

AN ABSTRACT OF THE THESIS OF

Mark A. Ricca for the degree of Master of Science in Wildlife Science presented on December 8, 1999.

Title: Movements, Habitat Associations, and Survival of Columbian White-tailed deer in Western Oregon.

Signature redacted for privacy. -

Abstract approved: _____

Robert G. Anthony

Columbian white-tailed deer (*Odocoileus virginianus leucurus*, CWTD) are a geographically isolated and federally endangered sub-species for which there is a paucity of recent ecological information. I described and examined sources of variation in spatial use patterns (i.e. home range, areas of concentrated use, and movements), habitat associations, and survival for adult and fawn CWTD in Douglas County, Oregon. I radio-collared and monitored 64 adult CWTD and 36 newborn fawn CWTD from ca. December 1995 – September 1998. Locations for adults were obtained from September 1996 – December 1998. Locations for fawns were obtained from June – September, 1997 – 1998.

Spatial use estimates for adults tended to be variable among deer. Mean 95% fixed kernel home range size was 74.5 ha (CV = 83%), while areas of concentrated use averaged 8.5 ha (CV = 93%). The sexes appeared to be partitioning space because males had larger home ranges, areas of concentrated use (which are analogous to core areas), and movements than females. Deer inhabiting human-influenced areas (suburban deer) consistently exhibited smaller movements and used less space than those away from human influence (wild deer). Mean home range size, area of concentrated use size, and distance between successive locations was generally greatest in fall and lowest in winter. Site fidelity to seasonal home ranges and areas of concentrated use was lowest between fall-winter and summer-fall. Unexpectedly, size of home ranges and areas of concentrated use were positively correlated with cover type heterogeneity. Annual adult survival rates averaged 0.73. Neither annual survival rates nor functions differed by

sex or type. Survival over the entire 3 year study was low (0.39). Most deer died in winter from a combination of emaciation and disease and generally were in poor body condition.

Oak-hardwood woodland, riparian, and oak-hardwood savanna shrub were the most frequently used cover types. On an annual basis, the majority of deer (31%) selected riparian areas. The frequency of selection of all non-riparian cover types was < 13%, as most deer either exhibited avoidance or 'neutral selection-avoidance' of these cover types. The probability of use for a particular patch was positively associated with proximity to a stream for 56% of all deer. However, the relative amount of edge within a particular patch had little effect on the odds of use. Patterns of use and selection tended to be similar between the sexes, but suburban deer used conifer and yard cover types more frequently than wild deer. Use and selection of cover types by deer did not significantly differ among seasons. CWTD also demonstrated higher use for more open cover types during crepuscular and nocturnal periods. Areas of concentrated use were random with respect to cover type composition, but were significantly associated with proximity (≤ 200 m) to streams.

Home ranges, areas of concentrated use, and movements of fawns were variable but tended to reflect their sedentary nature. Home range and area of concentrated use size were not correlated with percent coverage of oak-hardwood woodland, riparian, or shrub dominated cover types. Habitat use patterns were characterized by frequent use of oak-hardwood woodland and riparian cover types, and areas within 200 m of streams. These habitat use patterns may represent some degree of rigidity in habitat composition within fawning areas. However, there was no apparent selection of cover types or distance to stream classes within areas of concentrated use. Fawn survival to 6 months was low (0.15, 95% CI = 0.009 – 0.308) and was most similar to estimates from previous CWTD studies and un hunted white-tailed deer populations. Mortality was highest during approximately the first 1 – 1.5 months of life. There were no differences in survival to 6 months by sex, but females had significantly higher survival during the neonatal period than males. Survival time was unrelated to both movements and use of oak-hardwood

woodland and riparian cover types. Predation was the most frequent ($n = 8$) cause of death, followed by abandonment ($n = 5$).

Overall, adult CWTD were sedentary, dispersal movements were not readily apparent, and survival rates were within the range of rates reported for other white-tailed deer populations. Adult CWTD also exhibited a degree of specialization for riparian areas, and generalized use patterns for other cover types. CWTD fawns tended to use small areas, exhibited frequent use of oak-hardwood woodlands and areas near streams. Survival rates of adults and fawns may be suggestive of density dependent population responses.

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Movements, Habitat Associations, and Survival of Columbian White-tailed Deer in Western
Oregon.

by

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This thesis is dedicated to the memory of my father, Antone H. Ricca.. Thanks Pop, this is for you!

Movements, Habitat Associations, and Survival of Columbian White-tailed Deer in Western Oregon.

INTRODUCTION

The recovery of most white-tailed deer (*Odocoileus virginianus*) populations from near extirpation at the turn of the 19th century is viewed as a success story for ungulate management. In many instances, the recovery has been so successful that a large amount of current research and management on white-tailed deer is focused on trying to cope with problems associated with deer overabundance (Woolf and Roseberry 1998). In contrast, recovery and geographic range expansion has occurred slowly for Columbian white-tailed deer (*O. v. leucurus*, CWTD). Along with the Key deer (*O. v. clavium*), CWTD are the only endangered sub-species of white-tailed deer in the United States (United States Fish and Wildlife Service 1983). Thus, CWTD represent a unique departure from one of the current paradigms in ungulate management.

CWTD were ubiquitous throughout the Umpqua, Willamette, Lower Columbia, and Cowlitz river valleys of western Oregon and Washington until the late 1900's (Smith 1985a). Due to a variety of possible factors, including conversion of native oak woodland and savanna complexes into agricultural fields, fire suppression, overexploitation, and competition with expanding populations of sympatric Columbian black-tailed deer (*O. hemionus columbianus*), the geographic range of CWTD became limited to 2 remnant and allopatric sub-populations (Smith 1985a). The first sub-population is relatively small and is located along the floodplains of the lower Columbia River near and within the Julia Butler National Wildlife Refuge. The other sub-population, which is the focus of this study, is larger and inhabits the interior valleys of the Umpqua Basin in Douglas County, Oregon (henceforth referred to as Douglas County CWTD) (Smith 1985a). Both sub-populations were listed as federally endangered in 1968 and protection of the Douglas County sub-population began in 1978 (United State Fish and Wildlife Service, 1983). However, the Douglas County sub-population appears to have

increased in the last 20 years, and has recently been proposed for delisting (Federal Register 1999).

Previously, Smith (1981) conducted an extensive study of Douglas County CWTD. He found that adult home ranges were relatively small and widespread movements were not evident, while adult survival tended to be low and was closely tied to winter severity. Adults were also most strongly associated with riparian areas and lowland deciduous oak woodland – savanna habitats. Furthermore, he argued that CWTD might be considered habitat specialists, as compared to sympatric Columbian black-tailed deer which occupied a wider breadth of habitats. For fawns, he stressed the importance of woodland, riparian, and shrub dominated habitats. Fawn survival rates to 3 – 6 months of age were variable (0.30 to 0.80) over a 3-year period.

Current information on the ecology of Douglas County CWTD is needed to aid in management and sustained recovery in the event of de-listing. Spatial use, habitat association, and demographic patterns of ungulates tend to be variable due to changes in density, resource availability, or habitat quality over time (Harestad and Bunnell 1979, McCullough 1979, Clutton-Brock et al. 1982). Although precise population estimates are lacking, densities of CWTD appear to have possibly doubled since Smith's (1981) study but widespread dispersal into historic areas has not been apparent (Oregon Department of Fish and Wildlife, unpublished data). In addition, there has been a concurrent increase in the conversion of available natural habitat to suburban/urban subdivisions. Sites along the north bank of the North Umpqua River that are further away from human development and contain more xeric habitats have also become accessible to research since Smith's study. Thus, the ability to intensively sample more sites within the range of CWTD in Douglas County may reveal different trends.

Furthermore, important sources of variation in spatial use, habitat associations, and survival need to be identified. Ecological differences between the sexes are common which contribute to intersexual resource partitioning (Main et al. 1996), and it is important to identify differences between the sexes because recruitment is most closely tied to the female portion of deer populations (McCullough 1979). Proximity to human development or disturbance can also influence movements, habitat associations, and survival (Happe 1982, Vogel 1989, Bellantoni et al. 1993, Nicholson et al. 1997). The effects of human development and influence need to be elucidated because conversion of native habitat to housing may be a threat to CWTD recovery (United States Fish and Wildlife Service 1983). Moreover, current information on survival and sources of mortality are necessary for any future modeling of demographic processes (McCullough 1979, Fuller 1990). Survival rates and assessment of body condition can also serve as useful fitness correlates to compare different groups of animals, and possibly act as surrogates to density (McCullough 1979, Clutton-Brock et al. 1987a, Sams et al. 1996).

In Chapter 1, I quantified sources of variation in adult spatial use (home range, area of concentrated use, site fidelity, and movements) and survival patterns. To assess sources of variation in spatial use, I formulated the following hypotheses. First, differences should be pronounced between males and females because of sex-specific life history traits (Main et al. 1996). Second, deer living near human development should have smaller spatial use patterns than deer living away from human development, presuming human harassment is not problematic. Third, spatial use patterns should vary across seasons, presumably due to changing resource availability or quality (Harestad and Bunnell 1979) and deer behavior (Beier and McCullough 1990). Fourth, home range and area of concentrated use size should decrease with increasing habitat type diversity which should provide more edge (Beier and McCullough 1990, Tufto et al. 1996).

My hypotheses regarding survival were much simpler. I assessed yearly variation in survival rates and tested for differences relative to sex and proximity to human development. I anticipated that males and deer near human development should incur higher mortality rates. I also examined sources of mortality and body condition.

In chapter 2, I described habitat associations and examined variation in third order habitat use and selection (i.e. within individual deer home ranges, Johnson 1980) among deer to ascertain the degree of habitat specialization or generalization exhibited by adult CWTD. I hypothesized that if CWTD were habitat specialists, then they should exhibit consistent selection for few cover types and be strongly associated with riparian areas (Smith 1987a). I also examined sources of variation by sex, proximity to human development, season, diel period, and relative amount of edge, and formulated the following hypotheses. First, habitat associations of females and deer living near human development should be more restrictive than males and deer living away from human development. Second, open habitats would be used more frequently at night, and habitat use would be inconsistent among seasons. Third, because habitat edges can provide increased forage quality and abundance, the odds of use for a particular patch should be positively associated with increasing relative amount of edge (Kremsater and Bunnell 1992). Finally, I examined habitat composition of areas of concentrated use in order to describe habitats that received disproportionate use and may be important for fitness (Bingham and Noon 1997).

In Chapter 3, I described spatial use patterns, habitat associations, and survival for CWTD fawns to 6 months post parturition, which represents a critical life stage in deer population dynamics (Jackson et al. 1972). I predicted that if CWTD have restricted fawning areas, then consistent use for similar cover types should be evident. I also hypothesized that home ranges, areas of concentrated use, and movements should be consistently small, assuming that hiding cover for neonates and high quality forage for post-partum females was

abundant. Lastly, I estimated survival rates to approximately six months of age, tested for differences by sex and fawn age, examined how survival may be affected by movements and habitat use, and described sources of mortality.

Chapter 1

Home Range, Movements, and Survival of Adult Columbian White-tailed Deer in Western Oregon.

Mark A. Ricca

INTRODUCTION

Historically, Columbian white-tailed deer (*Odocoileus virginianus leucurus*, CWTD) were ubiquitous throughout the Umpqua, Willamette, Lower Columbia, and Cowlitz river valleys of western Oregon and Washington (Smith 1985a). Due to a variety of uncertain factors, possibly including habitat loss and overexploitation (Smith 1987a), CWTD became restricted to 2 allopatric sub-populations: one along the lower Columbia River near Cathlamet, Washington and the other along the North Umpqua River near Roseburg, Douglas County, Oregon. Consequently, both sub-populations were listed as endangered in 1967 (United State Fish and Wildlife Service, 1983). However, the Douglas County sub-population has been proposed for delisting (Federal Register 1999) and current ecological information is needed.

In the late 1970's, Smith (1981) conducted an extensive study of the Douglas County sub-population and found that home ranges were relatively small and widespread movements were not evident. Survival tended to be low and was closely tied to winter severity. However, spatial use and demographic patterns of ungulates tend to be quite variable due to changes in density, resource availability, or habitat quality over time (Harestad and Bunnell 1979, McCullough 1979, Clutton-Brock et al. 1982). Densities of CWTD and conversion of available natural habitat to suburban/urban subdivisions seemingly have increased over the last 20 years, while widespread dispersal into historic areas has not been apparent (Oregon Department of Fish and Wildlife, unpublished data). In addition, new sites along the north bank of the North Umpqua River that are further away from human development and contain a greater abundance of xeric habitats have become accessible to research since Smith's (1981) study. Thus, the ability to intensively sample more sites within the range of CWTD in Douglas County may reveal different trends than previously described.

Spatial use (e.g. home range, core area, and movements) patterns have received wide attention in the ungulate literature. Estimates of home range size provide information on how

much area is used during the course of normal activity (Burt 1943), while core areas represent areas that receive disproportionate use within a home range (Samuel et al. 1985, Bingham and Noon 1997). The stability of spatial use patterns across seasons is often indicative of changing resource distribution and deer sociality (Harestad and Bunnell 1979, Beier and McCullough 1990, Weckerly 1993), and can also help assess whether an animal is sedentary or dispersing.

Sexual differences in spatial use patterns have been well documented in most ungulate populations, presumably because of sex-specific life history patterns and energetic requirements. Female movements often tend to be restrictive, while males tend to occupy larger areas to exploit a wider breadth of resources (Main et al. 1996). Presumably, these differences may be partly associated with the relation between energetic requirements and body size, which can also provide a useful construct for examining sex-related differences in spatial use (McNab 1963, Harestad and Bunnell 1979, Weckerly 1993). Proximity to human development may also cause changes in spatial use. The amount of human development may influence deer activity and movements (Vogel 1989), and home ranges may either decrease when humans provide a limited resource or increased security (Happe 1982, Bellatoni et al. 1993), or increase due to harassment by humans (Nicholson et al. 1997). Deer movements also tend to be strongly affected by changing diel period (Kammermeyer and Marchinton 1977, Beier and McCullough 1990). Lastly, habitat composition may influence spatial use. For example, small home ranges may result from highly interspersed habitat types which provide more edge, and presumably more available forage (Beier and McCullough 1990, Tufto et al. 1996).

Estimates of survival can yield insight into the status of population growth (e.g. increasing, decreasing, or stable) and are necessary for modeling ungulate demography (McCullough 1979, Fuller 1990). Sex-specific survival often occurs in ungulate populations because males tend to incur lower survival due to higher energetic costs (Clutton-Brock et al.

1982, Main and Coblentz 1990). Furthermore, survival rates and assessments of body condition can serve as useful fitness correlates to compare different groups of animals.

The first objective of my study was to determine spatial use patterns (e.g. home range, area of concentrated use, and movements) of Douglas County CWTD. In general, I wanted to ascertain whether CWTD were exhibiting spatial use patterns characteristic of nomadic or sedentary behavior. Furthermore, I tested for the effects of sex, proximity to human development or contact, season, and habitat diversity on spatial use. Specifically, I made the following predictions:

1. If the sexes are partitioning space due to different life history strategies, then females should move less, use smaller areas, and show stronger site fidelity compared to males. In addition, females should have consistently small areas of concentrated use relative to home range size when compared to males. Because the sexes may have different energetic needs imposed by sexual dimorphism, the ratio of female to male home range, as well as areas of concentrated use, should be similar to the ratio of female to male body size.
2. Assuming harassment is minimal and resources are predictable and concentrated, deer inhabiting areas near human development should also move less, use smaller areas, and show stronger site fidelity compared to deer living away from human development.
3. Spatial use patterns should vary across seasons, presumably due to changing resource availability or quality and deer behavior.
4. Home range and area of concentrated use size should decrease with increasing habitat type diversity.

The second objective of my study was to determine survival rates and sources of mortality for Douglas County CWTD. I assessed yearly variation in survival rates and tested for differences due to sex and proximity to human development. I predicted that males and deer near human development would incur higher mortality rates.

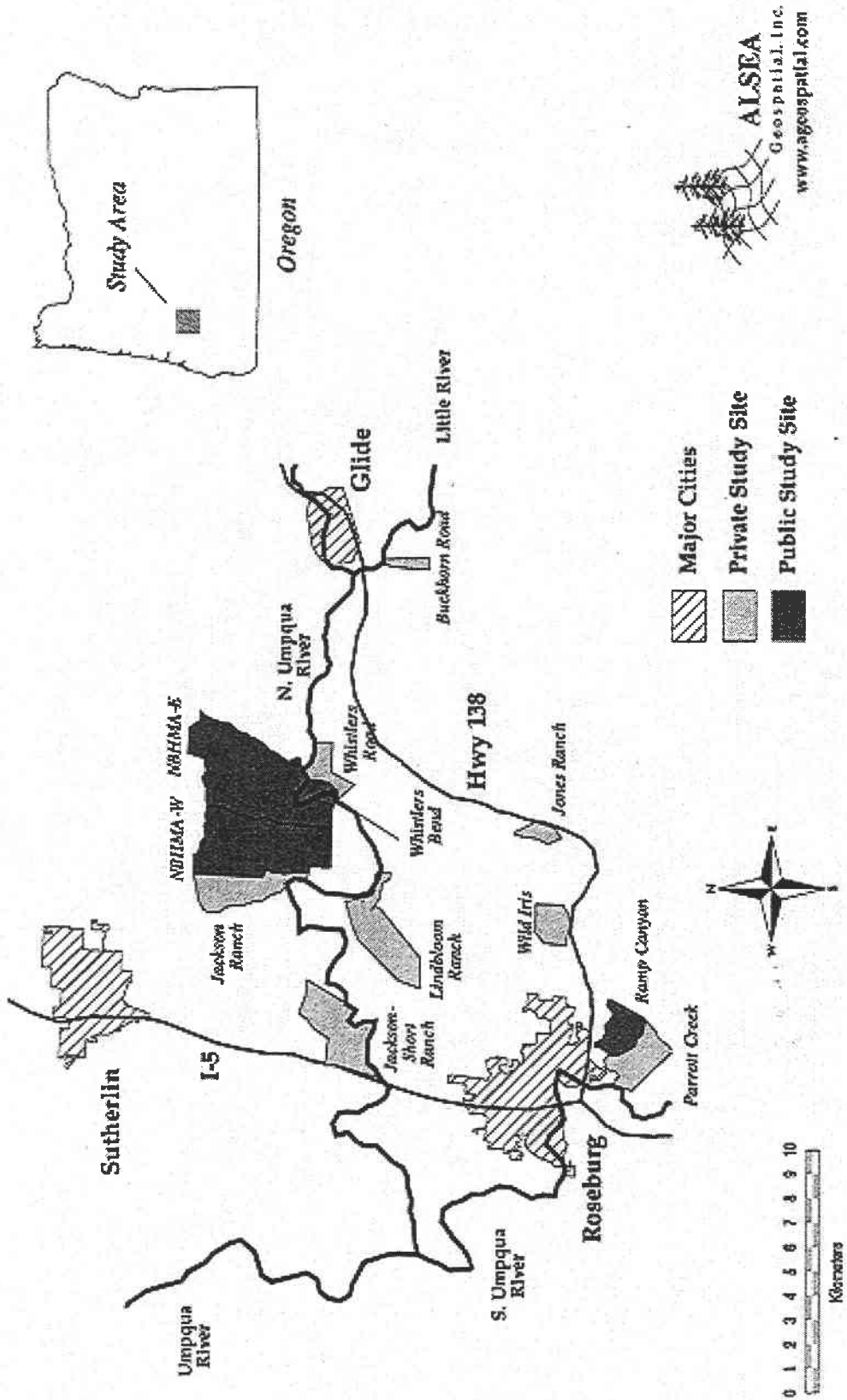
STUDY AREA

The study area was located within the lower North Umpqua watershed in Douglas County, Oregon. It was approximately bordered by the towns of Roseburg to the south, Glide to the east, Sutherlin to the north, and Interstate 5 to the west (Fig. 1.1). The majority (ca. 80%) of the study area was privately owned, while the remainder (ca 20%) was open to the public. The landscape was characterized by undulating topography intersected by several small drainages. Elevation ranged from 165 to 595 m. The climate was characterized by rainy winters and hot dry summers. Monthly average temperatures ranged from a low of 1.7 °C in January to a high of 29.4 °C in August. Average annual precipitation was 84.2 cm and monthly rates ranged from a low of 1.6 cm in August to a high of 15.8 cm in December (Western Region Climate Center, Reno, Nevada; 1965 -1997). Snowfall was rare.

Smith (1981, 1985b) gave an extensive description of plant communities and species composition found in the study area. While some stands of continuous deciduous hardwood/mixed conifer forest, and undisturbed riparian areas were present, vegetative communities typically represented a relatively disturbed environment due to past or current history of fire management, grazing, agricultural conversion to improved pasture, and housing development. In most parts, the study area was characterized by a mosaic of finely interspersed cover types which typically consisted of oak (*Quercus* sp.), madrone (*Arbutus menzeissi*), conifer, and grassland plant associations intersected by numerous riparian drainages. Large expanses of coniferous forest were rare, and smaller conifer stands had typically been logged and were regenerating.

Because of constraints imposed by limited access to private lands, study sites were not chosen at random. Instead, study sites were chosen based on where access could be readily obtained. Three study sites were chosen on public land, while 5 were on private land (Fig. 1.1).

Figure 1.1. Geographic location of Columbian white-tailed deer study sites in Douglas County, Oregon, 1996-98.



If access was available, some sites were expanded when marked deer moved off existing sites. Privately owned sites were often grazed by cattle and/or sheep and pastures were cut for hay in early summer. Some sites were either bordered or intersected by rural homes or suburban subdivisions (Figure 1.1).

METHODS.

Deer captures.

Adult deer were captured during fall and winter months from 12/8/95 through 1/28/98. Deer were captured using modified clover live traps (McCullough 1975) baited with apples, salt, or alfalfa. Traps were set in the late morning or evening and checked the following morning. Deer were also darted opportunistically over baited tree stands or blinds during day and night with Pneu-Dart (Pneu-Dart Incorporated, Williamsport, Pennsylvania, USA) or TelinJect (TelinJect USA Incorporated, Saugus, California, USA) dart guns. Darded deer were immobilized with a 3:1 ratio of ketamine hydrochloride and xylazine hydrochloride. Yohimbine hydrochloride was usually administered intravenously to hasten recovery time. Trapped deer were rarely ($n = 1$) chemically immobilized. I administered 1 – 3 cc of Maxim-200 (Phoenix Scientific Inc., St. Joseph, MO), a broad spectrum but short duration oxytetracycline antibiotic, to deer that suffered minor injuries during capture which could have become infected.

Upon capture, deer were ear-tagged, fitted with radio collars, sexed and aged. Only yearlings ($> 1 \frac{1}{2}$ years) and adults ($> 2 \frac{1}{2}$ years) were radio-collared. Color coded numbered ear-tags were used to expedite visual observations and sex differentiation. Radio collars (LMTR-3, Lotek Engineering, London, Ontario, Canada) weighed 280 – 290 g, were equipped with a 6-hour delay mortality sensor, and were expected to last 48 months. Non-expandable

collars were placed on adult males and females. Yearling males (1 ½ - 2 ½ years) were fitted with expandable nylon weave collars. To allow for neck swelling during the rut, collars placed on adult males were fitted by placing the handler's fist perpendicular to the base of the deer's neck. This was used as a sizing gauge to determine how tight to fit the collar, which normally allowed enough room for the neck to swell during the rut. In one instance (see survival methods), the collar cut into a male's neck during the rut. Immediately afterwards, all collared males were visually checked and there was no evidence that other males were experiencing a similar problem.

Radio telemetry error assessment and location protocol.

Deer were located with TR-4 receivers/scanners and handheld 3-element Yagi antennas (Telonics Incorporated, Mesa, Arizona, USA). My sampling protocol relied heavily on visual locations or triangulating from multiple (≥ 2) points which were usually < 500 m from the estimated deer location. To test this protocol, test collars were placed at known deer locations (but unknown to observers) within randomly selected deer home ranges. This test most closely simulated real radio-tracking conditions where general animal locations are not completely unknown to the observer. There was no difference between observers on paired bearings (Hottelings test for paired angles: $F = 0.34$, $P > 0.25$, Zar 1996:645), so all test data were pooled. Accuracy and precision of bearings was relatively poor (mean bearing error = -2.38° , $SD = 15.9$, $n = 605$), but the average distance from estimated to true location was only 59 m ($SD = 53.4$, $n = 118$). Because I wanted to evaluate telemetry precision with confidence ellipses generated from bearing standard deviations, I followed the suggestion of Lee et al. (1985) and considered all bearings with absolute errors $> 10^\circ$ as signal bounce. These bearings were deleted which resulted in a much improved bearing SD of 5.78° (mean bearing error = -2.32° , $n = 331$). I believed using a bearing standard deviation generated from all test bearings greatly

overestimated confidence ellipses. Thus the 5.78° bearing SD was used to calculate all confidence ellipses for triangulated deer locations. This bearing SD generated from the reduced data set was a more realistic, yet still conservative, estimate of bearing precision. Error ellipses were calculated with the program LOCATE II (version 1.5, Truro, Nova Scotia, Canada).

Deer were located between 3 and 5 times per week from late August 1996 through December 1997. I systematically tracked different deer at the beginning of each tracking session to ensure that all deer would be located at different times. To ensure adequate representation of diurnal and nocturnal locations (Beyer and Haufler 1994), deer were sampled from as early as 0400 PST to as late as 0100 PST. Tracking schedules were alternated weekly between early and late time periods. Early tracking began 1 – 2 hrs before sunrise and usually concluded in late-morning or mid-afternoon. Late tracking began in the afternoon and usually ended between 2200 and 0100 PST. Normally, a tracking session did not end until all deer were located. To maintain temporal independence, I attempted to sample deer a minimum of 12 hours apart. Time of day (PST), habitat type, location type (triangulation, visual, or estimated visual), and level of disturbance were recorded when deer were located. Level of disturbance was defined as either an unbiased movement (deer did not flee, or if it did flee due to my presence, I was able to determine its location before disturbance), or biased movement (deer fled area due to my presence and I was unable to determine its location before it fled). All locations were plotted in the field on 1:24,000 USGS topographic maps.

Deer type, seasonal, and diel period classifications.

Deer were categorized into 2 types: 'suburban/park' (henceforth suburban) and 'wild'. The amount of 'human interface area' within sites provided a repeatable criteria and was used to determine deer type within sites. Human interface area consisted of urban or suburban subdivisions, rural residential areas, ranch houses, and a county park. The county park (i.e.

Whistler's Bend) was included because deer in these areas were most often habituated to human presence. Thus, deer within sites that contained < 10% human interface were classified as 'wild', while deer within sites that contained > 10% human interface were considered 'suburban'.

Seasons were classified as winter (Jan – Mar), spring (Apr – June), summer (July – Sept), and fall (Oct – Dec). These classifications closely matched changing plant phenology and deer life history stages. Fall corresponded to the rut, spring to the period of rapid plant growth and fawning, winter to the peak of the rainy season, and summer to the hot dry months. Diel periods were classified as crepuscular (2 hrs before and after sunrise or sunset), diurnal (2 hrs after sunrise to 2 hrs before sunset), and nocturnal (2 hrs after sunset to 2 hrs before sunrise). Crepuscular and nocturnal periods were ultimately pooled.

I did not attempt to differentiate between adult and yearling deer in my analyses because of small sample sizes for yearling males (most of which became adults before the radio tracking portion of the study was initiated), and poor confidence in my ability to accurately age yearling females.

Home range, areas of concentrated use, and movements

Annual home ranges were estimated with the 100% minimum convex polygon method (Mohr 1947) to facilitate qualitative comparison with Smith's (1981) estimates, as well as other home range estimates in the published literature. Fixed kernel density estimators with bandwidths calculated using least squares cross validation (LSCV) (Seaman and Powell 1996) were used to estimate 99 and 95% annual and seasonal utilization distributions. Fixed kernels do not vary bandwidth with local kernel density. When used with LSCV, fixed kernels have been shown to produce less biased estimates of utilization distributions when compared to adaptive kernel density estimators (Seaman and Powell 1996). Minimum convex polygons

were calculated in program CALHOME (Kie et al. 1996) while fixed kernels were calculated in program KERNELHR (Seaman et al. 1998). Annual home ranges were only calculated for deer that remained alive for at least 11 months.

Sample size affects minimum convex polygon (White and Garrott 1990:148) and fixed kernel (Seaman et al. 1999) home range size estimates. Minimum convex polygons were only calculated on an annual basis. For fixed kernel home range estimates, Seaman et al. (1999) recommended that at least 30 (but preferably 50) locations should be used. Because my field observations indicated that deer movements were small, it was possible that fewer than 50 locations in a given season could result in reliable and non-fluctuating home ranges. Therefore, I examined the effect of increasing sample size on percent change in 95% fixed kernel home range size by randomly selecting 1 adult deer that lived for the entire study from each of the sex and type classifications (i.e. suburban male, suburban female, wild male, wild female). For each seasonal data set and starting at $n = 10$, increasing sample sizes at intervals of 3 were randomly selected. This was basically a resampling with replacement procedure but with only 1 randomization for each sample size. Ninety-five % fixed kernel home range estimates were calculated for each sample size in KERNELHR. All deer were then pooled and sample size was plotted against percent change in 95% fixed kernel home range size. Percent change stabilized at about 25% at $n = 22$ (Appendix 1.1). Thus, for any given season, it was reasonable to assume that sample sizes < 50 could result in reliable home range estimates, and seasonal home ranges and movements were only calculated for deer with > 22 locations.

Annual and seasonal areas of concentrated use were estimated using a KERNELHR subroutine called PLOTENR (Seaman et al. 1998; available from B. Griffith, Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks). PLOTENR estimates areas of concentrated use by calculating the average observation density of all locations in a given set and then determines the contour where the observation density is greater than average.

The average observation density is calculated as the sum of the linear array of the observed densities divided by the number of observed locations. The average observation density is calculated as the sum of the linear array of the observed densities divided by the number of observed locations. The advantage of this methodology is that it avoids subjective and arbitrary contour selections, and each area of concentrated use is based solely on the change in density of locations for an individual deer (S. A. Wolfe, Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks, pers. commun.). I refrained from calling areas of concentrated use 'core areas' because they were not tested against a null distribution of bivariate uniform locations within the home range (Samuel et al. 1985, Bingham and Noon 1997).

Because elapsed time between successive locations tended to be variable and deer movements tend to be linked to changing diel periods (Kammermeyer and Marchinton 1977), simple movement rates were not calculated. Instead, each successive movement was categorized by whether a diel period shift occurred between successive locations or not. Successive locations that occurred between identical diel periods were coded 'no diel period shift', whereas successive locations that occurred between either a crepuscular/nocturnal period and a diurnal period were coded 'diel period shift'.

Cover types were delineated from scanned 7.5 minute ortho-photo quadrangle maps in Arc Info (Environmental Systems Research Institute, Redlands, California, USA, version 7.2.1). Cover types were based upon a modification of Smith's (1981, 1985b) detailed descriptions of percent coverage and species composition. Cover types were classified as: 1) grassland, 2) grass shrub, 3) oak-hardwood savanna, 4) oak-hardwood savanna shrub, 5) oak-hardwood woodland, 6) oak-hardwood conifer, 7) conifer, 8) riparian. Areas within at least 50 m of human development were classified as 'yard' (Fig. 1.2). Detailed descriptions of plant composition and structural characteristics of cover types, as well as GIS map preparation, are provided in Chapter 2.

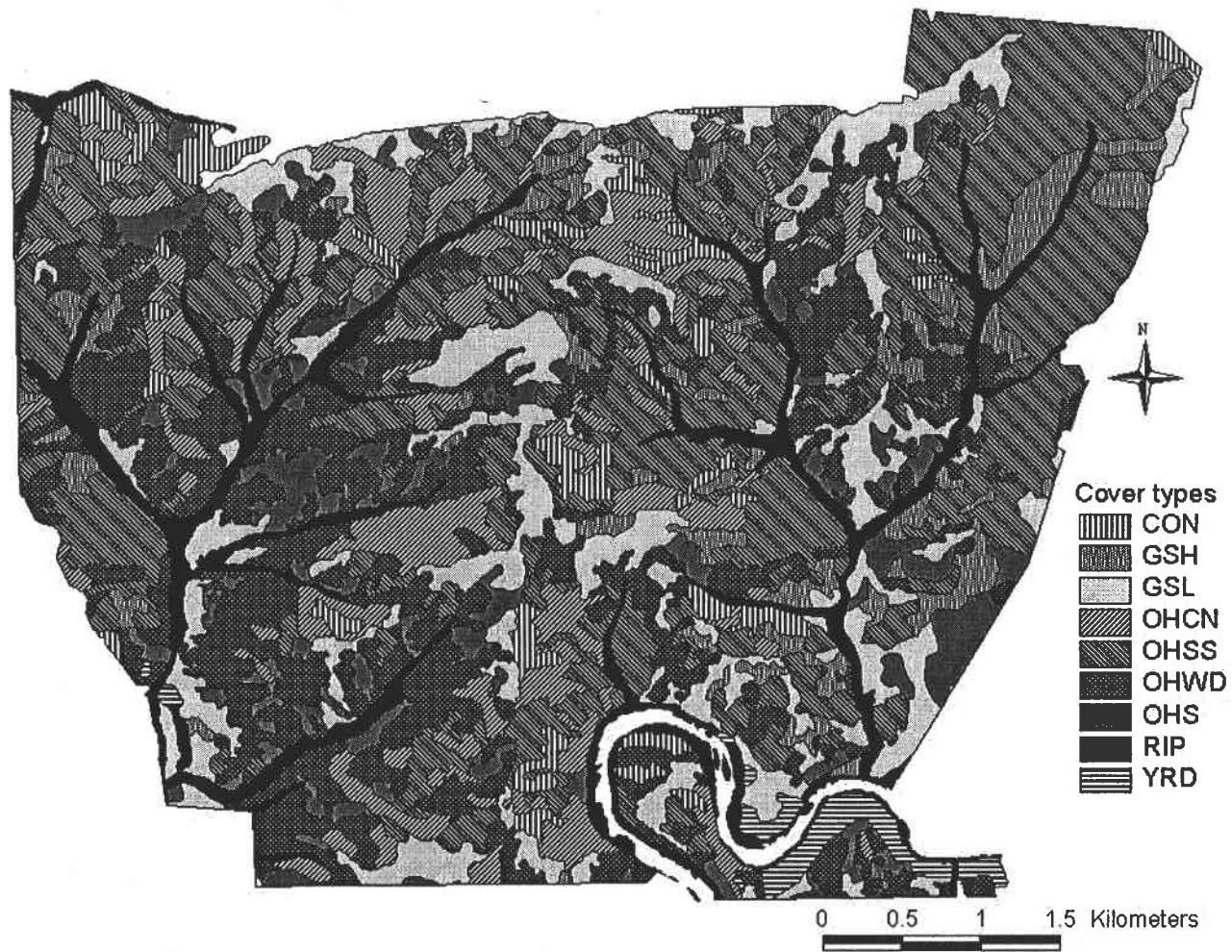


Figure 1.2. Representative sample of cover types classified for Columbian white-tailed deer habitat associations in Douglas County Oregon. CON = conifer, GSH = grass shrub, GSL = grassland, OHCN = oak-hardwood conifer, OHSS = oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHS = oak-hardwood savanna, RIP = riparian, YRD = yard.

