing such effects as "damage" or simply as an alternative ecological state depends largely on management perspective (Riggs et al. 2005). When deer browsing negatively impacts other resource management objectives, such as some specified future condition, its effects may be considered deleterious (Côté et al. 2004, Allombert et al. 2005, Gaston et al. 2006). For example, attempts to restore degraded riparian corridors have been compromised by excessive deer herbivory (Opperman and Merenlender 2000). Deer browsing can also foster cascading ecological effects extending to invertebrates (Warner and Cushman 2002, Allombert et al. 2005) and small mammal and bird components of communities exploited by black-tailed deer (Côté et al. 2004). Alternate ecological states facilitated by excessive deer herbivory can be relatively stable and difficult to reverse (Côté et al. 2004).

Deer herbivory impacts to commercial forestry have been well documented across North America (Crouch 1981b, Gill 1992). Characterizing deer browsing impacts as damage seems justifiable in the context of economic losses to forest management operations. These losses can include lost production due to deer herbivory constraining growth rates of commercially valuable trees, actual tree mortality, and more broad scale effects of deer browsing on forest succession patterns (Brown 1961, Black 1994, Riggs et al. 2005). The relative impact of deer browsing usually corresponds to deer population cycles, but may also reflect the general availability of quality seasonal foraging areas for deer. Silvicultural practices may also influence deer damage to commercial forests via effects on the patchiness of deer foods and its relationship to deer distribution. Even-aged forestry is a cost-effective management technique, and the early seral stage blocks it creates are often preferred black-tailed deer habitat, at least in the southern 2/3 of the Coastal Rainforest Ecoregion (Brown 1961, Hanley 1980, Crouch 1981a). However, because recent clearcuts and very young second-growth stands are attractive deer foraging habitat, even-aged management may concentrate deer use and facilitate damage to young conifers (Black 1994). Uneven-aged management typically disperses the disturbance effects of logging and because stands typically retain a substantial overstory component, deer use and damage potential may be reduced relative to young even-aged stands.

A variety of approaches have been explored to reduce deer damage to commercially managed forests, with variable success (Crouch 1981b, Black 1994). Although fencing and protective netting can be effective at protecting ornamental shrubs and trees, they are impractical for large tracts of managed forest (Crouch 1981b). Numerous chemical deterrents to deer browsing have been explored. Experimentally treating Douglas-fir seedlings with wild ginger (*Asarum caudatum*) and putrefied fish extract deterred deer foraging (Campbell and Bullard 1972). A commercial repellent marketed as Big Game Repellent, derived from whole eggs, has been effective for deterring deer foraging for short periods (approx. 2-3 months) following application to conifer foliage (Black 1994, Nolte 1998, Wagner and Nolte 2000). Other commercial compounds producing sulfurous odors (Deer Stopper and Plantskydd) similarly deterred black-tailed deer browsing for a period extending up to 14 weeks (Nolte 1998). Capsaicin, the active component of chili peppers (*Capsicum* spp.), was demonstrated to be aversive to black-tailed deer when applied to western red cedar seedlings, but only for approximately 2 weeks post-treatment (Wagner and Nolte 2000). Wolfin, a synthetic predator odor, was relatively ineffective as a black-tailed deer repellent (Nolte et al. 2001) as was a bitter tasting compound known as ECX95BY (active ingredient denatonium benzoate) (Nolte 1998). Formulations containing various concentrations of hydrolyzed casein were effective at reducing deer damage to western red cedar saplings (Kimball and Nolte 2006). Little research has addressed effects of chemical herbivory deterrents on non-target organisms or environmental quality (e.g., water quality). Chemical deterrents to herbivory have been demonstrated to work in specific contexts, but generally have geographic and temporal scale limitations that constrain their use as a practical tool for managing excessive deer browsing.

An alternative to trying to protect young conifer foliage from deer browsing using chemical deterrents is management designed to provide alternative forage (Becker et al. 1996). Artificial feeding has been used to deter ungulate damage to forests in Europe, but has had little application in North America (Black 1994). Feeding is not a practical alternative for managing deer damage in the Coastal Rainforest Ecoregion given expense, logistic difficulties, and the well documented negative consequences of artificial feeding programs. A somewhat different approach that has been used in the Pacific Northwest is to seed palatable herbs and grasses in young conifer stands in an attempt to focus deer feeding on non-conifer forage (Black 1994). This approach has been touted to be effective, but lack of stringent monitoring criteria has been a criticism of this strategy (Becker et al. 1996).

