AN ABSTRACT OF THE THESIS OF

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Title: Habitat Use of Female Columbian Black-tailed Deer in Western Oregon.

Abstract approved:

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Jimmy D. Taylor

Columbian black-tailed deer (*Odocoileus hemionus columbianus)* are important economically, ecologically, and culturally as an indigenous species in western Oregon. Oregon Department of Fish and Wildlife (ODFW) observed declines in black-tailed deer populations since the late 1980's and attributes these declines to reduction in quality and availability of habitat, following the decline of timber harvest on federal lands. Additionally, black-tailed deer pose a perceived economic impact on private industrial forests by browsing seedlings during stand establishment. In western Oregon, where wildlife habitat management is tied to forest management, effective management for black-tailed deer would be facilitated by investigating home range sizes and habitat use in forested landscapes. To understand habitat preferences and use by female black-tailed deer in western Oregon, I quantified their seasonal and annual habitat use in the Indigo and Alsea Wildlife Management Units (WMU). I conducted home range analysis for 32 individuals in the Alsea and 30 individuals in the Indigo WMU using compositional analysis to investigate second-

(home range establishment) and third- (within home range) order habitat use in proportion to availability at annual and seasonal intervals.

Mean annual home range sizes for female black-tailed deer in the Alsea and Indigo WMU was 64.26 ha (SD = 22.65) and 262.45 ha (SD = 419.50), respectively. Home range sizes increased with decreasing area of early seral (forest age 0-10 years) and mid-seral (forest age 11-20 years) habitat availability, and home ranges were larger with increasing amounts of federal land. Throughout their annual cycle, female deer in the Alsea WMU used forest ages 0-3 years and 11-20 years in greater proportion to its availability and more than other land cover categories in establishing home ranges. Female deer also spent disproportionately more time in the same forest types within their home ranges. In the Indigo WMU, female deer used all land cover categories in proportion to availability in establishing and within home ranges. During periods of anticipated deer herbivory (i.e., damage) to conifer plantations in early summer (May 20 to July 4) and winter (November 25 to March 17), female black-tailed deer also used early (forest age 0-3 years) and mid-seral (forest age 11-20 years) forest cover types in greater proportion than available within their home ranges.

Although I did not quantify deer health or population dynamics, my results support the hypothesis that food and cover are more readily available and used by female black-tailed deer on industrial forestlands than federal forestlands in western Oregon. Future studies should investigate the effects that black-tailed deer habitat use is having on fitness at multiple scales.

Habitat Use of Female Columbian Black-tailed Deer in Western Oregon

by

Timothy J. Schrautemeier

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APPROVED:

Major Professor, representing Forest Ecosystems and Society

Head of the Department of Forest Ecosystems and Society

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Timothy J. Schrautemeier, Author

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CONTRIBUTION OF AUTHORS

Dr. DeWaine H. Jackson with Oregon Department of Fish and Wildlife and associated staff designed and collected the data presented here, as part of the Oregon Department of Fish and Wildlife Black-tailed Deer Management Plan. Dr. Jimmy D. Taylor and Dr. Matthew Betts assisted with the statistical analysis and interpretation of data.

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CHAPTER 1: GENERAL INTRODUCTION

Forests of western Oregon are highly productive and provide a variety of goods and services, yet the effects of management actions applied on a multi-owner landscape are not well understood (Spies et al. 2007). Over 80% of western Oregon is estimated to be forested and dominated by Douglas-fir (*Pseudotsuga menziesii*), a species of high economic value for timber production and industry (Campbell et al. 2004). This economic incentive motivated landowners to manage property to maximize rapidly growing conifer plantations while suppressing hardwoods and early seral vegetation (Spies et al. 2007). However, the development of the Northwest Forest Plan in 1994 shifted the focus of federal forest management from timber harvest to the conservation of late-seral forest biodiversity (Thomas et al. 2006), most notably the Northern Spotted Owl (*Strix occidentalis caurina*) an endangered species associated with old-growth forests. This shift in legislation resulted in disparate forest management practices among federal, state, and private ownerships and altered forest structure across the landscape creating a mosaic of forest stands in various states of succession (Thomas et al. 2006, Spies et al. 2007). The resulting effect of this landscape mosaic on biodiversity is understudied.

One species speculated to be highly influenced by this landscape mosaic is the Columbian black-tailed deer (*Odocoileus hemionus columbianus*, hereafter black-tailed deer). Black-tailed deer are important economically, ecologically, and culturally as an indigenous species in western Oregon. However, Oregon Department of Fish and Wildlife (ODFW) has observed declines in black-tailed deer populations since the late 1980's and believes the declines are caused primarily by a reduction in quality and availability of habitat, following the decline of timber harvest on federal lands (ODFW 2008). Black-tailed deer are a natural component of forest ecosystems and are considered habitat generalists (Wallmo 1981). While early successional sites provide forage, cover provided by mature forests may be the most important habitat element for maintaining high, year-round carrying capacity (Wallmo 1981). Black-tailed deer also are able to forage in a variety of forest stand ages classes by exploiting small canopy gaps created by disturbances in established forest stands (Ulappa 2015). More specifically, female black-tailed deer were documented using conifer stands for cover throughout the day and meadow or open habitat at night (Loft et al. 1984). Hanley (1984) found that black-tailed deer displayed preferences for conifer stands ranging from 14-19 years of age, and avoided closed-canopy forests (28-45 years). However, it is speculated that a sub-species, the Sitka black-tailed deer (*Odocoileus hemionus sitkensi*s) inhabiting the northern portion of their range, may have evolved with old-growth forests (Yeo and Peek 1992). The importance of this habitat association for black-tailed deer warrants further investigation in western Oregon.

Logging activities (e.g., clearcut harvests and thinning) are believed to produce vegetative growing conditions favorable to black-tailed deer, particularly for forage (Dasmann and Dasmann 1963). Following a disturbance (e.g., clearcut), the stand initiation process is capable of supporting greater wildlife alpha diversity, although current industrial forest management seeks to truncate this successional stage in favor of predominantly conifer forests for timber production (Hansen et al. 1991, Hagar 2007). Herbicides are commonly used on intensively managed forests to control competing vegetation with conifers and increase timber yields (Clark et al. 2009). Herbicides used in conifer plantations are designed to remove only target species and efficacy varies by site conditions, phenology, application technique and timing (Clark et al. 2009). Additionally, herbicides alter vegetative composition and abundance in forest stands for a limited duration and may not fully repel herbivory, thus altering herbivory patterns or displacing browsers temporally from these forest stands (Crouch 1979, Clark et al. 2009). While using herbicides can be beneficial to production of conifers on industrial forests, recent research has stressed the importance of overall vegetative diversity for wildlife and ecosystem function (Hagar 2007, Franklin and Johnson 2012). Ultimately, variation in vegetation types, disturbance, forest stand structures and their arrangement across the landscape will influence black-tailed deer behavior and their use of forest structures.

The lack of early seral vegetation in the spring due to herbicide use on industrial forests may increase browse of conifer seedlings when neighboring vegetation has been reduced (Brandeis et al. 2002). Alternatively, even with early seral vegetation present, conifer production of palatable buds may also increase browsing pressure during bud development (Crouch 1968). In western Oregon, conifer seedling loss to ungulates is perceived as an economic loss, yet the costs and benefits of management to reduce damage are unknown (Rochelle 1992). There have been attempts to control damage through traditional fencing, which although effective is expensive to install and maintain (Côté et al. 2004). Vexar tubing has also been used as a protective measure against ungulate browsing, although with low efficacy in protecting conifer seedling from ungulate browse (Brandeis et al. 2002). Repellents are also commonly used to deter ungulate browse (Wagner and Nolte 2001). Repellents creating fear (e.g., predator urine) generally have the highest efficacy over others (Wagner and Nolte 2001). However, efficacy decreases with time since application, individual hunger, attractiveness of forage and environmental conditions, such as increased precipitation (Wagner and Nolte 2001, Côté et al. 2004). Other studies have attempted silviculture prescriptions to retain woody debris (e.g., slash) that provide protection to seedlings and saplings from ungulate browse by making it more difficult for ungulates to navigate through recently harvested stands (Pellerin et al. 2010). Campbell and Evans (1978) established native forbs in clearcuts to reduce browsing pressure on conifer seedlings, but introduced non-native vegetation due to contaminated seed source. That study, moreover, was carried out in federal forests and may not be applicable to private industrial forests.

Black-tailed deer play an important role in nutrient cycling, forest structure, and ecosystem function by browsing and disturbing vegetation (Cowan 1945, Hobbs 1996, Kie and Czech 2000). Black-tailed deer are considered selective browsers and preferred forage in western Oregon generally consists of trailing blackberry (*Rubus ursinus*), red huckleberry (*Vaccinium parvifolium*), vine maple (*Acer circinatum*), red alder (*Alnus rubra*), forbs, shrubs, grasses, salal (*Gaultheria shallon*), acorns, lichens, mushrooms and conifers (Brown 1961, Crouch 1966, Miller 1968, Maser et al. 1981, Hanley 1984, Gill 1992, Ulappa 2015). Cowan (1945) conducted stomach analysis to determine black-tailed deer diet composition and found that autumn forage comprised of 27% salal and 25% alder (*Alnus spp.*); winter 47% Douglas-fir and 36% *Usnea spp.*; spring 24% Douglas-fir and 21% willow (*Salix spp.*); and summer 41% salal and 25% miscellaneous vegetation. This study suggested that black-tailed deer consume a wide array of forage, but selectivity and increased forage efficiency may occur when available forage biomass is high. Thus, nutrient content of available forage is a predominant factor indicating the amount of time spent foraging and driving overall fitness (Weckerly 1994). A recent study in Washington by Ulappa (2015), indicated available forage biomass was low during stand establishment (1-3 years), greatest in stands 4-9 years old, and decreased as stands aged past 10 years, along with canopy closure between 14-20 years. However, this study lacked the resolution to detect possible differences across a range of site conditions on intensively managed forest stands, such as site productivity and differences among forest owner management strategies.

Habitat selection by black-tailed deer is not only determined by the abundance and quality of forage, but also by the availability of cover (Wallmo 1981, Massé and Côté 2009). Black-tailed deer are well adapted to edges (Maser et al. 1981). Patch heterogeneity in western Oregon can be viewed as a checkerboard pattern resulting from land management objectives of private and public forests of varying stages of forest succession (Franklin and Forman 1987). Further, creating edge habitat that benefit black-tailed deer and many game species (Kremsater and Bunnell 1992). Early seral sites may provide greater forage availability than forests (Cowan 1945). Hanley (1983) found evidence supporting that habitats along edges were used disproportionally to habitat found further into the core of clear-cuts or forests. Black-tailed deer habitat use is strongly associated with availability of both high-quality forage and dense forest structure (Hanley 1984, ODFW 2008). For instance, black-tailed deer exhibit periods of foraging in high-quality patches that provide an ample array of palatable vegetation and periods of rest under cover to allow for rumination, predator avoidance, or shelter from adverse weather events (Kie 1999, Jarnemo et al. 2014).

The purpose of this study was to quantify seasonal and annual habitat use of female black-tailed deer across a forest dominated landscape under different land ownerships in the Indigo and Alsea Wildlife Management Units (WMU) of western Oregon. I used Johnson’s (1980) orders of selection and compositional analysis (Aebischer et al. 1993) to determine annual and seasonal habitat use and preference by female black-tailed deer. Further, I used linear models to determine home range size as a function of early seral (forest age 0-10 years) and mid-seral (forest age 11-20 years) habitat characteristics. Black-tailed deer behavior and home range size also may vary with elevational gradients and be affected by seasonal changes in weather, mainly snowpack (Bunnell 1990), however these factors were not considered for this study.

LITERATURE CITED

Aebischer, N.J., P.A. Robertson, and R.E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313-1325.

Brandeis, T.J., M. Newton, and E.C. Cole. 2002. Biotic injuries on conifer seedlings planted in forest understory environments. New Forests 24:1-14.

Brown, E.R. 1961. The black-tailed deer of western Washington. Washington State Game Department Bulletin. 13, pp. 124.

Bunnell, F.L. 1990. Ecology of black-tailed deer. Pages 31-63 *in* Nyberg, J.B., and D.W. Janz, (technical editors), Deer and elk habitats in coastal forests of southern British Columbia. B.C. Ministry of Forests, Special Report Series 5, Victoria.

Campbell, D.L., and J. Evans. 1978. Establishing native forbs to reduce black-tailed deer browsing damage to Douglas-fir. Proceedings of the 8th Vertebrate Pest Conference. Paper 7.

Campbell, S., D. Azuma, and D. Weyermann. 2004. Forests of western Oregon: an overview. US Department of Agriculture Forest Service, Portland, Oregon. 20 pages.

Clark, L. A., G.J. Roloff, V.L. Tatum, and L.L. Irwin. 2009. Forest herbicide effects on pacific northwest ecosystems: a literature review. National Council for Air and Stream Improvement Technical Bulletin No. 970.

Côté, S.D., T.P. Rooney, J.P. Tremblay, C. Dussault, and D.M. Waller. 2004. Ecological impacts of deer overabundance. Annual Review of Ecology, Evolution, and Systematics 35: 113-147.

Cowan, I. M. 1945. The ecological relationships of the food of the Columbian black-tailed deer, *Odocoileus hemionus columbianus*, in the coast forest region of southern Vancouver Island, British Columbia. Ecological Monographs 15:110–139.

Crouch, G.L. 1966. Preferences of black-tailed deer for native forage and Douglas-fir seedlings. Journal of Wildlife Management 32:542-553.

Crouch, G.L. 1968. Availability in relation to browsing of Douglas-fir seedlings by black-tailed deer. Journal of Wildlife Management 32:542-553.

Crouch, G.L. 1979. Atrazine improves survival and growth of ponderosa pine threatened by vegetative competition and pocket gophers. Forest Science 25:99-111.

Dasmann, R.F., and W.P. Dasmann. 1963. Mule deer in relation to a climatic gradient. Journal of Wildlife Management 27:196-202.

Franklin, J.F., and R.T.T. Forman. 1987. Creating landscape patterns by forest cutting: ecological consequences and principles. Landscape Ecology 1:5-18.

Franklin, J.F., and K.N. Johnson. 2012. A restoration framework for federal forests in the pacific northwest. Journal of Forestry 110:429-439.

Gill, R.M.A. 1992. A review of damage by mammals in north temperate forests: 1. deer. Forestry 65:145-169.

Hagar, J.C. 2007. Wildlife species associated with non-coniferous vegetation in pacific northwest conifer forests: a review. Forest Ecology and Management 246:108-122.

Hanley, T.A. 1983. Black-tailed deer, elk, and forest edge in a western cascades watershed. Journal of Wildlife Management 47:237-242.

Hanley, T.A. 1984. Habitat patches and their selection by wapiti and black-tailed deer in a coastal montane coniferous forest. Journal of Applied Ecology 21:423-436.

Hansen, A.J., T.A. Spies, F.J. Swanson, and J.L. Ohmann. 1991. Conserving Biodiversity in Managed Forests. Bioscience 41:382-392.

Hobbs, N. T. 1996. Modification of ecosystems by ungulates. Journal of Wildlife Management 60:695-713.

Jarnemo, A., J. Minderman, N. Bunnefeld, J. Zidar, and J. Månsson. 2014. Managing landscapes for multiple objectives: alternative forage can reduce conflict between deer and forestry. Ecosphere 5: Article 97.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Kie, J.G. 1999. Optimal foraging and risk of predation: effects on behavioral and social structure in ungulates. Journal of Mammalogy 80:1114-1129.

Kie, J. G., and B. Czech. 2000. Mule and black-tailed deer. Pages 629–657 *in* S. Demarais and P. R. Krausman, editors. Ecology and management of large mammals in North America. Prentice Hall, Upper Saddle River, New Jersey, USA.

Kremsater, L.L., and F.L. Bunnell. 1992. Testing responses to forest edges: the example of black-tailed deer. Canadian Journal of Zoology 70:2426-2435.

Loft, E.R., J.W. Menke, and T.S. Burton. 1984. Seasonal movements and summer habitats of female black-tailed deer. Journal of Wildlife Management 48:1317-1325.

Maser, C., B.R. Mate, J.F. Franklin, and C.T. Dyrness. 1981. Natural history of Oregon coast mammals. USDA Forest Service. General Technical Report PNW-133, Pacific Northwest Forest and Range Experiment Station, Portland, OR, pp. 496.

Massé, A., and S.D Côté. 2009. Habitat selection of a large herbivore at high density and without predation: trade-off between forage and cover? Journal of Mammalogy 90:961-970.

Miller, F.L. 1968. Observed use of forage and plant communities of black-tailed deer. Journal of Wildlife Management 32:142-148.

Oregon Department of Fish and Wildlife (ODFW). 2008. Oregon black-tailed deer management plan. Oregon Department of Fish and Wildlife, Salem, Oregon, USA.