Statistical analyses

Factorial analysis of variance (ANOVA) was used to test for differences due to sex and type in annual minimum convex polygon home range size, as well as annual and seasonal fixed kernel home range and area of concentrated use size. Seasonal 95% fixed kernel home range and area of concentrated use estimates were often larger than annual estimates because seasonal data sets contained fewer and less tightly clustered locations than annual data sets. This resulted in increased smoothing for seasonal home range and areas of concentrated use estimates (Seaman and Powell 1996), and direct comparisons between the 2 types of estimates were not made. The association between annual and seasonal 95% fixed kernel home range and area of concentrated use size was modeled with multiple regression using sex, type, and season as explanatory indicator variables.

To determine how sexual differences in home range size related to predictions based on metabolic rate and body size, average female 95% fixed kernel home range and area of concentrated use size was divided by that of males both annually and seasonally. Based on previous research on CWTD (Oregon Department of Fish and Wildlife, unpublished data), other white-tailed deer (Beier and McCullough 1990), and similarly sized black-tailed deer (*Odocoileus hemionus columbianus*) (Weckerly 1993), the predicted ratio should be between ca. 0.75 and 0.80. A modified variance estimator of a ratio (Manly et al. 1993:38) was calculated, although the covariance between males and females was not calculated due to unequal sample size. This resulted in more conservative (e.g. wider) 95% confidence intervals for ratios (see Weckerly 1993).

The effects of sex, type, season, and changing diel period on distance traveled between successive locations were examined with ANOVA. The maximum distance traveled between successive locations was used a rough index of dispersal, and differences in mean maximum distance traveled by sex, type, and season were tested with ANOVA.

Site fidelity was determined by examining spatial stability of locations between sequential seasons (i.e. fall- winter, winter – spring, spring – summer, summer – fall). Multi-response Permutation Procedure (MRPP) was used to test whether locations within individual deer 95% fixed kernel home ranges and areas of concentrated use shifted between sequential seasons. MRPP tests the null hypothesis that 2 sets of locations come from the same probability distribution (Mielke and Berry 1982, *cited in* White and Garrott 1990:135). To better facilitate accurate comparisons, seasonal home ranges and areas of concentrated use were recalculated using identical grid cell widths for individual deer for this analysis (E. D. Seaman, pers. commun). However, grid cell resolution has little effect on fixed kernel estimates. The chance-corrected within group treatment agreement (R) statistic, which is a measure of tightness within groups and ranges from -1 to 1 , was reported along with the usual P value. $R < 0$ indicated less homogeneity within groups than expected by chance, while $R > 0$ was indicative of greater homogeneity than expected by chance (McCune and Mefford 1997). Bonferroni adjustments were applied to reduce experiment wide error rates because most analyses were done on a family of data. Results were summarized by the percentage of significant shifts between sequential seasons that occurred for each deer (i.e. a significant shift meant locations within 2 sequential seasonal home ranges or areas of concentrated use came from a different probability distribution). Differences between the proportions of deer with significant shifts between sequential seasons by sex and type were tested with a Z test for equal proportions (Ramsey and Schafer 1997:523).

To address how habitat compositional diversity influences home range and concentrated use area size, the reciprocal of Simpson's index (Krebs 1989:360) of habitat heterogeneity was calculated and then plotted against annual 95% fixed kernel home range size for each deer. The reciprocal of Simpson's index ranges from 0 (low diversity) to the total number of cover types available (high diversity). The necessity for models containing interactions between

Simpson's index and sex or type was assessed with extra sums of squares *F*-tests (Ramsey and Schafer 1997:268).

Annual and seasonal 99 and 95 % fixed kernel home range and area of concentrated use estimates were natural log transformed to improve normality for all analyses. Means and variances are reported as untransformed values. Differences between seasons were tested with bonferroni multiple comparison procedure. All significance levels were set $\alpha = 0.05$. All ANOVA and regression tests were performed in NCSS 2000 (Hintze 1998). MRPP analyses were conducted in PC-ORD (McCune and Mefford 1997).

Survival rates and sources of mortality

Survival was monitored at a minimum of bi-weekly intervals throughout the entire study. Staggered entry Kaplan-Meier product limit estimators (Pollack et al. 1989) were used to estimate annual survival rates. Each 'year' began on 8 December. Deer that disappeared ($n = 2$) were censored on the day after they were last detected. One male whose neck was severely constricted by an overly tight collar and eventually died was censored on 15 September 1996, which was before male necks began to noticeably swell. Log rank tests were used to examine differences in survivorship functions between groups (White and Garrott 1990:240), and Z tests were used to compare survival curves at particular points in time (i.e. end of year or 3 years) (Pollack et al. 1989). Groups consisted of sex, year, and type. Cause of death was determined by visual examination or internal gross necropsy when dead deer were located expeditiously. Weighted means (Zar 1996:131) and variances (Ramsey and Schafer 1997:461) were used to calculate average annual survival rates. When possible, information on presence or absence of body and/or kidney fat, lungworms (*Dictyocaulus* sp.), and ecto-parasites such as ticks (*Ixodes* sp.) and deer louse flies (*Lipoptena* sp.) was recorded. Ecto-parasite infestation was recorded as high if > 50 were found on the head or abdomen.

RESULTS

Deer captures and location sample size

Sixty-eight adult deer were captured and radio-collared. Of these, 4 eventually died from capture related complications (e.g. capture myopathy) and were excluded from all analyses. Seventy-six % ($n = 52$) of deer were captured in clover traps and 24% ($n = 16$) were darted. (Appendix 1.2) A total of 5195 locations were obtained for 40 deer monitored from September 1996 to December 1997. Annually, the number of locations for 32 deer ranged from 134 to 174. Across seasons, sample sizes ranged from 22 to 48 locations per deer, while the number of deer with spatial use estimates ranged from 32 to 38 locations (Appendix 1.3). Most (73%) locations were obtained by visually observing deer, while triangulations comprised the remaining 27%. Triangulated locations whose error ellipses exceeded 15 ha were deleted from spatial use analyses ($n = 104$). Average error ellipse size for the remaining triangulated locations was 1.45 ha (SD = 2.02) (Appendix 1.4). Average elapsed time between locations was 2.45 days (SD = 2.45), and median elapsed time (which is less influenced by extreme time intervals between locations) was 1.46 days. Thus, biological and statistical independence of locations was maintained because I obtained a representative and systematic sample of locations across a time period long enough for a deer to traverse its entire home range (White and Garrott 1990:148, McNay et al. 1994).

Home ranges, areas of concentrated use, and movements.

Home ranges were variable on an annual basis. Minimum convex polygon (100%) home ranges averaged 143 ha (CV = 79%) and ranged from 9.1 to 476.9 ha among individual deer. Fixed kernel (95%) home ranges were usually smaller than minimum convex polygon home ranges. They averaged 74.5 ha (CV = 83%) and ranged from 6.8 to 259.8 ha among individual deer (Table 1.1). Males ($\bar{x} = 117.3$ ha) and wild deer ($\bar{x} = 88.1$ ha) had significantly

($P = 0.000$) larger annual 95% fixed kernel home ranges than females ($\bar{x} = 41.2$ ha) and suburban deer ($\bar{x} = 54.6$ ha), respectively. Differences in home range size remained consistent between sex and type because the interaction was not significant ($P = 0.2963$) (Table 1.2). Across seasons, males and wild deer again had significantly ($P < 0.000$) larger home ranges than females and wild deer, respectively. Home ranges were significantly ($P = 0.003$) largest in fall ($\bar{x} = 101.7$ ha) as compared to winter ($\bar{x} = 50.9$ ha), and summer ($\bar{x} = 50.8$ ha) (Bonferonni multiple comparison: d.f. = 124, critical value = 2.68) (Table 1.2) (Appendix 1.5). There was no interaction between sex and type when controlling for season ($P = 0.153$), and differences in home range size remained consistent by sex ($P = 0.16$) and type ($P = 0.368$) across seasons.

On an annual basis, areas of concentrated use tended to be small ($\bar{x} = 8.5$ ha) and variable (CV = 93%, range = 0.9 – 32.2 ha). On average, areas of concentrated use were found near the 70% (CV = 6%) contour of observation densities, meaning that a consistently high percentage of locations comprised areas of concentrated use (Table 1.1). Like home ranges, annual areas of concentrated use were significantly ($P \leq 0.02$) larger for males ($\bar{x} = 13.2$ ha) and wild deer ($\bar{x} = 10.0$ ha) compared to females ($\bar{x} = 4.7$ ha) and suburban deer ($\bar{x} = 6.3$ ha), respectively (Table 1.3). Across seasons, males and wild deer still had significantly ($P = 0.000$) larger areas of concentrated use than females and suburban deer. Furthermore, no interactions were present as differences in area of concentrated use size remained consistent between sexes ($P = 0.326$) and types ($P = 0.427$) among seasons. Areas of concentrated use during fall ($\bar{x} = 14.9$ ha) were significantly ($P = 0.009$) larger than summer ($\bar{x} = 6.5$ ha), while spring ($\bar{x} = 7.1$ ha) and winter ($\bar{x} = 6.7$ ha) were not different from either fall or summer (Bonferonni multiple comparison test: d.f. = 124, critical value = 2.68) (Table 1.3) (Appendix 1.6).

Table 1.1. Annual 100% minimum convex polygon home range (MCP), 95% fixed kernel (FK) home range, and area of concentrated use (ACU) estimates for 32 adult CWTD in Douglas County, Oregon, 1996 – 97. Areas are expressed as hectares.

ID	Sex	Type	100% MCP	95% FK	ACU	
					area	contour(%)
22	Male	Suburban	361.8	259.8	26.1	72
51	Male	Wild	168.2	113.3	13.3	72
62	Female	Wild	76.4	42.3	4.3	77
71	Female	Suburban	259.1	48.1	6.1	74
82	Male	Suburban	99.6	88.1	15.2	71
90	Male	Suburban	134.9	105.9	8.4	68
132	Female	Wild	67.2	49.9	9.1	73
151	Female	Suburban	47.2	42.2	6.7	71
171	Female	Suburban	9.1	6.7	1.0	72
181	Female	Wild	105.2	42.7	4.8	74
201	Male	Wild	254.7	149.5	18.5	73
212	Female	Wild	95.2	45.8	3.3	71
221	Male	Wild	476.9	166.7	12.7	68
232	Female	Suburban	14.4	8.5	0.9	71
290	Female	Wild	123.3	69.2	13.6	69
300	Female	Wild	125.2	74.1	7.5	77
311	Female	Wild	113.9	66.5	8.7	78
321	Female	Wild	208.2	71.9	4.5	75
352	Female	Suburban	62.9	25.1	4.0	74
361	Female	Wild	104.7	47.1	2.3	63
371	Male	Suburban	92.6	27.1	2.6	75
391	Male	Wild	302.6	153.2	11.2	70
401	Male	Wild	296.9	176.2	26.3	70
411	Female	Suburban	18.4	11.1	1.2	72
431	Female	Suburban	16.3	12.3	1.8	67
462	Male	Wild	242.2	78.5	3.6	58
471	Female	Wild	60.6	21.3	2.0	74
481	Female	Wild	122.0	56.1	4.3	70
1042	Male	Suburban	124.9	46.0	3.2	71
1061	Male	Wild	66.6	49.0	7.5	69
1072	Male	Wild	293.4	200.4	32.2	71
1092	Male	Suburban	33.6	29.1	4.7	65
		mean	143.1	74.5	8.5	71.1
		SD	113.6	61.7	7.9	1.1
		CV	79%	83%	93%	6%
		range	9.1 – 476.9	6.7 - 259.8	0.9 – 32.2	58 – 78

Table 1.2. Effects of sex, type, and season on 95% fixed kernel home range estimates for adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97. Means and standard errors are expressed as un-transformed values.

Period	Factor	Level	\bar{x}	SE	<i>n</i>	<i>F</i>	<i>P</i>
Annual	Sex	Male	117.3	18.6	14	26.5	0.000
		Female	41.2	5.2	18		
	Type	Suburban	54.6	19.0	13	15.3	0.000
		Wild	88.1	12.4	19		
	Sex*Type	--	--	--	--	1.1	0.293
Seasonal	Sex	Male	104.1	11.4	60	66.8	0.000
		Female	37.7	3.2	77		
	Type	Suburban	46.5	7.1	57	44.5	0.000
		Wild	77.3	8.6	80		
	Season	Fall	107.2	17.4	38	5.0	0.003
		Winter	35.9	6.1	35		
		Spring	48.7	8.6	32		
		Summer	46.4	8.2	32		
	Sex * Type	--	--	--	--	2.0	0.153
	Sex * Season	--	--	--	--	1.7	0.160
Type * Season	--	--	--	--	1.1	0.368	

Table 1.3. Effects of sex, type, and season on area of concentrated use estimates for adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Period	Factor	Level	\bar{x} (ha)	SE	<i>n</i>	<i>F</i>	<i>P</i>
Annual	Sex	Male	13.5	2.5	14	15.1	0.001
		Female	4.8	0.7	18		
	Type	Suburban	6.3	1.9	13	6.6	0.016
Wild		10.0	1.8	19			
	Sex*Type	--	--	--	--	0.1	0.725
Seasonal	Sex	Male	14.1	1.8	60	40.9	0.000
		Female	5.2	0.6	77		
	Type	Suburban	6.2	1.1	57	28.9	0.000
		Wild	11.0	1.4	80		
	Season	Fall	17.1	2.8	38	4.0	0.009
		Winter	6.7	0.9	35		
		Spring	7.1	1.1	32		
Summer		6.4	1.2	32			
	Sex * Type	--	--	--	--	1.0	0.305
	Sex * Season	--	--	--	--	1.5	0.326
	Type * Season	--	--	--	--	0.9	0.428

There was a positive linear association ($r = 0.90$, $P = 0.000$) between area of concentrated use and 95% fixed kernel home range size when controlling for the effects of sex and type ($\ln \text{ area of concentrated use} = -1.97 + 0.94 \ln \text{ home range} - 0.12 \text{ sex} - 1.19 \text{ type} + 0.07 \text{ sex} * \ln \text{ home range} + 0.23 \text{ type} * \ln \text{ home range}$). On a median basis, core areas comprised approximately 14% of 95% FK home ranges. However, no significant interactions were present which indicated that the slope of the relation did not differ by either sex ($t = 0.324$, $P = 0.748$) or type ($t = 1.033$, $P = 0.311$) (Fig. 1.3).

Annually, the mean ratio of female to male 95% fixed kernel home range size was 0.35, and 0.36 for areas of concentrated use. Mean seasonal ratios of female to male home range and area of concentrated use were greatest in winter (home range = 0.54, concentrated use = 0.60), but were similar to annual estimates the remainder of the year. Confidence intervals were wide and overlapped 0.75 during all seasons and annually (Fig. 1.4).

Differences in movements between successive locations were similar to trends in home range and areas of concentrated use. Annually, males ($\bar{x} = 428.6$ m) moved significantly ($P = 0.000$) greater distances than females ($\bar{x} = 269.4$ m), as did wild deer ($\bar{x} = 392.6$ m) relative to suburban deer ($\bar{x} = 260.7$ m) ($P = 0.016$) (Table 1.4). Moreover, movements occurring between 2 different diel periods ($\bar{x} = 359.3$ m) were significantly ($P = 0.052$) greater than movements occurring between the same diel period on different days ($\bar{x} = 318.8$ m). All interactions were not significant. On a seasonal basis, males and wild deer had significantly ($P = 0.000$) larger movements than females and suburban deer, respectively. Movements were significantly ($P < 0.000$) greatest during fall ($\bar{x} = 373.8$ m) and spring ($\bar{x} = 364.8$ m) and lowest in winter ($\bar{x} = 304.3$ m) and summer ($\bar{x} = 315.3$ m) (Bonferonni multiple comparison test: d.f. = 255, critical value = 2.64). Deer again moved more when a location occurred between changing diel periods than the same diel periods. Controlling for season, there was a significant ($P = 0.043$) interaction between sex and type whereby wild males ($\bar{x} = 501.7$ m)

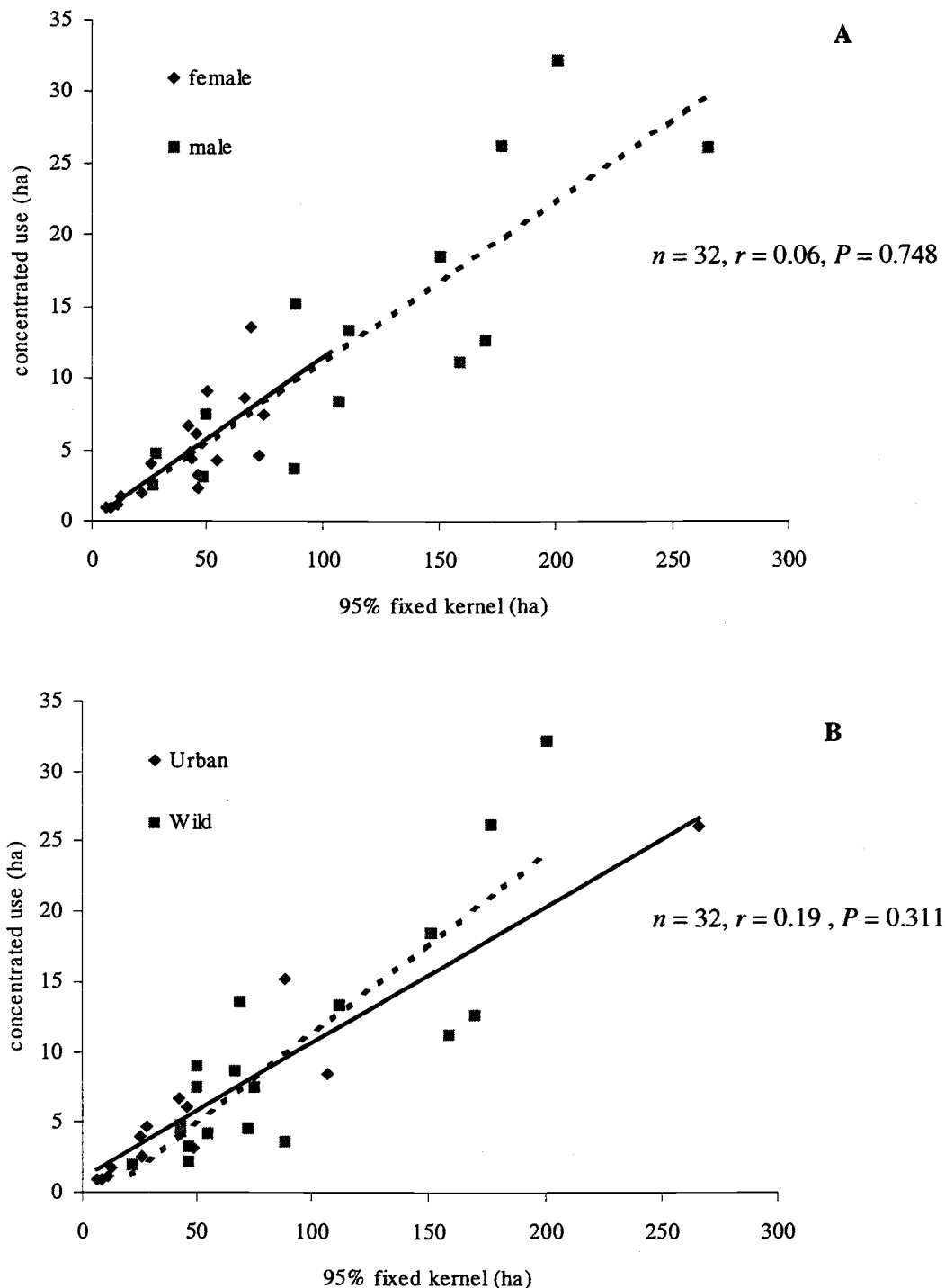


Figure 1.3. Relation between annual area of concentrated use and 95% fixed kernel (FK) home range size for male versus female (A) and wild versus suburban (B) adult Columbian white-tailed deer, Douglas County, Oregon; 1996 – 97. Un-transformed values are presented on axes for simplicity. *P*-values and partial correlation coefficients (*r*) are reported for interaction terms

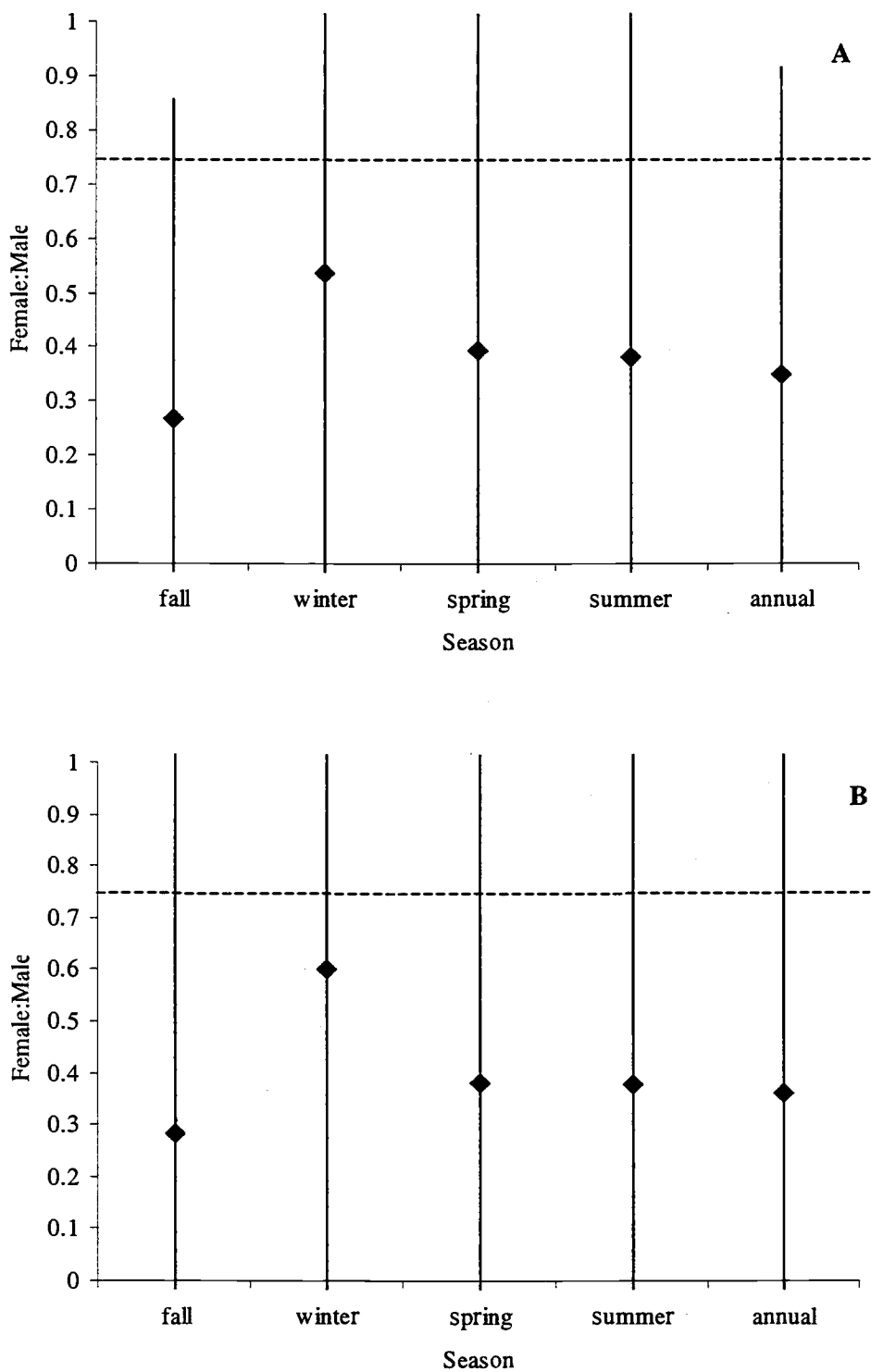


Figure 1.4. Ratio of female to male 95% fixed kernel home ranges (A) and areas of concentrated use (B), with associated 95% confidence intervals, for adult Columbian white-tailed deer, Douglas County, Oregon; 1996 – 97. Dashed lines are the predicted ratio of 0.75 based on intersexual differences in body size.

Table 1.4. Effects of sex, type, season, and diel period on mean distance traveled between successive locations for adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Period	Factor	Level	\bar{x} (m)	SE	<i>n</i>	<i>F</i>	<i>P</i>
Annual	Sex	Male	428.5	23.9	36	69.9	0.000
		Female	269.4	14.2	28		
	Type	Suburban	260.7	21.8	26	48.5	0.016
		Wild	392.6	19.1	38		
	Diel	Diel change	359.3	23.5	32	3.9	0.052
		No change	318.8	22.7	32		
	Sex * Type	--	--	--	--	--	1.4
Type * Diel	--	--	--	--	--	0.2	0.637
Sex * Diel	--	--	--	--	--	0.2	0.684
Seasonal	Sex	Male	429.7	15.6	120	136.4	0.000
		Female	270.5	8.6	154		
	Type	Suburban	268.5	12.5	114	102.8	0.000
		Wild	391.5	12.3	160		
	Season	Fall	373.8	22.5	76	9.3	0.000
		Winter	304.3	14.6	70		
		Spring	364.8	18.8	64		
		Summer	315.3	18.1	64		
	Diel period	Diel change	363.0	13.5	137	10.4	0.001
		no change	317.5	13.3	137		
	Sex * Type	--	--	--	--	--	4.1
Sex * Season	--	--	--	--	--	5.4	0.000
Type * Season	--	--	--	--	--	2.3	0.083
Sex * Diel	--	--	--	--	--	0.7	0.391
Type * Diel	--	--	--	--	--	0.5	0.464
Season * Diel	--	--	--	--	--	0.4	0.782

moved more than suburban females ($\bar{x} = 202.6$ m). A significant ($P < 0.000$) sex by season interaction indicated that males moved the farthest in fall ($\bar{x} = 513.7$ m) and females moved most in spring ($\bar{x} = 293.7$ m). All other interactions were non-significant (Table 1.4).

Maximum distance traveled between successive locations averaged 1333 m and ranged from 392 m to 3797 m (Table 1.5). By season, mean maximum distance traveled ranged from 1058 m in fall to 950 m in winter (Table 1.5), but differences were not significant among seasons ($F = 1.65$, $P = 0.181$). Males ($\bar{x} = 1233$ m) had significantly greater maximum distances traveled than females ($\bar{x} = 884$ m) ($F = 16.33$, $P > 0.000$), as did wild deer ($\bar{x} = 1171$ m) when compared to suburban deer ($\bar{x} = 849$ m) ($F = 19.96$, $P > 0.000$). All interactions were not significant ($P \geq 0.06$).

Locations comprising 95% fixed kernel home ranges came from different probability distributions most often between fall - winter (53% of home ranges shifted) and summer - fall (63% of home ranges shifted). Conversely, home ranges were most stable (38% of home ranges shifted) between both winter-spring and spring - summer (Appendix 1.7). By sex, the proportion of male home ranges that shifted was nearly 2 times greater than the proportion of female home ranges that shifted between fall - winter ($Z = 2.42$, $P = 0.01$), spring - summer ($Z = 2.02$, $P = 0.02$), and summer - fall ($Z = 1.66$, $P = 0.05$). However, the proportion of male (0.36) and female (0.39) home ranges that shifted was similar between winter - spring (Fig 1.5) ($Z = 0.18$, $P = 0.43$). By type, a significantly greater proportion ($Z = 2.09$, $P = 0.02$) of suburban deer home ranges (0.71) shifted between fall - winter as compared to wild deer (0.35). Conversely, wild deer home ranges (0.52) appeared to be the least stable between winter-spring when compared to suburban deer (0.24), although the difference between these proportions was not significant ($Z = 1.39$, $P = 0.08$). The proportion of wild and suburban home ranges that shifted did not significantly differ between spring - summer ($Z = 0.84$, $P = 0.20$) and summer - fall ($Z = 1.66$, $P = 0.25$) (Fig 1.5).

Table 1.5. Maximum distance traveled between successive locations by season for adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	Sex	Type	Maximum distance traveled (m)				Max
			Fall	Winter	Spring	Summer	
22	Male	Suburban	1668	1324	1188	1132	1669
51	Male	Wild	1459	856	1362	1615	1615
62	Female	Wild	387	1228	1177	1219	1228
71	Female	Suburban	2527	3797	624	617	3797
82	Male	Suburban	1009	814	731	769	1010
90	Male	Suburban	1414	1209	928	823	1415
101 ^a	Female	Wild	872	1006	--	--	1006
112 ^a	Female	Wild	862	--	--	--	862
132	Female	Wild	487	925	869	816	925
151	Female	Suburban	754	991	697	820	991
161 ^a	Female	Suburban	417	--	--	--	418
171	Female	Suburban	228	270	351	392	392
181	Female	Wild	980	1011	1183	1306	1306
201	Male	Wild	1517	1444	1453	1375	1517
212	Female	Wild	826	819	804	864	864
221	Male	Wild	2190	1121	1284	1594	2190
232	Female	Suburban	409	343	371	277	409
252 ^a	Female	Suburban	1158	--	--	--	1158
270 ^a	Male	Suburban	1407	--	--	--	1407
290	Female	Wild	772	1052	1397	885	1397
300	Female	Wild	1146	925	1116	950	1146
311	Female	Wild	1267	637	1207	741	1267
321	Female	Wild	1040	1161	1332	1588	1588
352	Female	Suburban	693	382	1582	924	1582
361	Female	Wild	887	1227	1178	1177	1227
371	Male	Suburban	1059	336	1342	355	1342
381 ^a	Male	Wild	--	--	--	901	901
391	Male	Wild	1574	894	2229	1180	2229
401	Male	Wild	2259	1420	1539	1161	2259
411	Female	Suburban	372	488	701	507	701
431	Female	Suburban	604	415	520	454	604
462	Male	Wild	1143	937	3208	2482	3208
471	Female	Wild	819	592	802	433	819
481	Female	Wild	712	411	1367	936	1367
1042	Male	Suburban	971	1027	1328	733	1328
1051 ^a	Male	Suburban	1076	1125	--	--	1125
1061	Male	Wild	919	797	795	937	937
1072	Male	Wild	1845	867	2243	1677	2243
1092	Male	Suburban	481	482	519	466	519

Table 1.5. Continued

mean	1058.1	949.6	1169.6	975.1	1332.5
SD	540.6	591.8	587.2	476.6	707.7
CV	51%	62%	50%	49%	53%

^a deer did not survive entire year, estimate based on locations from seasons with $n > 22$

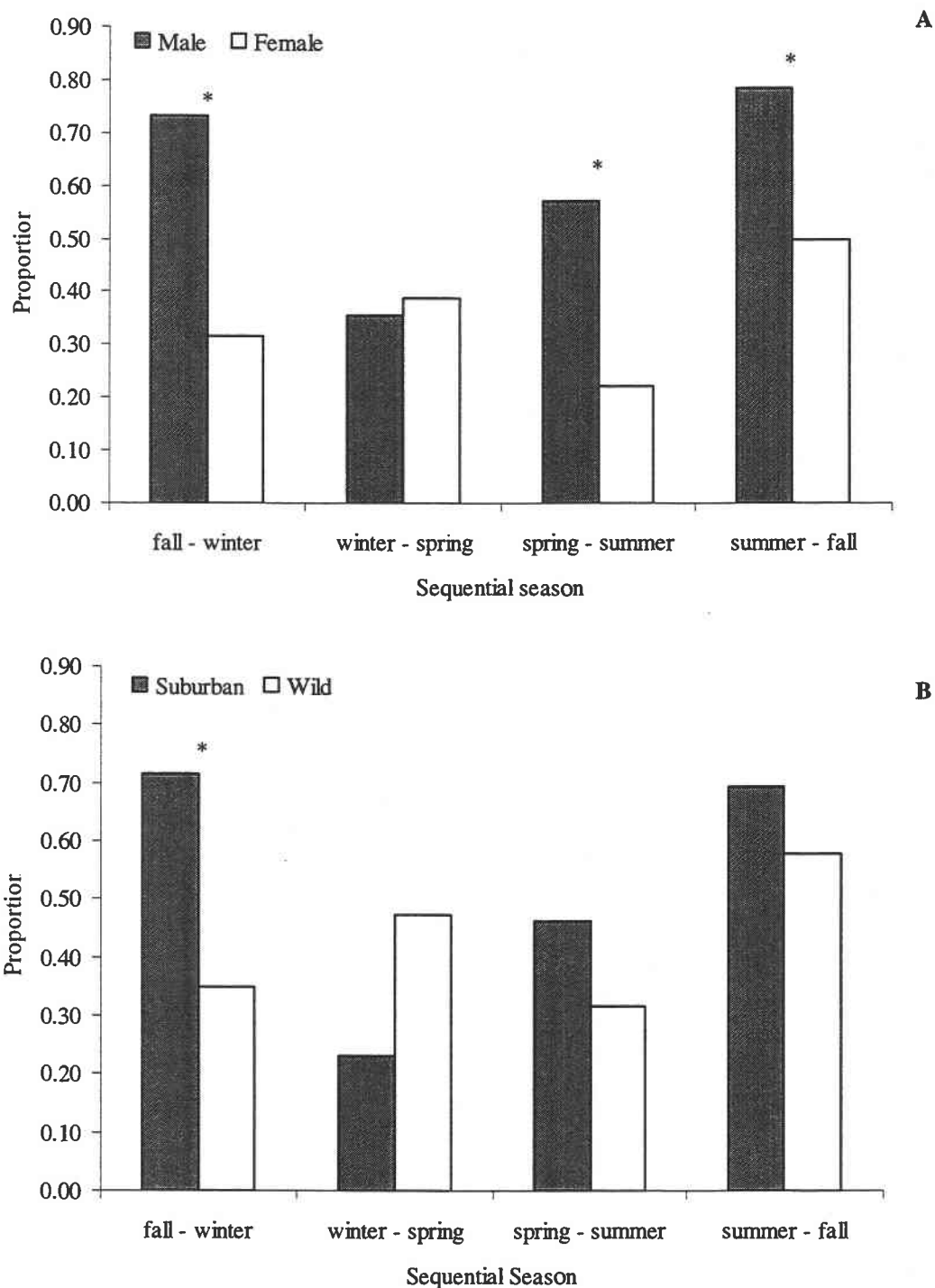


Figure 1.5. Proportion of adult Columbian white-tailed deer whose locations comprising 95% fixed kernel home ranges came from different probability distributions between sequential seasons (i.e. a significant home range shift occurred) as determined by MRPP analyses, Douglas County, Oregon, 1996 – 97. Asterisks indicate proportions of male and female (A) or wild and suburban (B) home ranges that shifted are significantly ($P < 0.05$) different.