The simplest and most cost-effective approach to reducing deer damage to commercially managed forests has been hunting. Special late hunting seasons were used in western Oregon to reduce deer damage to Douglas-fir second-growth forests (Crouch 1980). Browsing damage in areas that were hunted under this strategy was reduced relative to control areas, even though it was estimated that the total number of deer removed by hunting was small. Similarly, the effect of hunting on deer behavior, rather than deer survival, was touted as the mechanism responsible for reducing black-tailed deer damage to regenerating conifers in the Queen Charlotte Islands of British Columbia (Martin and Baltzinger 2002).

Guidelines

Published guidelines for forage removal or residual dry matter specific to the Coastal Rainforest Ecoregion are few, presumably because of limited livestock grazing on federal, state, and provincial forests of this area. For example, forest planning documents for the Chugach and Tongass National Forests in Alaska and Olympic National Forest in Washington do not identify livestock grazing as a major land use. This partly reflects the impracticalities of seasonally deploying and retrieving livestock over much of the ecoregion's landscape (i.e., remote and poorly accessible), as well as forested plant communities that are not well suited to traditional livestock use (e.g., low

Table 5. Minimum residual dry matter (RDM) standards (lbs/acre) for coastal prairie (dry wt) (from Bartolome et al. 2006).

	RDM standard			
Woody cover (%)	**0-10% slope**	**10-20% slope**	**20-40% slope**	**>40% slope**
0-25	1,200	1,500	1,800	2,100
25-50	800	1,000	1,200	1,400
50-75	400	500	600	700
75-100	200	250	300	350

Table 6. Minimum RDM standards (lbs/acre) for annual grassland-hardwood rangeland (dry wt) (from Bartolome et al. 2006).

	RDM standard			
Woody cover (%)	**0-10% slope**	**10-20% slope**	**20-40% slope**	**>40% slope**
0-25	500	600	700	800
25-50	400	500	600	700
50-75	200	300	400	500
75-100	100	200	250	300

graminoid abundance and diversity compared to other deer ranges). Because livestock grazing represents a minor land use on state, federal, and provincial coastal forests, little research has been done specific to issues of sustainability and effects of livestock grazing, and very few formal grazing guidelines have been proffered for public lands of the ecoregion. However, Tables 5 and 6 summarize published guidelines for residual dry matter for California rangelands within the Coastal Rainforest Ecoregion.

1. Monitoring and managing for the effects of herbivory are relatively unexplored concepts for the region. Ideally, whatever metrics are used to monitor impacts of herbivory should include more than just residual matter; metrics reflecting species composition, percent composition, or other measures of habitat complexity and the value of forage species as they relate to deer should also be included.
2. If quantity and quality of plant species are deemed to be sub-par and domestic livestock are part of the herbivore guild, stocking rate of domestic livestock should be adjusted down to allow plant recovery.
3. If quantity and quality of plant species are deemed to be sub-par and the herbivore guild is composed of wild ungulates that are above desired levels, adjustments should be made to increase hunter harvest to reduce ungulate density and ultimately promote plant composition recovery.
4. Correlating plant community attributes with body condition of wild ungulates (Cook et al. 2004, Cook et al. 2007) could be used to index the effects of herbivory and indicate times when wild ungulate populations should be reduced, or forage quantity or quality should be increased.

SUMMARY

Black-tailed deer range in the Coastal Rainforest Ecoregion encompasses a narrow band along the northwestern coast of North America. Historically, mild maritime climates, abundant water, and expansive tracts of mature conifer forest dominated the ecoregion. The activities of humans following the arrival of Europeans have tremendously altered the landscape occupied by black-tailed deer.

Forest management activities have had, and continue to have dramatic, ecosystem altering effects on the habitat of black-tailed deer. Timber harvest, forest regeneration, and various other components of forestry may be conducted in ways that are either of great detriment or potentially beneficial to blacktails (Fig. 37). The methods by which quality habitats are maintained or developed differ greatly within the ecoregion. In the northern range of Sitka blacktails, maintenance of mature forest with a patchy understory for foraging and a well-developed canopy for snow interception are of paramount importance. In the southern range of Columbian blacktails, the development of timber management strategies that limit stem-exclusion stage forests and maintain understory vegetation is critical on both private industrial tree farms and public forests.