Pellerin, M., S. Saïd, E. Richard, J.L. Hamann, C. Dubois-Coli, and P. Hum. 2010. Impact of deer on temperate forest vegetation and woody debris as protection of forest regeneration against browsing. Forest Ecology and Management 260: 429-437.

Rochelle, J.A. 1992. Deer and elk. In: Black, H.C. (Ed.), Silvicultural approaches to animal damage management in Pacific Northwest Forests. U.S. Dept. of Agriculture, Forest Service Pacific Northwest Research Station, Portland, OR, pp. 333–349.

Spies, T.A., K.N. Johnson, K.M. Burnett, J.L. Ohmann, B.C. McComb, G.H. Reeves, P. Bettinger, J.D. Kline, and B. Garber-Yonts. 2007. Cumulative ecological and socioeconomic effects of forest policies in coastal Oregon. Ecological Applications 17:5-17.

Thomas, J.W., J.F. Franklin, J. Gordon, and N.K. Johnson. 2006. The northwest forest plan: origins, components, implementation experience, and suggestions for change. Conservation Biology 20:277-287.

Ulappa, A.C. 2015. Using foraging dynamics to answer landscape management questions: The nutritional ecology of black-tailed deer (Thesis), Washington State University, Pullman, USA.

Weckerly, F.W. 1994. Selective feeding by black-tailed deer: forage quality or abundance? Journal of Mammalogy 75:905-913.

Wagner, K.K., and D.L. Nolte. 2001. Comparison of active ingredients and delivery systems in deer repellents. Wildlife Society Bulletin 29:322-330.

Wallmo, O.C., editor. 1981. Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln, Nebraska, USA.

Yeo, J.J., and J.M. Peek. 1992. Habitat selection by female sitka black-tailed deer in logged forests of southeastern Alaska. Journal of Wildlife Management 56:253-261.

CHAPTER 2: HABITAT USE OF FEMALE COLUMBIAN BLACK-TAILED DEER IN WESTERN OREGON.

Timothy J. Schrautemeier, *Department of Forest Ecosystems and Society, Oregon State University, Corvallis, Oregon 97331*

INTRODUCTION

In western Oregon, Columbian black-tailed deer (*Odocoileus hemionus columbianus*, hereafter, black-tailed deer) are important economically, ecologically, and culturally as an indigenous species. Oregon Department of Fish and Wildlife (ODFW) has observed declines in black-tailed deer populations since the late 1980's and believes declines are caused primarily by a reduction in habitat quality and availability, following the decline of timber harvests on federal lands (ODFW 2008). Habitat management for black-tailed deer is tied to forest management in areas of the landscape that are dominated by timber industry. In western Oregon, 80% of the landscape is forested with Douglas-fir (*Pseudotsuga menziesii*) as the dominant tree species of high economic value for timber production (Campbell et al. 2004). Previous studies have indicated that black-tailed deer prefer conifer stands ranging from 14-19 years in age while avoiding closed-canopy forests of 28-45 years (Hanley 1984). Additionally, black-tailed deer generally use conifer stands during the day for cover and meadow or open habitats during the night (Loft et al. 1984). Results of these prior studies, however, may no longer be congruent with modern forestry management: specifically, changes in the age at which forest stands now have a closed canopy may affect these conclusions, and thus black-tailed deer habitat use in modern landscapes warrants further investigation.

Forage availability plays a vital role in habitat selection by black-tailed deer, yet habitat selection is also influenced by the availability of cover to allow for rumination, predator avoidance and shelter from adverse weather events (Wallmo 1981, Kie 1999, Massé and Côté 2009, Jarnemo et al. 2014). Black-tailed deer are an edge-adapted species and use vegetation types along edges disproportionally compared to those found further from edges (Maser et al.

1981, Hanley 1983). Further, black-tailed deer are considered selective browsers and preferred forage in western Oregon generally consists of trailing blackberry (*Rubus ursinus*), red huckleberry (*Vaccinium parvifolium*), vine maple (*Acer circinatum*), red alder (*Alnus rubra*), forbs, shrubs, grasses, salal (*Gaultheria shallon*), acorns, lichens, mushrooms and conifers (Brown 1961, Crouch 1966, Miller 1968, Maser et al. 1981, Hanley 1984, Gill 1992, Ulappa 2015). A food habits study using stomach content analysis (Cowan 1945) found that black-tailed deer consumed 27% salal (*Gaultheria shallon*) and 25% alder (*Alnus* spp.) in autumn; 47% Douglas-fir and 36% *Usnea* spp. in winter; 24% Douglas-fir and 21% willow (*Salix* spp.) in spring; and 41% salal and 25% miscellaneous vegetation in summer. In some areas, early seral sites provide highly productive habitat with high forage biomass compared to within forests (Cowan 1945), yet mature forests may be critical habitat for maintaining a high, year-round carrying capacity (Wallmo 1981). However, site to site vegetative composition and abundance is highly variable across the western Oregon landscape.

Silvicultural treatments such as clearcut harvests and thinning act as disturbances that may provide high quality forage (Dasmann and Dasmann 1963). However, herbicide use in modern site preparation controls for competing vegetation with conifers to increase timber yields (Clark et al. 2009), reducing overall early seral vegetative biodiversity. The effects of herbicide use on conifer plantations may temporally alter the vegetative composition available as forage, displacing browsers from the harvested stand for a period of time (Crouch 1979, Clark et al. 2009). Therefore, stand composition immediately following disturbances (e.g., clearcuts) can be described as shrub dominated, capable of supporting greater wildlife diversity. Current forest management seeks to truncate early successional stages in favor of predominantly conifer forests for timber production (Hansen et al. 1991, Hagar 2007). Black-tailed deer also are able to forage in a variety of forest stand ages classes by exploiting small canopy gaps created by disturbances in established forest stands (Ulappa 2015).

The spatial patterns resulting from a diversity of forest landownership and management objectives create spatial heterogeneity in vegetative structure and composition, influencing the distribution of wildlife and their interactions and adaptations on the landscape (Wiens 1976). Influential policy such as the Northwest Forest Plan of 1994 shifted the management focus of federal forests to the conservation of late-seral forest biodiversity, rather than focusing on sustainable timber harvests (Thomas et al. 2006, Spies et al. 2007). Past and present forest management in Oregon has impacted wildlife habitat by influencing forest stand structure, function and composition, altering patterns of forest succession across the landscape (Boyle et al. 1997). The value of early successional forest ecosystems, occurring between stand-replacement disturbance and forest canopy closure, are often underappreciated (Swanson et al. 2011). Betts et al. (2010) found evidence of population declines in several bird species associated with reduction in broadleaf-dominated early-seral forests due to succession and intensive forest management in the Pacific Northwest. Although timber production may be the dominant resource managed, the western Oregon landscape provides other goods and services, resulting from a diversity of landownership and management objectives influencing biodiversity at a larger spatial extent (Spies et al. 2007). Examining habitat use of female black-tailed deer may provide relationship of habitat spatial heterogeneity and the spatial distribution of female black-tailed deer because they play a key role in ecosystem processes. Black-tailed deer influence vegetation regimes (Kie et al. 2002) and compared to other wildlife species, their biology is relatively well documented

(Wallmo 1981). Effective management for black-tailed deer in western Oregon can benefit from further investigation of home range size and habitat use in a landscape dominated by forest management.

The advancements of telemetry technology associated with the use of global positioning systems (GPS) have allowed researchers to increase the accuracy of tracking wildlife behavior, movement, and habitat selection (Tomkiewicz et al. 2010). This increased amount of spatial data involved in research studies has led to the development of data-intensive, statistical and geospatial approaches in analyzing data (Kie et al. 2010). However, these advances in wildlife technology still warrant further investigation into precision, accuracy and potential bias of GPS location data (Pellerin et al. 2008). Additionally, it is important to maintain consistency in the use of terminology associated with wildlife-habitat relationships. “Habitat” refers to the resources and conditions present in an area that produce occupancy by a given organism (Hall et al. 1997) or the physical environmental features that an organism requires to survive and reproduce (Block and Brennan 1993). “Habitat use” refers to the way organisms utilize habitats to meet life history requirements (Block and Brennan 1993). Usage may be viewed as selective if components (e.g., vegetation types) are used disproportionately to their availability (Johnson 1980). “Habitat selection” is described as a hierarchical process involving a series of innate and learned behavioral decisions made by an animal regarding use at different spatial scales (Hutto 1985). Selection may involve decisions based on how organisms value the quality of habitat, as well as the costs and benefits of occupying space (Jones 2001). Habitat selection implies knowledge of complex processes that habitat use does not (Jones 2001). “Habitat preference” is an ambiguous term that may be used to describe habitat selection; however, an underlying principal is that a component being chosen is offered on an equal basis as all others (Johnson 1980). Aebischer et al. (1993) warned that absolute statements about preference are dangerous due to non-independence of proportions, and that the term preference is useful only when habitat types are ranked on a relative scale.

The objective of this study was to quantify seasonal and annual habitat use of female black-tailed deer in western Oregon, given a diverse mosaic of public and private lands with varying ages of forest succession in the Indigo and Alsea Wildlife Management Units (WMU). Further, I used compositional analysis to investigate second- (home range establishment) and third- (within home range) order habitat selection for annual and seasonal intervals (Johnson 1980). The seasonal analysis is unique to this study in that I created artificial seasons that reflect expected periods of high black-tailed deer herbivory on conifer plantations. Industrial conifer plantations may receive more damage to recently planted conifer seedlings due to relatively low forage availability in the winter or during new growth and bud development in the late spring and early summer (Crouch 1968). Thus, I hypothesized that female black-tailed deer would use habitats in proportion to what is available in establishing home ranges (second-order selection) because they are a generalist species. Second, I hypothesized that within home ranges (third-order selection), female black-tailed deer would select for young forest stands disproportionately as they use these early seral habitats to obtain forage. Additionally, I hypothesized that during periods of anticipated browse damage to conifer plantations (early summer and winter), female black-tailed deer will use young conifer stands disproportionately within home ranges due to the need to obtain forage. Lastly, I hypothesized that female black-tailed deer home range size would be smaller with greater availability of early seral habitat characteristics.

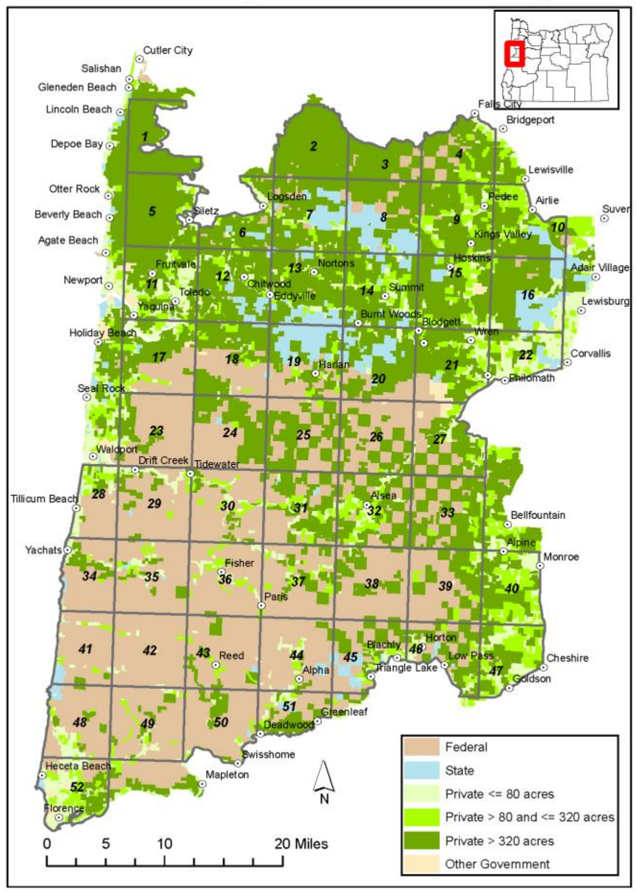
STUDY AREAS

I conducted this study in collaboration with ODFW in two ODFW designated Wildlife Management Units (WMU) that are used to manage game and non-game species in western Oregon (Mace et al. 1995). The Alsea WMU is located in the Oregon Coast Range, and the northern extent approximately follows the Siletz River from the coastal town of Kernville to State Highway 99, south to the town of Cheshire along State Highway 36, and along the Siuslaw River west to the coastal town of Florence (Figure 1). The Alsea WMU consists of ~42% public lands encompassing a total area of 4,653.37 km^2. Mean elevation is approximately 457 meters (range 0—1,249 meters) with consistently steep slopes and drainage basins (Franklin and Dyrness 1988). Data recorded near the center of the Alsea WMU for 1954-2016 showed an average high of 14.3°C and average low of 5.4°C, with average precipitation of 233.4 cm and snowfall of 12.5 cm (Alsea Fish Hatchery, Fall Creek, Western Regional Climate Center).

The Indigo WMU is located in the Oregon Cascade Range, and the northern extent follows State Highway 58 from the town of Goshen to the Pacific Crest Trail, south to State Highway 138 near Diamond Lake, west along State Highway 138 to the Dixonville-Albany main power transmission line, and north back to the town of Goshen (Figure 2). The Indigo WMU consists of approximately 79% public land encompassing a total area of 5,000 km^2. The elevation gradient ranges from 145—2,659 meters with mean elevation being approximately 1,500 meters with more gentle slopes compared to the eastern cascades (Franklin and Dyrness 1988). Data recorded near the southern border of the Indigo WMU for 1953-2016 showed an average high of 16.8°C and average low of 3.8°C, with average precipitation of 121.6 cm and snowfall of 98.8 cm (Toketee Falls, Western Regional Climate Center).

Given the spatial extent of these two study areas, I assumed Douglas-fir to be the dominant tree species followed by other conifers including western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) (Franklin and Dyrness 1988). However, the vegetative composition changes with elevation and moisture gradients and site-to-site productivity. Further, it has been reported that the biomass ratio of hardwoods to conifers in this region is 1:1,000 based on timber value (Waring and Franklin 1979, Franklin and Dyrness 1988). Therefore, for the purposes of this study, I assumed this proportion remained the same, in that most industrial managed forests aim to remove hardwoods in favor of growing conditions for conifer plantations. Most mid-sized to large private industrial forest owners continue logging activity year-round to minimize interference to their respective harvest schedules, while acknowledging environmental constraints and ensuring good land stewardship practices (Mike Rochelle, Weyerhaeuser, Personal Communication). Therefore the landscapes in these two study areas are under constant fluctuation as logging activities take place year round. Further, the checkerboard effect (Franklin and Forman 1987) is present in both WMUs, based on different management strategies between private and state forestland, as well as fragmented and continuous national forestlands.

Alsea Wildlife Management Unit Ownership Groups



ODFW GIS; Dec 29, 2011

Figure 1. Distribution of dominant ownership groups in the Alsea Wildlife Management Unit of western Oregon. Grid cells are 10km^2 and display majority landownership within each cell; they help guide management objectives over large expanses. Figure provided by Oregon Department of Fish and Wildlife GIS Unit.

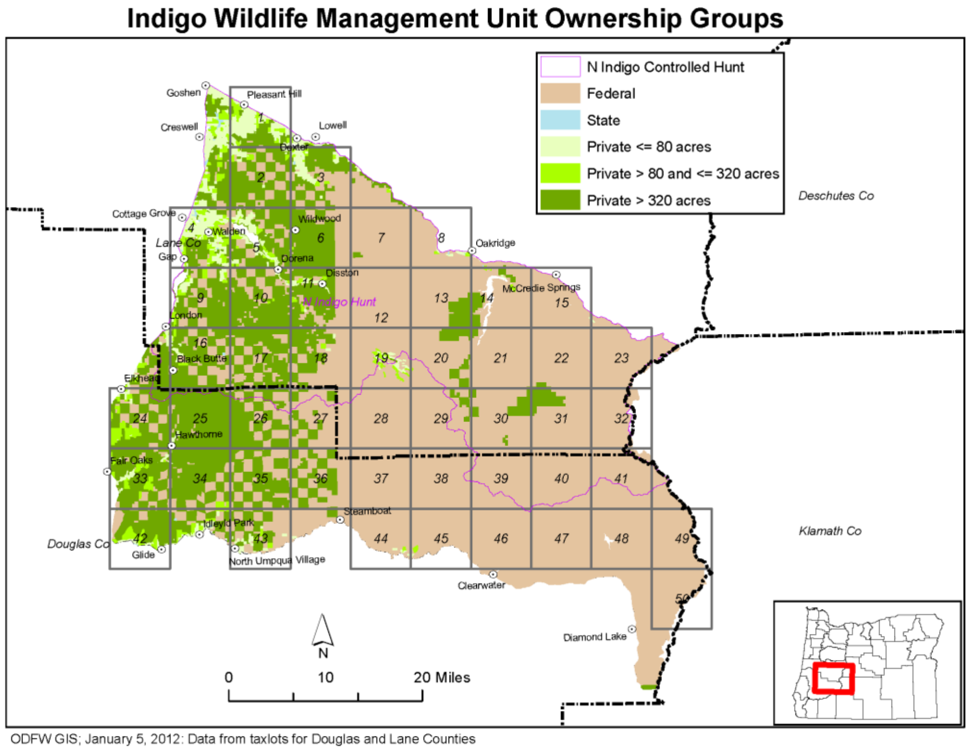


Figure 2. Distribution of dominant ownership groups in the Indigo Wildlife Management Unit of western Oregon. Grid cells are 10km^2 and display majority landownership within each cell; they help guide management objectives over large expanses. Figure provided by Oregon Department of Fish and Wildlife GIS Unit.