Seasonal areas of concentrated use were somewhat less stable than home ranges, as shifts in locations comprising areas of concentrated use between sequential seasons occurred 65% to 72% of the time (Appendix 1.8). By sex, a significantly higher proportion of males showed less site fidelity (shifted more) than females between summer – fall ($Z = 2.23, P = 0.01$) and fall – winter ($Z = 1.66, P = 0.05$). There were no differences in the proportions of male and female areas of concentrated use that shifted between winter – spring ($Z = 1.06, P = 0.14$), and spring – summer ($Z = 1.06, P = 0.14$). However, the proportion of females who shifted areas of concentrated use remained consistently high (53 – 61%) across all sequential seasons (Fig. 1.6). By type, a significantly higher proportion of suburban deer (0.86) areas of concentrated use shifted compared to wild deer (0.50) between fall-winter ($Z = 2.14, P = 0.02$). There were no differences in the proportions of suburban and wild concentrated use areas that shifted between winter – spring ($Z = 0.73, P = 0.23$), and spring – summer ($Z = 0.05, P = 0.48$), and summer – fall ($Z = 1.33, P = 0.09$) (Fig. 1.6). Most R values (89 - 100%) were greater than 0 for both home range (Appendix 1.7) and concentrated use areas (Appendix 1.8) across sequential seasons, meaning that there was more agreement between groups than would be expected by chance.

There was a significant positive relation between cover type heterogeneity and both 95% fixed kernel home range ($r = 0.81, t = 2.92, P = 0.006$) and area of concentrated use size ($r = 0.72, t = 2.97, P = 0.006$) when controlling for sex and type (Fig. 1.7). Models containing only main effects explained as much variation as models with interactions between Simpson's index and sex or type for both home range (Extra sum of squares $F = 0.16, \text{d.f.} = 2, 28, P = 0.85$) and area of concentrated use size (Extra sum of squares $F = 0.43, \text{d.f.} = 2, 28, P < 0.65$). Therefore, the slope of the relation remained constant for both sex and type.

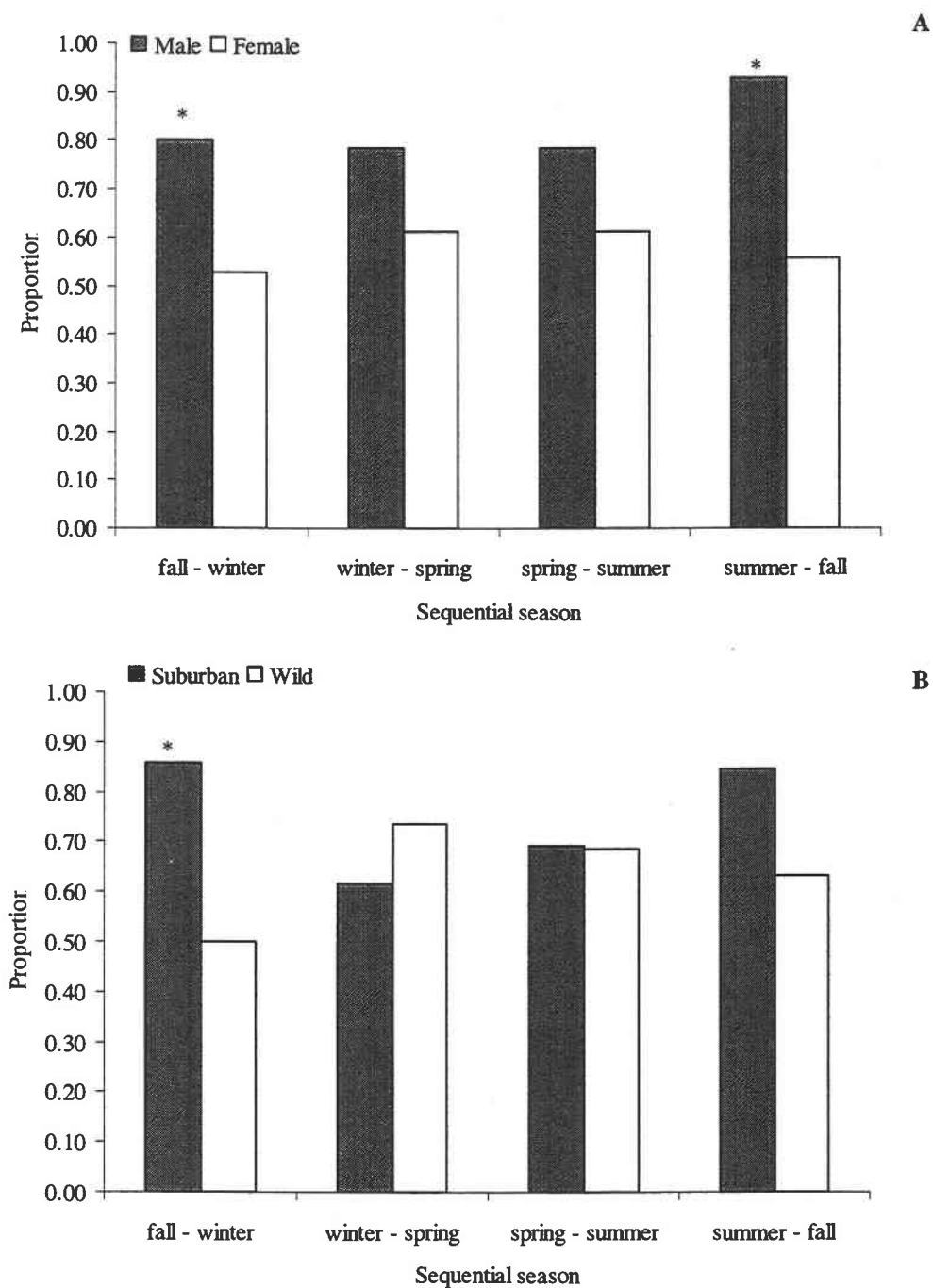


Figure 1.6. Percent of adult Columbian white-tailed deer whose locations comprising areas of concentrated use came from different probability distributions between sequential seasons (i.e. a significant home range shift occurred) as determined by MRPP analyses, Douglas County, Oregon, 1996 – 97. Asterisks indicate proportions of male and female (A) or wild and suburban (B) areas of concentrated use that shifted are significantly ($P < 0.05$) different.

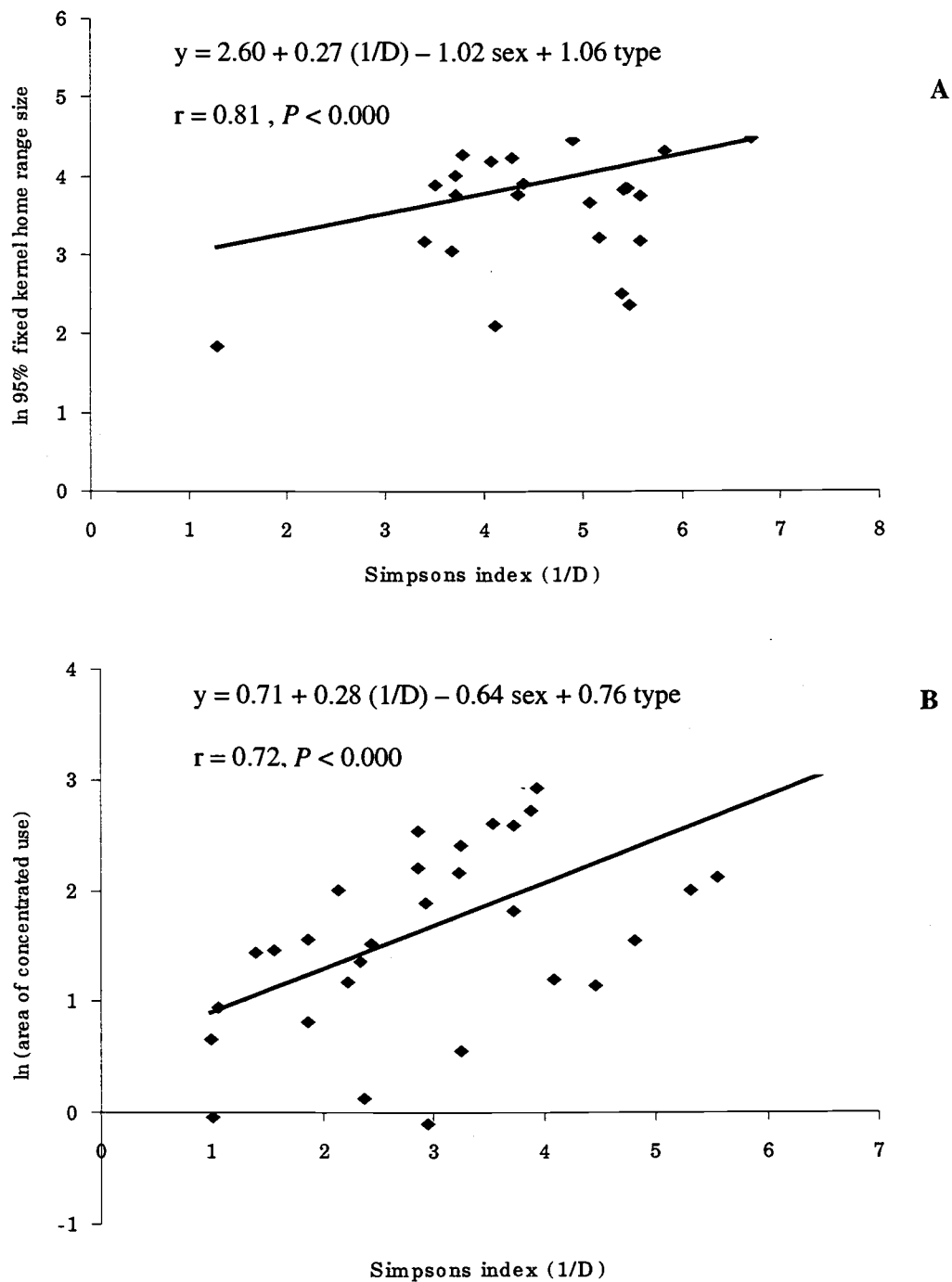


Figure 1.7. Effect of cover type heterogeneity on annual home range size (A) and concentrated use area size (B) for 32 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97. Cover type heterogeneity was calculated with Simpson's index (1/D) and ranged from 0 to the total number of cover types available. *P* value is for overall model significance.

Survival

Survival rates

A total of 29 out of 64 radio-collared deer died from 1996 to 1998. Sample sizes were reasonably large ($n \geq 38$) within years, and males ($n = 33$) and females ($n = 31$) were evenly represented across all 3 years. However, there were more wild deer ($n = 41$) monitored than suburban deer ($n = 23$) across all 3 years, especially during 1998 when only 10 suburban deer were monitored compared to 28 wild deer. Only 2 deer were censored (Table 1.6).

Adult annual survival rates ranged from 0.642 in 1996 to 0.866 in 1998. Average annual survival was 0.729 (SD = 0.065) (Table 1.6). Survival rates at the end of 1998 were significantly higher than the end of 1997 ($P = 0.025$) and 1996 ($P = 0.007$). All other comparisons of annual survival rates and survivorship functions were insignificant (Table 1.7). Average annual survival was 0.78 for both males (SD = 0.09) and females (SD = 0.10) (Table 1.6). Neither annual rates nor survivorship significantly varied in any year by sex (Table 1.7). Differences in survival were more apparent when examined by type. Average annual survival was 0.84 (SD = 0.07) for wild deer, compared to 0.73 (SD = 0.11) for suburban deer (Table 1.6). Annual survivorship functions were significantly different ($P = 0.007$) by type because wild deer apparently died more rapidly than suburban deer in 1998. Conversely, there was suggestive evidence that survival rates were higher for wild deer in 1997 ($P = 0.052$) (Table 1.7).

Cumulative survival across all 3 years was 0.39 (95% CI = 0.25 – 0.52) (Table 1.6), and most mortality occurred from late fall to early spring (Fig. 1.8). Cumulative survival rates and survivorship functions curves were equivalent by sex and type (Table 1.7).

Table 1.6. Annual and cumulative (3 year) Kaplan-Meier survival rate estimates for adult Columbian white-tailed deer; Douglas County, Oregon, 1996 – 98.

Group	Year	S(t)	95% CI	n	# Mortalities	# Censored
1996	--	0.642	0.480 – 0.803	42	12	1
1997	--	0.696	0.550 – 0.834	46	12	1
1998	--	0.866	0.757 – 0.975	38	5	0
males	1996	0.659	0.437 – 0.880	20	6	1
females	1996	0.616	0.375 – 0.857	22	6	0
males	1997	0.675	0.462 – 0.888	22	6	1
females	1997	0.717	0.525 – 0.909	24	6	0
males	1998	0.839	0.673 – 1.000	19	3	0
females	1998	0.894	0.756 – 1.000	19	2	0
suburban	1996	0.680	0.449 – 0.911	18	5	1
wild	1996	0.588	0.355 – 0.821	24	7	0
suburban	1997	0.564	0.324 – 0.805	17	7	0
wild	1997	0.792	0.629 – 0.954	29	5	1
suburban	1998	0.900	0.714 – 1.000	10	1	0
wild	1998	0.855	0.723 – 0.986	28	4	0
male	all	0.373	0.189 – 0.560	33	15	2
female	all	0.395	0.198 – 0.592	31	14	0
suburban	all	0.345	0.144 – 0.546	23	13	1
wild	all	0.398	0.210 – 0.586	41	16	1
all	all	0.387	0.252 – 0.522	64	29	2

Table 1.7. Summary of results from log rank tests (χ^2) and Z tests on annual and cumulative survival for adult Columbian white-tailed deer, Douglas County, Oregon; 1996 – 98. Log rank tests test for differences in survivorship functions, Z tests compare survival curves at a particular point in time (i.e. end of year, or end of 3 years).

Group 1	Year	n ₁	S ₁	var S ₁	Group 2	Year	n ₂	S ₂	var S ₂	Z	P	χ^2	P
all	1996	42	0.642	0.005	all	1997	46	0.696	0.004	-0.553	0.291	1.380	0.241
all	1996	42	0.642	0.005	all	1998	38	0.866	0.003	-2.484	0.007 ^a	2.720	0.099
all	1997	46	0.696	0.004	all	1998	38	0.866	0.003	-1.962	0.025 ^a	0.427	0.513
males	1996	20	0.659	0.011	females	1996	22	0.616	0.009	0.300	0.382	0.050	0.823
males	1997	22	0.675	0.010	females	1997	24	0.717	0.008	-0.313	0.378	0.080	0.780
males	1998	19	0.839	0.007	females	1998	19	0.894	0.005	-0.501	0.309	0.212	0.645
suburban	1996	18	0.680	0.012	wild	1996	24	0.588	0.008	0.639	0.261	0.417	0.519
suburban	1997	17	0.564	0.014	wild	1997	29	0.792	0.006	-1.631	0.052	0.058	0.809
suburban	1998	10	0.900	0.009	wild	1998	28	0.855	0.004	0.389	0.348	7.300	0.007 ^a
male	all	33	0.373	0.005	female	all	31	0.395	0.006	-0.210	0.417	0.023	0.879
suburban	all	23	0.345	0.009	wild	all	41	0.398	0.004	-0.471	0.319	2.590	0.107

^a Survivorship curves or rates are significantly different

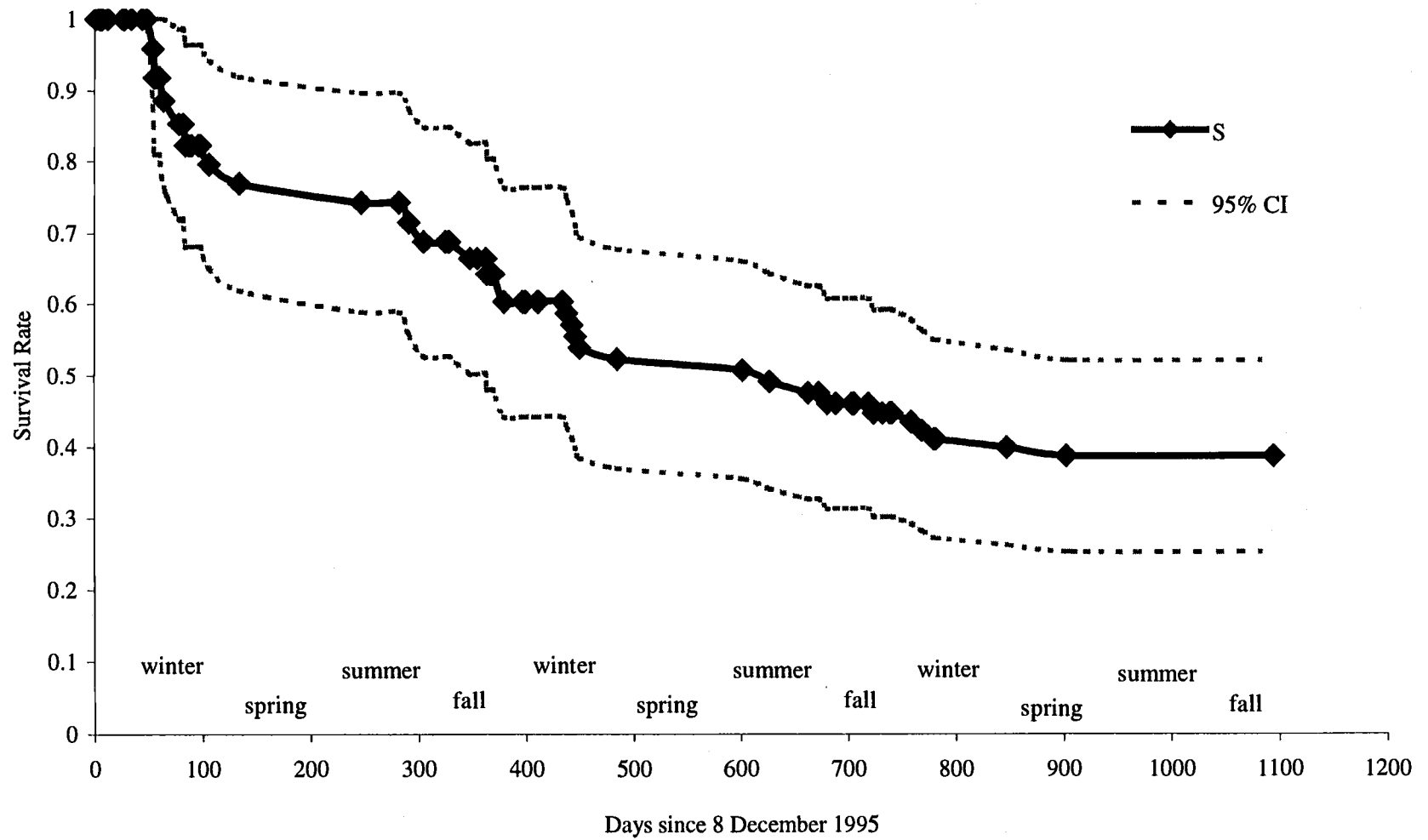


Figure 1.8. Cumulative 3-year (8 December 1995 – 1998) Kaplan-Meier survival rate estimate for 64 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 98

Proximate sources of mortality

Of the 29 adult CWTD that died over the 3 year study, the most frequent (28%) known cause of death was a combination of emaciation and disease (Table 1.8). Pneumonia ($n = 3$) appeared to be the primary identifiable disease, while *Yersina pseudotuberculosis* was found in one deer. Road kill (17%) were the second most frequent known cause of death. Poaching (10%) did occur, and it was likely that one deer that disappeared was actually poached. Identifiable predation (3%), along with fence entanglement (7%) did not occur frequently. There were 10 (35%) unknown causes of death (Table 1.8). Sources of mortality appeared to be relatively similar by sex and type, although females and suburban deer were hit by vehicles more frequently ($n = 4$) than males and wild deer ($n = 1$), while most unknown causes of death were from wild deer ($n = 8$) (Table 1.8). Of the 12 necropsied deer, most ($n = 11$) had high levels of ecto-parasite infestation. Furthermore, 92% of deer examined ($n = 11$) lacked any apparent subcutaneous body fat, and 83% ($n = 10$) of kidneys examined lacked any perineal fat. All kidneys examined were from deer that died in winter. Lungworms were present in 50% ($n = 4$) of examined deer where internal parasite information was recorded.

DISCUSSION

Home ranges, areas of concentrated use, and movements

CWTD were relatively sedentary overall, and there is some evidence that large dispersal movements were not occurring. For example, areas of concentrated use, which deer typically inhabited 70% of the time, constituted a rather small percentage of home range size. Thus, relative to the total area they inhabited during the course of their normal activity, CWTD tended to repeatedly use and 'key in on' the same small areas which presumably represented areas of increased biological importance. Gavin et al. (1984) noted that CWTD along the lower Columbia River were remarkably sedentary. In addition, large scale movements in this study,

Table 1.8. Proximate sources of mortality by sex, type, and total for 29 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 98.

Cause of death	Sex		Type		Total
	male	female	suburban	wild	
emaciation/disease	4	4	3	5	8
road-kill	1	4	4	1	5
poaching	2	1	2	1	3
fence kill	2	0	2	0	2
predation	1	0	0	1	1
unknown	5	5	2	8	10

as estimated by maximum distances traveled between successive locations, were never larger than 3.8 km and averaged ca. 1.3 km. (Table 1.5). Also, there was no season during which mean maximum movements were significantly larger. It should be noted that most dispersal among white-tailed deer appears to occur among yearling males (Nelson and Mech 1984), and I did not stratify my data by age because too few yearling males were captured. However, females may wait 3 years before dispersing (Hawkins and Klimstra 1970), and I found little evidence of permanent large scale movements by females. In addition, Bunnell and Harestad (1983) estimated dispersal distances of 15.2 and 12.2 km for male and female black-tailed deer (*O. hemionus columbianus*), respectively, which are much larger than maximum distances traveled for CWTD in my study. There is a likely tradeoff between remaining sedentary and dispersing. Staying within a well known area can minimize energy expenditure and predation risk, but competition for limited resources (e.g. food or mates) may be high. Conversely, dispersal into new areas may increase risk of mortality due to higher energy demands and unfamiliarity with the new area (Nelson and Mech 1984).

Home ranges of CWTD in this study fall within the range of reported minimum convex polygon estimates from other white-tailed deer. Among northern migratory white-tailed deer, Nelson and Mech (1981) reported average home ranges of 83 ha in summer and 44 ha in winter for females in Minnesota, while Tierson et al. (1985) reported average home ranges of 225 ha in summer and 135 ha in winter for males and females in New York. Moreover, Dusek (1987) reported a mean annual home range of 560 ha for resident deer along the Yellowstone River in Montana, while migratory males used 255 and 32 ha in summer and winter, respectively, and migratory females used 58 and 47 ha, respectively.

Spatial use estimates were highly variable. However, the effects of sex, type, season, and habitat explained much of the variation. Males consistently had larger home ranges, areas of concentrated use, and movements than females. These findings are in concordance with

other studies of sexually dimorphic ungulates that have found sexual differences in spatial use (Taber and Dasmann 1956, Nelson and Mech 1981, Beier and McCullough 1990, Weckerly 1993), and likely indicate that a degree of intersexual partitioning of space was occurring. Males may roam over larger areas in order to maximize body size and breeding potential, while females are often more sedentary to maximize offspring survival (Main et al. 1996, Bleich et al. 1997). However, not all predictions of sexual segregation based on life history, body size, and energetic needs were substantiated in this study. First, there was no difference in the slope of the relation between home range and area of concentrated use by sex. This analysis was basically a test of 'core area' selectivity, whereby females should have consistently small concentrated use areas regardless of home range size. Thus, the slope of the relation should be shallower for females than males because females are often viewed as the 'choosier' sex due to narrower niche breadths imposed by smaller body size (Beier 1987, McCullough et al. 1989, Weckerly 1993). Second, as both Beier and McCullough (1990) and Weckerly (1993) suggested, body size and its relation to metabolic rate apparently cannot solely explain variation in spatial use. In all seasons except winter, the ratio of female-male home range or area of concentrated use was much lower than 0.75. More importantly, the extremely wide confidence intervals are likely an indication that more complex models incorporating factors such as predation pressure and food quality are needed to explain sexual differences in spatial use (Beier and McCullough 1990, Weckerly 1993).

Whether or not a deer inhabited a site that was near human development explained a large amount of variation in spatial use patterns. Although I failed to find a difference in the slope of the relation between home range and area of concentrated use size between suburban and wild deer, meaning that suburban deer did not utilize consistently small areas of concentrated use relative to home range size, suburban deer consistently had significantly smaller home ranges, areas of concentrated use, and movements than wild deer. Vogel et al.

(1989) found that home range size of white-tailed deer decreased with increasing housing density. Happe (1982) also found smaller home ranges for a small sample of female black-tailed deer in suburban areas and proposed that the interface of suburban and undeveloped areas provided more interspersion of open and closed habitat. Cornicelli et al. (1996) suggested that smaller home ranges of suburban deer may be indicative of ample resources in small areas. Several residents fed deer during this study, which along with existing lawns and gardens, may have provided ample forage within small areas. Also, several suburban deer were habituated to people, thus it did not appear that movements by these deer were affected by increased human harassment which has been demonstrated by others (Nicholson et al. 1997). In addition, differences in home range size estimates between my study and Smith's (1981) study may be attributable to deer proximity to human development or influence. Differences between the 2 studies were not statistically compared due to differences in sample size and sampling length. However, annual home range estimates in this study generated by the minimum convex polygon method (all: \bar{x} = 144 ha, SE = 20.0; males: \bar{x} = 203 ha, SE = 24.0; females: \bar{x} = 85.3 ha, SE = 21.2) were substantially larger than previously estimated by Smith (all: \bar{x} = 33.0 ha, SE = 5.7; males: \bar{x} = 48.3 ha, SE = 12.0; females: \bar{x} = 27.0 ha, SE = 7.4). A possible reason for this difference was that several deer in Smith's study were in areas that I classified as suburban interfaces and parks. Furthermore, deer that I sampled in these same suburban areas (i.e. areas near or within Whistler's Bend County Park) had home range sizes (\bar{x} = 68.3 ha, SE = 107.4, n = 5, range = 9.1 - 259.1) that were more similar to what Smith reported. Also, Gavin et al. (1984) observed larger home ranges for CWTD along the lower Columbia River where suburban interface areas were not prevalent. Thus, there appears to be substantial evidence that CWTD living in suburban interface areas use less space than 'wild' deer.

Home ranges and concentrated use areas were larger in fall than in all other seasons, and no differences were detected among the remaining 3 seasons. This result should be

expected because white-tailed deer activity normally increases dramatically during the breeding period (Nelson and Mech 1981, Smith 1981, Gavin et al. 1984). Similarity in home range and area of concentrated use size in all other seasons may suggest that seasonal fluctuations in resource (i.e. food) quality were not strongly influential (Harestad and Bunnell 1979, Kilgo and Labisky 1997). However, movements were significantly lower during winter. Movements often decline during winter because metabolic activity and forage intake decrease in response to declining forage quality (Seal et al. 1982, Moen 1976, Beier and McCullough 1990).

Differences in movements by sex were not consistent across seasons. Relative to males, females moved more in spring, which may be due to searching for suitable fawning areas. In addition, movements between changing diel periods (diurnal and crepuscular/nocturnal periods) were greater than movements between the same diel period. Previous studies have also found an effect of diel period on deer movements and activity (Kammermeyer and Marchinton 1977, Hayes and Krausman 1993, Beier and McCullough 1990, Dusek et al. 1992). It is possible that increased movements during changing diel periods corresponds to a transition from bedding to feeding areas.

Site fidelity to seasonal home ranges was lowest during transitional periods into or out of fall. This is not surprising and agrees with the higher fall movements that my study and others (e.g. Nelson and Mech 1981, Smith 1981, Gavin et al. 1984) have observed. Compared to home ranges, however, deer exhibited consistently lower site fidelity to areas of concentrated use across all sequential seasons. Deer may seasonally shift their areas of concentrated use because resources in these very small areas have become exhausted. Thus, they may move to find areas containing more abundant or seasonally required resources. By sex, females showed stronger site fidelity to their home ranges and areas of concentrated use during most sequential seasons. Strong site fidelity, especially by females, has been demonstrated in other deer (Smith 1981, Gavin et al. 1984, Dusek et al. 1989, Beier and McCullough 1990, Weckerly 1993). The nearly

equivalent site fidelity between winter and spring months for males and females observed in this study should be expected because movements were lowest during winter, presumably because the need to conserve energy was greatest during this time (Moen 1976). However, it was surprising that females did not show the greatest shifts in home ranges or concentrated use areas between spring-summer when females should be searching or moving to fawning sites. It is possible that fawning areas were not far from areas used throughout the year, and all females may not have been pregnant.

Previous work has suggested that home range size should decrease as habitat diversity that provides increased edge and high quality resources increases (McNab 1963, Loft et al. 1984, Beier and McCullough 1990, Tufto et al. 1996). Contrary to this prediction, I failed to find a negative association between either home range or area of concentrated use size and cover type heterogeneity. It is possible that the minimum scale (1 ha) at which cover types were delineated was too coarse to detect a trend, and my analysis did not attempt to partition which cover type interfaces created the most high quality resources. However, if high quality resources were highly concentrated into the interior portions a few cover types, then an inverse relation between habitat diversity and amount of area used should not be expected.

Survival and sources of mortality

Overall, annual survival of adults averaged approximately 0.73 in this study. Significant yearly variation in annual survivorship was generally absent. However survival rates were higher at the end of 1998 compared to the end of 1996 and 1997, which may be related to fewer suburban deer sampled during 1998 (see below). Most mortality occurred between fall and early spring during all 3 years (Fig. 1.8). Smith (1981) also found that most CWTD mortality occurred during winter and survival in his study was negatively associated with winter severity and my results support his findings. Over the course of the entire study (3

years) cumulative survival was rather low (0.39), which indicates a high rate of turnover and low longevity in my sample of CWTD.

The lack of sex-specific differences in any of the comparisons of annual or cumulative survival rates and functions was unexpected. Prior studies of CWTD (Smith 1981, Gavin et al. 1984), as well as studies of other white-tailed deer populations (Kie and White 1985, Nelson and Mech 1986, Dusek 1987, Nixon et al. 1991), have documented lower male survival (Table 1.9). Male mortality may often be higher because traits that increase mating success, but increase energetic costs and mortality have likely been selected for (Clutton-Brock et al. 1982). For example, males often incur high winter mortality if they enter winter with their energy reserves depleted from rutting activities (Nicholson et al. 1997). In addition, males may inhabit areas that are more conducive to increasing body mass but have greater predation risk (Main and Coblenz 1996, Bleich et al. 1997). It is possible that males may increase their survival by their decreasing activity and forage intake during winter to conserve energy (Seal et al. 1972, Moen 1976, Beier and McCullough 1990), but no data on seasonal foraging rates are available for CWTD to support this contention. However, my spatial use results may provide a framework to explain the equal survival rates between the sexes. Males may have compensated for increased mortality risk on a short term basis by sequestering a wider range of resources through larger movements they exhibited during non-winter seasons. Conversely, female mortality may have been elevated because small movements and areas of concentrated use resulted in increased intrasexual competition causing resources to be rapidly exhausted and slowly replenished.

There was evidence that survival by type was not consistent among years, although interpretation of this effect was not straightforward. The weighted average of annual survival was higher for wild deer (0.84) than suburban deer (0.73), and annual survival appeared to be higher for suburban deer compared to wild deer in 1997. Conversely, the significant difference

in survivorship functions by type in 1998 indicated that wild deer died more rapidly than suburban deer. However, this statistical difference may not be biologically meaningful because few ($n = 10$) suburban deer were monitored in 1998. It is possible that survival has the potential to be negatively affected by human influence for several reasons. First, suburban deer collided with vehicles more frequently. Second, direct supplemental feeding or indirect feeding (e.g. predictable forage in yards and gardens) by residents may result in locally high deer densities. High deer densities in small areas can be associated with increased disease transmission (Woolf and Kradel 1977), and accelerated density dependent mortality.

Compared to other white-tailed deer populations, CWTD survival rates are within the reported range of white-tailed deer survival rates. This range is variable, but CWTD appear to fall on the lower end of the range (Table 1.9). In some Midwestern areas, annual survival of hunted white-tailed deer can exceed 90% (Nixon et al. 1991). Conversely, hunted white-tailed deer can experience low survivorship in harsh northern climates with high wolf predation rates (Nelson and Mech 1986, Fuller 1992). Whereas previous studies of CWTD survival have relied on life table analysis (Gavin 1979) and median age of death (Smith 1981), my study presents the first estimates of survival rates based on analysis of known fates for Douglas County CWTD.

There appeared to be a mixture of direct human caused and 'natural' mortality. Emaciation and disease, which could also be classified as malnutrition, was most frequent. High infestations of ectoparasites likely contributed to mortality of malnourished deer. Other diseases such as epizootic hemorrhagic disease, which can be common in the southeast U.S. (Davidson and Doster 1997), and hoof-root/lumpy jaw (*necrobacillosis*) which occurs in the lower Columbia River CWTD (Gavin et al. 1984), were not identified in my sample. However, I did find evidence of hoof rot (i.e. osteomyelitis in the mouth cavity) during incidental discoveries of unmarked dead deer. Previously, Smith (1981) found that vehicle collisions were

Table 1.9. Annual survival rates for adult white-tailed deer from various geographical regions. Yearlings have been pooled with adults in order to facilitate comparison with this study. Annual survival is reported as either a mean (single value) or a range (2 values).

Sex	Year (s)	Geographic Region	Annual Survival	Estimator ^a	Hunted?	Source
female	1980-89	Montana	0.43 - 0.83	daily survival	yes	Dusek et al. 1992
male	1984	S. Texas	0.65 - 0.74	daily survival	yes	DeYoung 1989
male	1980-85	E Central Illinois	0.38 - 0.39	daily survival	yes	Nixon et al. 1991
female	1980-85	E Central Illinois	0.63 - 0.71	daily survival	yes	Nixon et al. 1991
male	1981-86	N. Central Minn.	0.44 - 0.48	daily survival	yes	Fuller 1990
female	1981-86	N. Central Minn.	0.60 - 0.71	daily survival	yes	Fuller 1990
male	1973-88	NE Minnesota	0.41 - 0.47	daily survival	yes	Nelson and Mech 1986
female	1973-87	NE Minnesota	0.79 - 0.80	daily survival	yes	Nelson and Mech, 1986
male	1994-97	New Brunswick	0.38 - 0.57	daily survival	yes	Whitlaw et al. 1998
female	1994-7	New Brunswick	0.48 - 0.92	daily survival	yes	Whitlaw et al. 1998
male	1962-68	S. Illinois	0.89	prop alive	unknown	Hawkins et al. 1971
female	1962-68	S. Illinois	0.98	prop alive	unknown	Hawkins et al. 1971
male	1974	Julia Butler CWTD	0.65 ^b	life table	no	Gavin 1979
female	1974	Julia Butler CWTD	0.82 ^b	life table	no	Gavin 1979

^a daily survival calculated with program MICROMORT (Heisey and Fuller 1985)

^b value expressed as 1- q_x

the most frequent cause of death, followed by malnutrition. This discrepancy may reflect different methods between the 2 studies. I completely relied on radio-marked deer to estimate cause of death, whereas Smith relied on opportunistic findings (e.g. road-kills, systematic searches reports from ranchers) which may have overestimated the proportion of road-kills compared to other sources of mortality. Predation was not prevalent which was not surprising considering Douglas County engages in active predator control. Although poaching was not frequent, all 3 instances occurred during the non-hunting season and were likely not innocently mistaken for black-tailed deer. In addition, it was likely that 1 censored male that disappeared during the fall was poached.