Figure 37. Black-tailed deer in old cut on federally managed forest. Note the forage growth in the openings, which have not been treated with herbicides (Photo by Scott McCorquodale/WDFW).

Human encroachment into the habitats of black-tailed deer is pervasive, especially in the southern portion of the ecoregion. Unlike forest management, urban development, suburban sprawl, and the establishment of associated infrastructure come at the complete detriment of deer. Efforts to minimize these impacts to blacktail habitat may moderate or slow these negative effects. For example, zoning laws favoring open space, maintenance of forestry and agricultural industries, wildlife friendly crossings on highways, conservation easements, and the outright purchase of land for its habitat value can slow the loss. In spite of efforts of this nature and in light of the projected increase in human population within the ecoregion, the continual loss of habitat will be a reality throughout those portions of the ecoregion not held in public ownership.

Fire suppression has greatly altered the fire regime in portions of the Coastal Rainforest Ecoregion. The following axiom generally describes this relationship: in the northern and wetter portions of the region fire regimes are less altered, but in the southern and more arid areas, fire currently occurs much less frequently than the historic rate.

Lengthening the frequency at which fires occur on the landscape generally leads to a somewhat predictable pattern that simplifies forest stands. As fire-adapted forests mature in the absence of fire, canopies close, understory vegetation is reduced, and fuel loads build. This simplification of forest communities and loss of herbaceous vegetation translates into poor deer habitat. Fuel buildup can result in large-scale fires that may then lead to damaged soil or the establishment of undesirable, monotypic plant communities.

In contrast, historical fires burned in an uneven pattern over the landscape, happened with more regularity, and invigorated the growth of forage plants (Fig. 38). Where feasible, returning the forests of the ecoregion to a schedule of burning that more closely resembles historic rates or using mechanical or chemical means to mimic such events could be of great benefit to black-tailed deer.

Invasive plants compete directly and very successfully with many native plant species favored by blacktails. Invasive, largely non-native plant species often develop into dense monotypic stands that offer little value to deer. These species are often found in open microhabitats on disturbed soil, thereby occupying a very similar niche to that historically held by favorable forage species. Treatment of these infestations through chemical, mechanical, and biological methods is expensive, difficult, and erodes resources that could be used elsewhere. Implementing strategies that limit the spread of these species and promptly treating areas of small infestations before they spread are the most cost-effective means of addressing this threat to black-tailed deer habitat.

Figure 38. Black-tailed deer in year-old burn on lower elevation state managed land (Photo by Scott McCorquodale/WDFW).

Competitive interactions among ungulate species are ecologically complex. Unlike the case over much of mule deer range, competition or displacement of blacktails by domestic livestock within the Coastal Rainforest Ecoregion is not regarded as an important impact to habitat quality or quantity. However, interaction and competition with other native ungulates, primarily elk, may have impacts on the ecosystem. It could be argued that elk, because they need more food, have higher reach, and occupy more of an ecological generalist niche, may be able to successfully outcompete deer when quality forage is limited. Little conclusive data comes from the Coastal Rainforest Ecoregion on this topic. Forest management activities, fire suppression, and invasion of non-native plants have simplified and fragmented forest habitat on a broad scale. Elk may be better able to deal with current forest communities by feeding on a wider range of plants, and may, therefore, detrimentally affect deer where the species overlap and where forage resources are compromised by habitat degradation. In contrast, where a wide variety of forage resources are present and herbaceous understory vegetation is diverse and vigorous, resource partitioning among Roosevelt elk and black-tailed deer likely reduces or eliminates interspecific competition.

Incorporation of the habitat needs of black-tailed deer into planning efforts, management plans, and guidelines (including both forest management plans and wildlife management plans) could be of tremendous benefit to the species. However, black-tailed deer are often relegated to the status of a non-primary resource in land management planning. Similarly, because public sentiment generally perpetuates the view that any timber harvest is good for deer, management objectives or regulations that would benefit deer habitat are largely absent from forest management. An emphasis on deer habitat conservation and improvement should be incorporated into all forms of land use planning activities.