METHODS

Black-tailed Deer Capture and Data Collection

For each study WMU, 10-km^2 grid cells were placed over a landownership coverage of the entire WMU which was derived from county assessor data and post-processed by the ODFW GIS Unit. For each landownership, ODFW GIS Unit categorized each cell based on the calculated percentage of landownership distribution within each 10-km^2 grid cell for the entire WMU (Figures 1 & 2). Further, each 10-km^2 grid cell was categorized by the dominant landownership and fell into the following categories: federal, state, private ≤ 80 acres (small), private > 80 & ≤ 320 acres (medium), and private > 320 acres (large). When attempting to capture or immobilize individual black-tailed deer, trap sites and immobilization had to occur on the landownership that was dominant for the individual 10-km^2 grid cell within the WMU.

Female black-tailed deer were captured from March 2012 through July 2015 using collapsible clover traps (McCullough 1975) and chemical immobilization. Clover traps were the primary capture method and were generally baited with salt blocks throughout the year. Chemical immobilization was used opportunistically or from a stand over an attractant using a Dan-inject dart-gun (Dan-Inject, Austin, Texas, USA) and BAM (Butorphanol-Azaperone-Medetomidine) (Butorphanol Tartrate 27.3 mg/ml, Azaperone Tartrate 9.1 mg/ml, and Metedomidine HCL 10.9 mg/ml). Atipamezole (25 mg/ml) and Naltrexone HCL (50 mg/ml) were administered intramuscularly to antagonize BAM and the individuals were monitored for safe recovery. Female black-tailed deer were assigned a unique identification number, ear-tagged in both ears with colored, uniquely numbered Rototags (Nasco, Modesto, CA), and fitted with a 285 gram Lotek 3300S GPS collars (Lotek Wireless Inc., Newmarket, Ontario, Canada). ODFW stopped immobilization 30 days prior to all deer hunting seasons as a safety issue to avoid potential human consumption. Additionally, trapping and immobilization were stopped 2-3 weeks prior to and after June 14, which Pamplin (2003) noted as the peak in parturition for female black-tailed deer. All GPS collars were programmed to acquire locations every 4 hours for a duration of 72 weeks. Male black-tailed deer were not used in this study due to expected changes in neck girth during a 72 week period. Each collar possessed a break-away mechanism that was programmed to deploy just after 72 weeks, as well as a unique VHF frequency which was used to locate collars by homing after they were dropped. All GPS data were downloaded directly to a desktop computer using Lotek proprietary software.

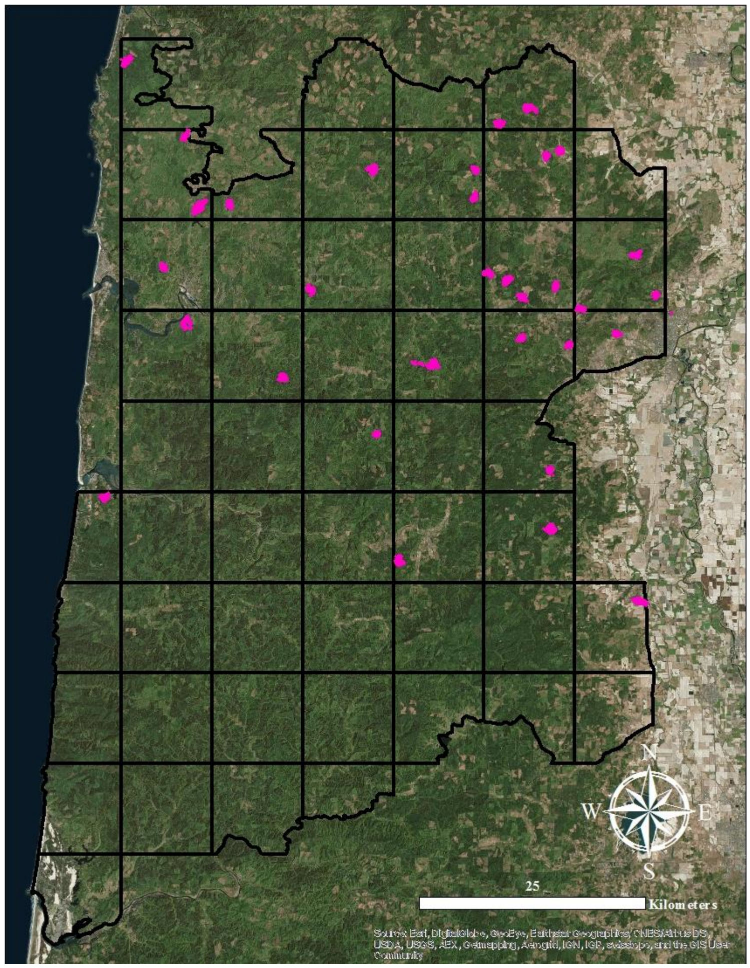


Figure 3. Capture site distribution of 32 female black-tailed deer in the Alsea Wildlife Management Unit in western Oregon, represented by each deer’s 95% kernel home range polygon.

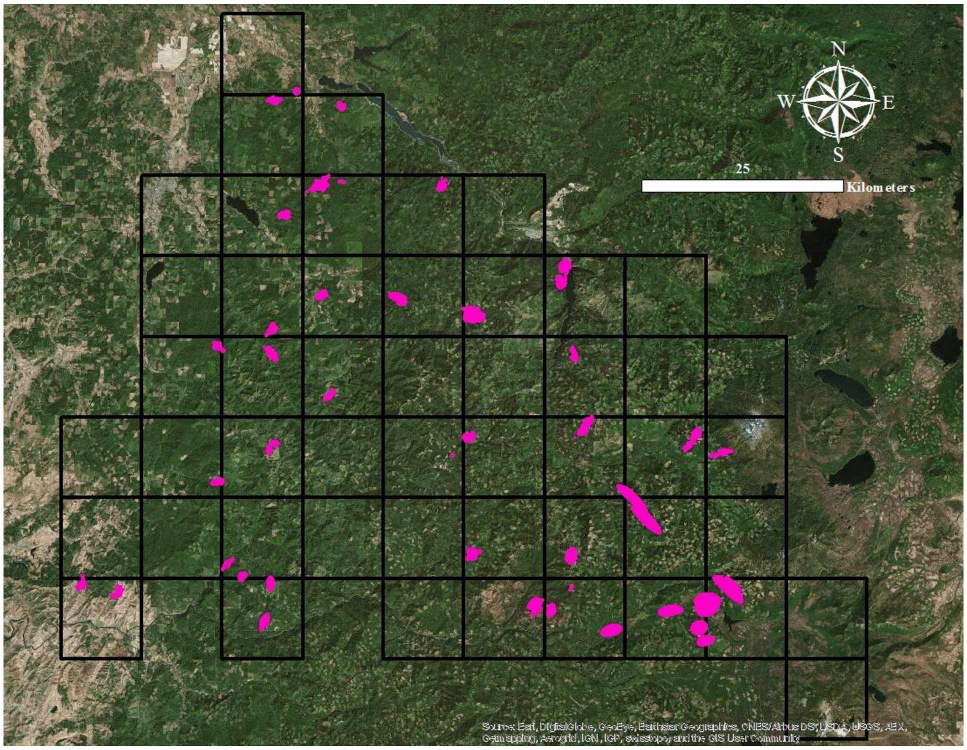


Figure 4. Capture site distribution of 30 female black-tailed deer in the Indigo Wildlife Management Unit in western Oregon, represented by each deer's 95% kernel home range polygon.

Preparation of Home Ranges

Prior to constructing home ranges for each female black-tailed deer, I verified that the time stamp at the beginning of each GPS collar coincided with the local time in which each deer was captured and released on field data sheets. Additionally, I removed points with a high probability of locational error by deleting all 3-dimensional points with a positional dilution of precision (PDOP) > 10 and all 2-dimensional points with PDOP ≥ 5 (Lewis et al. 2007). I constructed 95% kernel home range distributions (hereafter, home range) for each individual with ≥ 50 locations (Seamen et al.1999) using ArcMap 10.2.2 (Environmental Systems Research

Institute, Inc., Redlands, CA) and the Geospatial Modelling Environment 0.7.3.0 software (GME, Spatial Ecology LLC, http://www.spatialecology.com/gme). I used a cell size of 30 m to maintain congruency between home range polygon cell size and spatial data. Additionally, within GME, I used the ‘plugin’ bandwidth option, which has been shown to perform better than least squares cross-validation (LSCV) with large sample sizes (Amstrup et al. 2004, Gitzen et al. 2006). Individuals that had data points for $\geq$12 months were used to construct annual and seasonal home ranges. Deer with <12 months of data but $\geq$50 locations in early summer and/or winter were used to construct seasonal home ranges.

I defined seasons based on periods when foresters observe damage to seedlings in intensively managed forests of western Oregon (Mark Gourley, Starker Forests, personal communication). I defined the summer interval as May 20 through July 4 that coincided with spring growth and bud development in Douglas-fir. I defined the winter interval as November 25 through March 17 that coincided with periods when vegetative energy is concentrated belowground, making conifers one of the few above ground sources of forage.

Preparation of Land Cover Categories

I obtained land cover data for non-forest sites from the USGS GAP Land Cover Data Set (GAP), which focused on defining land cover for biodiversity (Comer et al. 2003, USGS 2011). Data pertaining to developed areas were derived from the USGS National Land Cover Database (NLCD). This data set contained raster cells with a resolution of 30×30 m^2 per grid cell. I clipped the data using the ‘clip’ tool in ArcMap to the Alsea and Indigo WMU boundaries, which resulted in 24 and 30 non-forest land cover categories respectively. I further consolidated these into six general categories: developed, open water, agriculture, grassland-prairie, shrub and rock/sand/ice (Table 1 & 2), which were used for all years (2012-2015).

Table 1. The consolidated non-forest land cover categories for the Alsea Wildlife Management Unit, derived from USGS GAP Land Cover Dataset.

New Category	Consolidated Categories
Developed	Developed, Open Space
	Developed, Low Intensity
	Developed, Medium Intensity
	Developed, High Intensity
Open Water	Open Water (Brackish/Salt)
	Open Water (Fresh)
	North Pacific Bog and Fen
	North Pacific Shrub Swamp
	Temperate Pacific Freshwater Aquatic Bed
	Temperate Pacific Freshwater Emergent Marsh
	Temperate Pacific Tidal Salt and Brackish Marsh
Agriculture	Orchards Vineyards and Other High Structure Agriculture
	Cultivated Cropland
Grassland-Prairie	Pasture/Hay
	Willamette Valley Wet Prairie
	Willamette Valley Upland Prairie and Savanna
Shrub	Northern California Coastal Scrub
	Northern and Central California Dry-Mesic Chaparral
	North Pacific Hypermaritime Shrub and Herbaceous Headland
Rock/Sand/Ice	North Pacific Coastal Cliff and Bluff
	North Pacific Herbaceous Bald and Bluff
	North Pacific Montane Massice Bedrock, Cliff and Talus
	North American Alpine Ice Field
	North Pacific Mairitime Coastal Sand Dune and Strand

Table 2. The consolidated non-forest land cover categories for the Indigo Wildlife Management Unit, derived from USGS GAP Land Cover Dataset.

New Category	Consolidated Categories
Developed	Developed, Open Space
	Developed, Low Intensity
	Developed, Medium Intensity
	Developed, High Intensity
Open Water	Open Water (Fresh)
	North Pacific Bog and Fen
	North Pacific Shrub Swamp
	Temperate Pacific Freshwater Emergent Marsh
	Mediterranean California Subalpine-Montane Fen
Agriculture	Orchards Vineyards and Other High Structure Agriculture
	Cultivated Cropland
Grassland-Prairie	Pasture/Hay
	Willamette Valley Wet Prairie
	Willamette Valley Upland Prairie and Savanna
	Mediterranean California Subalpine Meadow
	North Pacific Alpine and Subalpine Dry Grassland
	North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow
	North Pacific Montane Grassland
	Temperate Pacific Montane Wet Meadow
	Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland
Shrub	Northern and Central California Dry-Mesic Chaparral
	North Pacific Avalanche Chute Shrubland
	North Pacific Montane Shrubland
	Inter-Mountain Basins Montane Sagebrush Steppe
Rock/Sand/Ice	North Pacific Herbaceous Bald and Bluff
	North Pacific Montane Massice Bedrock, Cliff and Talus
	Mediterranean California Serpentine Barrens
	North Pacific Alpine and Subalpine Bedrock and Scree
	North Pacific Volcanic Rock and Cinder Land
	North American Alpine Ice Field

I used the gradient nearest neighbor (GNN) dataset for western Oregon to generate forest land cover categories for this study (Ohmann and Gregory 2002). GNN was originally developed in the Northwest Forest Plan for monitoring vegetative change and habitat suitability for species of concern (Ohmann and Gregory 2002). I obtained predictive land cover data for forest sites from the ‘age-dominate’ variable embedded in the GNN dataset (Ohmann and Gregory 2002). The vegetative data utilized to create Ohmann and Gregory’s (2002) vegetative predictive mapping were derived from: (1) the Natural Resource Inventory (NRI) of the Bureau of Land Management; (2) the Current Vegetation Survey (CVS) of the USDA Forest Service, Pacific Northwest Region (Max et al. 1996); (3) the Forest Inventory and Analysis (FIA) of the USDA Forest Service, Pacific Northwest Research Station; (4) and the Old Growth Study (OGS) of the USDA Forest Service, Pacific Northwest Research Station (Spies and Franklin 1991). Due to the inconsistencies of non-forest regional data, the GNN model applies only to forestland or areas with, or with the potential to support ≥10% tree cover (Ohmann and Gregory 2002).

The GNN data has an extensive list of categorical and continuous variables. I chose to use the age-dominant variable, although it was similar to other variables of interests (e.g., canopy cover, basal area, quadratic mean diameter, stand height and tree density). I categorized the continuous age-dominant variable into 7 distinct categories: forest age 0-3 years, forest age 4-10 years, forest age 11-20 years, forest age 21-60, forest age 61-120, forest age 121-180 and forest age 181-474 (Alsea), 181-652 (Indigo). These categories were developed based on two considerations, forage biomass and silviculture prescriptions. Ulappa (2015) indicated forage biomass for black-tailed deer was lowest during stand initiation (0-3 years), greatest in stands 4-9 years old, and decreased as stands aged past 10 years along with canopy closure between 14-20 years. Regarding silvicultural prescriptions, 0-3 years corresponds with heavy herbicide use and stand initiation, 4-12 years coincides with pre-closure vegetation recovery, and 10-20 corresponds to the onset of crown closure in intensively managed plantations. For this study, I divided the forest age classification of 21+ years into 4 categories, which allowed me to capture the diversity of forest stand age and arrangement on the landscape (Doug Maguire, Director, Center for Intensive Planted-Forest Silviculture, personal communication). However, I made no differentiation between conifer or hardwood dominant forests, tree density, site preparation and landownership. I used the ‘clip’ tool in ArcMap to utilize these data from the Alsea and Indigo WMU boundaries and merged them with the non-forest land cover data using the ‘mosaic’ tool in ArcMap.

I accounted for annual increases in forest age by adding a value of 1 to all preexisting pixels for forest age categories in the 2012 GNN map and repeated this process through 2015. This process allowed me to capture temporal variation and the progression of forest succession between years that female black-tailed deer were captured and released and the change in habitat availability between years. Further, I used LandTrendr data which captured annual images from mid-July to late-August, detecting disturbances such as clear- and partial-cutting, fires, insect related mortality, and post disturbance regrowth that occurred on the western Oregon landscape annually (Kennedy et al. 2010). I considered forest stands with ≥ 50% annual canopy cover loss as a disturbance and reclassified them as forest age 0-3 years, reflecting clear-cutting activity or other disturbances occurring annually in the 2 study areas. This process allowed me to generate land cover categorical maps for years 2012-2015, reflecting land cover composition available to black-tailed deer (Table 3 & 4). Lastly, I used the ‘tabulate intersection’ tool in ArcMap to generate the proportion of land cover categories available to individuals within and outside their home range polygons.

Table 3. Percent land cover (ha) present in the Alsea Wildlife Management Unit in western Oregon between the years 2012-2015.