There are 2 plausible reasons for relatively low adult survival in winter, frequent incidence of emaciation/disease and parasites, and poor body condition. First, fall and winter forage quality is key for male most white-tailed deer to recover from energetic losses incurred during the breeding season. Smith (1981) inferred that winter herbaceous forage found in open cover types (grasslands and pastures) had a high water content and thus has little nutritional value. Also, the nutritional value of grasses and forbs are generally poor until the growing season begins in spring (Suring and Vohs 1979, Robbins 1993). It is possible that herbaceous winter forage quality provides insufficient energy for maintenance needs, and/or recovery from energetic losses incurred during different life stages (i.e. females from lactation and males from rut). Secondly, the relatively low adult survival and reduced physiological condition observed in this study are often indicative of density-dependent population responses. Adult survival may decrease as a population nears or over-shoots carrying capacity (McCullough 1979). Dense populations of deer in the southeastern U.S. may also display high incidences of malnutrition and parasitism (Davidson and Doster 1997). Also, Swihart et al. (1998) found that deer from hunted and lower density populations in Indiana were in better nutritional condition than unhunted or lightly hunted populations at higher densities. There are some data from

Oregon Department of Fish and Wildlife deer counts that suggest CWTD densities can locally be as high as 48 – 72 deer per km² (Oregon Department of Fish and Wildlife 1995, unpublished data). It is plausible to assume that these are relatively high densities. Smith (1981) previously estimated a CWTD density of 23 - 27 deer per km², and McCullough (1979) determined that 38 deer per km² constituted K-carrying capacity for white-tailed deer on the George Reserve in Michigan. However, correct inference of density dependence can be problematic. Density dependence can often be mis-inferred when confounded by temporal variation, or go undetected due to low statistical power and inappropriate study design (White and Bartmann 1997). Also, some physiological correlates may be insensitive to changes in density (Shea et al. 1992), and the physical condition data collected from this study were qualitative. Still, my results are suggestive of a density dependent response by CWTD, and it is possible that CWTD population densities are fluctuating near carrying capacity.

Chapter 2

Habitat Associations of Adult Columbian White-tailed Deer in Western Oregon.

Mark A. Ricca

INTRODUCTION

A sound understanding of a species' habitat associations is fundamental to its management. Much is known about habitat associations for white-tailed deer (*Odocoileus virginianus*) across their geographical range, and they are often thought of as being habitat generalists. White-tailed deer tend to exploit a wide variety of habitats ranging from lowland riparian and agricultural areas (Compton et al. 1988, Bell et al. 1992), upland coniferous habitats (Dusek 1987, Pauley et al. 1993), insular desert mountain ranges (Anthony and Smith 1977), and intensively farmed areas (Nixon et al. 1991), and midwestern - eastern deciduous forests (Torgerson and Porath 1984, Mattfeld 1984).

However, because their populations are disjunct from other white-tailed deer, Columbian white-tailed deer (*O. v. leucurus*, CWTD) present a somewhat unique situation. CWTD are a subspecies that were once ubiquitous throughout western Oregon and Washington. Presently, only 2 isolated and federally endangered sub-populations remain; one resides along the lower Columbia River mostly within the Julia Butler National Wildlife Refuge and the other along the North Umpqua River near Roseburg, Douglas County, Oregon (United State Fish and Wildlife Service, 1983). Smith (1981, 1987a) found that the Douglas County sub-population of CWTD was strongly associated with riparian areas and lowland deciduous oak woodland - savanna communities within the interior valleys of the Umpqua Basin. He argued that CWTD might be considered habitat specialists due to their strong affinity for riparian, oak-woodland/savanna and conifer habitat, as compared to sympatric Columbian black-tailed deer (*Odocoileus hemionus columbianus*) which occupied a wider breadth of habitats.

Because the Douglas County sub-population of CWTD has been proposed for delisting (Federal Register 1999), there is a need for current information on deer-habitat associations. Densities of CWTD and conversion of available natural habitat to suburban/urban

subdivisions seemingly have increased over the last 20 years, while widespread dispersal into historic areas has not been apparent (Oregon Department of Fish and Wildlife, unpublished data). In addition, new sites along the north bank of the North Umpqua River that are further away from human development and contain a greater abundance of xeric habitats have become accessible to research since Smith's (1981) study. Thus, there was an opportunity to ascertain whether previously documented habitat associations of CWTD were still evident when examined across a broader portion of their range in Douglas County, and under presumably higher density conditions.

There are also several ecological reasons to re-examine habitat associations of CWTD. CWTD have been viewed as 'habitat specialists' for particular (e.g. riparian and oak woodland) cover types available within their home ranges in the Umpqua Basin (Smith 1981), while other white-tailed deer populations across their geographic range can exhibit plasticity in habitat use (e.g. Halls 1984). Thus, viewing CWTD as habitat specialists can be somewhat peculiar when compared to other white-tailed deer. However, a degree of specialization may become more apparent if proximity to stream is considered. Because streams and riparian areas may strongly influence CWTD habitat use (Smith 1981, 1987a), non-riparian habitats may be used more frequently when juxtaposed to streams. Second, differences in habitat associations may often be related to sex, anthropogenic, temporal, or edge-related effects. For example, sexual differences in habitat use often occur due to sex-specific life history traits, whereby females may exhibit more restrictive patterns of habitat use (McCullough et al. 1989, Main et al. 1996). Proximity to human development may also influence habitat associations whereby deer may either avoid habitats close to humans because of elevated harassment (Nicholson et al. 1997) or, select habitats near development that provide increased forage and security if deer are habituated to humans (Bellatoni et al. 1993). In addition, there have been relatively few studies to date that have examined habitat associations of deer living near human development. On a

temporal basis, seasonal differences in habitat associations can be reflective of changing plant phenology, thermal cover, and deer behavior, while changing diel period is often associated with different deer activity patterns which may result in differences in habitat use between day and night (Beier and McCullough 1990). Habitat edges often result in increased forage quality and quantity which should correspond to higher deer use. However, the amount of available edge can have a variable effect on deer-habitat associations (Kremsater and Bunnell 1992).

My goal was to describe habitat associations for adult CWTD within the Douglas County sub-population. My primary objective was to examine variation in third order habitat use and selection (i.e. within individual deer home ranges, Johnson 1980) among deer in order to determine the degree of habitat specialization or generalization exhibited by CWTD. I hypothesized that there should be little variation among deer in habitat use and selection if CWTD are restricted to particular habitats. Conversely, variation in use and selection among deer would suggest that CWTD can utilize a broad range of habitats. Because Smith (1981, 1987a) suggested that CWTD were strongly associated with riparian and low lying areas, I also hypothesized that proximity to streams should strongly influence use. My second objective was to examine sources of variation in CWTD habitat use and selection patterns by formulating the following predictions:

1. Because females generally have narrower niche breadths than males (Main et al. 1996), and inter-sexual differences in habitat use can be mechanism for resource partitioning (McCullough et al. 1989), differences in habitat associations between the sexes should be expected.
2. Deer living near human development should also use habitats in different proportions and be more strongly associated with housing than deer inhabiting areas less affected by humans, presuming harassment by humans is minimal.

3. Regarding diel period, deer should use open habitats more frequently during crepuscular and/or nocturnal periods when they are presumably more active and feeding (Smith 1981, Beier and McCullough 1990). On a seasonal basis, closed habitats should be used more frequently during the hot summer months while open habitats dominated by herbaceous forage should be used more frequently during the growing season and onset of fall rains (Smith 1981, Beier and McCullough 1990).
4. Habitat patches with larger amounts of edge should be used more frequently, presuming forage and cover occur in distinct habitats (Kremsater and Bunnell 1993).

Lastly, managers are often interested in ascertaining critical habitat for threatened or endangered species. However, critical habitat can only be determined from manipulative studies and is often widely mis-inferred in associative habitat selection studies (White and Garrott 1990:198). Given these limitations, cover type composition and proximity to streams within areas of concentrated use may provide a more useful construct for determining habitats that receive disproportionate use. These habitats may then have increased biological importance and implications for fitness (Samuel et. al 1985, Bingham and Noon 1997). Examining habitat composition and proximity to streams within areas of concentrated use can also help further test hypotheses regarding habitat specialization or generalization.

STUDY AREA

The study area was located within the lower North Umpqua watershed in Douglas County, Oregon. It was bordered approximately by the towns of Roseburg to the south, Glide to the east, Sutherlin to the north, and Interstate 5 to the west (Fig. 1.1). The majority (ca. 80%) of the study area was privately owned, while the remainder (ca 20%) was open to the public. The landscape was characterized by undulating topography intersected by several small drainages. Elevation ranged from 165 to 595 m. The climate was characterized by long

rainy winters and hot dry summers. Monthly average temperatures ranged from a low of 1.7 °C in January to a high of 29.4 °C in August. Average annual precipitation was 84.2 cm and monthly rates ranged from a low of 1.6 cm in August to a high of 15.8 cm in December (Western Region Climate Center, Reno, Nevada; 1965 – 1997). Snowfall was rare.

Smith (1981, 1985b) gave an extensive description of plant communities and species composition found in the study area. While some stands of continuous deciduous hardwood/mixed conifer forest, and undisturbed riparian areas were present, vegetative communities typically represented a relatively disturbed environment due to past or current history of fire management, grazing, agricultural conversion to improved pasture, and housing development. In most parts, the study area was characterized by a mosaic of finely interspersed cover types which typically consisted of oak (*Quercus* sp.), madrone (*Arbutus menzeissi*), conifer, and grassland plant associations intersected by numerous riparian drainages. Large expanses of coniferous forest were rare, and smaller conifer stands had typically been logged and were regenerating.

Because of constraints imposed by limited access to private lands, study sites were not chosen at random. Instead, study sites were chosen based on where access could be readily obtained. Three study sites were chosen on public land, while 5 were on private land (Fig. 1.1)., If access was available, some sites were expanded when marked deer moved off existing sites. Privately owned sites were often grazed by cattle and/or sheep and pastures were cut for hay in early summer. Some sites were either bordered or intersected by rural homes or suburban subdivisions (Figure 1.1).

METHODS

Deer captures.

Adult deer were captured during fall and winter months from 12/8/95 through 1/28/98. Deer were captured using modified clover live traps (McCullough 1975) baited with apples, salt, or alfalfa. Traps were set in the late morning or evening and checked the following morning. Deer were also darted opportunistically over baited tree stands or blinds during day and night with Pneu-Dart (Pneu-Dart Incorporated, Williamsport, Pennsylvania, USA) or TelinJect (TelinJect USA Incorporated, Saugus, California, USA) dart guns. Darded deer were immobilized with a 3:1 ratio of ketamine hydrochloride and xylazine hydrochloride. Yohimbine hydrochloride was usually administered intravenously to hasten recovery time. Trapped deer were rarely ($n = 1$) chemically immobilized. I administered 1 – 3 cc of Maxim-200 (Phoenix Scientific Inc., St. Joseph, MO), a broad spectrum but short duration oxytetracycline antibiotic, to deer that suffered minor injuries during capture which could have become infected.

Upon capture, deer were ear-tagged, fitted with radio collars, sexed and aged. Only yearlings ($> 1 \frac{1}{2}$ years) and adults ($> 2 \frac{1}{2}$ years) were radio-collared. Color coded numbered ear-tags were used to expedite visual observations and sex differentiation. Radio collars (LMTR-3, Lotek Engineering, London, Ontario, Canada) weighed 280 – 290 g, were equipped with a 6-hour delay mortality sensor, and were expected to last 48 months. Non-expandable collars were placed on adult males and females. Yearling male were fitted with expandable nylon weave collars. To allow for neck swell during rut, collars placed on adult males were fitted by placing the handler's fist perpendicular to the base of the deer's neck. This was used as a sizing gauge to determine how tight to fit the collar, which normally allowed enough room for the neck swell during rut. In one instance (see survival methods), the collar cut into a

male's neck during rut. Immediately afterwards, all collared males were visually checked and there was no evidence that other males were experiencing a similar problem.

Radio telemetry error assessment and location protocol.

Deer were located with TR-4 receivers/scanners and handheld 3-element Yagi antennas (Telonics Incorporated, Mesa, Arizona, USA). My sampling protocol relied heavily on visual locations or triangulating from multiple (≥ 2) points which were usually < 500 m from the estimated deer location. To test this protocol, test collars were placed at known deer locations (but unknown to observers) within randomly selected deer home ranges. This test most closely simulated real radio-tracking conditions where general animal locations are not completely unknown to the observer. There was no difference between observers on paired bearings (Hottelings test for paired angles: $F = 0.34$, $P > 0.25$, Zar 1996:645), so all test data were pooled. Accuracy and precision of bearings was relatively poor (mean bearing error = -2.38° , $SD = 15.9$, $n = 605$), but the average distance from estimated to true location was only 59 m ($SD = 53.4$, $n = 118$). Because I wanted to evaluate telemetry precision with confidence ellipses generated from bearing standard deviations, I followed the suggestion of Lee et al. (1985) and considered all bearings with absolute errors $> 10^\circ$ as signal bounce. These bearings were deleted which resulted in a much improved bearing SD of 5.78° (mean bearing error = -2.32° , $n = 331$). I believed using a bearing standard deviation generated from all test bearings greatly overestimated confidence ellipses. Thus the 5.78° bearing SD was used to calculate all confidence ellipses for triangulated deer locations. This bearing SD generated from the reduced data set was a more realistic, yet still conservative, estimate of bearing precision. Error ellipses were calculated with the program LOCATE II (version 1.5, Truro, Nova Scotia, Canada).

Deer were located between 3 and 5 times per week from late August 1996 through December 1997. I systematically tracked different deer at the beginning of each tracking session to ensure that all deer would be located at different times. To ensure adequate representation of diurnal and nocturnal locations (Beyer and Haufler 1994), deer were sampled from as early as 0400 PST to as late as 0100 PST. Tracking schedules were alternated weekly between early and late time periods. Early tracking began 1 – 2 hrs before sunrise and usually concluded in late- morning or mid-afternoon. Late tracking began in the afternoon and usually ended between 2200 and 0100 PST. Normally, a tracking session did not end until all deer were located. To maintain temporal independence, I attempted to sample deer a minimum of 12 hours apart. Time of day (PST), habitat type, location type (triangulation, visual, or estimated visual), and level of disturbance were recorded when deer were located. Level of disturbance was defined as either an unbiased movement (deer did not flee, or if it did flee due to my presence, I was able to determine its location before disturbance), or biased movement (deer fled area due to my presence and I was unable to determine its location before it fled). All locations were plotted in the field on 1:24,000 USGS topographic maps

Deer type, seasonal, and diel period classifications.

Deer were categorized into 2 types: 'suburban/park' (henceforth suburban) and 'wild'. The amount of 'human interface area' within sites provided a repeatable criteria and was used to determine deer type within sites. Human interface area consisted of urban or suburban subdivisions, rural residential areas, ranch houses, and a county park. The county park (i.e. Whistler's Bend) was included because deer in these areas were most often habituated to human presence. Thus, deer within sites that contained < 10% human interface were classified as 'wild', while deer within sites that contained > 10% human interface were considered 'suburban'.

Seasons were classified as winter (Jan – Mar), spring (Apr – June), summer (July – Sept), and fall (Oct – Dec). These classifications closely matched changing plant phenology and deer life history stages. Fall corresponded to the rut, spring to the period of rapid plant growth and fawning, winter to the peak of the rainy season, and summer to the hot dry months. Diel periods were classified as crepuscular (2 hrs before and after sunrise or sunset), diurnal (2 hrs after sunrise to 2 hrs before sunset), and nocturnal (2 hrs after sunset to 2 hrs before sunrise). Crepuscular and nocturnal periods were ultimately pooled.

I did not attempt to differentiate between adult and yearling deer in my analyses because of small sample sizes for yearling males (most of which became adults before the radio tracking portion of the study was initiated), and poor confidence in my ability to accurately age yearling females.

Habitat associations

GIS mapping and habitat classification

A vector based GIS approach was chosen because I wanted to identify finely interspersed habitats which characterized the study area. A map of the study area was created by obtaining 1985 1:24,000 USGS orthophoto quadrangle maps. Orthophotos were scanned at 300 dpi, geo-registered, and rectified in Arc/Info (Environmental Systems Research Institute, Redlands, California, USA, version 7.2.1). Eight known latitude-longitude tic marks were used as control points for each quad map. Registration error was low (range of root mean square error: 2.9 – 3.2 meters). The map projection was then converted to UTM - NAD 1927, which allowed for accurate overlaying of deer locations and home ranges.

This 'base map' was used as background image for digitizing cover types. Perennial streams, major rivers, and roads were digitized from commercially available geo-referenced

1:24,000 topographic maps (SureMaps Raster™). In addition, 1:12,000 stereo-scopic aerial photographs taken in 1994 were used to aid in habitat type delineation and to identify areas that had changed since 1985 due to land use practices (e.g. clearing oak woodlands for grazing land, timber harvest, recent housing development). The map was then verified in field for accuracy. Discrepancies were noted and changes were made accordingly. Errors were frequent (45%) between classifications of oak and hardwood (madrone) woodlands. Therefore, these 2 cover types were pooled because I could not reliably distinguish them from aerial photographs. All digitizing was done 'on screen' in Arc/Edit (Environmental Systems Research Institute, Redlands, California, USA, version 7.2.1).

Cover types were based upon a modification of Smith's (1981,1985b) detailed descriptions of percent coverage and species composition. Initial pooling of habitats was done to provide the most power for detecting selection of habitats that shared common features and could be reasonably interpreted from aerial photographs. Separation into many finely interspersed cover types (i.e. grassland and pasture) would have resulted in lower power to detect habitat selection (White and Garrott, 1986). The 9 cover types used in my analyses (Fig. 1.2.) were:

1. Grassland: This cover type was dominated by annual and perennial grasses and forbs described extensively by Smith (1981, 1985b). Dominant grass species included tall fescue (*Festuca arundinacea*), perennial ryegrass (*Lolium perenne*), hedgehog dogtail (*Cynosurus echinatus*), medusahead (*Taeniatherum asperum*) and soft brome (*Bromus mollis*). Shrub and tree canopy cover were < 25% and 5 < %, respectively. Improved sub-clover (*Trifolium subterraneum*) pastures that were variably grazed by cattle and sheep were pooled with grassland. Some grasslands and sub-clover pastures were cut for hay and burned annually in early summer.

2. Grass shrub: Poison oak (*Rhus diversifolia*), wild rose (*Rosa eganteria*), introduced hawthorne (*Crataegus* sp.), native and introduced blackberry (*Rubus*) species dominated this cover type. Sapling douglas fir (*Psuedotsuga menziessi*) and hardwoods, as well as several species of grasses and forbs, were widely interspersed. Shrub and tree canopy cover were > 25% and < 5%, respectively. Clear-cut conifer/hardwood conifer stands and oak/hardwood woodlands were included in this cover type.
3. Oak-hardwood savanna: Species composition in this cover type was similar to grassland, but tree canopy cover varied from roughly 5 – 50%. Tree species most commonly consisted of Oregon white oak (*Quercus garryana*) and black oak (*Quercus kelloggii*), but madrone (*Arbutus menziessi*) occasionally occurred as well.
4. Oak-hardwood savanna shrub: Species composition in this cover type was similar to grass-shrub, but tree canopy cover varied from roughly 5 – 50%. Tree species most often consisted of madrone, Oregon white oak, black oak, and regenerating douglas fir. Selectively harvested conifer/hardwood conifer stands and partially cleared oak-hardwood woodlands were pooled into this habitat type.
5. Oak-hardwood woodland: This cover type was dominated by > 50% closed canopy Oregon white oak and black oak. Understory was usually closed and consisted primarily of poison oak. However, understories tended to be open in areas grazed by livestock. Hardwood woodlands were included in this cover type and were characterized by madrone dominated stands with dense understories of poison oak and wild rose.
6. Oak-hardwood conifer: This cover type was characterized by a variable mixture of oaks, madrones, douglas fir, and western red cedar (*Thuja plicata*). Conifers composed at least 25% of canopy cover. Understories consisted of poison oak, wild rose and various blackberry species.

7. Conifer: This cover type was dominated by > 90% canopy closure of monotypic douglas fir. Stands usually lacked a well developed shrub understory and few grasses and forbs, except when there were openings in the canopy. In lower elevations, these stands typically were remnants of larger cut-over stands or were found in a county park (Whistler's Bend). Higher elevation stands tended to be more expansive industrial forests and often bordered the study sites.
8. Riparian: This cover type was characterized by stream associated plant communities in low lying, gradual slope areas, generally within at least 10 m of a stream. Overstory canopies varied from > 50% closed to completely open. Tree species in closed canopied riparian areas included Oregon ash (*Fraxinus latifolia*), red alder (*Alnus rubra*), big-leaf maple (*Acer macrophyllum*), and Oregon white oak. Shrub species within dense understories included poison oak, various blackberry species, hawthorne, and wild rose. Open riparian areas were found in poorly drained soils and dominated by common rush (*Juncus effusus*), sedge (*Carex* sp.), and various grasses.
9. "Yard": This cover type included areas < 50m of human development. It was characterized by houses, gardens, lawns, manicured fields, and small orchards and tree farms.

Minimum patch size was approximately 1.0 ha. A grid of 1.0 ha cells was generated and placed over the base map to enable visual estimation of minimum patch sizes, as well as percent life-form (e.g. grass, shrub, tree) coverage and overstory composition. "Yard" cover types were allowed to be less than 1 ha because I did not want to over-estimate the amount of human influenced habitat. Furthermore, riparian and developed habitats were not buffered by a set width due to their irregular and often unpredictable shapes and extent of vegetation or development. For example, riparian areas could either be relatively intact and wide or

disturbed up to the existing stream-bed, while 'yards' ranged from small ranch houses to extensive sub-divisions. Habitat attributes for all subsequent analyses were obtained from overlays in Arc/Info.

Annual habitat association analyses

Annual patterns of habitat use were examined by calculating the proportion of each animal's locations in each cover type. Observed use was defined as the percentage of locations within a particular cover type. Differences in annual habitat use by sex and type were tested with a multivariate analysis of variance (MANOVA). If significant ($P < 0.05$) overall differences in use were identified by the MANOVA, univariate analysis of variance (ANOVA) were conducted on each cover type to determine which cover types were 'causing' the overall significant difference (Hintze 1998). The conifer cover type was deleted from the MANOVA because the proportional use of cover types would sum to 1 if all cover types were included (Weckerly 1993) and it was the least used and available cover type. A separate 2 factor ANOVA was conducted to examine the effects of sex and type on conifer cover type use. Transformations of response variables were performed by taking the arc-sine of the square root of each proportion in order to meet assumptions of normality and homoscedasticity. Wilks' lambda was the test statistic reported for MANOVA results.

All annual habitat selection analyses were of a 'design 3' type, where both use and availability were measured at the individual level (Thomas and Taylor 1990, Manly et al. 1993:7). Availability of cover types and landscape features was quantified within 100% minimum convex home range polygons for 32 deer. The quality of a deer location was assessed by error ellipse size for triangulations and degree of disturbance for visual locations of deer. I did not use triangulations whose error ellipse area exceeded the size of the cover type

patch containing the location. Also, locations where biased movements occurred were excluded from all habitat selection analyses.

Henceforth, I describe selection patterns as the disproportionate use of a cover type relative to its availability. I avoid using the term 'preference' because invoking preference involves presenting an animal with a choice of several equally available resources (Johnson 1980). Bonferroni confidence intervals were used to test for annual patterns of cover type selection (use greater than expected) or avoidance (use less than expected) for individual deer based on the proportion of locations in available cover types (Neu et al. 1974, Byers et al. 1984). I referred to instances where use was neither greater than nor less than expected as 'neutral selection-avoidance'. I was most interested in determining selection for individual cover types, thus I do not report results from chi-square analyses which are often used 'as a first step' to test the null hypothesis that overall habitat use is proportionate to availability (Neu et al. 1974). According to Cherry (1998), chi-square tests can often lead to non-sensical results because the null hypothesis can be rejected but then there is no evidence of selection or avoidance when confidence intervals for individual habitats are used. Differences between the proportion of cover types available and selected by sex and type were tested with Z tests for equal proportions (Ramsey and Schafer 1997:523).

Distance to stream and edge effects

Logistic regression (Manly et al. 1993:71) was used to determine the effect of distance to stream and edge on annual habitat selection. Distance to stream was calculated for each location in Arc Info. Relative amount of edge was calculated as the ratio of perimeter to area for each cover type patch, and locations that fell within a particular patch were assigned that patch's relative amount of edge attribute. Approximately 500 random locations within each deer's home range (100% MCP) were generated to estimate availability of distance to stream

and relative amount of edge. Due to the type 3 design where availabilities differed for each deer, all deer could not be pooled into a single analysis, so models were fit for each deer. Only main effects were fit in order to provide easy and parsimonious comparisons among deer. Results were summarized for all deer by whether the odds of use significantly increased or decreased relative to distance to stream and cover type patch size. Z tests for equal proportions were used to test for differences in the proportions of deer by sex and type that exhibited significant increase in use with decreasing distance from stream and increasing amount of edge. Wald chi-square tests were used to determine significance ($P < 0.05$), and 95% confidence intervals for odds ratios are reported.

Diel period

Logistic regression was also used to model the effect of diel period on annual habitat selection. Locations obtained during nocturnal and crepuscular periods were pooled into a single 'night' category. Availability was assumed to be equal during night and day. Thus, day and night locations were treated as a binomial response variable. Because the question of interest was whether open cover types were selected at night, cover types were pooled into open and closed cover type categories. Open cover types included grassland, grass-shrub, oak-hardwood savanna, oak-hardwood savanna shrub, and yard. Closed cover types included oak-hardwood woodland, oak-hardwood conifer, conifer, and riparian. Again, different cover type availabilities for each deer prohibited pooling of all deer into 1 model, so separate models were fit for each deer. One deer was excluded from this analysis because limited access hindered nocturnal sampling. Results were summarized for all deer by whether the odds of use for open cover types significantly increased or decreased at night and were categorized by sex and type. Differences in the proportion of deer by sex and type that exhibited a significant increase in use of open cover type at night were tested with Z tests of equal proportions. Wald chi-square tests

were used to determine significance ($P < 0.05$), and 95% confidence intervals for odds ratios are reported.

Seasonal habitat associations

Seasonal habitat use was examined in a similar manner as annual habitat use, where the proportion of each animal's locations in each of the 9 cover types within a particular season was calculated. Differences in habitat use by sex, type, and season were tested with MANOVA. If significant ($P < 0.05$) overall differences in cover type use were identified by the MANOVA, ANOVA was conducted on each cover type in order to determine which cover types were 'causing' the significance (Hintze 1998). Conifer was omitted from the MANOVA, and differences in conifer use by sex, type, and season were examined with ANOVA. Proportions were arc-sine square root transformed to meet assumptions of normality and homoscedasticity. Wilks' lambda was the test statistic reported for MANOVA results.

To examine seasonal habitat selection, individual deer were pooled by site in order to obtain adequate sample sizes. Of the original 12 study sites (Fig. 1.1), 3 adjacent sites (NBHMA-W/Jackson Ranch, Whistlers Bend Park/Whistlers Road, and Ramp Canyon/Parrot Creek) were pooled together, and 2 sites (Jones Ranch and Buckhorn Road) were deleted because they contained only 1 deer each. This resulted in a total of 6 sites used for seasonal habitat selection analyses. Cover type availability for each study site was delineated by a 100% MCP home range calculated from all deer locations. Bonferroni confidence intervals were used to test for selection or avoidance of particular cover types within sites. Differences in habitat selection by sex and type were not examined because of inadequate and inconsistent sample sizes between study sites.

Habitat selection within areas of concentrated use:

Program KERNELHR (Seaman et al. 1998) was used to estimate annual 99% fixed kernel utilization distributions. Annual areas of concentrated use were estimated using a subroutine for program KERNELHR (Seaman et al. 1998) called PLOT CNTR (available from B. Griffith, Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks). PLOT CNTR estimates areas of concentrated use by calculating the average observation density of all locations in a given set and then determines the contour where the observation density is greater than average. The average observation density is calculated as the sum of the linear array of the observed densities divided by the number of observed locations. The advantage of this methodology is that it avoids subjective and arbitrary contour selections, and each area of concentrated use is based solely on the change in density of locations within a particular sample (S. A. Wolfe, Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks, pers. commun.). I refrain from calling areas of concentrated use 'core areas' because I did not test against a null distribution of bivariate uniform locations within the home range (Samuel et al. 1985, Bingham and Noon 1997).

Compositional analysis (Aebischer et al. 1993) was used to test the null hypothesis that proportions of area within areas of concentrated use were random with respect to cover type and proximity to streams when compared to proportions of area within 99% fixed kernel utilization distributions. Compositional analysis accounts for the non-independence of proportions summing to 1, uses each animal as an experimental unit, and is well suited for testing differences between proportions of used and available habitat (Aebischer et al. 1993). Used and available habitats were the proportion of area for a particular cover type or distance to stream class within concentrated use areas and 99% fixed kernel utilization distributions of individual deer, respectively. Compositional analysis consisted of 2 stages. First, the proportion of use for a particular habitat for a given deer was divided by its availability. In

order to account for non-independence of proportions, one used:available habitat proportion was deleted and was then used to divide the remaining resource proportions. The choice of the habitat to use as the denominator does not affect results (Aitchison 1986). The resulting ratios were log transformed to produce log ratios (Aebischer et al. 1993, Warnock and Takekawa 1995). Multivariate analysis of variance (MANOVA) was then used to test for differential habitat use (i.e. the average of the log ratios is significantly different from zero). Second, when significant differences are detected, differences between mean log ratios were tested with *t*-tests, and habitats were ranked from least to most utilized (Aebischer et al. 1993, Warnock and Takekawa 1995). Cover types were pooled into 6 classes in order to ameliorate problems associated with zero availability (Aebischer et al. 1993). The pooled cover types, based on common shrub and conifer characteristics, were 1) grassland - oak savanna, 2) grass shrub - hardwood savanna shrub, 3) oak - hardwood woodland, 4) hardwood conifer – conifer, 5) riparian, and 6) yard. Streams were buffered by successive 100 m increments in Arc/Info. Distance to stream was then categorized into 5 distance classes (0 –100 m, 101 – 200 m, 201 – 300 m, 301 – 400 m, > 401 m). A value of 0.001 was substituted for all remaining missing pooled cover type and distance to stream use and availability values to ameliorate statistical problems with zeros. Lastly, differences in log-ratios between sex and type were tested with MANOVA when significant differences in overall resource utilization occurred (Aebischer et al. 1993, Warnock and Takekawa 1995). All compositional analyses were conducted in Resource Selection for Windows (Leban 1999).

RESULTS

After removing locations with excessive telemetry error and disturbance ($n = 151$), 4760 locations from 32 deer were used for annual habitat association analyses, and 4914 locations from 36 deer were used for seasonal habitat association analyses. Average elapsed

time between locations was 2.48 days (SD = 2.49), and median elapsed time (which is less influenced by extreme time intervals between locations) was 1.44 days. Thus, biological and statistical independence of locations was maintained because I obtained a representative sample of locations across a time period long enough for a deer to traverse its entire home range and chose an unique habitat type (White and Garrott 1990:148, McNay et al. 1994).

Annual habitat associations

Cover type use

On an annual basis, oak-hardwood woodland (23%) was the most frequently used cover type, followed by riparian (18%), oak-hardwood savanna shrub (15%) and grassland (10%). All other cover types were used < 10% of the time (Fig. 2.1 , Appendices 2.1 – 2.9). Excluding conifer cover types, differences in annual overall cover type use were not significant between sexes ($\lambda = 0.779$, d.f. = 8, 21, $P = 0.653$), but were significant between types ($\lambda = 0.413$, d.f. = 8, 21, $P = 0.007$). Univariate ANOVA's revealed that wild deer used grassland more frequently ($\bar{x} = 0.15$) than suburban deer ($\bar{x} = 0.09$) ($F = 4.40$, d.f. = 1, 28, $P = 0.045$), while wild deer used yard less frequently ($\bar{x} = 0.00$) than suburban deer ($\bar{x} = 0.21$) ($F = 16.22$, d.f. = 1, 28, $P = 0.0003$). Differences in cover type use between suburban and wild deer were consistent by sex because there was no significant interaction between sex and type ($\lambda = 0.611$, d. f. = 1, 28, $P = 0.165$). There were no significant differences in annual use of conifer cover types by sex ($F = 2.68$, d. f. = 1, 28, $P = 0.112$) or type ($F = 2.03$, d.f. = 1, 28, $P = 0.165$), and there was no significant interaction between sex and type ($F = 1.24$, d. f. = 1, 28, $P = 0.275$).