In spite of these challenges, the guidelines presented in this chapter will aid resource managers in creating and maintaining favorable habitat conditions for deer in the ecoregion. Incorporating the needs of black-tailed deer into natural resource management at a broad scale, as well as active manipulation of habitats, is needed. These guidelines are presented with the hope that they will foster a higher profile for deer and improved habitat conditions for black-tailed deer in the Coastal Rainforest Ecoregion.

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Appendix A.

Alphabetical listing by category of common names (scientific names) of species cited in the text.

Trees and Shrubs

Alder, Red (*Alnus rubra*)
Blackberry, Himalayan (*Rubus armeniacus*)
Blackberry, trailing (*Rubus ursinus*)
Broom, Scot's (*Cytisus scoparius*)
Cedar, Alaska Yellow (*Chamaecyparis nootkatensis*)
Cedar, Western Red (*Thuja plicata*)
Cherry (*Prunus* spp.)
Devil's Club (*Oplopanax horridum*)
Douglas-fir (*Pseudotsuga menziesii*)
Elderberry (*Sambucus* spp.)
Fir, Grand (*Abies grandis*)
Fir, Pacific Silver (*Abies amabilis*)
Fir, subalpine (*Abies lasiocarpa*)
Fir, White (*Abies concolor*)
Gorse (*Ulex europaeus*)
Hazelnut (*Corylus cornuta*)
Hemlock, Western (*Tsuga heterophylla*)
Huckleberry (*Vaccinium* spp.)
Huckleberry, Red (*Vaccinium parvifolium*)
Madrone, Pacific (*Arbutus menziesii*)
Manzanita (*Arctostaphylos* spp.)
Maple, vine (*Acer circinatum*)
Maple, big-leaf (*Acer macrophyllum*)
Oak, Oregon White (*Quercus garryana*)
Oak, California Black (*Quercus kelloggii*)
Redwood, Coast (*Sequoia sempervirens*)
Rhododendron, Pacific (*Rhododendron macrophyllum*)
Salal (*Gaultheria shallon*)
Salmonberry (*Rubus spectabilis*)
Spruce, Sitka (*Picea sitchensis*)
Thimbleberry (*Rubus parviflorus*)
Willow (*Salix* spp.)

Forbs and Grass

Bramble, Five-leaved (*Rubus pedatus*)
Bunchberry (*Cornus canadensis*)
Foamflower (*Tiarella trifoliata*)
Goldthread, Spleenwort-leaved (*Coptis asplenifolia*)
Groundsel, Common (*Senecio vulgaris*)
Knapweed (*Centaurea* spp.)
Knapweed, Diffuse (*Centaurea diffusa*)
Lady-fern (*Athyrium filix-femina*)
Oxalis, Oregon (*Oxalis oregana*)
Pepper, Chili (*Capsicum* spp.)
Ragwort, Tansy (*Senecio jacobaea*)
Star-thistle, Yellow (*Centaurea solstitialis*)
Sword-fern (*Polystichum munitum*)
Thistle, Bull (*Cirsium vulgare*)
Thistle, Canada (*Cirsium arvense*)
Thistle, Scotch (*Onopordum acanthium*)
Violets (*Viola* spp.)
Wild ginger (*Asarum caudatum*)

Animals

Bear (*Ursus* spp.)
Cattle, Domestic (*Bos taurus*)
Deer, Columbian Black-tailed (*Odocoileus hemionus columbianus*)
Deer, Columbian White-tailed (*Odocoileus virginianus leucurus*)
Deer, Mule (*Odocoileus hemionus*)
Deer, Sitka black-tailed (*Odocoileus hemionus sitkensis*)
Coyote (*Canis latrans*)
Elk (*Cervus elaphus*)
Elk, Roosevelt (*Cervus elaphus roosevelti*)
Elk, Tule (*Cervus elaphus nannodes*)
Goat, Mountain (*Oreamnos americanus*)
Lion, Mountain (*Puma concolor*)
Moose (*Alces alces*)
Murrelet, Marbled (*Brachyramphus marmoratus*)
Sheep, Mountain (*Ovis canadensis* and *Ovis dalli*)
Wolf, Gray (*Canis lupus*)

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