Alsea Percent Land Cover Composition[a]				
Land Cover Category	**2012**	**2013**	**2014**	**2015**
Developed	6.62	6.62	6.62	6.62
Open Water	0.29	0.29	0.29	0.29
Agriculture	0.96	0.96	0.96	0.96
Grassland-Prairie	3.33	3.33	3.33	3.33
Shrub	0.08	0.08	0.08	0.08
Rock/Sand/Ice	0.30	0.30	0.30	0.30
Forest Age 0-3 Years	4.90	5.44	5.44	5.44
Forest Age 4-10 Years	1.06	0.51	0.13	0.04
Forest Age 11-20 Years	5.50	5.75	5.66	4.67
Forest Age 21-60 Years	44.51	43.51	43.65	44.11
Forest Age 61-120 Years	17.13	17.39	17.48	17.70
Forest Age 121-180 Years	9.80	10.33	10.57	10.99
Forest Age 181-474 Years	5.51	5.49	5.49	5.49

[a] Percent of hectares present for each land cover category.

Table 4. Percent land cover (ha) present in the Indigo Wildlife Management Unit in western Oregon between the years 2012-2015.

Indigo Percent Land Cover Composition[a]				
Land Cover Category	**2012**	**2013**	**2014**	**2015**
Developed	0.83	0.83	0.83	0.83
Open Water	0.62	0.62	0.62	0.62
Agriculture	0.56	0.56	0.56	0.56
Grassland-Prairie	2.94	2.94	2.94	2.94
Shrub	0.28	0.28	0.28	0.28
Rock/Sand/Ice	0.45	0.45	0.45	0.45
Forest Age 0-3 Years	3.28	3.83	3.83	3.83
Forest Age 4-10 Years	2.51	1.34	0.12	0.11
Forest Age 11-20 Years	4.56	5.25	6.01	5.70
Forest Age 21-60 Years	24.80	24.63	24.62	24.42
Forest Age 61-120 Years	16.90	17.05	17.33	17.57
Forest Age 121-180 Years	12.69	12.40	12.36	12.43
Forest Age 181-652 Years	29.58	29.82	30.05	30.26

[a] Percent of hectares present for each land cover category.

Habitat Use

I compared proportions of each land cover type in the study area (availability) with proportions found in each individual's home range (use) to estimate habitat use equivalent to second-order selection (Johnson 1980, Aebischer et al. 1993, Janke and Gates 2013). At this scale, I defined 'available' habitat as each deer's home range buffered ('buffer' tool in ArcMap) by the median home range size for the respective WMU; Alsea WMU (median = 0.57 km) and Indigo WMU (median = 1.11 km). Large home ranges in the Indigo WMU deviated significantly from the unit average, which may over-estimate available habitat for those individuals with smaller home ranges. Therefore, I felt setting a standard metric to determine 'available' habitat was appropriate for this study due to the difficulties surrounding determining what was truly available to the organism in question (Wiens 1984, Aebischer et al. 1993). I then compared proportions of land cover types in each home range (availability) with GPS locations of each individual (use) to estimate third-order use (Johnson 1980, Aebischer et al. 1993).

I used the package 'adehabitatHS' (Calenge 2006) with 2,000 permutations and $\alpha = 0.05$ in R-Studio, version 1.0.136 (RStudio, Inc., Boston, MA) to perform compositional analysis and test for habitat use in proportion to availability (Aebischer et al. 1993). Individual female black-tailed deer were considered experimental units. Compositional analysis is multivariate, utilizes log-ratio transformation, and meets the unit sum constraint (Aebischer et al. 1993). Since not all individuals in this study used all land cover types or had all cover types available to them, I replaced all zero values to meet the unit sum constraint (Aebischer et al. 1993, Janke and Gates 2013). When land cover values were zero, I divided the smallest value in that category by 2 and used the quotient to replace null values. Because replacing null values can lead to spurious results when use is extremely low, I also used boxplots to visualize log ratios of the raw use data over all scenarios and both WMUs. Land cover categories that were not used or available to all individuals may be present in the compositional analysis. However, land cover categories that were not used or available will not be displayed in the box plots.

Home Ranges

I used linear models to investigate home range size for the Alsea and Indigo WMUs collectively (n = 62) as a function of: (1) the proportion of early seral characteristics (forest age 0-3 and 4-10 years) within home ranges, (2) the proportion of mid-seral characteristics (forest age 11-20 years) within home ranges and (3) the landownership in which female black-tailed deer were captured and released. I log-transformed home range size (km) to improve interpretability and appearance of figures. All analyses were conducted using R-Studio, version 1.0.136 (RStudio, Inc., Boston, MA). The linear models I used were:

(1) lm (log(Home Range Size) ~ Early Seral

(2) lm (log(Home Range Size) ~ Mid-Seral

(3) lm (log(Home Range Size) ~ Landownership

RESULTS

Data from 32 female black-tailed deer were used to estimate home range size in the Alsea WMU (number of locations ranged from 180—2756) and data from 30 female black-tailed deer were used for the Indigo WMU (number of locations ranged from 67—2756). In the Alsea WMU, the percentage of 32 female black-tailed deer captured and released on each landownership type were 28% on small private, 63% on large private, 6% on federal and 3% on state landownership. In the Indigo WMU, the percentage of 30 female black-tailed deer captured and released on each landownership were 3% on small private, 37% on large private, 60% on federal landownership. Mean home range size for the Alsea WMU was 64.26 ha (SD = 22.65) and 262.45 ha (SD = 419.50) for the Indigo WMU (Table 5). Mean early summer home range size for 24 individuals (29 home ranges; 5 deer had 2 seasons) for the Alsea WMU was 46.53 ha (SD= 21.57) and 90.71 ha (SD = 89.16) for 22 individuals (26 home ranges; 4 deer had 2 seasons) in the Indigo WMU (Table 5). Mean winter home range size for 24 individuals in the Alsea WMU was 45.59 ha (SD = 14.88) and 128.19 ha (SD = 157.67) for 23 individuals in the Indigo WMU (Table 5). Mean home range size (SD) for all seasons and land ownerships are presented in Table 5.

Table 5. Mean home range sizes (ha) of female black-tailed deer by study site (Alsea, Indigo), season (all, early summer, winter), and general landownership where captured (federal/state and private lands) in western Oregon, 2012-2015.

	All			**Private**			**Federal**		
Alsea	***n***	$\bar{x}$	**SD**	***n***	$\bar{x}$	**SD**	***n***	$\bar{x}$	**SD**
All	32	64.26	22.65	29	63.04	22.81	3	76.04	20.97
Early Summer	29	46.53	21.57	27	45.31	21.59	2	63.08	18.12
Winter	24	45.59	14.88	21	44.97	13.18	3	49.95	27.86

	All			**Private**			**Federal**		
Indigo	***n***	$\bar{x}$	**SD**	***n***	$\bar{x}$	**SD**	***n***	$\bar{x}$	**SD**
All	30	262.45	419.50	12	100.60	33.65	18	370.34	518.32
Early Summer	26	90.71	89.16	15	67.96	57.96	11	121.72	115.48
Winter	23	128.19	157.67	12	66.53	23.63	11	195.45	211.05

Habitat Use

Throughout their annual cycles, female black-tailed deer (n = 22) in the Alsea WMU showed disproportionate use of land cover categories at both spatial scales (second-order Λ = 0.169, p = 0.011; third-order Λ = 0.230, p = 0.045). In establishing female black-tailed deer home range (second-order) and within home ranges (third-order), forest age 0-3 years and forest age 11-20 years were ranked highest among land cover categories and were used in greater proportion than their availability (Tables 6 & 7; Figures 5 & 6). Female deer also used land cover categories disproportionately within home ranges for the winter (n = 24) and early summer (n = 24) seasons in the Alsea WMU (winter third-order Λ = 0.263, p = 0.029; early summer third-order Λ = 0.199, p = 0.001). Within winter home ranges for individuals in the Alsea WMU, the land cover categories forest age 0-3 years, forest age 11-20 years, shrub, and open water were ranked higher than other land cover categories (Table 8); however, the effects of shrub and open water are negligible in Figure 7. Within early summer home ranges for individuals in the Alsea WMU, the land cover categories shrub, grassland-prairie, and rock/sand/ice ranked higher than other land cover categories (Table 9), although the effects of shrub and grassland-prairie were insignificant in Figure 8.

Female black-tailed deer (n = 19) in the Indigo WMU used all land cover categories in proportion to availability at both spatial scales (second-order Λ = 0.248, p = 0.199; third-order Λ = 0.229, p = 0.147). Female deer (n = 23) in the Indigo WMU also used all land cover categories within their home ranges in proportion to availability for the winter season (third-order selection Λ = 0.506, p = 0.594). However, female deer (n = 22) showed disproportionate use of land cover categories within home ranges for the early summer season in the Indigo WMU (third-order selection $\Lambda = 0.265$, $p = 0.012$). Land cover categories agriculture and forest age 11-20 years ranked higher than other land cover categories and were used in greater proportion than availability (Table 10 & Figure 9), although forest age 0-3 years may also be used in greater proportion than available in summer home ranges in the Indigo WMU (Figure 9).

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Table 6. Annual ranking matrix for second-order habitat selection by female black-tailed deer in the Alsea Wildlife Management Unit in western Oregon, 2012-2015. I used compositional analysis to compare selection ratios and defined availability as the composition of each individual's home range buffered by the median home range size for the WMU. I defined use as the composition of each individual's home range. Note that forest age 0-3 years and forest age 11-20 years were significantly preferred over other land cover categories.

		Land Cover Type[a,b]												
Land Cover Type[a,b]	**Rank**	**Dev.**	**O. Water**	**Ag.**	**Grass.-Prairie**	**Shrub**	**Rock/Sand/Ice**	**FA 0-3 Yrs**	**FA 4-10 Yrs**	**FA 11-20 Yrs**	**FA 21-60 Yrs**	**FA 61-120 Yrs**	**FA 121-180 Yrs**	**FA 181-474 Yrs**
Developed	6		+	+	+	-	+	---	+	-	-	-	+	+
Open Water	9	-		+	+	-	-	---	+	---	-	-	-	+
Agriculture	12	-	-		+	-	-	---	-	---	-	-	-	-
Grassland-Prairie	13	-	-	-		-	-	---	-	---	---	---	---	-
Shrub	5	+	+	+	+		+	---	+	---	-	-	+	+
Rock/Sand/Ice	8	-	+	+	+	-		---	+	---	-	-	-	+
FA 0-3 Years	1	+++	+++	+++	+++	+++	+++		+++	+	+++	+++	+++	+++
FA 4-10 Years	10	-	-	+	+	-	-	---		-	-	-	-	+
FA 11-20 Years	2	+	+++	+++	+++	+++	+++	-	+		+++	+++	+++	+++
FA 21-60 Years	3	+	+	+	+++	+	+	---	+	---		+	+	+
FA 61-120 Years	4	+	+	+	+++	+	+	---	+	---	-		+	+
FA 121-180 Years	7	-	+	+	+++	-	+	---	+	---	-	-		+
FA 181-474 Years	11	-	-	+	+	-	-	---	-	---	-	-	-	

[a] (+) indicates row land cover type is preferred over column land cover type; (-) indicates column cover type is preferred over row land cover type; sign is tripled (e.g, +++) if relationship is significant ($\alpha = 0.05$).

[b] FA = forest age

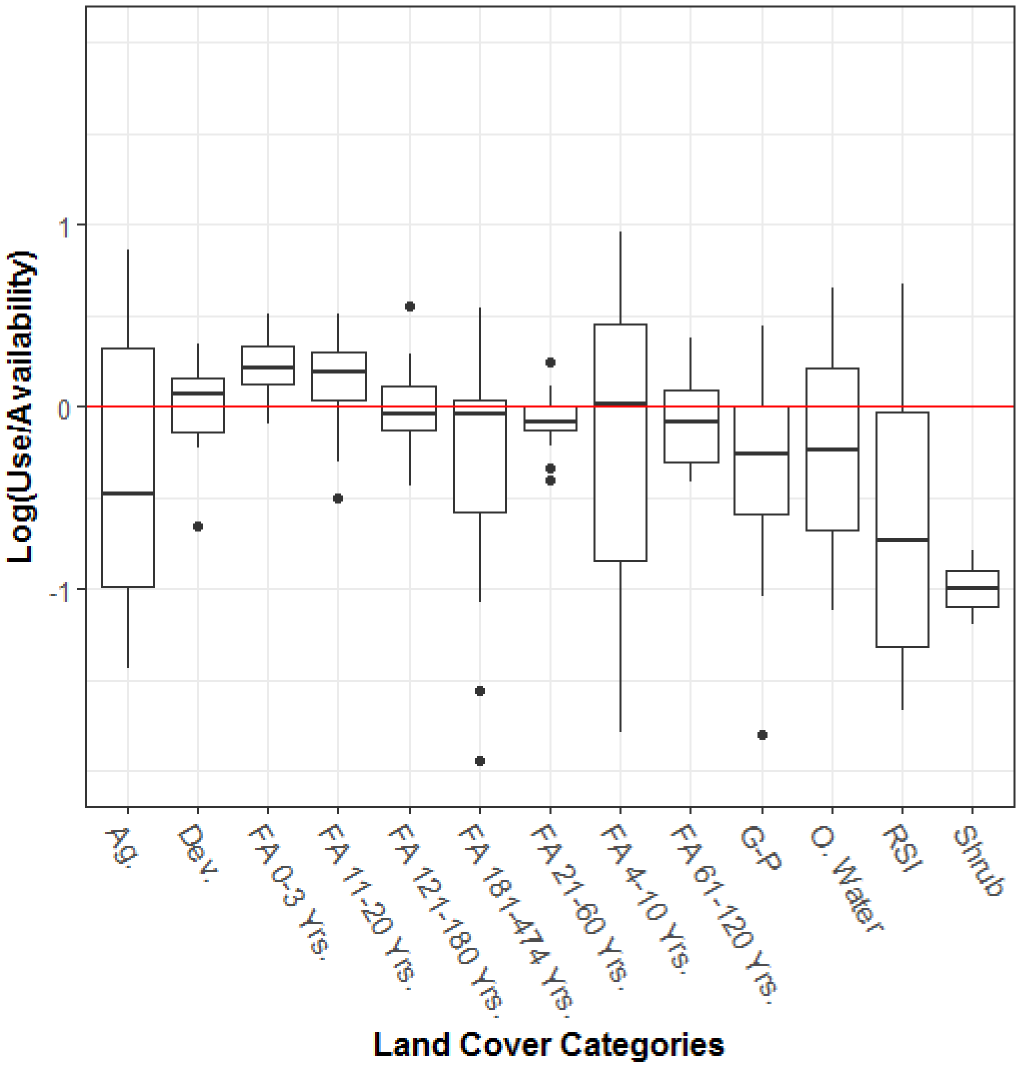

Figure 5. Boxplot of the log ratios of annual female black-tailed deer habitat use by each available land cover category in the Alsea Wildlife Management Unit at second-order selection (home range establishment), including agriculture (Ag.), developed (Dev.), forest ages up to 474 years (e.g., FA 0-3 Yrs.), grassland-prairie (G-P), open water (O. Water), rock/sand/ice (RSI), and shrub.

Table 7. Annual ranking matrix for third-order habitat selection by female black-tailed deer in the Alsea Wildlife Management Unit in western Oregon, 2012-2015. I used compositional analysis to compare selection ratios and defined availability as the composition of individuals' home range and use as the proportion of GPS locations in each land cover category. Note that forest age 0-3 years and forest age 11-20 years were significantly preferred over other land cover categories.

		Land Cover Type[a,b]												
Land Cover Type[a,b]	**Rank**	**Dev.**	**O. Water**	**Ag.**	**Grass.-Prairie**	**Shrub**	**Rock/Sand/Ice**	**FA 0-3 Yrs**	**FA 4-10 Yrs**	**FA 11-20 Yrs**	**FA 21-60 Yrs**	**FA 61-120 Yrs**	**FA 121-180 Yrs**	**FA 181-474 Yrs**
Developed	7		-	+	-	---	---	---	+	-	+	+	+	+
Open Water	6	+		+	-	-	-	-	+	-	+	+	+	+
Agriculture	12	-	-		-	-	-	-	-	-	-	-	-	+
Grassland-Prairie	5	+	+	+		-	-	-	+	-	+	+	+	+
Shrub	4	+++	+	+	+		---	-	+	-	+++	+++	+++	+++
Rock/Sand/Ice	3	+++	+	+	+	+++		-	+	-	+++	+++	+++	+++
FA 0-3 Years	2	+++	+	+	+	+	+		+	-	+++	+++	+++	+++
FA 4-10 Years	10	-	-	+	-	-	-	-		-	-	-	+	+
FA 11-20 Years	1	+	+	+	+	+	+	+	+		+	+	+	+++
FA 21-60 Years	8	-	-	+	-	---	---	---	+	-		+	+	+
FA 61-120 Years	9	-	-	+	-	---	---	---	+	-	-		+	+
FA 121-180 Years	11	-	-	+	-	---	---	---	-	-	-	-		+
FA 181-474 Years	13	-	-	-	-	---	---	---	-	---	-	-	-	

[a] (+) indicates row land cover type is preferred over column land cover type; (-) indicates column cover type is preferred over row land cover type; sign is tripled (e.g, +++) if relationship is significant (α = 0.05).