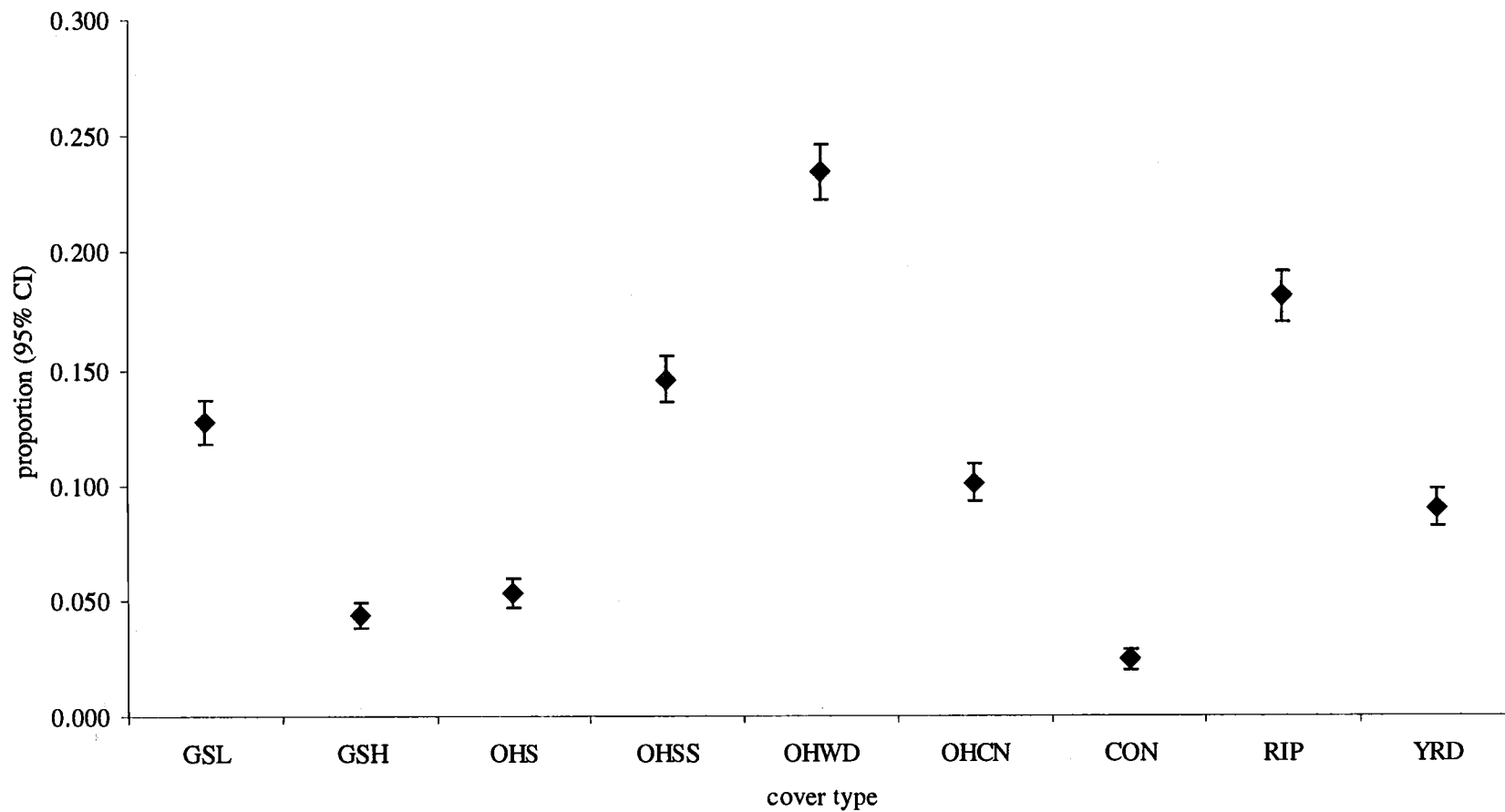


Figure 2.1 Proportion of annual radio telemetry locations (and 95% confidence intervals) by cover type for 32 adult Columbian white-tailed deer in Douglas County, Oregon, 1996-97. GSL = grassland, GSH = grass shrub, OHS = oak savanna, OHSS = oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHCN = oak-hardwood conifer, CON = conifer, RIP = riparian, YRD = yard.

Cover type selection

Selection patterns of use relative to availability tended to be quite variable among individual deer for all cover types (Fig. 2.2). The range of percent use - availability in most cases was within $\pm 20\%$. Grassland, oak-hardwood savanna, oak-hardwood savanna shrub, oak-hardwood woodland, and oak-hardwood conifer exhibited the greatest variability in percent use - availability because use - availability of these cover types was almost equally divided between greater than and less than zero. Conversely, percent use - availability for riparian and yard was positive for most deer (Fig. 2.2). When selection was quantified by the Neu et al. (1974) method, no single cover type appeared to be consistently selected on an annual basis (Fig. 2.3, Appendices 2.1 - 2.9). The most frequently selected cover type by deer was riparian (31%). Yard and oak-hardwood conifer were selected by 13% of deer, while oak-hardwood woodland, conifer, oak-hardwood savanna shrub, and grassland cover types were selected by 9% of deer. Grass shrub and oak-hardwood savanna were rarely selected (3%). Conversely, the most apparent trend was for avoidance and neutral selection-avoidance. The percentage of deer exhibiting avoidance and neutral selection-avoidance was nearly equivalent for most cover types, except for riparian and conifer cover types. A lower percentage of deer exhibited avoidance of riparian (6%) compared to neutral selection-avoidance (63%), while a higher percentage of deer appeared to exhibit avoidance of conifer (31%) compared to neutral selection-avoidance (12%). Most cover types were available to at least 80% of deer except for conifer (47%) and yard (44%), which were the least available cover types within deer home ranges (Fig. 2.3).

Patterns of selection were similar between sexes. Males (0.89) had a higher proportion of cover types available within their home ranges than females (0.81) ($Z = 1.86$, $P = 0.03$), but the overall proportion of cover types selected by males (0.11) did not differ from females (0.15) ($Z = 1.05$, $P = 0.14$). Riparian and yard were selected equivalently by males and

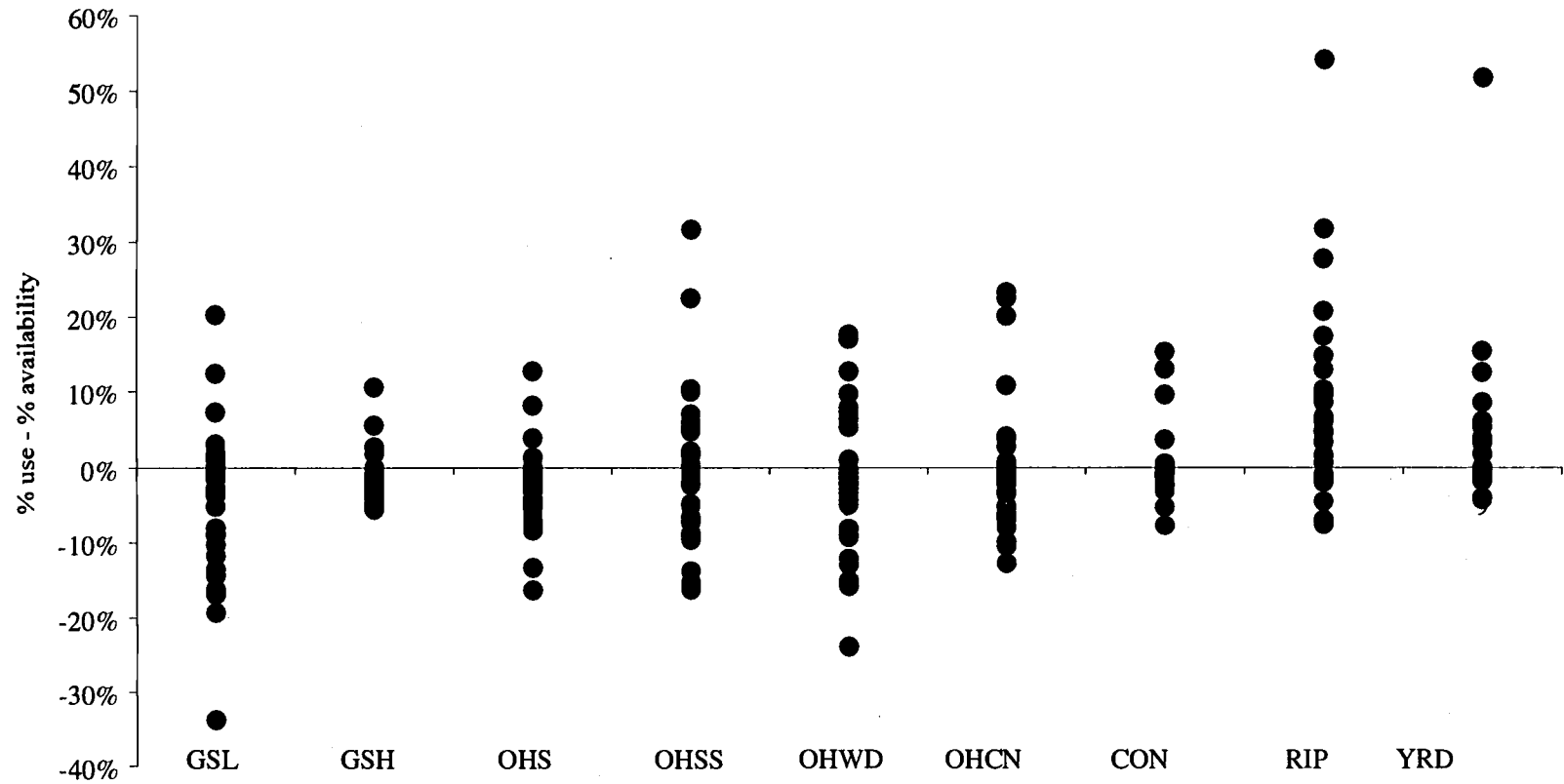


Figure 2.2. Percent use minus percent availability within annual MCP home ranges which illustrates variability in cover type selection among individual adult Columbian white-tailed deer, Douglas County, Oregon, 1996-97. Not all cover types are available for all 32 deer. Each 'dot' represents an individual adult deer. GSL = grassland, GSH = grass shrub, OHS = oak savanna, OHSS = oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHCN = oak-hardwood conifer, CON = conifer, RIP = riparian, YRD = yard.

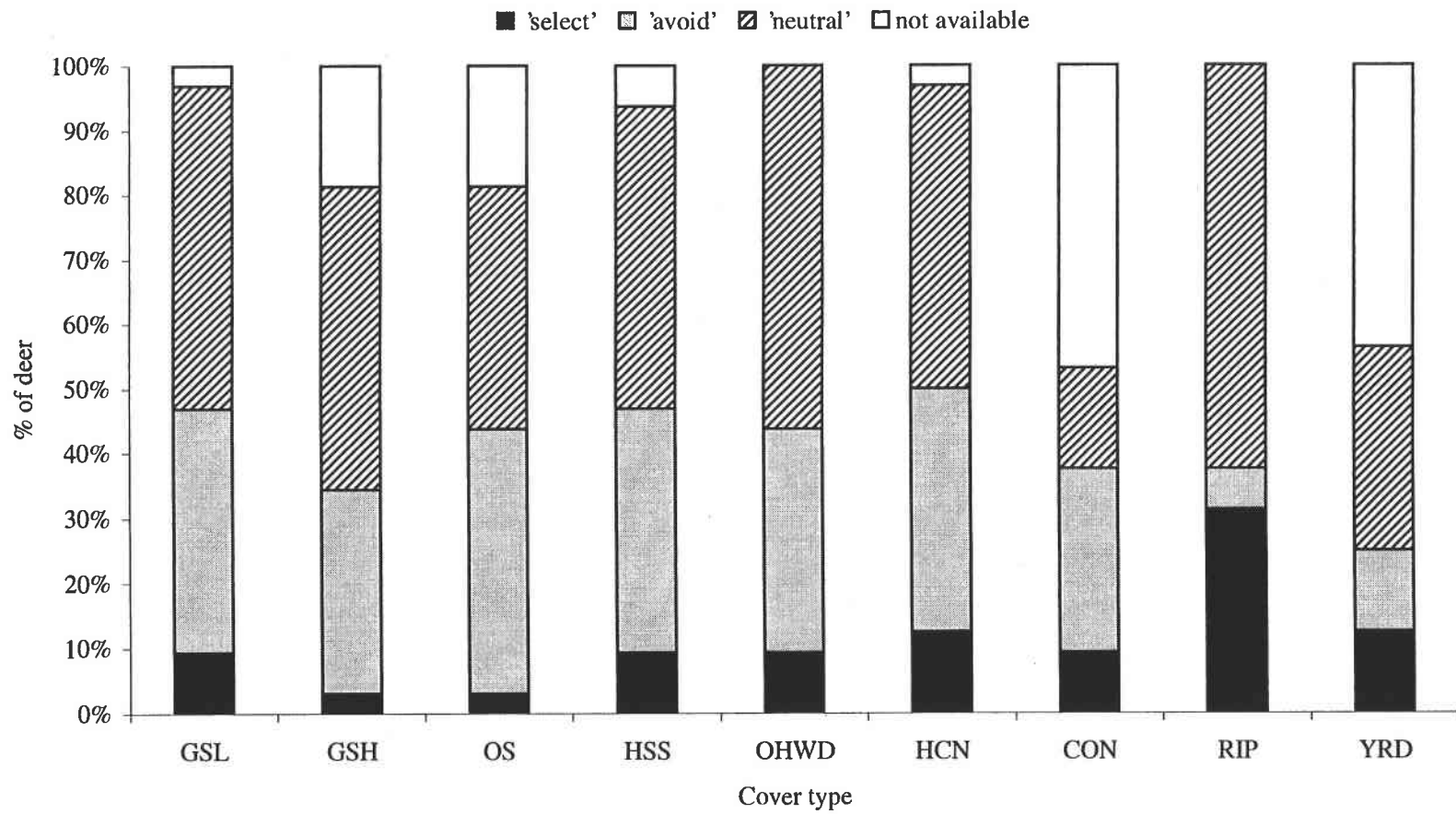


Figure 2.3. Annual cover type selection patterns for 32 adult Columbian white-tailed in Douglas County, Oregon, 1996-1997. GSL = grassland, GSH = grass shrub, OHS = oak savanna, OHSS = oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHCN = oak-hardwood conifer, CON = conifer, RIP = riparian, YRD = yard.

females although only females selected oak-hardwood savanna shrub and oak-hardwood conifer. Males never selected oak-hardwood savanna, oak-hardwood savanna shrub, or oak-hardwood conifer, whereas females never selected grass-shrub (Fig. 2.4A).

Patterns of selection were also similar when examined by type. The overall proportion of available cover types did not differ between wild (0.85) and suburban deer (0.84) ($Z = 0.24$, $P = 0.41$). Also, the overall proportion of cover types selected by wild deer (0.11) was not significantly different from suburban deer (0.16) ($Z = 1.20$, $P = 0.12$). However, twice as many wild deer selected riparian relative to suburban deer. Nearly by definition, only suburban deer selected yards. Suburban deer never selected grassland or oak-hardwood savanna, and wild deer never selected grass shrub cover types (Fig. 2.4B).

Distance to stream and edge effects

Proximity to streams had a strong effect on habitat use. The odds of use significantly decreased with increasing distance away from streams for 56% of all deer on an annual basis, and only 13% of all deer exhibited higher odds of use for areas farther away from streams (Table 2.1, Appendix 2.10). However, there was little overall effect due to amount of edge within individual cover types patches because there was no significant relation between edge and odds of use for 81% of deer. Only 6% of deer demonstrated a significant increase in odds of use for patches with high amounts of edge, and 13% of deer exhibited a significant decrease in odds of use with increasing amount of edge. There was no significant difference in the proportion of males (0.56) and females (0.55) using habitats closer to streams ($Z = 0.09$, $P = 0.46$). Similarly, there was no significant difference in the proportion of suburban deer (0.62) and wild deer (0.74) exhibiting increasing use with decreasing distance from streams ($Z = 0.72$, $P = 0.23$). Differences in the effect of relative amount of edge between sex and type were not

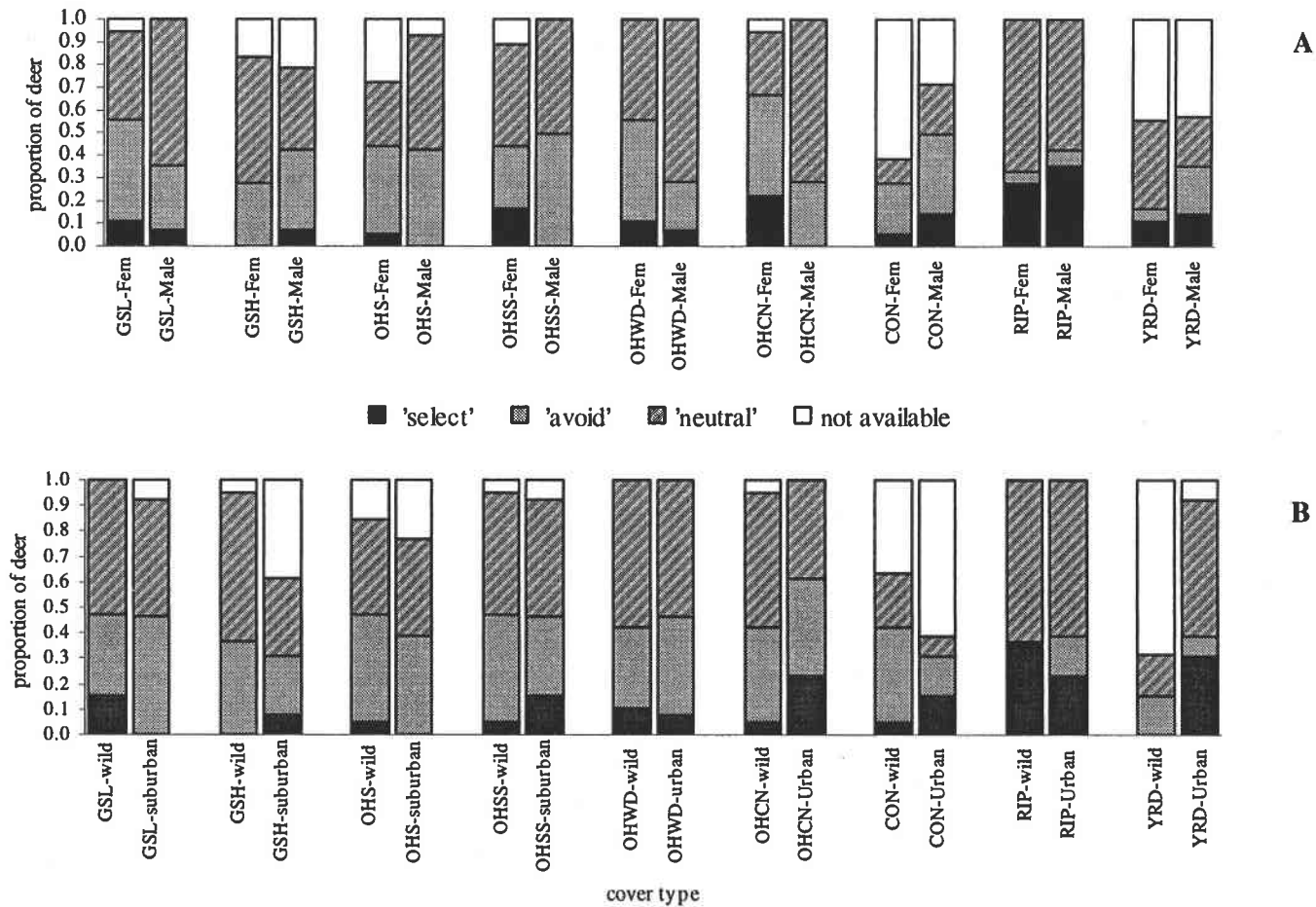


Figure 2.4. Annual cover type selection patterns by sex (A) and type (B) for 32 adult Columbian white-tailed in Douglas County, Oregon, 1996 – 1997. GSL = grassland, GSH = grass shrub, OHS = oak savanna, OHSS = oak-hardwood savanna shrub, OHWD = oak- hardwood woodland, OHCN = oak-hardwood conifer, CON = conifer, RIP = riparian, YRD = yard.

Table 2.1. Summary for the effects of distance to stream and relative amount of edge (edge ratio) on the odds of habitat use ^a for adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Variable		n	\bar{x} ^b	SD ^b	% Deer		
					Odds of Use Increase	Odds of Use Decrease	No effect
Distance to creek	Male	14	194.7	60.4	14	58	29
	Female	18	138.7	29.7	11	56	33
Edge ratio	Male	14	0.032	0.023	21	7	72
	Female	18	0.034	0.022	11	11	78
Distance to creek	Suburban	13	163.7	56.0	15	62	23
	Wild	19	162.5	53.1	11	74	16
Edge ratio	Suburban	13	0.039	0.034	15	8	77
	Wild	19	0.029	0.021	16	0	84
Distance to creek	All	32	163.2	54.0	13	56	31
Edge Ratio	All	32	0.033	0.023	6	13	81

^a odds of use relative to decreasing distance from creek and increasing amount of edge (edge ratio)

^b mean and standard deviation calculated from means from individual deer. Units of measurement are meters for distance to stream and edge ratio

tested because too few deer ($n = 2$) exhibited an increase in use with increasing edge (Table 2.1, Appendix 2.10).

Diel period

The majority of deer (68%) had significantly higher odds of use of open cover types compared to closed cover types at night. In addition, use of closed cover types was never higher than use of open cover at night, while 32% of deer exhibited no effect in cover type use due to diel period (Table 2.2). The proportion of males (0.71) and females (0.65) using open cover types more frequently at night was not significantly different ($Z = 0.35$, $P = 0.36$). The proportion of suburban deer (0.77) and wild (0.61) deer exhibiting increased use of open cover types at night also was not significantly different ($Z = 0.82$, $P = 0.21$) (Table 2.2).

Seasonal habitat associations

Cover type use

There were no significant differences in overall cover type use among seasons ($\lambda = 0.772$, d.f. = 24, 352, $P = 0.121$). Across all seasons, oak-hardwood woodland and riparian were the most frequently used cover types. Use of oak-hardwood woodland and riparian cover types increased (but not significantly) during spring and summer, respectively, while use of conifer and grass shrub remained consistently low (Fig. 2.5). However, there were significant overall differences in cover type use by sex ($\lambda = 0.867$, d. f. = 8, 121, $P = 0.024$) and type ($\lambda = 0.570$, d.f. = 8, 121, $P = 0.000$) when controlling for season and excluding conifer cover types. By sex, males ($\bar{x} = 0.13$) used grassland more frequently than females ($\bar{x} = 0.10$) ($F = 6.48$, d.f. = 1, 128, $P = 0.012$). All other univariate tests by sex were insignificant ($P \geq 0.12$). By

Table 2.2. Results from logistic regression models demonstrating the odds of open cover type use compared to closed cover type use during crepuscular-nocturnal periods, as compared to diurnal periods, for individual adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	regression coefficient	SE	Wald's χ^2	<i>P</i>	odds ratio	Lower LR CI ^a	Upper LR CI ^a
22	0.91	0.36	6.34	0.012	2.49	1.23	5.13
51	0.65	0.38	3.02	0.082	1.92	0.93	4.10
62	0.17	0.40	0.17	0.679	1.18	0.53	2.57
71	0.75	0.37	4.18	0.041	2.12	1.04	4.42
82	0.93	0.35	7.07	0.008	2.54	1.29	5.12
90	1.85	0.38	24.36	0.000	6.37	3.10	13.58
132	-0.13	0.36	0.13	0.723	0.88	0.43	1.76
151	1.71	0.38	20.76	0.000	5.52	2.69	11.78
171	1.47	0.68	4.69	0.030	4.35	1.27	20.03
181	-0.11	0.63	0.03	0.856	0.89	0.26	3.23
201	1.43	0.38	13.79	0.000	4.16	2.00	9.12
212	1.41	0.36	15.15	0.000	4.11	2.04	8.50
221	0.60	0.37	2.61	0.106	1.82	0.89	3.85
232	2.08	0.38	30.21	0.000	8.01	3.91	17.37
290	1.99	0.43	21.82	0.000	7.31	3.29	17.73
300	1.49	0.37	16.02	0.000	4.42	2.16	9.32
311	2.47	0.56	19.09	0.000	11.80	4.31	41.71
321	0.82	0.42	3.85	0.050	2.27	1.02	5.37
352	-0.68	0.44	2.41	0.120	0.50	0.20	1.16
361	1.74	0.38	21.01	0.000	5.70	2.74	12.23
371	0.17	0.42	0.16	0.685	1.18	0.52	2.69
391	0.43	0.35	1.50	0.221	1.53	0.77	3.06
401	1.28	0.35	13.13	0.000	3.61	1.82	7.34
411	0.27	0.35	0.61	0.435	1.32	0.66	2.64
431	0.86	0.37	5.49	0.019	2.37	1.16	4.95
462	1.41	0.37	14.35	0.000	4.11	2.01	8.73
481	-0.62	0.38	2.70	0.100	0.54	0.26	1.12
1042	2.40	0.40	35.83	0.000	11.01	5.16	25.05
1061	2.12	0.39	29.75	0.000	8.36	4.01	18.58
1072	0.78	0.35	5.08	0.024	2.18	1.13	4.34
1092	1.37	0.42	10.48	0.001	3.94	1.77	9.48

^a likelihood ratio based 95% confidence interval for odds ratio

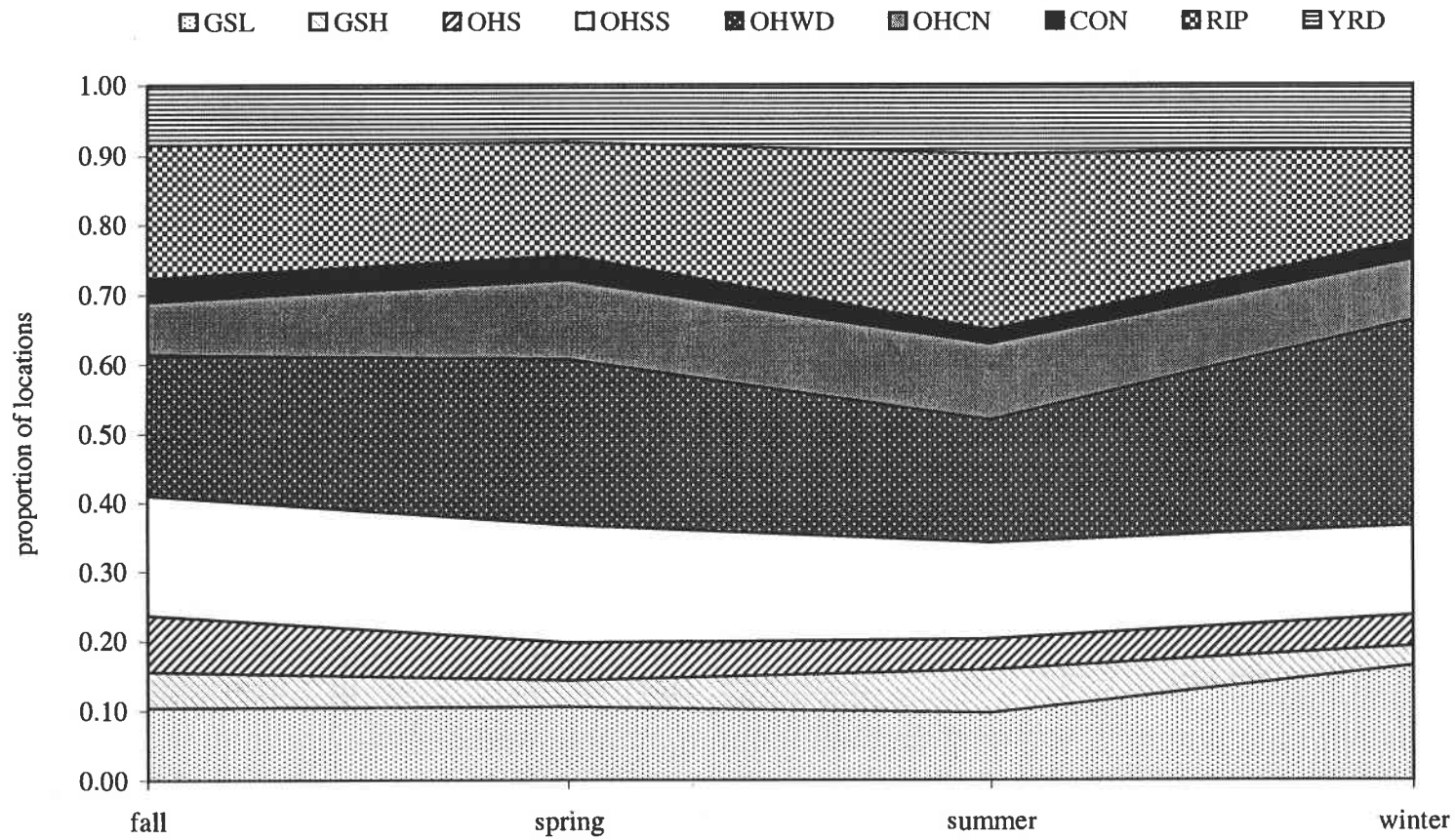


Figure 2.5. Proportion of radio telemetry locations within cover types and across seasons for adult Columbian white-tailed deer in Douglas County, Oregon, 1996-97. GSL = grassland, GSH = grass shrub, OHS = oak savanna, OHSS = oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHCN = oak-hardwood conifer, CON = conifer, RIP = riparian, YRD = yard.

type, wild deer used grassland, oak-hardwood savanna, oak-hardwood woodland, and riparian cover types more frequently than suburban deer. Conversely, use of yards and oak-hardwood conifer was 20% and 13% by suburban deer compared to 1% and 6% by wild deer, respectively (Appendix 2.11). There were no significant ($P \geq 0.749$) interactions between sex and season or type and season, although differences in cover type use were not consistent between sex and type when controlling for season ($\lambda = 0.814$, d.f. = 8, 121, $P = 0.001$).

Controlling for season, use of conifer cover types did not differ by sex ($F = 1.57$, d.f. = 1, 128, $P = 0.212$), but suburban deer used conifers more frequently ($\bar{x} = 0.5$) than wild deer ($\bar{x} = 0.01$) ($F = 8.04$, d.f. = 1, 128, $P = 0.005$). However, deer used conifers in equivalent proportions among seasons ($F = 0.20$, d.f. = 3, 128, $P = 0.893$). All interactions were insignificant.

Cover type selection

Patterns of seasonal cover type use compared to availability within the 6 sites were similar to annual cover type selection by individual deer. Riparian areas were the most frequently selected cover type, as they were selected in at least 4 sites during all seasons and were selected in 5 sites during summer and fall. Selection for other cover types tended to be low across seasons, as no cover type was selected in more than 2 sites during a particular season. The most prevalent trend was for avoidance or 'neutral' selection for most cover types. For example, oak-hardwood woodland was only selected in winter (1 site), and there was only neutral selection - avoidance during spring. Oak hardwood conifer was selected in 2 sites during spring, summer and winter. Oak-hardwood savanna shrub was only selected in winter, while neutral selection-avoidance was the most frequent pattern across all seasons. Grassland was avoided or neutrally selected - avoided in all sites in fall but was selected in at least 1 site in all other seasons. Oak-hardwood savanna was only selected at 1 site in fall and was avoided

in 4 sites during summer. Yard was selected 50% of sites where it was available, and was avoided in 1 site, during spring, summer, and fall (Fig. 2.6).

Habitat selection within areas of concentrated use

For all deer, cover types within areas of concentrated use were used at random. There were no significant patterns of cover type selection within areas of concentrated use because the composition of cover types in these areas was not significantly different from that of cover types within 99% fixed kernel utilization distributions ($\lambda = 0.82$, $\chi^2 = 6.21$, $P = 0.28$). This lack of cover type selection in areas of concentrated use remained consistent between sexes (males: $\lambda = 0.53$, $\chi^2 = 8.84$, $P = 0.11$; females: $\lambda = 0.67$, $\chi^2 = 7.43$, $P = 0.20$) and types (wild: $\lambda = 0.64$, $\chi^2 = 8.43$, $P = 0.13$; suburban: $\lambda = 0.49$, $\chi^2 = 9.20$, $P = 0.10$) (Table 2.3). However, areas of concentrated use were not used at random with respect to distance from stream ($\lambda = 0.28$, $\chi^2 = 40.54$, $P < 0.0001$). Areas of concentrated use had significantly more area within 0 – 100 m and 100 – 200 m from streams, and were least composed of areas > 301 m from streams, when compared to the amount of available distance to stream class area within 99% fixed kernel utilization distributions (Table 2.3). However, selection for distance to stream classes within areas of concentrated use was similar between sexes and types because log-ratios for distance to stream classes did not significantly differ between males and females ($\lambda = 0.83$, $P = 0.25$) and wild and suburban deer ($\lambda = 0.90$, $P = 0.57$).

DISCUSSION

Habitat specialist vs. generalist

According to Rosenzweig (1981), a generalist can be considered a ‘jack of all trades’ and has equal fitness in all patches, while a specialist has differential fitness between patches.

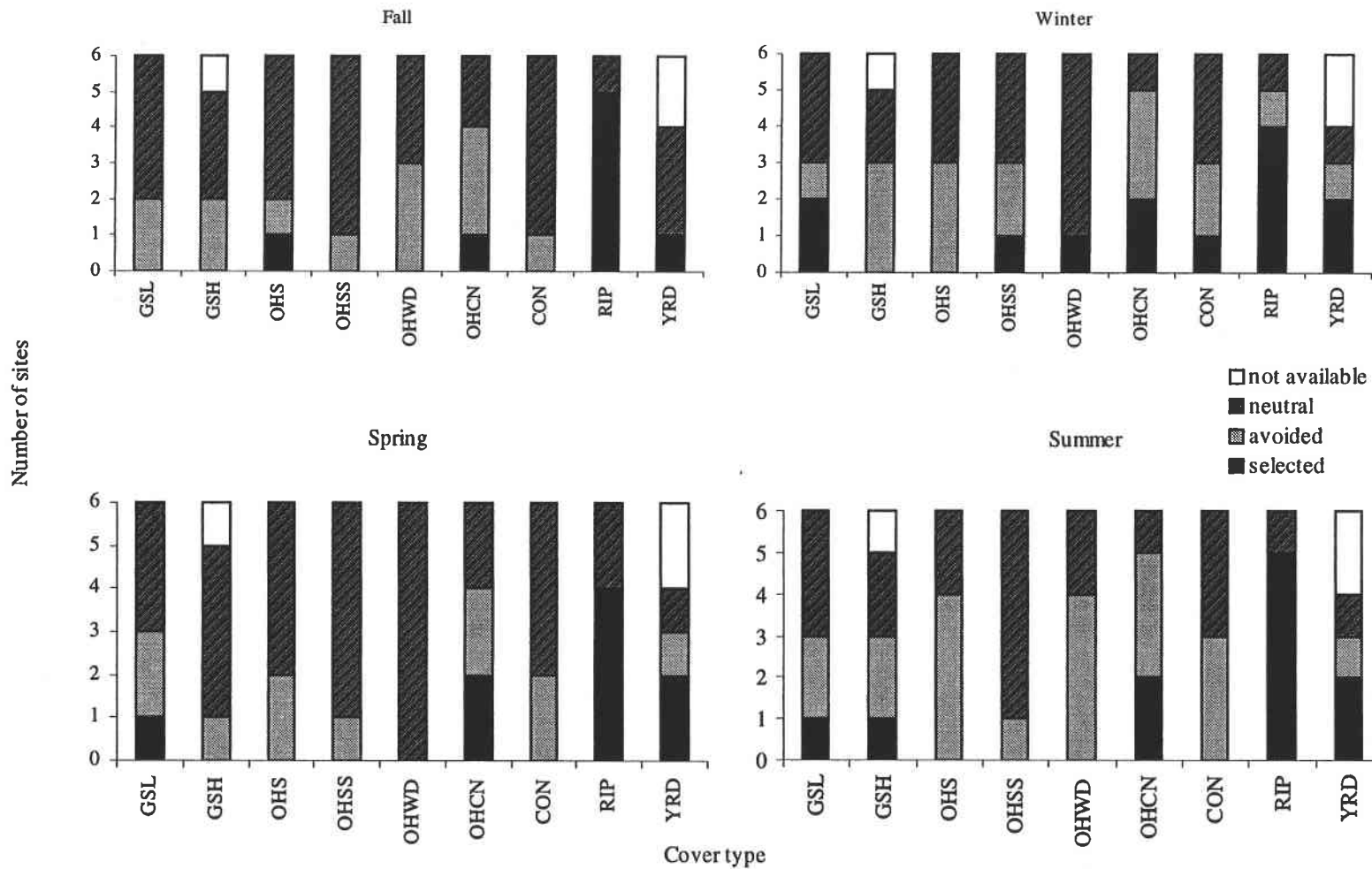


Figure 2.6. Seasonal cover type selection patterns for 6 sites containing adult Columbian white tailed in Douglas County, Oregon, 1996-1997. GSL = grassland, GSH = grass shrub, OHS = oak savanna, OHSS = oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHCN = oak-hardwood conifer, CON = conifer, RIP = riparian, YRD = yard.