[b] FA = forest age

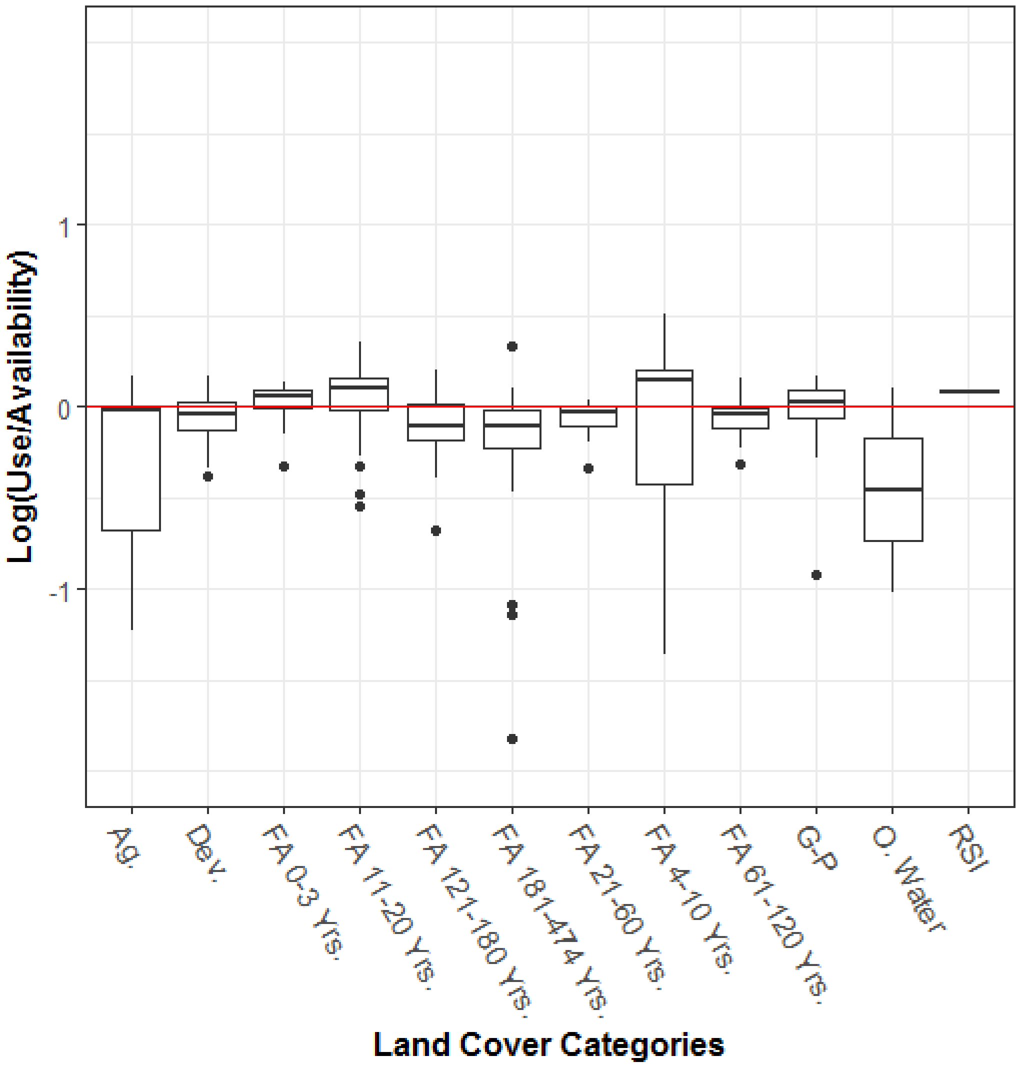

Figure 6. Boxplot of the log ratios of annual female black-tailed deer habitat use by each available land cover category in the Alsea Wildlife Management Unit at third-order selection (within home range), including agriculture (Ag.), developed (Dev.), forest ages up to 474 years (e.g., FA 0-3 Yrs.), grassland-prairie (G-P), open water (O. Water), rock/sand/ice (RSI), and shrub.

Table 8. Winter ranking matrix for third-order habitat selection by female black-tailed deer in the Alsea Wildlife Management Unit in western Oregon, 2012-2015. I used compositional analysis to compare selection ratios and defined availability as the composition of individuals' home range and use as the proportion of GPS locations in each land cover category. Note that forest age 0-3 years, forest age 11-20 years, shrub and open water were significantly preferred over other land cover categories.

		Land Cover Type[a,b]												
Land Cover Type[a,b]	**Rank**	**Dev.**	**O. Water**	**Ag.**	**Grass.-Prairie**	**Shrub**	**Rock/Sand/Ice**	**FA 0-3 Yrs**	**FA 4-10 Yrs**	**FA 11-20 Yrs**	**FA 21-60 Yrs**	**FA 61-120 Yrs**	**FA 121-180 Yrs**	**FA 181-474 Yrs**
Developed	10		---	+	-	---	---	---	+	-	-	-	-	+
Open Water	3	+++		+++	+	-	+	-	+	+	+	+	+	+
Agriculture	12	-	---		-	---	---	---	+	-	-	-	-	-
Grassland-Prairie	6	+	-	+		-	-	-	+	-	+	+	+	+
Shrub	2	+++	+	+++	+		+++	-	+	+	+++	+	+++	+
Rock/Sand/Ice	5	+++	-	+++	+	---		-	+	-	+	+	+	+
FA 0-3 Years	1	+++	+	+++	+	+	+		+	+	+	+	+++	+
FA 4-10 Years	13	-	-	-	-	-	-	-		-	-	-	-	-
FA 11-20 Years	4	+	-	+	+	-	+	-	+		+	+	+	+
FA 21-60 Years	8	+	-	+	-	---	-	-	+	-		-	+	+
FA 61-120 Years	7	+	-	+	-	-	-	-	+	-	+		+	+
FA 121-180 Years	9	+	-	+	-	---	-	---	+	-	-	-		+
FA 181-474 Years	11	-	-	+	-	-	-	-	+	-	-	-	-	

[a] (+) indicates row land cover type is preferred over column land cover type; (-) indicates column cover type is preferred over row land cover type; sign is tripled (e.g, +++) if relationship is significant ($\alpha = 0.05$).

[b] FA = forest age

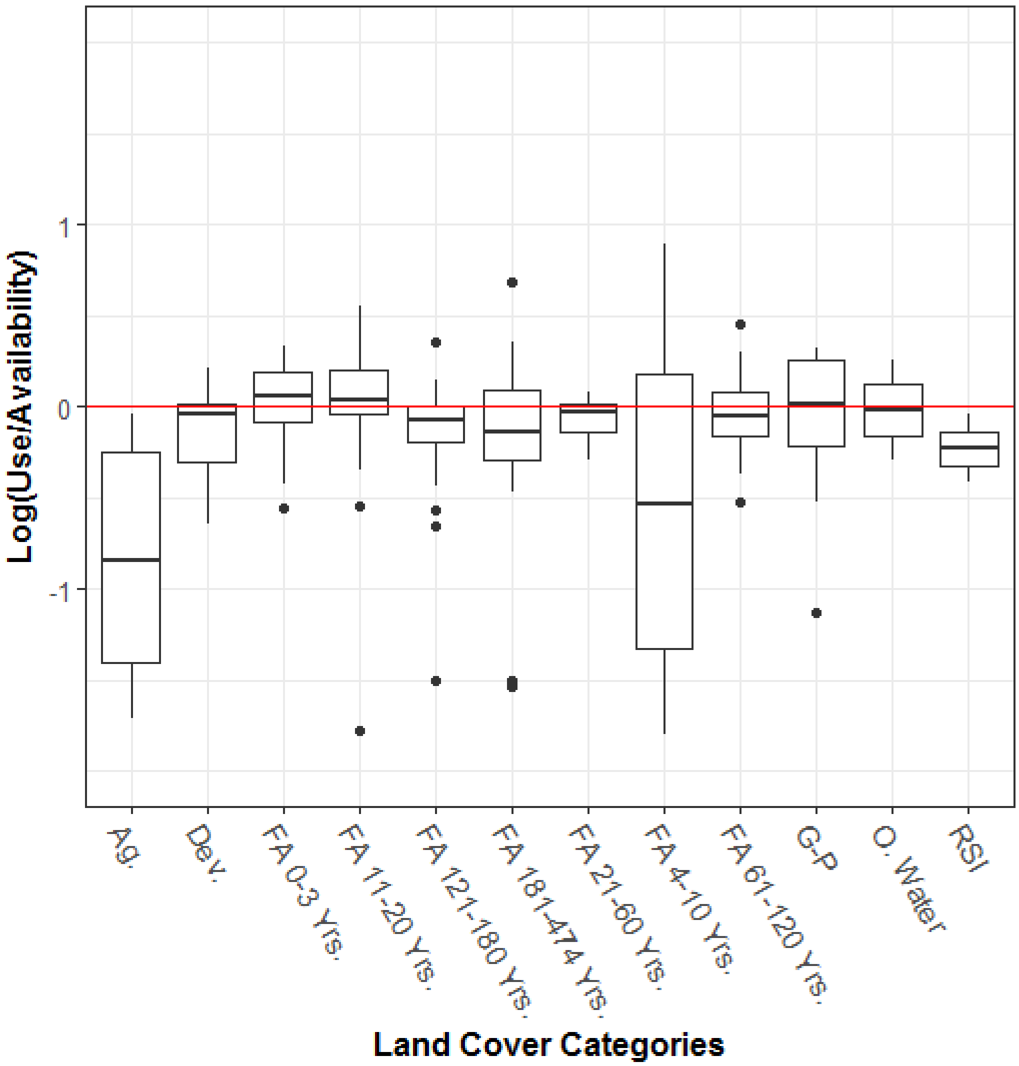

Figure 7. Boxplot of the log ratios of female black-tailed deer habitat use by each available land cover category in the Alsea Wildlife Management Unit at third-order selection (within home range) for the winter season, including agriculture (Ag.), developed (Dev.), forest ages up to 474 years (e.g., FA 0-3 Yrs.), grassland-prairie (G-P), open water (O. Water), rock/sand/ice (RSI), and shrub.

Table 9. Early summer ranking matrix for third-order habitat selection by female black-tailed deer in the Alsea Wildlife Management Unit in western Oregon, 2012-2015. I used compositional analysis to compare selection ratios and defined availability as the composition of individuals' home range and use as the proportion of GPS locations in each land cover category. Note that shrub, grassland-prairie and rock/sand/ice were significantly preferred over other land cover categories.

		Land Cover Type[a,b]												
Land Cover Type[a,b]	**Rank**	**Dev.**	**O. Water**	**Ag.**	**Grass.-Prairie**	**Shrub**	**Rock/Sand/Ice**	**FA 0-3 Yrs**	**FA 4-10 Yrs**	**FA 11-20 Yrs**	**FA 21-60 Yrs**	**FA 61-120 Yrs**	**FA 121-180 Yrs**	**FA 181-474 Yrs**
Developed	10		-	-	---	---	-	-	+	-	-	-	+	+
Open Water	8	+		-	-	---	-	+	+++	-	-	-	+	+
Agriculture	7	+	+		-	-	-	+	+	-	-	-	+	+++
Grassland-Prairie	2	+++	+	+		-	+	+	+++	+	+	+++	+++	+++
Shrub	1	+++	+++	+	+		+	+	+++	+	+++	+++	+++	+++
Rock/Sand/Ice	3	+	+	+	-	-		+	+++	+	+	+	+++	+++
FA 0-3 Years	9	+	-	-	-	-	-		+++	-	-	-	+	+++
FA 4-10 Years	12	-	---	-	---	---	---	---		---	---	---	-	+
FA 11-20 Years	5	+	+	+	-	-	-	+	+++		-	+	+	+++
FA 21-60 Years	4	+	+	+	-	---	-	+	+++	+		+	+++	+++
FA 61-120 Years	6	+	+	+	---	---	-	+	+++	-	-		+++	+++
FA 121-180 Years	11	-	-	-	---	---	---	-	+	-	---	---		+
FA 181-474 Years	13	-	-	---	---	---	---	---	-	---	---	---	-	

[a] (+) indicates row land cover type is preferred over column land cover type; (-) indicates column cover type is preferred over row land cover type; sign is tripled (e.g, +++) if relationship is significant ($\alpha = 0.05$).

[b] FA = forest age

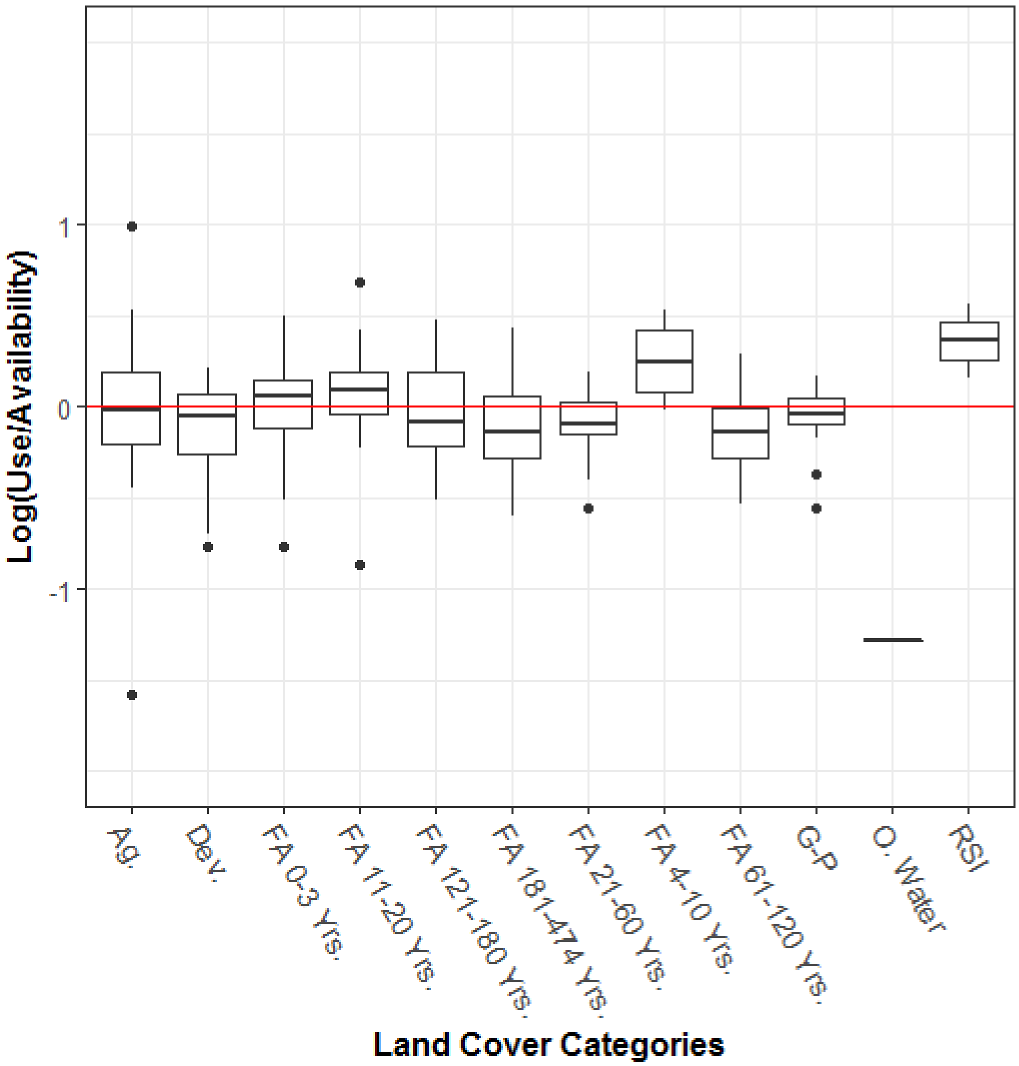

Figure 8. Boxplot of the log ratios of female black-tailed deer habitat use by each available land cover category in the Alsea Wildlife Management Unit at third-order selection (within home range) for the early summer season, including agriculture (Ag.), developed (Dev.), forest ages up to 474 years (e.g., FA 0-3 Yrs.), grassland-prairie (G-P), open water (O. Water), rock/sand/ice (RSI), and shrub.

Table 10. Early summer ranking matrix for third-order habitat selection by female black-tailed deer in the Indigo Wildlife Management Unit in western Oregon, 2012-2015. I used compositional analysis to compare selection ratios and defined availability as the composition of individuals' home range and use as the proportion of GPS locations in each land cover category. Note that agriculture and forest age 11-20 years were significantly preferred over other land cover categories.

		Land Cover Type[a,b]												
Land Cover Type[a,b]	**Rank**	**Dev.**	**O. Water**	**Ag.**	**Grass.-Prairie**	**Shrub**	**Rock/Sand/Ice**	**FA 0-3 Yrs**	**FA 4-10 Yrs**	**FA 11-20 Yrs**	**FA 21-60 Yrs**	**FA 61-120 Yrs**	**FA 121-180 Yrs**	**FA 181-652 Yrs**
Developed	3		+	---	+	+	+	+	+++	-	+	+	+++	+
Open Water	7	-		---	+	+	+	+	+	-	-	-	+	-
Agriculture	1	+++	+++		+	+	+++	+	+++	+	+++	+	+++	+
Grassland-Prairie	8	-	-	-		+	+	+	+	-	-	-	+	-
Shrub	9	-	-	-	-		+	+	+	-	-	-	+	-
Rock/Sand/Ice	11	-	-	---	-	-		-	+	-	-	-	+	-
FA 0-3 Years	10	-	-	-	-	-	+		+	-	-	-	+	-
FA 4-10 Years	13	---	-	---	-	-	-	-		---	---	---	-	-
FA 11-20 Years	2	+	+	-	+	+	+	+	+++		+	+	+++	+
FA 21-60 Years	5	-	+	---	+	+	+	+	+++	-		-	+	+
FA 61-120 Years	4	-	+	-	+	+	+	+	+++	-	+		+++	+
FA 121-180 Years	12	---	-	---	-	-	-	-	+	---	-	---		-
FA 181-652 Years	6	-	+	-	+	+	+	+	+	-	-	-	+	

[a] (+) indicates row land cover type is preferred over column land cover type; (-) indicates column cover type is preferred over row land cover type; sign is tripled (e.g, +++) if relationship is significant ($\alpha = 0.05$).

[b] FA = forest age

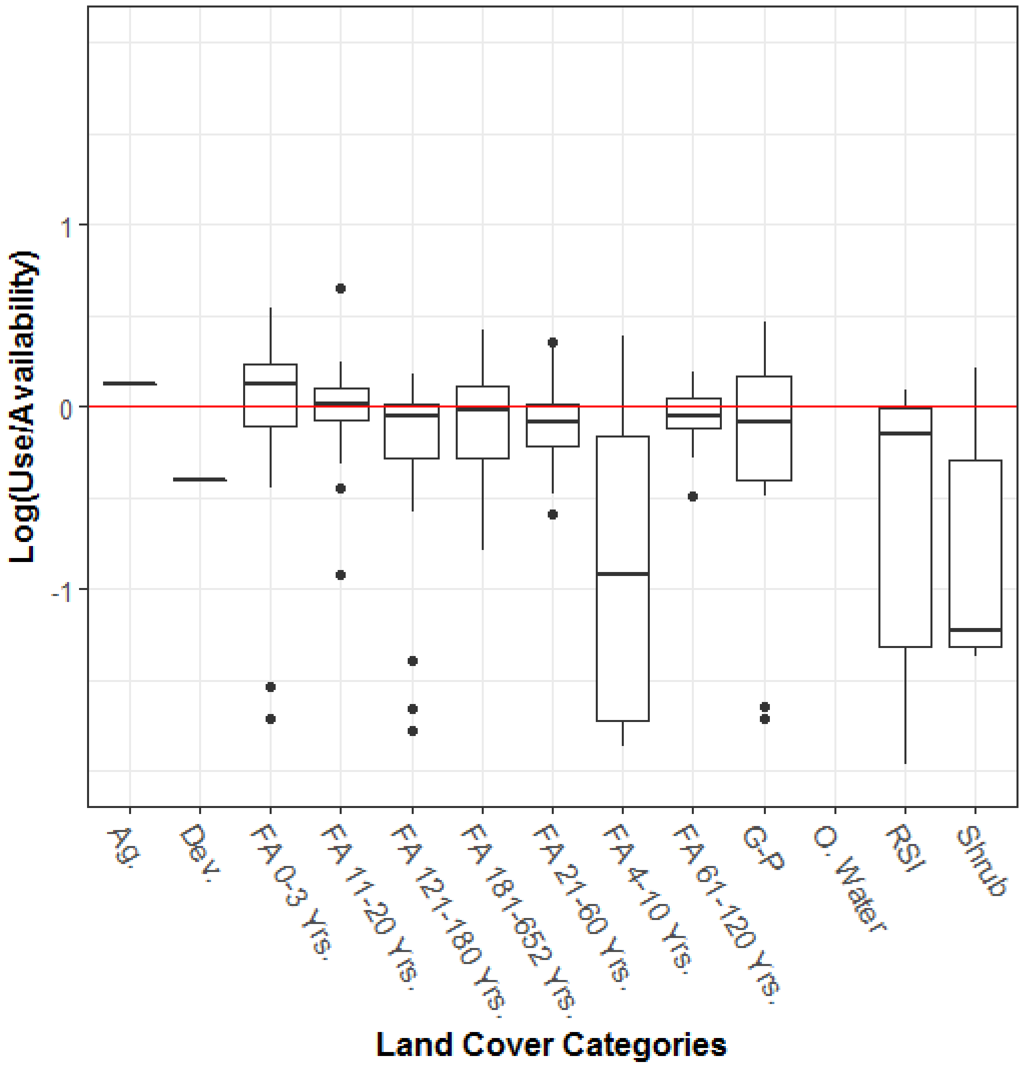

Figure 9. Boxplot of the log ratios of female black-tailed deer habitat use by each available land cover category in the Indigo Wildlife Management Unit at third-order selection (within home range) for the early summer season, including agriculture (Ag.), developed (Dev.), forest ages up to 652 years (e.g., FA 0-3 Yrs.), grassland-prairie (G-P), open water (O. Water), rock/sand/ice (RSI), and shrub.

Home Ranges

Home range size was smaller with increasing amounts (>10%) of forest in age classes 0-10 (LM: B = -1.78 +/- 0.70, t = -2.56, p = 0.013) and 11-20 (LM: B = -4.10 +/- 1.10, t =-3.7, p < 0.001; Figure 10), representing early and mid-seral forest conditions in intensively managed forests. Additionally, home range size was larger on federal land ownership (LM: B = 0.64 +/- 0.14, t = 4.49, p <0.001) compared to large private ownership (LM: B = -0.93 +/- 0.18, t = -5.11, p <0.001) and small private ownership (LM: B = -1.27 +/- 0.25, t = -5.15, p <0.001; Figure 11).

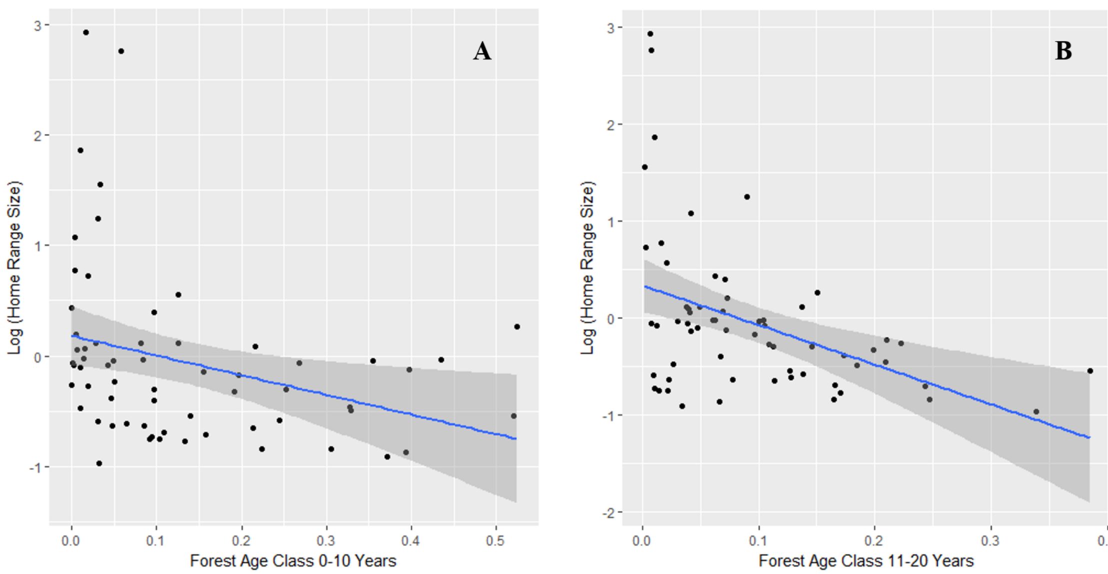

Figure 10. Relationship between home range size (log transformed) of female black-tailed deer from the Alsea and Indigo Wildlife Management Units in Western Oregon and the proportion of land cover categories available within home ranges: (A) early seral, forest age 0-3 years and forest age 4-10 years and (B) mid-seral, forest age 11-20 years.

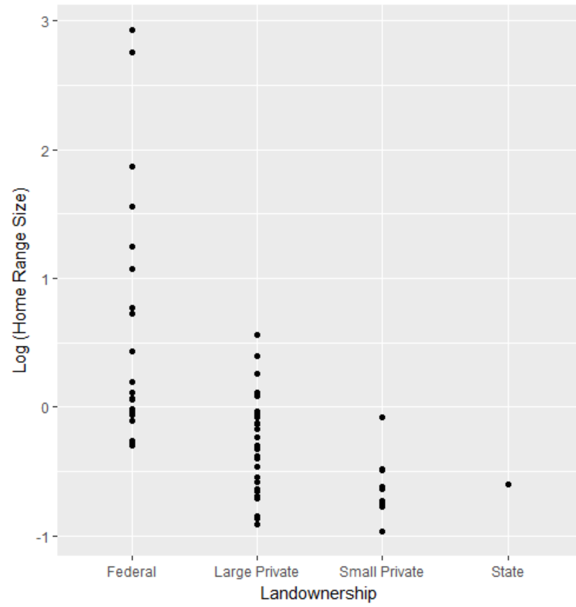

Figure 11. Relationship between home range size (log transformed) of female black-tailed deer from the Alsea and Indigo Wildlife Management Units in Western Oregon and the landownership where individuals were captured and released.

DISCUSSION

In western Oregon, female black-tailed deer are considered habitat generalist and home range establishment may primarily be driven by influences gained through neonatal experiences and maternal care (Schoen and Kirchhoff 1985). I observed differences in home range sizes of female black-tailed deer between the Alsea WMU located in the Coast Range and the Indigo WMU located in the Cascade Range. Mean home range size was larger in the Indigo WMU (262.45 hectares) compared to the Alsea WMU (64.26 hectares), which I attribute to the landownership, and thus stand characteristics, of areas in which individuals were captured and released (Table 5 & Figure 11). Further, home range sizes were smaller with >10% early seral habitat (forest age 0-10 years) availability, but became much larger with <10% early seral habitat availability (Figure 10). I also observed this pattern for mid-seral habitat (forest age 11-20 years) (Figure 10).

I conclude that early- and mid-seral forest characteristics matter enough to female black-tailed deer that they are willing to increase home range size to include more of these habitat characteristics in landscapes where they are limiting (Schoen and Kirchhoff 1985, Forrester et al. 2015), even though expanding home range presumably requires expending more energy or risking exposure to predation. Greater topographical variation in the Indigo WMU may also influence the home range size and distribution of individual female black-tailed deer, although I did not considered topography in this study. Additionally, local habitat quality may differ for each individual and that difference may influence home range size. In the future, fine scale measurements of habitat use and local population dynamics would be warranted to assess the distribution of used habitat elements associated with food, cover, and water (Dasmann and Taber 1956) in relation to home range size and local population densities.

In the Alsea WMU, female black-tailed deer displayed disproportionate use of forest age 0-3 years and forest age 11-20 years compared to other land cover categories in establishing and within home ranges. Forest age 0-3 years comprised ~5% and forest age 11-20 years comprised ~5.5% of the total WMU land cover composition between years 2012-2015. This further indicates that characteristics associated these 2 forest age classes are appealing to female black-tailed deer and coincide with prior studies of habitat preference of black-tailed deer for open habitat or meadows (Loft et al. 1984) and forest stands 14-19 years in age (Hanley 1984). However, in the Indigo WMU female black-tailed deer used all available habitat types in proportion to availability in defining their annual home ranges and within their home ranges, which may have resulted from lower early seral habitat availability. This may have caused individuals to pursue a generalist strategy, ultimately requiring more movement and facilitating a larger home range. The interspersion of various forest stand structures resulting in a checkerboard (Franklin and Forman 1987) effect based on landownership were present in both the Alsea and Indigo WMUs. The checkerboard effect on the western Oregon landscape may locally provide the habitat elements of forage and cover necessary for black-tailed deer to fulfill their annual life history requirements. Although, this effect was more prominent in the Alsea WMU in private forest which may indicate the disproportionate use of forest age 0-3 and 11-20 years based on industrial forest management and having adjacent stands in various stages of forest succession.

The winter and early summer seasonal analyses addressed habitat use within home ranges. For the Alsea WMU, female black-tailed deer displayed disproportionate use for forest age 0-3 years and forest age 11-20 years during winter (Table 8, Figure 7). Apparent prevalence for shrub was likely an artifact of replacing zero values to meet the unit sum constraint, as shrub was not used in winter at Alsea WMU (Figure 7). The ranking of open water (i.e., edges of streams, swamps, estuaries) also is somewhat surprising and may be explained by use of transition zones between water and other land cover types (i.e., edge habitat). Early successional forest use in winter in consistent with the hypothesis that deer forage on young conifers in winter when other plants are unavailable (Cowan 1945). This study did not include fine-scale assessment of forage consumption by black-tailed deer, nor did I measure health or fitness. However, proportional use land of cover types by deer in the Indigo WMU suggests that food and cover are not limited on federal lands in winter.

Results of compositional analysis for summer use in the Alsea WMU (Table 9) are inconsistent with boxplots of the log ratios (Figure 8). Although shrub was shown to be used in in greater proportion to its availability, it was not actually used (Figure 8). Thus, this is another artifact of meeting the unit sum constraint due to this category being present in at least 1 deer's home range. Grassland-prairie also ranked high in this analysis, yet this is inconsistent with the boxplot (Figure 8). Rock/sand/ice also ranked high in this analysis (Table 9) and this is consistent with the boxplot (Figure 8). Rock/sand/ice is present in only 0.03% of the Alsea WMU, therefore there may be a plant type or mineral present in this cover type that are important to female deer. Further research is needed to understand this effect. Interestingly, forest ages 0-3, 4-10, and 11-20 years all showed potential preferential use in the boxplot (Figure 8, although the scores were low in the compositional analysis ranking matrix (Table 9). Although female deer used land cover types in proportion to availability in establishing and within their annual home ranges, they did use agriculture and forest age 11-20 years disproportionately during early summer, although there was very little variation in use of agriculture (Table 10, Figure 9). Additionally, the log ratios of the raw data suggest that forest age 0-3 years also may be important to female deer during summer in the Indigo WMU (Figure 9). Use of areas with early and mid-seral vegetation types are consistent between WMUs for summer use and may be supported by the availability of new growth on Douglas-fir. I conclude that industrial forest managers may expect to observe herbivory to young conifer plantations due to disproportionate use of forest stands age 0-3 years by female black-tailed deer in both seasons and within both the Alsea and Indigo WMUs.

I expected that female black-tailed deer would display preference for forest age 4-10 years given higher forage biomass availability (Ulappa 2015); however, this covert type was very infrequent in both WMUs (range 0.11 - 2.51%). Despite current forest management seeking to truncate the process of stand initiation and early seral elements (Hansen et al. 1991, Hagar 2007), I would expect more of this cover type available in these WMUs. This may be an anomaly in the GNN spatial data in its ability to accurately detect spectral signatures of early seral forest stands (Ohmann and Gregory 2002). In the Alsea WMU, forest age 4-10 years comprised 1.06% of the land cover composition in 2012, dropping to 0.04% in 2015. Similarly, in the Indigo WMU, forest age 4-10 years comprised 2.51% of the land cover composition in 2012, dropping to 0.11% in 2015. Lastly, the forest land cover categories do not differentiate between coniferous and hardwood forests. Further investigation and detail covering the use of coniferous versus hardwood forest by black-tailed deer and the various forest management strategies executed by various landowners' warrants investigation.

A challenge encountered by this and similar studies is a limitation in the GAP land cover data for non-forest sites: rare land cover types may be missed given their patchy distribution and relatively small extents (Comer et al. 2003, USGS 2011). Additionally, the GAP land cover data were developed using Landsat 1999-2001 imagery and significant change may have endured since the development of this base map. I found the land cover categories rock/sand/ice and shrub actually represent forest stands that have recently been disturbed, in the process of stand initiation or were Christmas tree farms. This may strengthen the selection for forest stands undergoing stand initiation or characteristic of earl seral condition by female black-tailed deer in the Alsea and Indigo WMUs. The developers of the GNN spatial data are currently developing modeling techniques to address the accuracy of non-forest cover to incorporate into their existing model (Ohmann and Gregory 2002).