Table 2.3. Mean proportions of use (availability) for cover types and distance to stream classes for adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97. Proportions are based on the amount of area for a given cover type or distance to stream class within areas of concentrated use (used) and 99% fixed kernel home ranges (available). Selection for distance to stream classes with the same superscripts are not significantly ($P < 0.05$) different.

Group	Cover Type ^a					
	GSL – OHS	GSH – OHSS	OHWD	OHCN-CON	RIP	YRD
All	0.18 (0.22)	0.18 (0.20)	0.22 (0.26)	0.13 (0.12)	0.18 (0.12)	0.11 (0.07)
Male	0.16 (0.24)	0.16 (0.19)	0.27 (0.28)	0.13 (0.12)	0.18 (0.11)	0.11 (0.06)
Female	0.18 (0.21)	0.20 (0.21)	0.19 (0.23)	0.13 (0.13)	0.19 (0.13)	0.12 (0.09)
Wild	0.21 (0.24)	0.17 (0.23)	0.27 (0.29)	0.06 (0.10)	0.25 (0.13)	0.02 (0.01)
Suburban	0.12 (0.20)	0.19 (0.17)	0.15 (0.21)	0.22 (0.15)	0.08 (0.10)	0.25 (0.16)

Group	Distance to stream class (m)				
	0 – 100	101 – 200	201 – 300	301 – 400	> 401
All	0.48 (0.37) ^A	0.32 (0.25) ^A	0.11 (0.17) ^B	0.04 (0.09) ^{BC}	0.06 (0.12) ^{BC}
Male	0.52 (0.35)	0.22 (0.23)	0.08 (0.15)	0.05 (0.10)	0.12 (0.17)
Female	0.44 (0.38)	0.39 (0.27)	0.12 (0.18)	0.02 (0.09)	0.02 (0.09)
Wild	0.36 (0.37)	0.41 (0.27)	0.12 (0.18)	0.06 (0.08)	0.06 (0.10)
Suburban	0.56 (0.36)	0.26 (0.24)	0.09 (0.16)	0.02 (0.10)	0.07 (0.14)

Table 2.3. Continued

^a GSL-OS = grassland – oak-hardwood savanna, GSH-OHSS = grass shrub – oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHCN-CON = oak-hardwood conifer – conifer, RIP = riparian, YRD = yard.

Furthermore, specialization occurs on a gradient rather than within discrete categories. While I could not measure fitness, I failed to reject the hypothesis that adult Columbian white-tailed deer are generalists in terms of selection for most cover types within their home ranges for the following reasons. First, there appeared to be a high amount of plasticity in habitat use among deer compared to availability. Second, there were no dominant patterns of selection. Third, most cover types were either used in proportion to their availability or avoided. However, there are some lines of evidence that support the hypothesis that CWTD show at least some degree of specialization for riparian habitats and areas close to streams within their home ranges and areas of concentrated use. First, riparian areas were the most frequently selected (31%), and second most frequently used (18%) cover type. Second, for the majority (56%) of deer and regardless of cover type, the odds of use for a particular patch significantly increased as proximity to stream decreased. Third, there was a strong selection for riparian areas on a seasonal basis, as deer in at least 4 out of 6 sites selected riparian cover types across all seasons. Lastly, I found similar patterns of cover type use and effects of proximity to stream for areas of concentrated use. Cover type composition within areas of concentrated use was similar to availability within 99% utilization distributions, but a significantly larger proportion of area within areas of concentrated use occurred within 200 m of streams.

A high degree of association between white-tailed deer and riparian areas has been reported for several other western white-tailed populations (Compton et al. 1988, Dusek et al. 1988, Bell et al. 1992, Leach and Edge 1994). Furthermore, my results agree with Smith's (1981, 1987a) assessment that the Douglas County sub-population of CWTD show a strong affinity for riparian areas. The high degree of association of CWTD with riparian areas may be a mechanism for reducing competition with sympatric Columbian black-tailed deer (Smith 1987a). Previous studies have suggested that CWTD prefer habitats that provide an interspersed combination of palatable forage and adequate escape/hiding cover (Suring and

Vohs 1979, Smith 1981, 1985a, 1987a, Gavin et al. 1984). Riparian areas likely provide these habitat characteristics because their long and narrow shape may provide more access to resources, especially when juxtaposed to open habitats. Lastly, Smith (1981, 1985a) suggested that riparian areas also may serve as important corridors for dispersal and range expansion for CWTD.

Nevertheless, the observed lack of selection for non-riparian cover types within home ranges and areas of concentrated use does not necessarily equate to lack of importance of these habitats. Selection of a resource within a home range may often appear low when in reality the resource may have already been chosen at a higher order of selection (i.e. placement of the home range within the landscape) (Johnson 1980, Thomas and Taylor 1990). In addition, selection is often contingent upon the availability of a resource and how that availability is defined (Johnson 1980, McClean et al 1998, Mysterud and Ims 1998). It is easier to detect selection for a resource that is rare, whereas ubiquitous resources may be vital but do not appear to be selected because 1) relatively small amounts are needed to satisfy an animal's requirements, or 2) very high amounts of use (i.e. locations) are needed for adequate power to detect selection (Johnson 1980). These are inherent problems with the way selectivity indices are calculated.

For example, it is surprising that my results did not show stronger selection for other cover types, especially oak-hardwood woodland which was the most frequently used cover type both annually and seasonally. Smith (1981) found a strong selection for deciduous hardwoods, and documented an avoidance of more xeric madrone (non-deciduous) woodlands. My pooling of oak and madrones into a single cover type may be a reason why oak-hardwood woodland cover types were not frequently selected. However, when madrones were present within deer home ranges in this study, they were frequently interspersed with oaks, and only 1 site (Jones Ranch) was dominated by madrone. A more likely explanation is that oak-

hardwood woodland was one the most available cover types for most deer (Appendices 2.1 – 2.9) and because of its high availability, there may have been inadequate power to detect selection. Differences in sampling methodologies may further explain discrepancies. Smith (1981) primarily used a 'design 1' sampling protocol (Thomas and Taylor 1990) that relied on observations of unmarked deer along transects to calculate selection, whereas I only used repeated observations from unique deer. The importance of oak-hardwood woodlands should not be underestimated because of 1) the high amount of use by CWTD, and 2) their forage (mast, young foliage, and understory) and cover values (Smith 1981, Loft et al. 1988).

In addition, the lack of selection for grassland and other open cover types may not necessarily equate to non-importance. Previous work has suggested that CWTD rarely use open habitats that are far away (> 50m) from escape cover (Suring and Vohs 1979, Smith 1981, 1985a). Thus, the peripheries of large grasslands and improved pastures that likely provide high quality herbaceous forage may be selected, but selection is masked because interior portions likely are not heavily utilized and apparently avoided by CWTD. Also, while little selection was apparent for oak-hardwood savanna shrub, it was used relatively frequently (>20%) by several deer (e.g. 58% of the time for deer –ID 62, Appendix 2.4). Smith (1981) documented selection for shrub dominated cover types, and it is likely that these cover types provide a good interspersed cover and forage.

Sex, type, seasonal, diel period, and edge patterns

Pronounced differences in habitat associations between males and females were not apparent. First, there were no significant differences in annual cover type use. Second, sex-specific patterns of selection for cover types within home ranges and areas of concentrated use, as well as distance to stream classes within areas of concentrated use, were not apparent. There were only 2 minor instances where I found inter-sexual differences in habitat associations.

Females had significantly fewer cover types available than males within their home ranges, probably because females had smaller home ranges (Chapter 1), and males used grassland more frequently than females when the effects of season were controlled. Thus, differential habitat use between the sexes did not likely act as a mechanism for resource partitioning. Previously, Smith (1981) did not find substantial inter-sexual differences in CWTD habitat use. However, differential cover type use between the sexes has been demonstrated in other *Odocoileus* populations (McCullough et al. 1989, Beier and McCullough 1990, Weckerly 1993). McCullough et al. (1989) suggested that habitat use between the sexes should be dissimilar when spatial overlap is high and similar when overlap is low. In addition, Kie and Bowyer (1999) found an increase in habitat selection overlap, and a concomitant decrease in diet overlap, between the sexes at high density. While male and female CWTD in this study did not exhibit strong differences in habitat use, they showed pronounced differences in spatial use patterns (Chapter 1). Douglas County CWTD may also occur at high density in localized areas (Chapter 1). It is possible that similar patterns of habitat use and selection between the sexes, which may have also been influenced by high density, was compensated by decreased overlap in spatial use patterns.

To my knowledge, few studies have quantified habitat use patterns for deer living in suburban environments. Happe (1982) found few differences in habitat use for Columbian black-tailed deer relative to proximity to housing, with the exception that deer living near housing used grassy areas more frequently at night. In this study, there were significant differences in habitat use between suburban and wild deer, both annually and seasonally, although overall differences in selection by type were not as apparent. Wild deer used grassland, woodland, and riparian cover types more frequently than suburban deer, especially when controlling for seasonal effects. Use of these cover types by suburban deer was likely diminished because of their increased use of yards. Conversely, suburban deer used conifer

and oak-hardwood conifer cover types more frequently than wild deer. Conifer stands in suburban interface areas tended to be in low lying areas and county parks and were not large and expansive. Accordingly, Smith's (1981) determination that conifers were selected may have been influenced by proximity to suburban interface-park areas because he sampled heavily in these areas. In terms of selection, only suburban deer selected yards whereas all wild deer avoided or showed no selection/avoidance for yards. Suburban deer also selected riparian areas less frequently than wild deer. Deer inhabiting suburban interface areas were often supplementally fed and appeared less wary than wild deer, thus harassment did not appear to affect their use yards. Increased use of yards by suburban deer may be due to conditioning to human presence and increased forage availability, especially during periods when high quality forage is scarce. For example, Bellatoni et al. (1993) found increased use of yards by desert mule deer during dry periods.

There was no difference in cover type use among seasons, and there did not appear to be any dominant selection patterns for non-riparian cover types within study sites. This is somewhat surprising because seasonal variation in habitat use should occur presuming food availability and thermal/hiding cover changes seasonally (Taber and Dasmann 1956, Loft et al. 1984, Beier and McCullough 1990). Consistent selection of riparian areas in all sites during summer is likely reflective of increased insulation from solar radiation which minimizes energetic costs associated with thermal regulation and increased availability of succulent forage (Demarchi and Bunnell 1993, Mysterud and Østbye 1999). The only seasonal selection of grassland and oak-hardwood savanna occurred in spring and fall, respectively. Smith (1981) suggested that increased grassland use corresponded with increased biomass production of grasses and forbs in spring and the onset of fall rains.

A high percentage of deer used open cover types more frequently during crepuscular/nocturnal periods compared to diurnal periods. Other studies have documented

increased use of open habitats during non-diurnal periods (Smith 1981, Loft et al. 1984, Beier and McCullough 1990), although Hayes and Krausman (1993) generally found consistent habitat use between night and day. These results provide evidence that although open cover types (e.g. grassland, oak savanna) were not selected for strongly when diel period was ignored, their use increases significantly during non-diurnal periods. I typically observed deer feeding in open areas at dawn-dusk and night. Open cover types are likely primarily used for feeding and afford little hiding cover. Conversely, it is probable that closed cover types used during the day are primarily for bedding and rumination (Beier and McCullough 1990). It is also likely that when open habitats were used, they were near escape cover (Suring and Vohs 1979, Smith 1981, Bell et al. 1992).

It was surprising that the relative amount of edge within a particular cover type patch did not result in significantly higher odds of use for the majority of deer. Other studies have found little response of deer to edges when cover types consist of a fine grained mosaic of cover and forage (Sweeney et al. 1984, Kremsater and Bunnell 1992). It is possible that there was a high degree of variation in the ratio of cover to forage within cover type patches in my study which masked differences, especially within cover types containing a high degree of potential forage and cover (eg. grass-shrub, hardwood-savanna shrub, and riparian). The value of cover types edges may become diminished when forage and cover are contained in the same cover type (Kremsater and Bunnell 1992). Lastly, I did not attempt to identify particular types of edge (e.g. grassland to oak-hardwood woodland, so my inferences are limited to the relative amount of edge for a particular patch, irrespective of type of edge

Habitat selection in areas of concentrated use

In chapter 1, I reported that, on average, areas of concentrated use comprised less than 14% of home range size but contained over 70% of locations. Thus, relative to the total area

they inhabited during the course of their normal activity, CWTD tended to repeatedly use and 'key in on' the same small areas. Habitats comprising these small areas of concentrated use should have presumably represented areas of increased biological importance. However, proportions of cover types comprising areas of concentrated use were similar to proportions of cover types comprising home ranges, and selection for particular cover types within areas of concentrated was not evident. But, when habitat was classified by distance classes to streams, there was a significant association with proximity to streams as a significantly larger proportion of concentrated use areas were within 200 m of streams. It appears that riparian areas, as well as cover types closely juxtaposed to riparian areas, constitute biologically important habitat in areas within home ranges that receive disproportionate use. These results support Smith's (1985a) speculation that local extirpations of CWTD may be linked with destruction of riparian areas and areas close to streams should be a major focus for CWTD habitat management. However, some authors have cautioned against relying too heavily on results from 'core area' analyses to determine amounts and types habitats for mitigating potential losses, because core areas likely do not provide all necessary resources (Buchanan et al. 1998). For example, it is possible that other areas or cover types may provide needed resources during particular times of year, such as mineral licks and water sources during late gestation/lactation, or ephemeral acorn mast under oak woodlands or savannas in fall. Thus, my concentrated use results should be just one of a series of tools for developing habitat management strategies for CWTD. With these caveats in mind, however, my results further verify Smith's (1981, 1987a) conclusion that riparian areas represent an important habitat component for CWTD and strongly argue for protecting and enhancing/restoring areas near streams.

Chapter 3

Movements, Habitat Associations, and Survival of Columbian White-tailed Deer Fawns in
Western Oregon.

Mark A. Ricca

INTRODUCTION

Columbian white-tailed deer (*Odocoileus virginianus leucurus*, CWTD) are a subspecies once ubiquitous throughout western Oregon and Washington, but which now exists only as 2 geographically isolated and federally endangered sub-populations (Smith, 1985a). Although much research on habitat associations and survival has been conducted on fawns in other white-tailed deer populations (e.g. McCullough 1979, Porath 1980, Ozoga and Verme 1986, Huegel et al. 1985, 1986, Sams et al. 1996), there is a paucity of information on life history characteristics of CWTD neonates. The Douglas County sub-population of CWTD was listed as endangered in 1967 and has recently been proposed for delisting (Federal Register 1999).

Because neonates represent a critical life stage in deer population dynamics, characteristics of this life stage need elucidation (Jackson et al. 1972). For example, understanding macro-habitat associations of CWTD fawns is important to identify the range of cover types that comprise fawning and rearing areas and to make knowledgeable management decisions regarding habitats used by fawns and/or post-partum females. Home range and movement estimates may act as a surrogate to resource distribution and potential mortality risk (Ozoga and Verme 1986). Estimates of fawn survival are important population parameters that can provide valuable insight into recruitment processes (McCullough 1979, Clutton-Brock et al. 1987a) and maternal physiological condition (Sams et al. 1996).

Smith (1981) conducted a study of CWTD ecology approximately 20 years ago and described habitat use and survival patterns of 45 marked CWTD fawns within the Douglas County sub-population. In particular, he stressed the importance of woodland, riparian, and shrub dominated habitats. Survival rates to 3 – 6 months ranged from 0.30 to 0.80 over a 3 year period. However, data on neonatal movements was limited from his study.

My objectives were to determine movements, habitat use, and survival of neonatal CWTD in Douglas County. I examined habitat use patterns by sex, diel period, and fawn age, and predicted that if CWTD have restricted fawning areas, then consistent use for similar cover types would be evident. Also, cover type composition and proximity to streams within areas of concentrated use may provide a useful context for estimating cover types that receive disproportionate use (Samuel et. al 1985, Bingham and Noon 1997). My predictions regarding spatial use patterns and survival were much simpler and descriptive. I expected consistently small home ranges, areas of concentrated use, and movements provided that hiding cover for neonates and high quality forage for post-partum females was abundant. Lastly, I estimated survival rates to approximately six months and tested for differences by sex and fawn age. I also examined the effect of movement and cover type use on survival time and described sources of mortality.

STUDY AREA

The study area was located in Douglas County, Oregon within the lower North Umpqua watershed. It was bordered approximately by the towns of Roseburg to the south, Glide to the east, and Sutherlin to the north. Interstate 5 composed the western boundary (Fig. 1.1). The majority (ca. 80%) of the study area was privately owned, while the remainder (ca. 20%) was open to the public. The landscape was characterized by undulating topography intersected by several small drainages. Elevation ranged from 165 to 595 m. The climate was characterized by long, rainy winters and hot, dry summers. Monthly average temperatures ranged from a low of 1.7 °C in January to a high of 29.4 °C in August. Average annual precipitation was 84.2 cm, and monthly rates ranged from a low of 1.6 cm in August to a high of 15.8 cm in December (Western Region Climate Center, Reno, Nevada; 1965 – 1997). Snowfall was rare.

Smith (1981, 1985b) gives an extensive description of plant communities and species composition found in the study area. While some stands of continuous deciduous hardwood/mixed-conifer forest and undisturbed riparian areas were still present, vegetative communities most often represented a relatively disturbed environment due to past or current history of fire management, grazing, agricultural conversion, and housing development. In most parts, the study area was characterized by a mosaic of finely interspersed cover types which typically consisted of oak (*Quercus* sp.), madrone (*Arbutus menzeissi*), conifer, and grassland plant associations intersected by numerous riparian drainages. Large expanses of coniferous forest were rare, and smaller conifer stands had typically been logged and were regenerating.

METHODS

Fawn capture

Fawns were captured between late May and early July 1996, 1997, and 1998. A variety of capture techniques were employed including drives along transects with a large number of volunteers, observing open areas from distances > 100m and watching females return to their fawns, keying in on alarm behavior exhibited by females, and opportunistic encounters. In order to obtain as random a sample as possible, we attempted to search all cover types ranging from low elevation riparian areas to upland oak-woodlands and hardwood savanna shrub. Most of our capture efforts were restricted to public land where livestock grazing was absent or minimal.

Captured fawns were fitted with expandable break-away radio-collars equipped with mortality switches (CB - 1 break-away collar, Telonics Incorporated, Mesa, Arizona, USA). I attempted to estimate ages of fawns captured during 1997 and 1998 by measuring hoof growth

(Haugen and Speake 1958) and degree of umbilicus scabbing. Fawns were not weighed because I wanted to minimize over-handling which may cause abandonment (Livezey 1990).

Location protocol

Locations were obtained for fawns captured in 1997 and 1998. Fawns were located 3–5 times per week during diurnal, crepuscular, and nocturnal periods. I systematically tracked different fawns at the beginning of each tracking session to ensure that all fawns would be located at different times. I relied heavily on obtaining visual or estimated visual (i.e. 'homing in') locations to avoid problems associated with radio telemetry error (Chapter 1). When triangulations were necessary ($n = 23$), I was usually within 200 m of the signal and used a bearing standard deviation of 5.78° to construct error ellipses (Chapter 1). To maintain temporal independence (White and Garrott 1990:147), successive locations of individual fawns were at least 12 hours apart. Fawns were located as early as 0400 to as late as 2300 PST in order to ensure adequate representation of diurnal and nocturnal movements (Beyer and Haufler 1994). Cover type, level of disturbance, location type (visual or triangulation), and diel period were recorded when fawns were located. Level of disturbance was defined as unbiased movements (fawn did not flee, or if it did flee due to my presence, I was able to determine its location before disturbance), or biased movement (fawn fled the area due to my presence and I was unable to determine its location before it fled). Diel periods were defined as crepuscular (2 hrs. before and after sunrise or sunset), diurnal (2 hrs. after sunrise to 2 hrs. before sunset), and nocturnal (2 hrs. after sunset to 2 hrs. before sunrise). All locations were plotted in the field on 1:24000 USGS topographic maps. Although I continued to locate and monitor fawns that remained alive for the life of the radio-collar, only locations obtained between the date of capture and the end of August were used for spatial use and habitat

association analyses. This resulted in a scope of inference to approximately the first 3 months of life.

Spatial use

Only fawns ($n = 11$) with greater than 20 locations were used to generate spatial use estimates. Fixed kernel density estimators with bandwidths calculated using least squares cross validation (Seaman and Powell 1996) were used to estimate 99% and 95% utilization distributions (home ranges). Home ranges were calculated using program KERNELHR (Seaman et al. 1998). Areas of concentrated use were estimated using a subroutine for program KERNELHR (cited in Seaman et al. 1998) called PLOT CNTR (available from B. Griffith, Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks). PLOT CNTR estimates areas of concentrated use by calculating the average observation density of all locations in a given set and then determines the contour where the observation density is greater than average. The average observation density is calculated as the sum of the linear array of the observed densities divided by the number of observed locations. The advantage of this methodology is that it avoids subjective and arbitrary contour selections, and each area of concentrated use is based solely on the density of locations for an individual fawn (S. A. Wolfe, Alaska Cooperative Wildlife Research Unit, University of Alaska, Fairbanks, pers. commun.). I refrained from calling areas of concentrated use 'core areas' because they were not tested against a null distribution of bivariate uniform locations within the home range (Samuel et al. 1985, Bingham and Noon 1997). Movements were simply described by calculating the distance traveled between successive locations. Differences by sex were not tested because of the small sample size of fawns with spatial use estimates and only descriptive statistics are reported. The relation between 99% home range and area of concentrated use size (response variables), and percent oak-hardwood woodland – riparian cover and percent grass

shrub – oak-hardwood savanna shrub cover (explanatory variables) was examined with multiple regression. These cover types were chosen based on their relative degree of importance as reported by this study (see results) and Smith (1981). Response variables were natural log transformed and explanatory variables arcsine-square root transformed to meet assumptions of normality and homoscedasticity.

Habitat associations

Cover type classifications

Cover types were delineated from scanned 7.5 minute ortho-photo quadrangle maps in Arc/Info (Environmental Systems Research Institute, Redlands, California, USA, version 7.2.1). Cover types were based upon a modification of Smith's (1981,1985) detailed descriptions of percent coverage and species composition. Cover types were classified as: 1) grassland, 2) grass shrub, 3) oak-hardwood savanna, 4) oak-hardwood savanna shrub, 5) oak-hardwood woodland, 6) oak-hardwood conifer, 7) conifer, and 8) riparian. Areas near human development, including residential housing, lawns, orchards, and small tree plantations were classified as 'yard' (Fig. 1.2). Streams were buffered by successive 100m increments in Arc/Info to produce 5 distance to stream classes (0 – 100 m, 101 – 200 m, 201 – 300 m, 301 – 400 m, > 401 m). Detailed descriptions of plant composition and structural characteristics of cover types, as well as GIS map preparation, are provided in Chapter 2.

Habitat use and selection

I did not measure habitat use for individual fawns because of the relatively small number of locations (ca. < 40/fawn) which likely would have resulted in low power to detect individual habitat use patterns (White and Garrott 1986). Instead, all fawn locations were pooled to measure habitat use. A Chi-square test was used to determine if frequency of use

was equal among all cover types. Differences in cover type use by sex, diel period, and neonatal/post-neonatal period (see below) were tested with Chi-square contingency tables. Cover types that were never used (see results) were deleted from chi-square analyses. The precision of mean proportional use estimates was computed with 95% confidence intervals for proportions (Ramsey and Schafer 1997:521).

To ascertain selection, areas of concentrated use were pooled and mean percent composition of cover types and distance to stream classes were calculated. Confidence intervals (95%) for proportions were used to compute precision of mean use and availability. Sample sizes for these analyses were the number of fawn home ranges containing a particular cover type or distance to stream class. Selection for a particular cover type or distance to stream class was determined by comparing 95% confidence intervals for areas of concentrated use (used areas) to 99% fixed kernel home ranges (available areas). A range of 1 - 11 and 5 - 9 fawns were pooled to estimate mean percent composition of a particular cover type or distance to stream class, respectively, because not all cover types or distance to stream classes were available to fawns within their home range.

Survival and sources of mortality

Fawns were monitored for survival once every 1 – 3 days during the first 3 months post-capture. Thereafter, they were monitored at a minimum of bi-weekly intervals. Kaplan-Meier staggered entry estimators (Pollack et al. 1989) were used to calculate survival rates to approximately 6 months of age. Fawns whose collars fell off prematurely (before 6 months) were censored on the last known date they were alive. Survival rates also were estimated for the 'neonatal' and 'post-neonatal' periods. The neonatal period was the date of capture to July 15 (ca. 45 days for most fawns), and the post-neonatal period was as all days alive after July 15. These natal periods served as an index for fawn age. Log rank tests were used to test for

differences in survivorship functions by sex and natal period (White and Garrott 1990:240), and Z-tests were used to compare survival rates (Pollack et al. 1989).

The effect of movements and cover type use (explanatory variables) on survival time (response variable) was assessed with a proportional hazards regression model (White and Garrott 1990:244). Survival time was expressed as the number of days until death or censoring. Explanatory variables were mean movement between successive locations, coefficient of variation of mean movement, and percent use of pooled oak-hardwood woodland and riparian cover types. These cover types were chosen because they were the most frequently used cover types in this study (see results). Only fawns that had > 10 locations were used for this analysis.

I attempted to expeditiously locate dead fawns to determine proximate cause and approximate date. If dead fawns were still intact, gross necropsies were performed to qualitatively assess body condition and determine cause of death if external trauma was not apparent. In particular, rumen contents were examined for signs of nursing.

RESULTS

Thirty six fawns were captured and radio collared over a 3-year period (Appendix 3.1). The sex ratio of captured fawns was equal when all 3 years were pooled (18 males, 18 females), but tended to vary annually, (1996 -3 males : 4 females, 1997 - 6 males : 11 females, 1998 - 9 males : 3 females). The peak of the fawning season appeared to be during the first 2 weeks of June as the majority (64%) of fawns were captured between 28 May and 15 June, and the mean date of capture was 13 June (SD = 7.4 days). However, fawns continued to be captured through July 3. Average age at capture was 5.7 days for fawns that could be accurately aged ($n = 20$, SD = 3.0). After removing locations with observer bias and excessive

telemetry error, a total of 384 locations were obtained from the 11 fawns to describe spatial use and habitat selection; and 469 locations were obtained from all fawns to describe habitat use.

Spatial use patterns

Both home ranges and areas of concentrated use tended to be small but variable. Mean 95% and 99% home range size was 18.0 ha (CV = 88.1%) and 24.3 ha (CV = 94.3%), respectively (Table 3.1). Mean area of concentrated use size was 2.4 ha (CV = 94.4%) and, on average, they were found near the 71% contour of the observed densities. In addition, areas of concentrated use encompassed an area that included only 13.3% (SD = 3.0) of 95% utilization distribution (home range) area. Mean movements were less variable (CV = 44.3%) and averaged 194 m between successive locations. An average of ca. 38 locations per fawn (CV = 29.2%) were used to calculate these spatial use estimates (Table 3.1).

Ninety-nine (99) % home range size was unrelated to percent composition of oak hardwood woodland – riparian ($t = 1.68$, SE = 1.03, $P = 0.13$), and grass shrub – oak hardwood savanna shrub ($t = 1.91$, SE = 0.84, $P = 0.09$) cover types within home ranges. Area of concentrated use size was also unrelated to oak hardwood woodland – riparian ($t = 0.004$, SE = 0.73, $P = 0.99$), and grass shrub – oak hardwood savanna shrub ($t = -0.40$, SE = 1.02, $P = 0.70$) cover types within areas of concentrated use.

Habitat associations

Habitat use

Frequency of use was not equal among cover types for all fawn locations ($\chi^2 = 308.7$, d.f. = 7, $P < 0.0001$). Oak-hardwood woodland was the most frequently used cover type (33%) followed by riparian areas (26%). All other cover types were used only 5 – 9% of the time,

Table 3.1. Descriptive statistics for 99% and 95% fixed kernel home range, area of concentrated use, and mean movement between successive locations for 11 Columbian white-tailed deer fawns in Douglas County, Oregon, June – August, 1996-1997.

Deer ID	Sex	no. locations	99% home range area (ha)	95% home range area (ha)	concentrated use area (ha)	concentrated use area contour (%)	concentrated use: 95% home range area (%)	mean movement (m)
1130	female	30	19.5	14.9	1.2	69.6	7.9	191.8
1150	female	31	9.1	7.0	0.7	67.1	9.6	174.9
1750	female	44	29.7	22.9	3.6	78.9	15.7	173.6
1820	female	57	11.6	7.8	1.1	69.5	14.6	172.5
1890	female	43	41.4	30	3.6	61.8	11.9	357.1
1140	male	30	17.0	11.7	1.8	76.2	15.4	138.7
1240	male	25	11.6	8.7	1.4	74.6	15.7	90.3
1260	male	41	14.5	15.1	1.5	66.4	9.7	241.7
1790	male	54	86.3	60.4	8.5	68.6	14.1	334.2
1830	male	27	6.3	4.7	0.7	74.6	15.4	97.4
1860	male	31	19.9	15.1	2.4	73.4	15.8	162.6
	mean	37.5	24.3	18.0	2.4	71.0	13.3	194.1
	SD	11.0	22.9	15.9	2.3	5.0	3.0	86.0
	CV (%)	29.2	94.3	88.1	94.4	7.1	22.2	44.3
	range	25 - 57	6.3 - 86.3	4.7 - 60.4	0.7 - 8.5	61.8 - 78.9	7.9 - 15.8	90.3 - 357.1

and conifers were never used (Fig. 3.1). Cover type use significantly varied by sex ($\chi^2 = 82.1$, d.f. = 7, $P < 0.0001$). Female use of grass-shrub was 17% compared to no use by males (Fig. 3.2). Conversely, males used oak-hardwood woodland (42%) and yards (12%) more frequently than females (25% and 1%). When sexes were pooled, cover type use varied significantly by diel period ($\chi^2 = 17.83$, d.f. = 7, $P = 0.013$). Use of riparian areas was higher during crepuscular/nocturnal periods (34%) than diurnal periods (21%) while use of yards was slightly higher during diurnal periods (8%) than crepuscular nocturnal periods (3%) (Fig. 3.2). There was no difference in cover type use between neonatal and post neonatal periods with sexes pooled ($\chi^2 = 10.72$, d.f. = 7, $P = 0.151$) (Fig. 3.2).

Habitat selection

Use and availability of cover types within areas of concentrated use tended to be highly variable when combined for all 11 fawns. Oak-hardwood woodland (35%) and riparian (26%) comprised the largest average percentage of areas of concentrated use. All other cover types comprised less than 10% of pooled concentrated use areas. Conifer cover types were completely absent from areas of concentrated use (Fig. 3.3, Appendix 3.2). Furthermore, there did not appear to be any selection of particular cover types relative to availability as means were similar between areas of concentrated use and 99% home ranges and confidence intervals overlapped for all cover types (Fig. 3.3). Areas of concentrated use were near streams, as 52% and 74% of their cumulative area was within 100 m and 200 m of a stream, respectively. All other distance to stream classes comprised less than 20% of concentrated use areas (Fig. 3.3, Appendix 3.3). Again, use and availability were variable, and selection for particular distance to stream classes was not apparent because confidence intervals for areas of concentrated use and 99% home ranges overlapped for all distance to stream classes (Fig. 3.3).

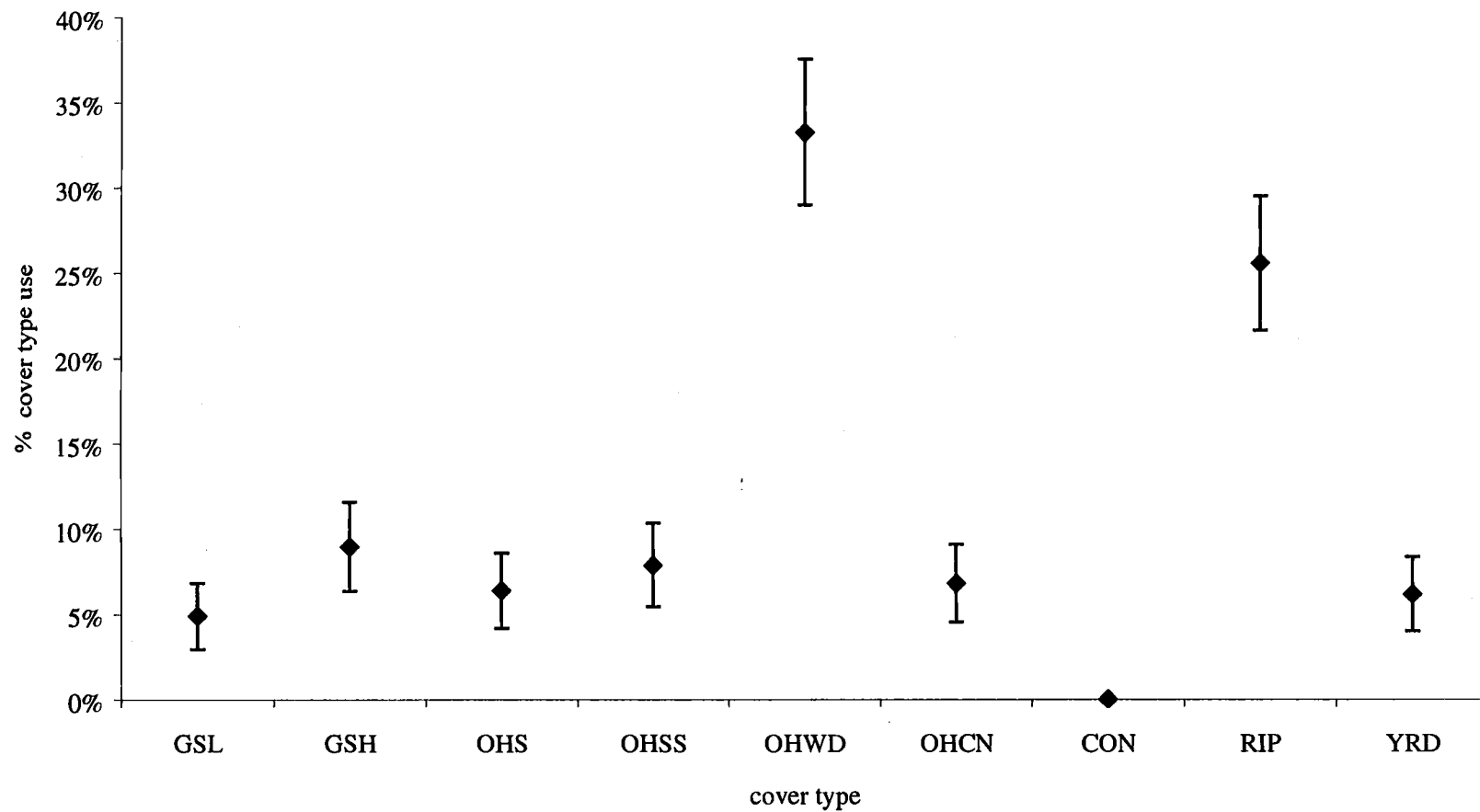


Figure 1.1. Mean percentages (and 95% confidence intervals) of Columbian white-tailed deer fawn locations (n = 545) by cover type, Douglas County, Oregon, 1997-98. GSL = grassland, GSH = grass shrub, OHS = oak-hardwood savanna, OHSS = oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHCN = oak-hardwood conifer, CON = conifer, RIP = riparian, YRD = yard.

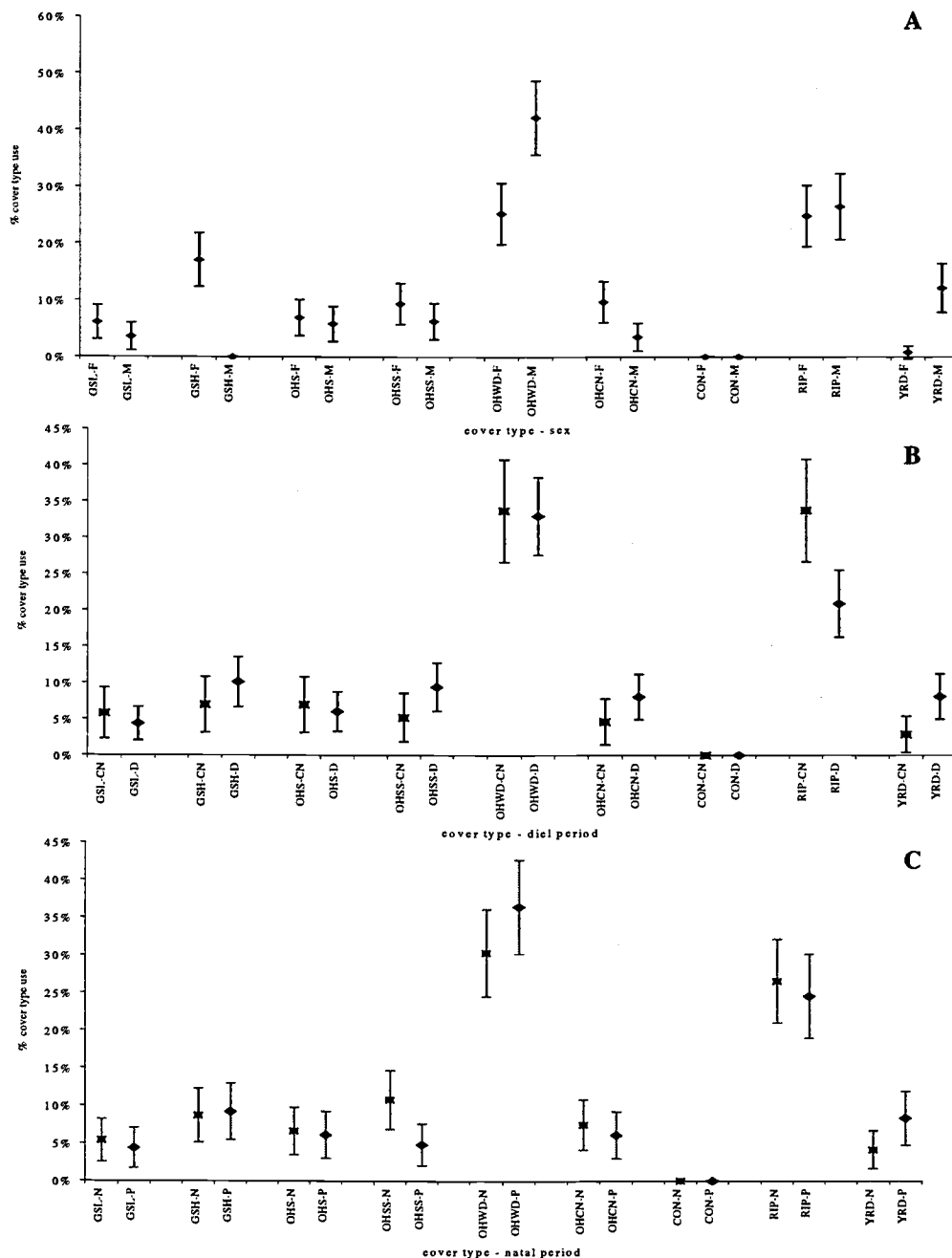


Figure 3.2. Mean percentages (and 95% confidence intervals) of locations ($n = 545$) by cover type, and sex (F = females, M = males) (A) diel period (CN = crepuscular/nocturnal, D = diurnal) (B), and natal period (neonatal = N, post neonatal = P) (C) for Columbian white-tailed deer fawns in Douglas County, Oregon; June – August, 1997 – 98. GSL = grassland, GSH = grass shrub, OHS = oak savanna, OHSS = oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHCN = oak-hardwood conifer, CON = conifer RIP = riparian YRD = veld

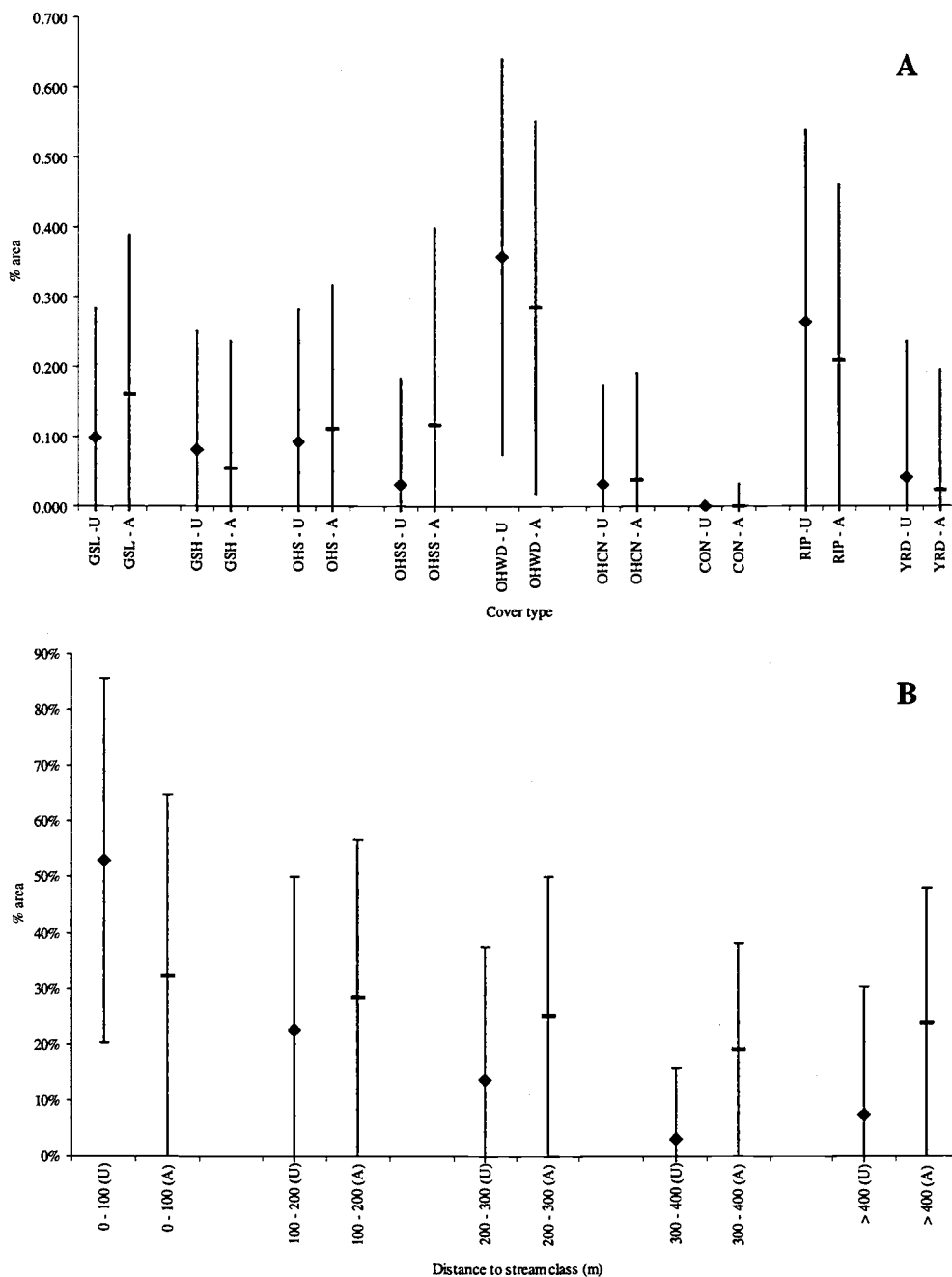


Figure 3.3 Mean percent composition of cover types (A) and distance to stream classes (B) within pooled areas of concentrated use (U) and 99% fixed kernel utilization distributions (A) for 1 - 11 Columbian white-tailed deer fawns in Douglas County, Oregon; June - August, 1997 - 98. GSL = grassland, GSH = grass shrub, OHS = oak savanna, OHSS = oak-hardwood savanna shrub, OHWD = oak-hardwood woodland, OHCN = oak-hardwood conifer, CON = conifer, RIP = riparian, YRD = yard.

Survival and sources of mortality

Survival

Fawn survival to 6 months was low during all 3 years and ranged from a high of 0.206 in 1997 to a low of 0.00 in 1996 (Table 3.2). Survival functions differed significantly between 1996 and 1997 ($\chi^2 = 4.86$, $P = 0.03$). With years pooled, survival to 6 months of age was 0.159 (Fig. 3.4). Precision was still relatively low (95% CI = 0.009 – 0.308), primarily because of high numbers ($n = 8$) of censored fawns whose collars slipped off prematurely (Appendix 3.1) (White and Garrott 1990:235). Survival appeared to decline most rapidly during the neonatal period (0.307), and then leveled off after July 15 (0.515) (Table 3.2, Fig. 3.4). There were no significant differences in 6 month ($\chi^2 = 0.00$, $P = 0.999$), neonatal ($\chi^2 = 0.252$, $P = 0.615$), and post-neonatal ($\chi^2 = 0.624$, $P = 0.429$) survival functions between sexes. In addition, survival rates were not significantly different between sexes ($Z = 0.073$, $P = 0.427$) or natal period ($Z = 1.092$, $P = 0.138$), but females had higher survival during the neonatal period ($Z = 2.31$, $P = 0.01$). Males appeared to have higher survival than females during the post-neonatal period but differences in these survival rates were not tested because sample sizes were too small (Table 3.2).

Number of days survived for 20 fawns was unrelated to mean movement between successive locations ($Z = -0.10$, $SE = 0.005$, $P = 0.919$), CV of mean movement ($Z = -1.27$, $SE = 4.69$, $P = 0.205$), and percent use of oak-hardwood woodland – riparian cover types ($Z = -1.04$, $SE = 1.73$, $P = 0.300$).

Sources of mortality

Predation was the most frequent ($n = 8$, 38%) known cause of death, most of which appeared to be by bobcats (*Lynx rufus*) ($n = 3$). One predation death was most likely by a fox

Table 3.2. Kaplan-Meier survival rate estimates for Columbian white-tailed deer fawns in Douglas County, Oregon, 1996 – 1998.

Year	Period	Sex	S(t)	95% CI	n	no. Died	no. Censored
1996	6 month	--	0.000 ^a	0.000 – 0.000	7	5	2
1997	6 month	--	0.206	0.000 – 0.457	17	8	7
1998	6 month	--	0.084	0.000 – 0.267	12	8	2
All	6 month	--	0.159	0.009 – 0.308	36	21	11
All	6 month	male	0.122	0.000 – 0.307	18	11	4
All	6 month	female	0.110	0.000 – 0.320	18	10	7
All	neonatal	--	0.307	0.080 – 0.533	36	15	5
All	post-neonatal	--	0.515	0.212 – 0.819	16	6	6
All	neonatal	male	0.173	0.000 – 0.409	18	9	1
All	neonatal	female	0.418	0.041 – 0.794	18	6	4
All	post-neonatal	male	0.729	0.405 – 1.000	8	2	3
All	post-neonatal	female	0.273	0.000 – 0.700	8	4	3

^a Survival to 153 days was 0.250 (0.000 – 0.650)

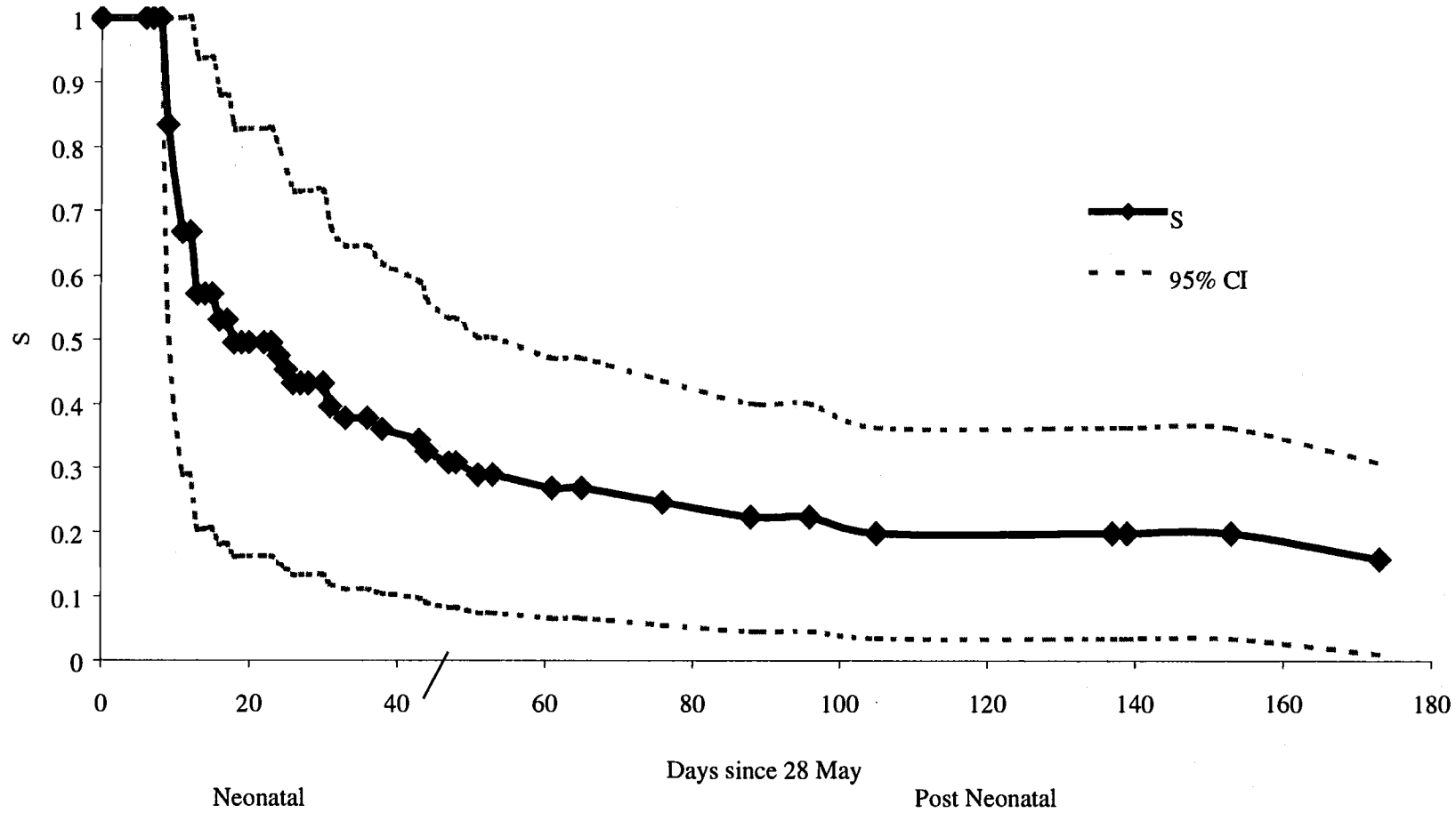


Figure 3.4. Approximate 6-month (28 May - 31 Dec) Kaplan Meier survival curve for 36 Columbian white-tailed deer fawns in Douglas County, Oregon, 1996 - 98.

and another appeared to be by domestic dogs. Known coyote (*Canis latrans*) predation did not occur. Excluding unknown deaths, 5 fawns (24%) were apparently abandoned because there were no signs of external trauma or evidence of nursing in their rumens. Three (14%) fawns apparently died of disease. The first death occurred for a 5-month old fawn and appeared to be related to pneumonia and malnutrition, the second appeared to be caused from a *Clostridium* sp. bacterial infection, and the third was likely due to an unknown viral infection. We found no evidence of epizootic hemorrhagic disease, and dead fawns were not infested with ectoparasites with the exception of a 5 month old fawn. Four fawns (19%) died from unknown causes, and 1 fawn (5%) was likely, but not conclusively predated.

DISCUSSION

Spatial use patterns

Overall, CWTD fawn home ranges, areas of concentrated use, and movements tended to be relatively small which was likely reflective of their sedentary nature during the early stages of life (Jackson et al. 1972). However, all spatial use estimates tended to be variable. Similar variability has been reported for other white-tailed deer in Texas (Carroll and Brown 1977) and Michigan (Ozoga and Verme 1986), as well as mule deer (*Odocoileus hemionus*) in Montana (Riley and Dood 1984) and Washington (Steigers and Flinders 1980). Ozoga and Verme (1986) suggested that home range and movements are largely maternally controlled and variation could be attributed to maternal age, but I have no data to support or reject this contention. Variability in spatial use estimates may also be reflective of resource distribution for post-partum females, whereby females and their fawns that have either ample high quality forage or hiding cover would be expected to have small home ranges. However, home range and area of concentrated use size in this study were unrelated to either oak-hardwood woodland – riparian or shrub habitats (grass-shrub – oak-hardwood savanna shrub). Although these

results suggest there is no relation between home range size and resource distribution in this study, it is more plausible that the cover types I classified represent too coarse of a delineation to identify fine scale resources (e.g. bed-sites, micro-nutrients) needed by lactating females and their fawns.

Habitat associations

Fawn/maternal female cover type use was mostly restricted to oak-hardwood woodland and riparian cover types. All other cover types were used < 10% of the time. These cover type use patterns were similar to those exhibited by adult females, which also used riparian and oak-hardwood woodland cover types most frequently (Chapter 2). Nevertheless, I failed to find any patterns of selection for particular cover types and distance to stream classes because confidence intervals for used (areas of concentrated use) and available (home ranges) cover types and distance to stream classes overlapped each other. However, lack of selection or avoidance does not necessarily equate with lack of importance. On average, oak-hardwood woodlands and riparian areas comprised 61% of concentrated use area, and the majority (74%) of concentrated use area was within 200 m of a stream. Selection for these habitats possibly was not detected because they were relatively ubiquitous throughout the landscape (Johnson 1980). Also, the number of fawns radio-collared and locations obtained was likely too small to result in adequate power to detect habitat selection (White and Garrott 1986). In addition, the low availability of conifer ($\bar{x} < 1\%$) and oak-hardwood conifer ($\bar{x} < 4\%$) (Appendix 3.2) suggests that these cover types were least favorable, and may have been avoided at a higher order of selection (i.e. selection of home range, Johnson 1980)

Variability in cover type composition of areas of concentrated use as well as home ranges (Appendix 3.2) suggests some degree of plasticity in fawn/maternal female cover type use. For example, the area of concentrated use for fawn-id 1130 was entirely composed of

'yard' cover type which was a Christmas tree plantation, while area of concentrated use for fawn-id-1790 was comprised of a diverse variety of cover types (Appendix 3.2). In addition, variability in habitat use was evident when examined by sex and diel period. Grass-shrub cover type was never used by male fawns, but was used 17% of the time by female fawns. This increased use of grass-shrub cover types by females partially supports Smith's (1981) observation of frequent grass-shrub use. Use of riparian areas was also higher during crepuscular-nocturnal periods than diurnal periods in this study. It is possible that maternal females hid their fawns in denser and presumably more secure riparian areas before they began foraging in more open habitats at night (Chapter 2:74). However I failed to find differences in habitat use between neonatal and post-neonatal periods although I expected open cover types to be used more frequently as fawns matured and became more active. Fawns were probably still following a 'hider' strategy (Lent 1974) during this time, or maternal females were still using the same exclusive habitats used for parturition.

With the possible exception of grass shrub which overall received low use, habitat use patterns observed in this study were similar to Smith's (1981) findings. Habitat use by fawns and maternal females may represent a trade-off between minimizing predation risk and climatic exposure, and maximizing forage acquisition (Main and Coblentz 1996, Bleich et al. 1997, Bowyer et al. 1998). Smith (1981) suggested that CWTD fawn habitat selection was primarily related to thermoregulation, followed by adequacy of escape/hiding cover. June temperatures can exceed 32 °C, and because of their poor thermoregulatory abilities, thermal cover is very important for fawns. In this study, oak-hardwood woodlands and riparian areas with their broadleaf overstories likely provided favorable thermal cover (Demarchi and Bunnell 1993). In addition, relatively frequent use of riparian areas and concentrated use areas < 200 m from streams not only represents favorable thermal cover, but also may be indicative of increased availability of free water and succulent, high quality vegetation which is important for lactation

(Bowyer 1991). Riparian areas have also been suggested to be critical habitat for black-tailed deer fawns and maternal females in northern California (Loft et al. 1984).

In addition, because CWTD tend to be hidiers, adequate hiding cover is probably important regardless of cover type (Smith 1981, Huegel et al. 1986, Alldredge et al. 1991). I recorded qualitative descriptions of 172 fawn bed sites. In most cases (88%), fawns were hidden in 0.5 – 1.2 m tall grass, rush, and/or thistle, which was often interspersed with dense poison oak or blackberry. In light of this, it is not surprising that oak-hardwood conifer and conifer cover types received very little to no use as they typically had sparse herbaceous understories. Lastly, although open cover types such as grassland and oak-hardwood savanna shrub were infrequently used by fawns, these open cover types may provide forage for lactating females with high energy demands.

Survival and sources of mortality

Fawn survival to 6 months was low (16%) and most mortality occurred during the neonatal period. Fawn survival rates in this study were similar to rates reported in previous CWTD studies and for other un hunted white-tailed deer populations. However, hunted populations can have low survival as well (Table 3.3).

Mortality of ungulate offspring is usually highest and occurs most rapidly when they are young and dependent on their mothers for nursing (Loudon 1985, Gaillard et al. 1997). Likewise, the lower fawn survival during the first 1.5 months of life in this study is a demographic characteristic that occurs in most white-tailed deer populations in the midwestern states (Porath 1980), Texas (Cook et. al 1971), Minnesota (Kunkel and Mech 1994), and CWTD in southwest Washington (Gavin 1979). There was no sex-specific survival to six months in this study was unexpected, but females had significantly higher survival during the

Table 3.3. Survival rates for free ranging white-tailed deer fawns from various geographical regions. All estimates are from date of birth to a maximum of 6 months to facilitate comparison with this study. Annual survival is reported as either a mean (single value) or a range (2 values).

Years	Geographic Area	Survival	Estimator	Hunted/ unhunted	Source
1986-89	Iowa	0.89	Kaplan Meier	hunted	D. H. Jackson ^a , unpublished data
1957-61	Texas	0.80	prop alive	hunted	Teer et al. 1965
1980-83	Iowa	0.78	daily survival	hunted	Heugel et, 1985
1978	New York	0.78	prop alive	hunted	O'Pezio 1978
1980-82	S. Illinois	0.70	prop alive	unknown	Nelson and Woolf, 1987
1978-79	Missouri	0.65 - 0.71	prop alive	unknown	Bryan 1980 (cited in Porath 1980)
1989-90	Minnesota	0.49	daily survival	unknown	Kunkel and Mech 1992
1994-7	New Brunswick	0.47	daily survival	hunted	Ballard et al. 1999
1970-72	Oklahoma	0.36 - 0.82	prop alive	unknown	Logan 1972 (cited in Porath 1980)
1984-86	S. Illinois	0.14	prop alive	hunted	Woolf and Yancy 1987
1971 -73	S. Texas	0.10 - 0.90	prop alive	hunted	Carroll and Brown, 1977
1976-77	Oklahoma	0.10	prop alive	unknown	Bartush 1978 (cited in Porath 1980)
1973	Texas	0.40	prop alive	unhunted	White 1973
1966-67	S. Texas	0.28 - 0.29	prop alive	unhunted	Cook et al. 1971
1996-98	Douglas Co. CWTD	0.00 - 0.26	Kaplan Meier	unhunted	This study
1978-80	Douglas Co. CWTD	0.30 - 0.80	prop alive	unhunted	Smith 1981
1978-81	Julia Butler CWTD	0.29	prop alive	unhunted	A. C. Clark ^b unpublished data
1975 -77	Julia Butler CWTD	0.17 - 0.25	prop alive.	unhunted	Gavin 1979
1996	Julia Butler CWTD	0.00	prop alive	unhunted	A. C. Clark ^b personal communication
1996-98	Douglas Co. CWTD	0.16	Kaplan-Meier	unhunted	This study

^a address for D. H. Jackson: Oregon Department of Fish and Wildlife, Roseburg, Oregon

^b address for A. C. Clark: Julia Butler National Wildlife Refuge, Cathlamet, Washington

neonatal period than males. Because of their larger body size, male fawns can be more energetically costly to gestate and rear (Trivers and Willard 1973, Kojola 1998), and therefore may have lower survival. Smith (1981) documented higher mortality among CWTD male fawns, and lower survival of male fawns has been documented in other white-tailed deer populations (Jackson et al. 1972). However, McCullough (1979) found that survival of male neonates was nearly equivalent to females until males became yearlings and were driven off by their mothers.

Fawn mortality is one of the primary density dependent mechanisms regulating cervid populations (McCullough 1979, Clutton-Brock et al. 1987a, Sams et al. 1996), and the low fawn survival rates I observed may be indicative of a density-dependent population response. Local densities of CWTD can be as high as 48 – 72 deer per km² (Oregon Department of Fish and Wildlife, unpublished data). It is plausible to assume that these are relatively high densities. Smith (1981) previously estimated a CWTD density of 23 - 27 deer per km², and McCullough (1979) determined that 38 deer per km² constituted K-carrying capacity for white-tailed deer on the George Reserve in Michigan. Smith (1981) also suggested that the significant increase in CWTD fawn survival and recruitment he documented may have been in response to a concomitant 24% reduction in population size during the previous winter, and Gavin (1979) observed that fall density influenced reproductive success for Julia Butler CWTD. Qualitative assessment of adult female body condition suggested that females may be living in a poor nutritional state during winter in this study (Chapter 1), and it is possible that some maternal females were unable to adequately recover from winter energy loss and successfully rear fawns (Verme 1969, Oftedal 1985, Clutton-Brock et al. 1987b, Sams et al. 1996). However, density dependence can often be mis-inferred when confounded by temporal variation, or go undetected due to low power and inappropriate study design (White and

Bartmann 1997). Thus, my results are only suggestive of a density dependent response and direct causal inference cannot be made.

Results from the proportional hazards regression indicated that movements and use of oak-hardwood woodland and riparian cover types were unrelated to survival time of fawns. Theoretically, fawns should remain consistently sedentary and occupy cover types that minimize energetic expenditures and risk of predation (Lent 1974, Ozoga and Verme 1986). However, inference from these data is very limited because a large number of fawns either died or were censored before I could obtain an adequate sample of movement and habitat use data.

Predation pressure appeared to be fairly strong because predation was the most frequent cause of mortality. The apparent lack of coyote predation was not surprising considering Douglas County had an active predator control program before and during the study. However, it appeared that other predators, especially bobcats, possibly compensated for the lack of coyote predation. Higher incidences (ca. 80%) of predation by coyotes have been reported for the sub-population of CWTD in southern Washington (A. C. Clark, unpublished data) as well as white-tailed deer populations in Minnesota (Kunkel and Mech 1994) and Texas (Carroll and Brown 1977, Kie and White 1985). Disease did not appear to be very frequent among neonates.

Abandonment was the second most frequent cause of death but its ultimate cause is perplexing. It is possible that my handling of fawns directly resulted in abandonment because of the presence of human scent and interruption of the mother – infant bonding during the imprinting period (Livezey 1990). However, most fawns were captured after they were at least a few days old which should have provided adequate time for the mother – infant bond to occur (Lent 1974, Ozoga and Clute 1988). In addition, I discovered 8 unmarked fawns that died from no apparent external trauma and appeared to be either stillborn or abandoned. Two of these fawns were necropsied and showed no signs of nursing. Previous studies have reported

that human scent on marked fawns had no effect on reunification with mothers (Jackson et al. 1972, Bowyer et al. 1998), and Ozoga and Clute (1988) determined that marking did not increase mortality risk. Although the effects of observer handling cannot be ignored completely, I propose that abandonment is most likely related to compromised maternal nutrition and possibly age. First, decreased nutritional condition of maternal females has been related to the occurrence of abandonment in several white-tailed deer populations (White et al. 1972, Langenau and Lerg 1976, Ozoga and Clute 1988). Second, while gestation is energetically inexpensive and less risky, the energetic cost of lactation can be 3 - 4.5 times greater (Oftedal 1985). Third, younger and less experienced females may be more likely to abandon their fawns than older, more protective females (Ozoga and Verme 1986). Thus, abandonment may represent a variable maternal strategy whereby female defense and care of neonates is highest when the probability of fawn survival is highest and females have enough energy to lactate. Conversely, defense and care is lowest when compromised maternal condition and continued neonatal care by possibly inexperienced females may result in decreased overall fitness. Thus, when the probability of neonatal survival is low, the female simply 'cuts her losses' by abandoning her fawn (Wilson 1975:569, Tait 1980, Smith 1987b).

SUMMARY

Adult spatial use estimates tended to be variable among deer. Mean 95% home range size was 74.5 ha (CV = 83%, range: 6.7 – 259.8 ha), while areas of concentrated use averaged 8.5 ha (CV = 93%, range: 0.9 – 32.2 ha). Males had larger home ranges, concentrated use areas and movements than females, although predictions based on body size and metabolic rate were not substantiated. Deer inhabiting suburban or park areas consistently exhibited smaller movements and used less space than wild deer. Home range and area of concentrated use was greatest in fall, while movements were lowest in winter. Deer showed the least amount of site fidelity to seasonal home ranges and areas of concentrated use between fall-winter and summer-fall. Both home ranges and areas of concentrated use were positively correlated with diversity of cover types. CWTD appeared to be relatively sedentary, and dispersal movements were not readily apparent.

Annual adult survival rates averaged 0.73 but did not differ by sex. However, annual survival appeared to be higher for 'wild' deer (0.84) than suburban deer (0.73). Survival over the entire 3 year study was low (0.39). Most deer died in winter from a combination of emaciation and disease, and tended to be in poor body condition. Survival rates were within the lower range of rates reported for other white-tailed deer populations.

In terms of habitat selection, adult CWTD exhibited restrictive use of riparian cover types and generalized use of non-riparian cover types. The only dominant pattern of selection was for riparian cover types, while non-riparian cover types were typically either avoided or neither selected or avoided. For most deer (56%), the probability of use of a particular area decreased as distance to stream increased, and areas of concentrated use were significantly associated with proximity (≤ 200 m) to stream. However, in terms of use, oak-hardwood woodlands, riparian areas, and oak-hardwood savanna shrub were the most frequently used cover types, and these cover types are likely important even though they were not selected frequently. Habitat

associations did not appear to differ by sex, although there were some differences by type as suburban deer used conifer and yard cover types more frequently than wild deer. Seasonal habitat associations did not significantly differ among seasons, and open cover types were used more frequently during crepuscular and nocturnal periods than diurnal periods. The relative amount of edge within a particular patch had little effect on habitat use.

Home ranges, areas of concentrated use, and movements were variable but tended to reflect the sedentary nature of post-partum females and their fawns. Fawn habitat use patterns were characterized by frequent use of oak-hardwood woodland and riparian cover types, and areas within 200 m of streams. Conifer and oak-hardwood conifer cover types were rarely available. These habitat use patterns may represent some degree of rigidity in cover types composition within fawning areas, although cover type composition within areas of concentrated use tended to be more variable. Fawn survival to 6 months was low (0.15, 95% CI = 0.009 – 0.308) and was most similar to estimates from previous CWTD studies and un hunted white-tailed deer populations. Mortality was highest during the first 1 – 1.5 months of life. Predation and abandonment were the most frequent causes of death. Though not experimentally determined, fawn survival and abandonment rates may be suggestive of density dependent factors and compromised maternal condition.

MANAGEMENT RECOMMENDATIONS

Home ranges and areas of concentrated use were small but variable. When determining how much area is used and presumably required for CWTD, several factors, such as sex, proximity to humans, season, and habitat diversity need to be considered. In addition, other factors, including habitat quality and density, would likely influence spatial use patterns. While the usefulness of the home range concept has come under scrutiny and the biological meaning of home range estimates by themselves can be nebulous (White and Garrott 1990:179), it could be useful to use the home range estimates generated in this study to aid in determining minimum area requirements for mitigation, environmental impacts, and/or habitat acquisitions.

Spatial use patterns that I observed indicated that CWTD were not moving across large distances. Rather, CWTD tended to be relatively sedentary and my results appear to support observations from Oregon Department of Fish and Wildlife (unpublished data) that suggest the Douglas County sub-population is not dispersing into portions of its historic range in the Umpqua watershed. However, in order to better ascertain the degree of dispersal, a larger sample of yearling males and < 3 year old females needs to be monitored.

Smith (1985a) suggested that local extirpations of CWTD were linked to the destruction of riparian areas. Riparian areas likely provide a diverse variety of forage types as well as ample hiding cover, and may serve as corridors for dispersal (Smith 1985a). Because I found that CWTD were strongly associated with riparian areas, management practices that promote the retention and restoration of riparian and/or wetland areas should be beneficial for CWTD. For example, stream restoration and grazing exclusion projects that result in the promotion and widening of complex riparian vegetation would likely increase habitat quality and availability for CWTD. In addition oak-hardwood woodlands were frequently used and are likely important for both feeding and resting. Management that preserves oak-hardwood woodlands, as well as silvicultural activities that promote the retention of oaks and hardwood stands within conifer

stands (Loft et al. 1988), should also benefit CWTD. Lastly, the potential importance of grass and shrub containing habitats should not be overlooked. Although grass-shrub cover types were rarely used, oak-hardwood savanna shrub cover types were used almost 15% of the time and are likely important foraging habitats. Previous research on Douglas County CWTD (Smith 1981), as well as lower Columbia River CWTD (Suring and Vohs 1979) has stressed the importance of early successional shrub habitats.