My analysis may also have been affected by the need to replace absent cover types with a small non-zero values. Aebishcer et al. (1993) recommend using 0.01% to replace non-zero values, while Bingham and Brennan (2004) recommend a higher value in the range of 0.3—0.7% to reduce the probability of making a type 1 error (Janke and Gates 2013). A review of compositional analysis and unused habitat conducted by Bingham et al. (2007), indicated that as the value replacing zero moves closer to zero, there is a higher chance of producing a type I or type II error. However, for this study design analyzing 13 land cover types, I observed values <0.001, in which I divided the smallest value in the data set by two to replace my zero values. Additionally, GPS points were used to determine third-order selection among land cover categories possibly resulting in too fine of scale for the GNN data. As the grain of a study increases, so does the precision of the GNN data (Ohmann and Gregory 2002). Janke and Gates (2013) analyzed third order selection by comparing the 95% kernel home range to the 50% kernal home range (core use area) to see where northern bobwhites (*Colinus virginianus*) focused activities and compared that to the specific land cover categories used within home ranges. This may be a better approach in using the GNN data when doing future analyses of black-tailed deer in western Oregon.

The results of this study provide a broad scale assessment of habitat use of female black-tailed deer at a landscape level in western Oregon and further stresses the importance of investigating landscape-scale variables (e.g. habitat patch size, patch interspersion, edge density and topography; Boroski et al. 1996, Kie et al. 2002, Farmer et al. 2006). In the Alsea and Indigo

WMU's, privately owned land is found in areas with an interspersion of federal, mature forests adjacent to private lands subjected to regular thinning and clearcut harvests, which ultimately provide the habitat elements required by black-tailed deer (Cowan 1945). However, the Indigo WMU represented female black-tailed deer habitat use on federal lands, resulting in larger home ranges and proportionate habitat use. Mature forests providing cover with adjacent clearcuts or other disturbances producing forage are necessary for black-tailed deer, indicating habitat management needs to be addressed at the landscape level. The importance of forest age 0-3 years and forest age 11-20 years should be further noted as they are important habitat elements that determine home range size and potentially local population densities. These results suggest that clearcuts or other disturbances and the stand initiation processes are vital to black-tailed deer, providing suitable forage biomass availability (Loft et al. 1984). This further indicates a need for collaboration among forest owners to generate early seral conditions to create habitat elements suitable to black-tailed deer within federal forests, but also ensuring that adjacent forests are capable of providing cover while balancing the needs of other species (Loft et al. 1984, Chang et al. 1995). Ultimately, these results will help guide ODFW's black-tailed deer management plan (ODFW 2008) in gaining greater insight into black-tailed deer ecology in western Oregon. These results improve estimates of home range sizes and habitat use of female black-tailed deer, and this approach may be used to conduct similar analyses of black-tailed deer in other WMUs of western Oregon.

LITERATURE CITED

Aebischer, N.J., P.A. Robertson, and R.E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313-1325.

Amstrup, S.C., T.L. McDonald, and G.M. Durner. 2004. Using satellite radiotelemetry data to delineate and manage wildlife populations. Wildlife Society Bulletin 32:661-679.

Betts, M.G., J.C. Hagar, J.W. Rivers, J.D. Alexander, K. McGarigal, and B.C. McComb. 2010. Thresholds in forest bird occurrence as a function of the amount of early-seral broadleaf forest at landscape scales. Ecological Applications 20:2116-2130.

Bingham, R.L., and L.A. Brennan. 2004. Comparison of type I error rates for statistical analyses of resource selection. Journal of Wildlife Management 68:206-212.

Bingham, R.L., L.A. Brennan, and B.M. Ballard. 2007. Misclassified resource selection: compositional analysis and unused habitat. Journal of Wildlife Management 71: 1369-1374.

Block, W.M., and L.A. Brennan. 1993. The habitat concept in ornithology: Theory and applications. Current Ornithology 11:35–91.

Boroski, B.B., R.H. Barrett, I.C. Timossi, and J.G. Kie. 1996. Modeling habitat suitability for black-tailed deer (Odocoileus hemionus columbianus) in heterogeneous landscapes. Forest Ecology and Management 88:157-165.

Boyle, J.R., J.E. Warila, R.L. Beschta, M. Reiter, C.C. Chambers, W.P. Gibson, S.V. Gregory, J. Grizzel, J.C. Hagar, J.L. Li, W.C. McComb, T.W. Parzybok, and G. Taylor. 1997. Cumulative effects of forestry practices: an example framework for evaluation from Oregon, U.S.A. Biomass and Bioenergy 13:223-245.

Brown, E.R. 1961. The black-tailed deer of western Washington. Washington State Game Department Bulletin. 13, pp. 124.

Calenge, C. 2006. The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197: 516-519.

Campbell, D.L., and J. Evans. 1978. Establishing native forbs to reduce black-tailed deer browsing damage to Douglas-fir. Proceedings of the 8th Vertebrate Pest Conference. Paper 7.

Campbell, S., D. Azuma, and D. Weyermann. 2004. Forests of western Oregon: an overview. US Department of Agriculture Forest Service, Portland, Oregon. 20 pages.

Chang, K.T., D.L. Verbyla, and J.J. Yeo. 1995. Spatial analysis of habitat selection by sitka black-tailed deer in southeast Alaska, USA. Environmental Management 4:579-589.

Clark, L. A., G.J. Roloff, V.L. Tatum, and L.L. Irwin. 2009. Forest herbicide effects on pacific northwest ecosystems: a literature review. National Council for Air and Stream Improvement Technical Bulletin No. 970.

Comer, P.J., D. Faber-Langendoen, R. Evans, S.C. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: a working classification of U.S. terrestrial systems. NatureServe, Arlington, Virginia.

Cowan, I. M. 1945. The ecological relationships of the food of the Columbian black-tailed deer, *Odocoileus hemionus columbianus*, in the coast forest region of southern Vancouver Island, British Columbia. Ecological Monographs 15:110–139.

Crouch, G.L. 1966. Preferences of black-tailed deer for native forage and Douglas-fir seedlings. Journal of Wildlife Management 32:542-553.

Crouch, G.L. 1968. Availability in relation to browsing of Douglas-fir seedlings by black-tailed deer. Journal of Wildlife Management 32:542-553.

Crouch, G.L. 1979. Atrazine improves survival and growth of ponderosa pine threatened by vegetative competition and pocket gophers. Forest Science 25:99-111.

Dasmann, R.F., and R.D. Taber. 1956. Behavior of Columbian black-tailed deer with reference to population ecology. Journal of Mammalogy 37:143-164.

Dasmann, R.F., and W.P. Dasmann. 1963. Mule deer in relation to a climatic gradient. Journal of Wildlife Management 27:196-202.

Farmer, C.J., D.K. Person, R.T. Bowyer. 2006. Risk factors and mortality of black-tailed deer in managed forest landscape. Journal of Wildlife Management 70:1403-1415.

Forrester, T.D., D.S. Casady, and H.U. Wittmer. 2015. Home sweet home: fitness consequences of site familiarity in female black-tailed deer. Behavioral Ecology and Socio Biology 69:603-612.

Franklin, J.F., and R.T.T. Forman. 1987. Creating landscape patterns by forest cutting: ecological consequences and principles. Landscape Ecology 1:5-18.

Franklin, J. F., and C. T. Dyrness. 1988. Natural vegetation of Oregon and Washington. U.S. Forest Service Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, USA.

Gill, R.M.A. 1992. A review of damage by mammals in north temperate forests: 1. deer. Forestry 65:145-169.

Gitzen, R.A., J.J. Millspaugh, and B.J. Kernohan. 2006. Bandwidth selection for fixed-kernel analysis of animal utilization distributions. Journal of Wildlife Management 70:1334-1344.

Hagar, J.C. 2007. Wildlife species associated with non-coniferous vegetation in pacific northwest conifer forests: a review. Forest Ecology and Management 246:108-122.

Hall, L.S., P.R. Krausman, and M.L. Morrison. 1997. The habitat concept and a plea for standard terminology. Wildlife Society Bulletin 25:173-182.

Hanley, T.A. 1983. Black-tailed deer, elk, and forest edge in a western cascades watershed. Journal of Wildlife Management 47:237-242.

Hanley, T.A. 1984. Habitat patches and their selection by wapiti and black-tailed deer in a coastal montane coniferous forest. Journal of Applied Ecology 21:423-436.

Hansen, A.J., T.A. Spies, F.J. Swanson, and J.L. Ohmann. 1991. Conserving Biodiversity in Managed Forests. Bioscience 41:382-392.

Hutto, R. 1985. Habitat selection by nonbreeding migratory land birds. Pages 455-476 in M. Cody, editor. Habitat selection in birds. Academic Press, London, UK.

Janke, A.K., and R.J. Gates. 2013. Home range and habitat selection of northern bobwhite coveys in an agricultural landscape. Journal of Wildlife Management 77:405-413.

Jarnemo, A., J. Minderman, N. Bunnefeld, J. Zidar, and J. Månsson. 2014. Managing landscapes for multiple objectives: alternative forage can reduce conflict between deer and forestry. Ecosphere 5: Article 97.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Jones, J. 2001. Habitat selection studies in avian ecology: a critical review. Auk 118:557-562.

Kennedy, R.E. 2010. Detecting trends in forest disturbance and recovery using yearly Landsat time series: 1. LandTrendr—temporal segmentation algorithms. Remote Sensing of Environment 114:2897-2910.

Kie, J.G. 1999. Optimal foraging and risk of predation: effects on behavioral and social structure in ungulates. Journal of Mammalogy 80:1114-1129.

Kie, J.G., R.T. Bowyer, M.C. Nicholson, B.B. Boroski, and E.R. Loft. 2002. Landscape heterogeneity at differing scales: effects on spatial distribution of mule deer. Ecology 83:530-544.

Kie, J.G., J. Matthiopoulos, J. Fieberg, R.A. Powell, F. Cagnacci, M.S. Mitchell, J.M. Galliard, and P.R. Moorcroft. 2010. The home-range concept: are traditional estimators still relevant with modern telemetry technology? Philosophical Transactions of the Royal Society 365:2221-2231.

Lewis, J.S., J.L. Rachlow, E.O. Garton, and L.A. Vierling. 2007. Effects of habitat on GPS collar performance: using data screening to reduce location error. Journal of Applied Ecology 44: 663-671.

Loft, E.R., J.W. Menke, and T.S. Burton. 1984. Seasonal movements and summer habitats of female black-tailed deer. Journal of Wildlife Management 48:1317-1325.

Mace, R. U., R. Denney, and R. Ingram. 1995. Big game history, 1890-1990. Oregon Department of Fish and Wildlife, Salem, USA.

Maser, C., B.R. Mate, J.F. Franklin, and C.T. Dyrness. 1981. Natural history of Oregon coast mammals. USDA Forest Service. General Technical Report PNW-133, Pacific Northwest Forest and Range Experiment Station, Portland, OR, pp. 496.

Massé, A., and S.D Côté. 2009. Habitat selection of a large herbivore at high density and without predation: trade-off between forage and cover? Journal of Mammalogy 90:961-970.

Max, T.A., Schreuder, H.T., Hazard, J.W., Oswald, D.O., Teply, J., and Alegria, J. 1996. The Pacific Northwest Region vegetation inventory and monitoring system. USDA Forest Service Research Paper, PNW-RP-493.

McCullough, D.R. 1975. Modification of the Clover deer trap. California Fish and Game 61:242-244.

Miller, F.L. 1968. Observed use of forage and plant communities of black-tailed deer. Journal of Wildlife Management 32:142-148.

Ohmann, J.L., and M.J. Gregory. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, U.S.A. Canadian Journal of Forest Research 32:725-741.

Oregon Department of Fish and Wildlife. 2008. Oregon black-tailed deer management plan. Oregon Department of Fish and Wildlife, Salem, Oregon, USA.

Pamplin, N.P. 2003. Ecology of Columbian black-tailed deer fawns in western Oregon. M.S. Thesis, Oregon State University, Corvallis, OR. 75 pp.

Pellerin, M., S. Saïd, and J.M. Gaillard. 2008. Roe deer *Capreolus capreolus* home-range size estimated from VHF and GPS data. Wildlife Biology 14:101-110.

Schoen, J.W., and M.D. Kirchhoff. 1985. Seasonal distribution and home-range patterns of sitka black-tailed deer on Admiralty Island, Southeast Alaska. Journal of Wildlife Management 49:96-103.

Seaman, E.D., J.J. Millspaugh, B.J. Kernohan, G.C. Brundige, K.J. Raedeke, and R.A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739-747.

Spies, T.A., and Franklin, J.F. 1991. The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington. USDA Forest Service General Technical Report PNW-GTR- 285. pp. 90–109.

Spies, T.A., K.N. Johnson, K.M. Burnett, J.L. Ohmann, B.C. McComb, G.H. Reeves, P. Bettinger, J.D. Kline, and B. Garber-Yonts. 2007. Cumulative ecological and socioeconomic effects of forest policies in coastal Oregon. Ecological Applications 17:5-17.

Swanson, M.E., J.F. Franklin, R.L. Beschta, C.M. Crisafulli, D.A. DellaSala, R.L. Hutto, D.B. Lindenmayer, and F.J. Swanson. 2011. The forgotten stage of forest succession: early-successional ecosystems on forest sites. Frontiers in Ecology and the Environment 9:117-125.

Thomas, J.W., J.F. Franklin, J. Gordon, and N.K. Johnson. 2006. The northwest forest plan: origins, components, implementation experience, and suggestions for change. Conservation Biology 20:277-287.

Tomkiewicz, S.M., M.R. Fuller, J.G. Kie, and K.K. Bates. 2010. Global positioning system and associated technologies in animal behavior and ecological research. Philosophical Transactions: Biological Sciences 1550:2163-2176.

Ulappa, A.C. 2015. Using foraging dynamics to answer landscape management questions: the nutritional ecology of black-tailed deer (thesis), Washington State University, Pullman, USA.

US Geological Survey, Gap Analysis Program (GAP). May 2011. National Land Cover, Version 2.

Wallmo, O.C., editor. 1981. Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln, Nebraska, USA.

Waring, R.H., and J.F. Franklin. 1979. Evergreen coniferous forests of the Pacific Northwest. Science 204:1380-1386.

Wiens, J.A. 1976. Population responses to patchy environments. Annual Review of Ecology and Systematics 7:81-120.

Wiens, J.A. 1984. Resource systems, populations, and communities. In A new ecology. Edited by P.W. Price, C.N. Slobodchikoff, and W.S. Gaud. John Wiley & Sons, New York. pp. 397–436.

CHAPTER 3: GENERAL CONCLUSIONS

The concluding chapter focuses on the next steps in analyzing data for Oregon Department of Fish and Wildlife’s black-tailed deer management program. I review potential weaknesses in the study here, and consider potential follow up analysis.

My findings may be sensitive to GPS collar setting. The collars I used were programmed to acquire locations every 4 hours for 72 weeks, allowing to obtain at least one annual interval of data for individuals. Increasing the acquisition rate of GPS locations comes at cost to battery life, so strategic decisions were made to meet management objectives set by ODFW. However, the acquisition rate and number of GPS locations in particular land cover categories does not necessarily reflect the true importance, or lack thereof, to individual female black-tailed deer (Garshelis 2000). In home range analysis, screening GPS location data for PDOP may misrepresent female black-tailed deer use among habitat types such as old-growth forest or riparian areas where satellite reception is poor. The obstruction that occurs between signals from satellites and the GPS receiver under dense canopy cover or topographical variation is a limitation of GPS technology that is still under investigation (D’Eon et al. 2002, Hebblewhite et al. 2007, Frair et al. 2010). By placing collars at stationary sites in a variety of cover types, such as under closed-canopy forests or in riparian areas within steep terrain, one could gain a better understanding of GPS collar fix-acquisition rates for the landscape under investigation. These results could then be applied to data obtained in these areas and gauge if major habitat types are being misrepresented.

Most wildlife studies are subjected to logistical and financial limitations, however Oregon Department of Fish and Wildlife is still acquiring more GPS collar data from individual female black-tailed deer in these two WMUs. The inclusion of more individuals may further strengthen the significance of the results presented here, particularly with a greater representation of individuals captured on federal land in the Alsea WMU and more individuals captured on private land in the Indigo WMU. Another analysis approach that could be utilized would be similar to Kie et al. (2002), which addressed landscape spatial heterogeneity at various spatial scales. Further, ODFW could focus on the 10-km2 grid cells and randomly select cells based on landownership and conduct more intensive studies that may look at fourth-order selection at finer spatial scales (Johnson 1980). Ideally, the use of spatial data provided by various landowners in study areas under investigation would provide suitable spatial data for black-tailed deer habitat use at finer spatial scales. Effective management for black-tailed deer in western Oregon will benefit from this study investigating home range sizes and habitat use in a landscape where wildlife habitat management is inevitably tied to forest management. Further investigation is warranted to fully comprehend the results of female black-tailed deer habitat use presented here, especially when accounting for landscape level variability and fine scale measurement of habitat use and population dynamics.

LITERATURE CITED

D'Eon, R.G., R. Serrouya, G. Smith, and C.O. Kochanny. 2002. GPS radiotelemetry error and bias in mountainous terrain. Wildlife Society Bulletin 30:430-439.

Frair, J.L., J. Fieberg, M. Hebblewhite, F. Cagnacci, N. DeCesare, and L. Pedrotti. 2010. Resolving issues of imprecise and habitat-biased locations in ecological analyses using GPS telemetry data. Philosophical Transactions of the Royal Society B 365:2187-2200.

Garshelis, D.L. 2000. Delusions in habitat evaluation: measuring use, selection, and importance. Pages 111-153 in L. Boitani and T.K. Fuller (eds.). Research Techniques in Animal Ecology: Controversies and Consequences. Columbia University Press, New York, NY.

Hebblewhite, M., M. Percy, and E.H. Merrill. 2007. Are all GPS collars created equal? A comparison of three brands for habitat-induced fix-rate bias. Journal of Wildlife Management 71:2026-2033.

Janke, A.K., and R.J. Gates. 2013. Home range and habitat selection of northern bobwhite coveys in an agricultural landscape. Journal of Wildlife Management 77:405-413.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Kie, J.G., R.T. Bowyer, M.C. Nicholson, B.B. Boroski, and E.R. Loft. 2002. Landscape heterogeneity at differing scales: effects on spatial distribution of mule deer. Ecology 83:530-544.

Ohmann, J.L., and M.J. Gregory. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, U.S.A. Canadian Journal of Forest Research 32:725-741.

BIBLIOGRAPHY

Aebischer, N.J., P.A. Robertson, and R.E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313-1325.

Amstrup, S.C., T.L. McDonald, and G.M. Durner. 2004. Using satellite radiotelemetry data to delineate and manage wildlife populations. Wildlife Society Bulletin 32:661-679.

Betts, M.G., J.C. Hagar, J.W. Rivers, J.D. Alexander, K. McGarigal, and B.C. McComb. 2010. Thresholds in forest bird occurrence as a function of the amount of early-seral broadleaf forest at landscape scales. Ecological Applications 20:2116-2130.

Bingham, R.L., and L.A. Brennan. 2004. Comparison of type I error rates for statistical analyses of resource selection. Journal of Wildlife Management 68:206-212.

Bingham, R.L., L.A. Brennan, and B.M. Ballard. 2007. Misclassified resource selection: compositional analysis and unused habitat. Journal of Wildlife Management 71: 1369-1374.

Block, W.M., and L.A. Brennan. 1993. The habitat concept in ornithology: Theory and applications. Current Ornithology 11:35–91.

Boroski, B.B., R.H. Barrett, I.C. Timossi, and J.G. Kie. 1996. Modeling habitat suitability for black-tailed deer (Odocoileus hemionus columbianus) in heterogeneous landscapes. Forest Ecology and Management 88:157-165.

Boyle, J.R., J.E. Warila, R.L. Beschta, M. Reiter, C.C. Chambers, W.P. Gibson, S.V. Gregory, J. Grizzel, J.C. Hagar, J.L. Li, W.C. McComb, T.W. Parzybok, and G. Taylor. 1997. Cumulative effects of forestry practices: an example framework for evaluation from Oregon, U.S.A. Biomass and Bioenergy 13:223-245.

Brandeis, T.J., M. Newton, and E.C. Cole. 2002. Biotic injuries on conifer seedlings planted in forest understory environments. New Forests 24:1-14.

Brown, E.R. 1961. The black-tailed deer of western Washington. Washington State Game Department Bulletin. 13, pp. 124.

Bunnell, F.L. 1990. Ecology of black-tailed deer. Pages 31-63 *in* Nyberg, J.B., and D.W. Janz, (technical editors), Deer and elk habitats in coastal forests of southern British Columbia. B.C. Ministry of Forests, Special Report Series 5, Victoria.

Calenge, C. 2006. The package “adehabitat” for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197: 516-519.

Campbell, D.L., and J. Evans. 1978. Establishing native forbs to reduce black-tailed deer browsing damage to Douglas-fir. Proceedings of the 8th Vertebrate Pest Conference. Paper 7.

Campbell, S., D. Azuma, and D. Weyermann. 2004. Forests of western Oregon: an overview. US Department of Agriculture Forest Service, Portland, Oregon. 20 pages.

Chang, K.T., D.L. Verbyla, and J.J. Yeo. 1995. Spatial analysis of habitat selection by sitka black-tailed deer in southeast Alaska, USA. Environmental Management 4:579-589.

Clark, L. A., G.J. Roloff, V.L. Tatum, and L.L. Irwin. 2009. Forest herbicide effects on pacific northwest ecosystems: a literature review. National Council for Air and Stream Improvement Technical Bulletin No. 970.

Comer, P.J., D. Faber-Langendoen, R. Evans, S.C. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: a working classification of U.S. terrestrial systems. NatureServe, Arlington, Virginia.

Côté, S.D., T.P. Rooney, J.P. Tremblay, C. Dussault, and D.M. Waller. 2004. Ecological impacts of deer overabundance. Annual Review of Ecology, Evolution, and Systematics 35: 113-147.

Cowan, I. M. 1945. The ecological relationships of the food of the Columbian black-tailed deer, *Odocoileus hemionus columbianus*, in the coast forest region of southern Vancouver Island, British Columbia. Ecological Monographs 15:110–139.

Crouch, G.L. 1966. Preferences of black-tailed deer for native forage and Douglas-fir seedlings. Journal of Wildlife Management 32:542-553.

Crouch, G.L. 1968. Availability in relation to browsing of Douglas-fir seedlings by black-tailed deer. Journal of Wildlife Management 32:542-553.

Crouch, G.L. 1979. Atrazine improves survival and growth of ponderosa pine threatened by vegetative competition and pocket gophers. Forest Science 25:99-111.

Dasmann, R.F., and R.D. Taber. 1956. Behavior of Columbian black-tailed deer with reference to population ecology. Journal of Mammalogy 37:143-164.

Dasmann, R.F., and W.P. Dasmann. 1963. Mule deer in relation to a climatic gradient. Journal of Wildlife Management 27:196-202.

D'Eon, R.G., R. Serrouya, G. Smith, and C.O. Kochanny. 2002. GPS radiotelemetry error and bias in mountainous terrain. Wildlife Society Bulletin 30:430-439.

Farmer, C.J., D.K. Person, R.T. Bowyer. 2006. Risk factors and mortality of black-tailed deer in managed forest landscape. Journal of Wildlife Management 70:1403-1415.

Forrester, T.D., D.S. Casady, and H.U. Wittmer. 2015. Home sweet home: fitness consequences of site familiarity in female black-tailed deer. Behavioral Ecology and Socio Biology 69:603-612.

Frair, J.L., J. Fieberg, M. Hebblewhite, F. Cagnacci, N. DeCesare, and L. Pedrotti. 2010. Resolving issues of imprecise and habitat-biased locations in ecological analyses using GPS telemetry data. Philosophical Transactions of the Royal Society B 365:2187-2200.

Franklin, J.F., and R.T.T. Forman. 1987. Creating landscape patterns by forest cutting: ecological consequences and principles. Landscape Ecology 1:5-18.

Franklin, J. F., and C. T. Dyrness. 1988. Natural vegetation of Oregon and Washington. U.S. Forest Service Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, USA.

Franklin, J.F., and K.N. Johnson. 2012. A restoration framework for federal forests in the pacific northwest. Journal of Forestry 110:429-439.

Garshelis, D.L. 2000. Delusions in habitat evaluation: measuring use, selection, and importance. Pages 111-153 in L. Boitani and T.K. Fuller (eds.). Research Techniques in Animal Ecology: Controversies and Consequences. Columbia University Press, New York, NY.

Gill, R.M.A. 1992. A review of damage by mammals in north temperate forests: 1. deer. Forestry 65:145-169.

Gitzen, R.A., J.J. Millspaugh, and B.J. Kernohan. 2006. Bandwidth selection for fixed-kernel analysis of animal utilization distributions. Journal of Wildlife Management 70:1334-1344.

Hagar, J.C. 2007. Wildlife species associated with non-coniferous vegetation in pacific northwest conifer forests: a review. Forest Ecology and Management 246:108-122.

Hall, L.S., P.R. Krausman, and M.L. Morrison. 1997. The habitat concept and a plea for standard terminology. Wildlife Society Bulletin 25:173-182.

Hanley, T.A. 1983. Black-tailed deer, elk, and forest edge in a western cascades watershed. Journal of Wildlife Management 47:237-242.

Hanley, T.A. 1984. Habitat patches and their selection by wapiti and black-tailed deer in a coastal montane coniferous forest. Journal of Applied Ecology 21:423-436.

Hansen, A.J., T.A. Spies, F.J. Swanson, and J.L. Ohmann. 1991. Conserving Biodiversity in Managed Forests. Bioscience 41:382-392.

Hebblewhite, M., M. Percy, and E.H. Merrill. 2007. Are all GPS collars created equal? A comparison of three brands for habitat-induced fix-rate bias. Journal of Wildlife Management 71:2026-2033.

Hobbs, N. T. 1996. Modification of ecosystems by ungulates. Journal of Wildlife Management 60:695-713.

Hutto, R. 1985. Habitat selection by nonbreeding migratory land birds. Pages 455-476 in M. Cody, editor. Habitat selection in birds. Academic Press, London, UK.

Janke, A.K., and R.J. Gates. 2013. Home range and habitat selection of northern bobwhite coveys in an agricultural landscape. Journal of Wildlife Management 77:405-413.

Jarnemo, A., J. Minderman, N. Bunnefeld, J. Zidar, and J. Månsson. 2014. Managing landscapes for multiple objectives: alternative forage can reduce conflict between deer and forestry. Ecosphere 5: Article 97.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Jones, J. 2001. Habitat selection studies in avian ecology: a critical review. Auk 118:557-562.

Kennedy, R.E. 2010. Detecting trends in forest disturbance and recovery using yearly Landsat time series: 1. LandTrendr—temporal segmentation algorithms. Remote Sensing of Environment 114:2897-2910.

Kie, J.G. 1999. Optimal foraging and risk of predation: effects on behavioral and social structure in ungulates. Journal of Mammalogy 80:1114-1129.

Kie, J. G., and B. Czech. 2000. Mule and black-tailed deer. Pages 629–657 *in* S. Demarais and P. R. Krausman, editors. Ecology and management of large mammals in North America. Prentice Hall, Upper Saddle River, New Jersey, USA.

Kie, J.G., R.T. Bowyer, M.C. Nicholson, B.B. Boroski, and E.R. Loft. 2002. Landscape heterogeneity at differing scales: effects on spatial distribution of mule deer. Ecology 83:530-544.

Kie, J.G., J. Matthiopoulos, J. Fieberg, R.A. Powell, F. Cagnacci, M.S. Mitchell, J.M. Galliard, and P.R. Moorcroft. 2010. The home-range concept: are traditional estimators still relevant with modern telemetry technology? Philosophical Transactions of the Royal Society 365:2221-2231.

Kremsater, L.L., and F.L. Bunnell. 1992. Testing responses to forest edges: the example of black-tailed deer. Canadian Journal of Zoology 70:2426-2435.

Lewis, J.S., J.L. Rachlow, E.O. Garton, and L.A. Vierling. 2007. Effects of habitat on GPS collar performance: using data screening to reduce location error. Journal of Applied Ecology 44: 663-671.

Loft, E.R., J.W. Menke, and T.S. Burton. 1984. Seasonal movements and summer habitats of female black-tailed deer. Journal of Wildlife Management 48:1317-1325.

Mace, R. U., R. Denney, and R. Ingram. 1995. Big game history, 1890-1990. Oregon Department of Fish and Wildlife, Salem, USA.

Maser, C., B.R. Mate, J.F. Franklin, and C.T. Dyrness. 1981. Natural history of Oregon coast mammals. USDA Forest Service. General Technical Report PNW-133, Pacific Northwest Forest and Range Experiment Station, Portland, OR, pp. 496.

Massé, A., and S.D Côté. 2009. Habitat selection of a large herbivore at high density and without predation: trade-off between forage and cover? Journal of Mammalogy 90:961-970.

Max, T.A., Schreuder, H.T., Hazard, J.W., Oswald, D.O., Teply, J., and Alegria, J. 1996. The Pacific Northwest Region vegetation inventory and monitoring system. USDA Forest Service Research Paper, PNW-RP-493.

McCullough, D.R. 1975. Modification of the Clover deer trap. California Fish and Game 61:242-244.

Miller, F.L. 1968. Observed use of forage and plant communities of black-tailed deer. Journal of Wildlife Management 32:142-148.

Ohmann, J.L., and M.J. Gregory. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, U.S.A. Canadian Journal of Forest Research 32:725-741.

Oregon Department of Fish and Wildlife. 2008. Oregon black-tailed deer management plan. Oregon Department of Fish and Wildlife, Salem, Oregon, USA.

Pamplin, N.P. 2003. Ecology of Columbian black-tailed deer fawns in western Oregon. M.S. Thesis, Oregon State University, Corvallis, OR. 75 pp.

Pellerin, M., S. Saïd, and J.M. Gaillard. 2008. Roe deer *Capreolus capreolus* home-range size estimated from VHF and GPS data. Wildlife Biology 14:101-110.

Pellerin, M., S. Saïd, E. Richard, J.L. Hamann, C. Dubois-Coli, and P. Hum. 2010. Impact of deer on temperate forest vegetation and woody debris as protection of forest regeneration against browsing. Forest Ecology and Management 260: 429-437.

Rochelle, J.A. 1992. Deer and elk. In: Black, H.C. (Ed.), Silvicultural approaches to animal damage management in Pacific Northwest Forests. U.S. Dept. of Agriculture, Forest Service Pacific Northwest Research Station, Portland, OR, pp. 333–349.

Schoen, J.W., and M.D. Kirchhoff. 1985. Seasonal distribution and home-range patterns of sitka black-tailed deer on Admiralty Island, Southeast Alaska. Journal of Wildlife Management 49:96-103.

Seaman, E.D., J.J. Millspaugh, B.J. Kernohan, G.C. Brundige, K.J. Raedeke, and R.A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739-747.

Spies, T.A., and Franklin, J.F. 1991. The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington. USDA Forest Service General Technical Report PNW-GTR- 285. pp. 90–109.

Spies, T.A., K.N. Johnson, K.M. Burnett, J.L. Ohmann, B.C. McComb, G.H. Reeves, P. Bettinger, J.D. Kline, and B. Garber-Yonts. 2007. Cumulative ecological and socioeconomic effects of forest policies in coastal Oregon. Ecological Applications 17:5-17.

Swanson, M.E., J.F. Franklin, R.L. Beschta, C.M. Crisafulli, D.A. DellaSala, R.L. Hutto, D.B. Lindenmayer, and F.J. Swanson. 2011. The forgotten stage of forest succession: early-successional ecosystems on forest sites. Frontiers in Ecology and the Environment 9:117-125.

Thomas, J.W., J.F. Franklin, J. Gordon, and N.K. Johnson. 2006. The northwest forest plan: origins, components, implementation experience, and suggestions for change. Conservation Biology 20:277-287.

Tomkiewicz, S.M., M.R. Fuller, J.G. Kie, and K.K. Bates. 2010. Global positioning system and associated technologies in animal behavior and ecological research. Philosophical Transactions: Biological Sciences 1550:2163-2176.

Ulappa, A.C. 2015. Using foraging dynamics to answer landscape management questions: The nutritional ecology of black-tailed deer (Thesis), Washington State University, Pullman, USA.

U.S. Geological Survey, Gap Analysis Program (GAP). May 2011. National Land Cover, Version 2.

Weckerly, F.W. 1994. Selective feeding by black-tailed deer: forage quality or abundance? Journal of Mammalogy 75:905-913.

Wagner, K.K., and D.L. Nolte. 2001. Comparison of active ingredients and delivery systems in deer repellents. Wildlife Society Bulletin 29:322-330.

Waring, R.H., and J.F. Franklin. 1979. Evergreen coniferous forests of the Pacific Northwest. Science 204:1380-1386.

Wallmo, O.C., editor. 1981. Mule and black-tailed deer of North America. University of Nebraska Press, Lincoln, Nebraska, USA.

Wiens, J.A. 1976. Population responses to patchy environments. Annual Review of Ecology and Systematics 7:81-120.

Wiens, J.A. 1984. Resource systems, populations, and communities. In A new ecology. Edited by P.W. Price, C.N. Slobodchikoff, and W.S. Gaud. John Wiley & Sons, New York. pp. 397–436.

Yeo, J.J., and J.M. Peek. 1992. Habitat selection by female sitka black-tailed deer in logged forests of southeastern Alaska. Journal of Wildlife Management 56:253-261.