Translocation is a management tool that has often been utilized to restore or augment both endangered species and ungulate populations (Griffith et al. 1989, Leberg and Ellsworth 1999), and could be used to expand the current and limited geographic range of CWTD. Several factors have been identified with the success (defined as a self sustaining population) of an translocation program, 2 of which are knowledge of habitat quality and location of release area with a species range (Griffith et al. 1989). My study provides some evidence that areas with ubiquitous oak-hardwood woodlands and riparian areas would be suitable for CWTD translocations. Although I did not assess habitat quality (e.g. in terms of available forage or hiding cover quality), the high use of oak-hardwood woodlands and riparian areas suggests that these cover types provide necessary resources. Furthermore, because habitat use was closely associated with distance to stream, most cover types within the interior valleys of the Umpqua Valley that are within close juxtaposition of a streams would likely comprise suitable translocation areas. Conversely, conifer cover types were used infrequently. Although conifers did not comprise a high proportion of the study area (thus their potential selection could not be completely assessed), and conifers can be important for white-tailed deer in eastern Oregon (Bell et al. 1992) and Idaho (Pauley et. al. 1993), it is doubtful that the industrial coniferous forests that surround the Douglas County sub-populations would comprise suitable areas for translocations. Coniferous forests do not to comprise a large portion of the historic CWTD range, which was primarily characterized by the lowland oak woodland and riparian assemblages of the interior valleys (Smith 1985a, 1987a). Accordingly, the probability of successful CWTD translocations

should increase if they occur within the historic range of CWTD, instead of areas on the periphery that may be more accessible (i.e. coniferous public lands surrounding the Umpqua, as well as Willamette Valleys).

Males and females appeared to be exhibiting some degree of sexual segregation, as evidenced by pronounced differences in spatial use patterns (but not habitat associations). Therefore, management should consider the 2 sexes separately, especially if competition is indirect and the sexes are partitioning resources (McCullough 1979, Clutton-Brock et al. 1982, Beier and McCullough 1990, Weckerly 1993). Along similar lines of reasoning, it would be prudent to manage 'suburban' and 'wild' CWTD as 2 separate groups. I found consistent differences in spatial use patterns and habitat associations between suburban and wild deer, as well as some evidence (though not conclusive) of lower survival rates for suburban deer. Monitoring and/or management plan should consider potential differences between suburban and wild CWTD, especially if delisting is approved. For example, differences in home range and area of concentrated use size between suburban and wild deer should be considered when estimating potential area requirements of deer in a particular site, or when designing potential habitat reserves that border suburban areas. Also, relying on suburban deer as a source population for re-introduction efforts could lead to reduced re-introduction success. Specifically, relocated suburban deer often experience high mortality due to physiological stress, and may disperse from their release sites to areas near human development. Also, suburban deer are often less wary because of conditioning to humans, which could then increase the chance of natural (e.g. predation) or human caused (e.g. vehicle collision) mortality in new and unfamiliar areas (O'Bryan and McCullough 1985, Jones and Witham 1990, Cromwell et al. 1999). Conversely, wild deer may more suited to use as a source population for re-introductions because they tend to be more evasive and do not rely on residential areas for habitat.

Coyotes are known to heavily predate on fawns from the Lower Columbia River CWTD sub-population (A. C. Clark, pers. commun.), as well as other white-tailed deer populations (Kie

and White 1985). Douglas County has conducted extensive predator control in recent years which has been largely targeted towards coyotes (Oregon Department of Fish and Wildlife, unpublished report). However, it is interesting that while coyote predation on fawns was almost non-existent in my study, mortality from other predators, such as bobcats, was high. It is possible that bobcat predation compensated for missing coyote predation. Coyote control is likely not a viable long term solution for increasing the productivity of Douglas County CWTD.

Adult survival rates were not alarmingly low and were higher than what Fuller (1990) estimated for a population of declining white-tailed in Minnesota with similarly low levels of simulated fawn survival. It is likely that CWTD are not declining and recruitment is marginally substantial to compensate for adult mortality. The demographic parameters that I documented (especially fawn survival) were suggestive of a population at high density, but I could not test for density dependence because of study design limitations and restrictions imposed by the endangered status of CWTD. However, my results provide a beginning foundation for future research on CWTD demographic processes. A long-term experimental design that allows for manipulation of deer densities and monitoring of pre and post-treatment fitness and/or physiological parameters would avoid many of the caveats associated with inferring density dependence from survival rates only, and could greatly add to our understanding of density dependent relations in ungulate populations (White and Bartmann 1997, 1998). This type of study could also be more easily implemented in the event that CWTD are removed from the endangered species list (Federal Register 1999).

Lastly, in order to make inferences from a sample to a population, the sample needs to have been randomly collected (Ramsey and Schafer 1997:9). It was impossible to obtain a truly random sample of marked deer due to the constraints imposed by the high proportion of private land in the study area. While I contend that I obtained a representative sample of radio-marked CWTD, care must be taken not to broadly extrapolate my results over the entire Douglas County CWTD sub-population because my sampling (capture) effort was not truly random.

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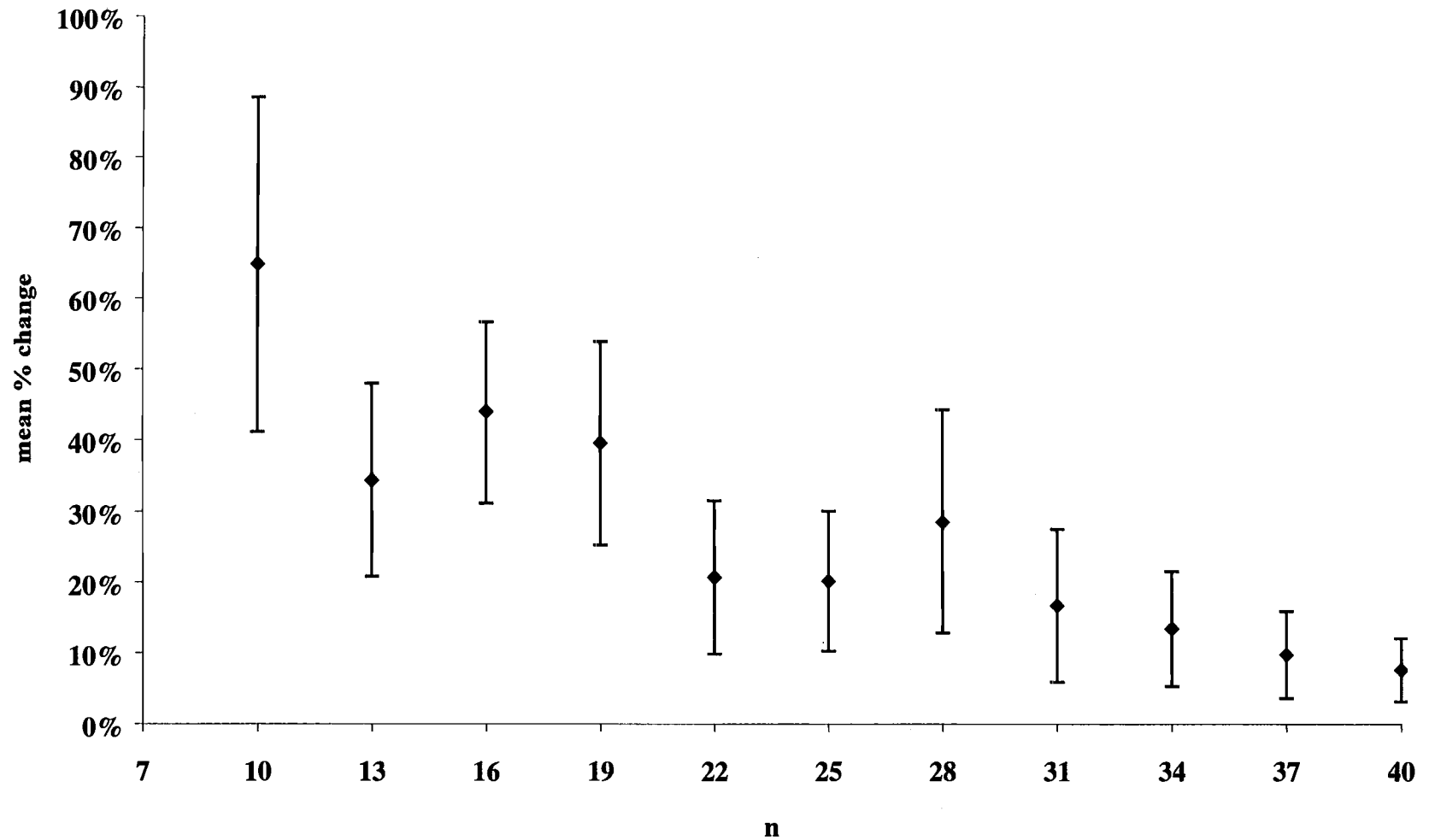
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APPENDIX



Appendix 1.1. Mean percent change in 95% fixed kernel home range area of adult Columbian white-tailed deer with increasing sample size, Douglas County, Oregon, 1996-97. Error bars represent 95% confidence intervals.

Appendix 1.2. Capture and cause of death information for 68 radio-collared adult Columbian white-tailed in Douglas County, Oregon; 1995-1998.

Deer-ID	Sex	Type	capture method	date of capture	date of death	Site	Cause of death
22	male	suburban	trap	12/08/95	08/26/97	Ramp Canyon/Parrot Creek	poaching
11	female	wild	trap	12/08/95	01/31/96	Ramp Canyon	unknown
32	male	wild	trap	12/12/95	03/01/96	Ramp Canyon	emaciation/disease
41	female	suburban	trap	12/12/95	02/01/96	Whistlers Bend Park	unknown
51	male	wild	trap	12/13/95		NBHMA-W	
71	female	suburban	trap	12/13/95	10/01/97	Whistlers Bend Park	unknown
62	female	wild	trap	12/13/95		NBHMA-E	
82	male	suburban	trap	12/14/95		Ramp Canyon	
1082	male	suburban	trap	12/15/95	11/20/96	Ramp Canyon	emaciation/disease
90	male	suburban	trap	12/20/95		Ramp Canyon	
1092	male	suburban	trap	12/20/95		Whistlers Bend Park	
1011	male	wild	trap	12/20/95	10/08/96	Jackson Ranch	unknown
101	female	wild	trap	12/20/95	04/06/97	NBHMA-W	unknown
1021	male	wild	trap	01/03/96	04/20/96	Jackson Ranch	unknown
122	female	wild	trap	01/03/96	02/10/96	NBHMA-W	emaciation/disease
112	female	wild	trap	01/03/96	02/18/97	NBHMA-E	emaciation/disease
132	female	wild	trap	01/04/96		NBHMA-E	
142	male	suburban	trap	01/05/96	02/24/96	Jackson-Short Ranch	fence-kill
171	female	suburban	dart	01/11/96		Whistlers Road	
151	female	suburban	trap	01/11/96		Ramp Canyon	
161	female	suburban	trap	01/11/96	12/22/96	Whistlers Bend Park	road-kill
1032	male	wild	trap	01/21/96	09/24/96	NBHMA-E	poaching
181	female	wild	trap	01/21/96		NBHMA-W	
1042	male	suburban	trap	01/25/96		Lindbloom Ranch	
1051	male	suburban	trap	01/31/96	03/02/97	Jackson-Short Ranch	road-kill
201	male	wild	trap	02/01/96		NBHMA-W	

192	female	wild	trap	02/01/96	08/11/96	Jones Ranch	unknown
Appendix 1.2. Continued.							
1061	male	wild	trap	02/03/96	04/04/98	Lindbloom Ranch	unknown
212	female	wild	trap	02/05/96	01/05/98	Jones Ranch	road-kill
221	male	wild	trap	02/06/96	10/27/97	NBHMA-W	
232	female	suburban	trap	02/28/96	10/19/97	Lindbloom Ranch	poaching
241	female	suburban	trap	02/28/96	03/23/96	Wild Iris	emaciation/disease
252	female	suburban	trap	03/04/96	12/06/96	Buckhorn Road	road-kill
262	male	suburban	trap	03/07/96	09/15/96	Wild Iris	
1072	male	wild	trap	03/13/96		Jackson-Short Ranch	
270	male	suburban	dart	03/15/96	12/22/96	Whistlers Road	fence-kill
301	female	wild	trap	10/15/96	10/17/96	Ramp Canyon	capture myopathy ^a
291	male	suburban	dart	10/27/96		Ramp Canyon	capture myopathy ^a
311	female	wild	trap	10/28/96		Ramp Canyon	
300	female	wild	trap	10/31/96		Ramp Canyon	
321	female	wild	trap	10/31/96		Ramp Canyon	
290	female	wild	trap	11/01/96		Ramp Canyon	
331	male	wild	trap	11/27/96	08/01/97	NBHMA-E/Wild Iris	unknown
361	female	wild	dart	12/05/96		NBHMA-E	
341	male	wild	trap	12/06/96		NBHMA-E	capture myopathy ^a
371	male	suburban	dart	12/09/96		Whistlers Road	
381	male	wild	dart	12/10/96	02/26/97	NBHMA-E	emaciation/disease
391	male	wild	dart	12/11/96		NBHMA-E	
401	male	wild	dart	12/12/96		NBHMA-E	
342	female	suburban	dart	01/08/97	02/23/97	Whistlers Bend Park	emaciation/disease
411	female	suburban	dart	01/10/97		Whistlers Bend Park	
462	male	wild	dart	01/11/97		Lindbloom Ranch	
431	female	suburban	dart	01/22/97		Whistlers Bend Park	
471	female	wild	dart	01/23/97		Jackson-Short Ranch	
481	female	wild	dart	01/23/97		NBHMA-W	
352	female	suburban	dart	02/14/97	01/15/98	Jackson-Short Ranch	road-kill

440	female	wild	dart	10/11/97		NBHMA-E	
281	male	wild	trap	11/11/97		NBHMA-W	

Appendix 1.2. Continued.

422	male	wild	trap	11/13/97	12/1/97	NBHMA-W	emaciation/disease
1022	male	wild	trap	11/12/97		NBHMA-W	
1102	male	wild	trap	11/26/97		NBHMA-W	
522	female	wild	trap	11/26/97		NBHMA-W	
531	male	wild	trap	12/09/97		NBHMA-W	
542	male	wild	trap	12/16/97		NBHMA-W	
452	male	wild	trap	12/16/97	1/26/98	NBHMA-E	predation
421	female	wild	trap	12/18/97		NBHMA-W	
562	male	wild	trap	01/28/98		NBHMA-E	capture myopathy ^a
500	male	wild	trap	01/28/98	5/29/98	NBHMA-E	unknown

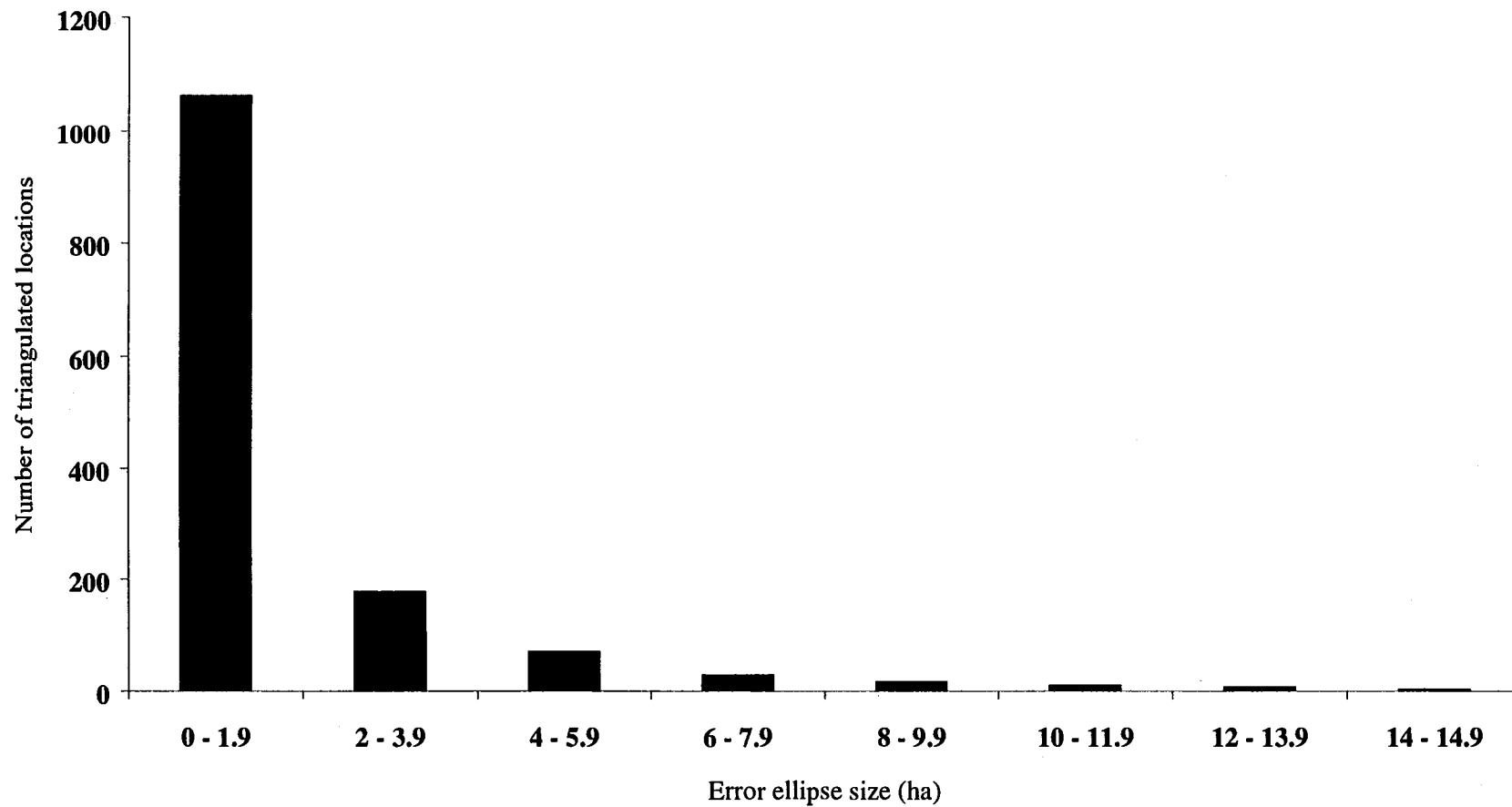
^a deer not used in survival analyses

Appendix 1.3. Number of radio-collared adult Columbian white-tailed deer and number of locations per deer used for annual and seasonal home range and area of concentrated use analyses, Douglas County, Oregon, 1996 – 1997.

Deer-ID	Sex	Type	number of locations				
			Annual	Fall	Winter	Spring	Summer
151	female	suburban	151	28	36	42	45
161	female	suburban	--	33	--	--	--
171	female	suburban	158	32	39	43	44
232	female	suburban	163	30	44	46	43
252	female	suburban	--	27	--	--	--
352	female	suburban	136	34	22	45	35
411	female	suburban	153	34	33	45	41
431	female	suburban	143	34	29	43	37
71	female	suburban	159	31	39	44	45
101	female	wild	--	32	42	--	--
112	female	wild	--	33	--	--	--
132	female	wild	170	33	44	46	47
181	female	wild	156	30	42	43	41
212	female	wild	158	31	38	44	45
290	female	wild	145	32	34	42	37
300	female	wild	145	31	34	42	38
311	female	wild	146	33	33	43	37
321	female	wild	149	33	34	44	38
361	female	wild	174	39	47	48	40
471	female	wild	147	32	31	43	41
481	female	wild	137	32	27	43	35
62	female	wild	173	36	45	45	47
1042	male	suburban	158	31	41	43	43
1051	male	suburban	--	30	28	--	--
1092	male	suburban	158	32	39	41	46
22	male	suburban	134	26	35	38	35
270	male	suburban	--	33	--	--	--
371	male	suburban	150	35	39	42	34
82	male	suburban	148	28	36	40	44
90	male	suburban	147	29	34	41	43
1061	male	wild	165	31	46	45	43
1072	male	wild	146	30	38	38	40
201	male	wild	159	31	42	43	43
221	male	wild	164	32	45	43	44
381	male	wild	--	--	26	--	--
391	male	wild	156	35	40	45	36
401	male	wild	162	35	44	46	37
462	male	wild	140	31	39	36	34
51	male	wild	160	32	42	43	43

Appendix 1.3. Continued.

no. deer	32	38	35	32	32
mean	153.7	31.9	37.2	43.2	40.8
SD	10.4	2.5	6.2	2.5	4.0
range	134 - 174	26 - 39	22 - 47	36 - 48	34 - 47



Appendix 1.4. Frequency distribution of error ellipse sizes for triangulated locations of Columbian white-tailed deer, Douglas County, Oregon, 1996-97.

Appendix 1.5. Seasonal 95% fixed kernel home range estimates for adult Columbian white-tailed deer in Douglas County, Oregon, 1996 – 97. Sample sizes of ≥ 22 locations were used to calculate estimates (see Appendix 1.3).

Deer-ID	Sex ^a	Type ^b	95% fixed kernel home range (ha)			
			Fall	Winter	Spring	Summer
22	M	S	305.4	81.2	107.4	88.5
51	M	W	257.4	52.1	97.7	129.8
62	F	W	10.7	54.4	35.9	50.6
71	F	S	88.9	31.7	22.6	27.2
82	M	S	147.5	76.8	61.4	65.4
90	M	S	104.4	133.6	78.8	27.3
101	F	W	119.6	85.7	--	--
112	F	W	64.0	--	--	--
132	F	W	46.9	59.6	48.8	27.2
151	F	S	68.6	41.5	36.8	25.9
161	F	S	12.6	--	--	--
171	F	S	7.8	6.6	7.4	3.6
181	F	W	68.6	28.1	56.9	45.3
201	M	W	404.0	88.3	147.6	174.5
212	F	W	19.2	45.0	41.6	29.3
221	M	W	296.4	70.6	104.2	140.9
232	F	S	8.7	7.2	10.7	2.8
252	F	S	5.4	--	--	--
270	M	S	41.1	--	--	--
290	F	W	96.8	94.4	63.6	30.3
300	F	W	50.6	51.8	47.3	40.9
311	F	W	146.4	38.5	35.6	46.2
321	F	W	23.7	19.3	100.6	52.5
352	F	S	9.2	38.6	16.7	58.2
361	F	W	45.7	19.6	48.2	20.7
371	M	S	48.7	13.9	5.5	8.3
381	M	W	59.0	--	--	--
391	M	W	388.6	58.6	64.8	92.4
401	M	W	41.4	129.1	131.6	169.0
411	F	S	8.5	5.1	11.9	8.4
431	F	S	26.1	17.6	10.3	4.2
462	M	W	116.8	17.3	72.9	28.7
471	F	W	43.9	10.7	11.7	15.9
481	F	W	67.9	39.2	25.2	48.2
1042	M	S	167.7	19.6	56.0	19.3
1051	M	S	110.6	131.5	--	--
1061	M	W	83.6	31.9	52.3	39.8
1072	M	W	272.3	90.8	232.4	87.5
1092	M	S	40.0	35.5	29.3	18.7

^a M = male, F = female

^a S = suburban, W = wild

Appendix 1.6. Seasonal area of concentrated use size (in hectares) and associated contour for observation densities for adult Columbian white-tailed deer in Douglas County Oregon., 1996 – 97. Sample sizes of ≥ 22 locations were used to calculate estimates (see Appendix 1.3).

Deer-ID	Sex ^a	Type ^b	area of concentrated use (contour) (%)			
			Fall	Winter	Spring	Summer
22	M	S	40.4 (60)	9.6 (70)	16.1 (78)	7.8 (75)
51	M	W	49.3 (70)	6.8 (60)	9.3 (62)	15.5 (68)
62	F	W	1.9 (75)	8.3 (70)	3.1 (65)	6.0 (73)
71	F	S	8.9 (79)	3.2 (77)	4.3 (67)	5.8 (73)
82	M	S	25.6 (67)	7.7 (75)	9.2 (62)	9.7 (74)
90	M	S	7.2 (56)	21.6 (64)	7.9 (71)	2.3 (76)
101	F	W	23.8 (63)	16.0 (72)	--	--
112	F	W	10.4 (74)	11.7 (71)	--	--
132	F	W	6.2 (77)	10.0 (80)	10.0 (72)	4.1 (62)
151	F	S	14.7 (72)	5.8 (78)	5.7 (64)	2.9 (71)
161	F	S	1.2 (62)	--	--	--
171	F	S	1.3 (75)	1.2 (62)	1.2 (79)	0.3 (66)
181	F	W	10.1 (80)	3.5 (80)	7.5 (76)	5.8 (70)
201	M	W	67.9 (59)	11.6 (79)	16.8 (70)	25.9 (77)
212	F	W	2.1 (68)	3.0 (70)	3.0 (71)	3.2 (66)
221	M	W	27.4 (71)	7.9 (77)	11.5 (74)	17.6 (79)
232	F	S	0.9 (67)	0.7 (57)	1.4 (66)	0.3 (77)
252	F	S	0.2 (61)	--	--	--
270	M	S	3.8 (71)	--	--	--
290	F	W	16.6 (70)	15.3 (69)	8.7 (69)	2.0 (61)
300	F	W	4.2 (82)	6.4 (85)	4.4 (70)	4.6 (55)
311	F	W	25.2 (74)	6.1 (74)	5.4 (74)	7.5 (69)
321	F	W	2.4 (70)	2.5 (84)	8.8 (63)	6.8 (76)
352	F	S	1.2 (81)	6.1 (73)	1.1 (60)	10.3 (74)
361	F	W	5.8 (69)	0.9 (67)	5.1 (67)	1.7 (63)
371	M	S	4.3 (77)	2.1 (63)	0.5 (68)	1.0 (77)
381	M	W	--	8.1 (60)	--	--
391	M	W	60.5 (79)	8.0 (71)	6.3 (69)	10.4 (70)
401	M	W	1.9 (60)	17.9 (63)	17.3 (71)	27.4 (58)
411	F	S	1.1 (67)	0.5 (78)	1.0 (66)	0.7 (72)
431	F	S	4.6 (75)	2.8 (71)	1.3 (67)	0.2 (63)
462	M	W	18.4 (74)	1.0 (76)	6.4 (64)	3.7 (73)
471	F	W	4.8 (73)	1.2 (74)	0.8 (69)	1.9 (80)
481	F	W	11.0 (62)	4.8 (81)	1.6 (52)	3.5 (71)
1042	M	S	34.2 (70)	1.0 (80)	5.9 (72)	1.8 (79)
1051	M	S	10.1 (63)	12.7 (71)	--	--
1061	M	W	12.9 (69)	2.8 (71)	8.5 (55)	4.4 (61)
1072	M	W	37.2 (74)	11.2 (69)	31.2 (62)	9.3 (76)
1092	M	S	6.4 (64)	7.3 (70)	5.0 (74)	2.6 (81)

Appendix 1.6. Continued.

^a M = male, F = female

^a S = suburban, W = wild

Appendix 1.7. Summary statistics for MRPP analyses estimating site fidelity between sequential seasons for locations within 95% fixed kernel home ranges for adult Columbian white-tailed deer, Douglas County, Oregon; 1996-97. A significant shift occurred when $P < 0.05$. R measures within group heterogeneity, and T is the test statistic. Significance for all P values is a bonferonni adjusted $\alpha = 0.0125$, except for Deer ID numbers 101, and 1051, where significance is $\alpha = 0.05$.

Deer ID	Sex	Type	Fall – Winter			Winter – Spring			Spring – Summer			Summer - Fall		
			T	R	P	T	R	P	T	R	P	T	R	P
22	Male	Suburban	-18.87	0.21	0.00	-11.22	0.09	0.00	-6.69	0.00	0.06	-14.58	0.21	0.00
51	Male	Wild	-1.34	0.01	0.10	- 2.89	0.02	0.02	0.59	0.67	0.00	-4.96	0.04	0.00
62	Female	Wild	-3.40	0.03	0.01	-3.98	0.03	0.01	-0.97	0.14	0.01	-6.45	0.05	0.00
71	Female	Suburban	-6.71	0.12	0.00	-18.42	0.28	0.00	-1.39	0.09	0.01	-7.63	0.07	0.00
82	Male	Suburban	-4.82	0.04	0.00	-9.18	0.08	0.00	-7.47	0.00	0.06	-8.55	0.07	0.00
90	Male	Suburban	-11.09	0.11	0.00	-0.59	0.00	0.21	-7.18	0.00	0.05	-14.77	0.13	0.00
101	Female	Wild	-5.90	0.05	0.01									
132	Female	Wild	0.23	0.00	0.46	-3.59	0.02	0.01	0.52	0.61	0.00	-4.57	0.04	0.00
151	Female	Suburban	-11.46	0.13	0.00	-1.69	0.01	0.07	-4.99	0.00	0.04	-7.92	0.08	0.00
171	Female	Suburban	-0.59	0.00	0.21	0.67	0.00	0.71	-0.87	0.35	0.00	-0.62	0.00	0.21
181	Female	Wild	-2.23	0.02	0.04	-2.15	0.01	0.04	-0.84	0.16	0.01	-2.35	0.02	0.03
201	Male	Wild	-1.75	0.01	0.06	-1.44	0.01	0.09	0.47	0.60	0.00	-2.21	0.02	0.04
212	Female	Wild	-8.81	0.08	0.00	-6.12	0.05	0.00	-3.95	0.01	0.03	-4.66	0.04	0.00
221	Male	Wild	-22.48	0.18	0.00	-3.33	0.02	0.01	-6.86	0.00	0.05	-7.74	0.06	0.00
232	Female	Suburban	-0.44	0.00	0.23	-1.90	0.01	0.06	-13.37	0.00	0.09	-0.75	0.01	0.18
290	Female	Wild	-1.20	0.01	0.11	-0.74	0.01	0.18	0.59	0.66	0.00	0.85	-0.01	0.87
300	Female	Wild	-1.72	0.02	0.07	-3.29	0.03	0.01	-2.43	0.03	0.02	-5.51	0.05	0.00
311	Female	Wild	-3.76	0.03	0.01	-6.15	0.04	0.00	-2.52	0.03	0.02	-4.40	0.04	0.01
321	Female	Wild	-2.31	0.02	0.03	-27.77	0.33	0.00	-17.54	0.00	0.20	-2.87	0.03	0.02
352	Female	Suburban	-12.86	0.13	0.00	0.70	-0.01	0.73	0.16	0.43	0.00	-5.83	0.05	0.00
361	Female	Wild	-0.21	0.00	0.27	-1.10	0.01	0.12	-1.24	0.10	0.01	-0.70	0.01	0.17
371	Male	Suburban	-21.89	0.22	0.00	-2.31	0.02	0.04	-0.28	0.25	0.00	-16.99	0.18	0.00
391	Male	Wild	-25.24	0.23	0.00	-0.66	0.00	0.19	-7.53	0.00	0.06	-13.48	0.12	0.00
401	Male	Wild	-1.80	0.02	0.06	-5.96	0.05	0.00	-3.30	0.02	0.03	-4.18	0.04	0.01
411	Female	Suburban	-1.34	0.01	0.10	-0.70	0.01	0.18	0.14	0.42	0.00	-0.24	0.00	0.29

431	Female	Suburban	0.93	-0.01	0.91	0.78	-0.01	0.79	-2.83	0.02	0.02	-4.92	0.04	0.00
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Appendix 1.7. Continued

462	Male	Wild	-21.38	0.23	0.00	-10.39	0.12	0.00	-20.20	0.00	0.33	-33.79	0.58	0.00
471	Female	Wild	-0.35	0.00	0.25	-2.31	0.02	0.04	-0.73	0.18	0.01	-0.34	0.00	0.26
481	Female	Wild	-6.91	0.07	0.00	-4.97	0.04	0.00	-0.65	0.19	0.00	-3.25	0.03	0.01
1042	Male	Suburban	-11.13	0.12	0.00	0.09	0.00	0.39	-0.88	0.14	0.01	-15.50	0.18	0.00
1051	Male	Suburban	-6.06	0.07	0.01									
1061	Male	Wild	0.49	0.00	0.60	-3.08	0.02	0.02	-0.61	0.19	0.00	0.73	-0.01	0.77
1072	Male	Wild	-20.74	0.24	0.00	-14.81	0.14	0.00	-21.99	0.00	0.25	-11.57	0.13	0.00
1092	Male	Suburban	-5.43	0.05	0.00	-1.65	0.01	0.07	-10.24	0.00	0.07	-2.48	0.02	0.03

number significant shifts	16	20	20	12
number non-significant shifts	18	12	12	20
% significant shifts	53%	38%	38%	63%

Appendix 1.8. Summary statistics for MRPP analyses estimating site fidelity between sequential seasons for locations within areas of concentrated use (ACU) for adult Columbian white-tailed deer, Douglas County, Oregon; 1996-97. A significant shift occurred when $P < 0.05$. R measures within group heterogeneity, and T is the test statistic. Significance for all P values is a bonferonni adjusted $\alpha = 0.0125$, except for Deer ID numbers 101, 112, and 1051, where significance is $\alpha = 0.05$.

Deer ID	Sex	Type	Fall – Winter			Winter-Spring			Spring-Summer			Summer-Fall		
			T	R	P	T	R	P	T	R	P	T	R	P
22	Male	Suburban	-15.99	0.62	0.00	-11.36	0.20	0.00	-11.32	0.21	0.00	-17.10	0.81	0.00
51	Male	Wild	-1.70	0.03	0.07	-10.00	0.20	0.00	-5.65	0.11	0.00	-7.24	0.13	0.00
62	Female	Wild	-1.75	0.03	0.06	-4.32	0.08	0.01	-2.37	0.04	0.03	-2.85	0.05	0.02
71	Female	Suburban	-7.84	0.27	0.00	-10.27	0.32	0.00	-3.52	0.05	0.01	-5.85	0.10	0.00
82	Male	Suburban	-11.48	0.26	0.00	-7.59	0.17	0.00	-3.31	0.07	0.01	-10.37	0.21	0.00
90	Male	Suburban	-14.64	0.50	0.00	-5.09	0.10	0.00	-14.08	0.27	0.00	-17.61	0.77	0.00
101	Female	Wild	-11.42	0.19	0.00									
132	Female	Wild	-2.79	0.05	0.02	-3.74	0.06	0.01	-2.72	0.05	0.03	-6.51	0.17	0.00
151	Female	Suburban	-15.14	0.33	0.00	-8.27	0.16	0.00	-3.53	0.07	0.01	-13.47	0.30	0.00
171	Female	Suburban	-4.73	0.08	0.00	-1.71	0.03	0.07	-8.64	0.14	0.00	-5.23	0.09	0.00
181	Female	Wild	-4.64	0.07	0.00	-2.45	0.04	0.03	-4.12	0.08	0.01	-1.14	0.02	0.11
201	Male	Wild	-1.45	0.03	0.09	-7.03	0.13	0.00	-0.06	0.00	0.34	0.41	-0.01	0.56
212	Female	Wild	-5.54	0.18	0.00	-1.84	0.04	0.06	-3.45	0.07	0.01	-5.08	0.15	0.00
221	Male	Wild	-24.08	0.60	0.00	-0.92	0.02	0.14	-6.57	0.14	0.00	-7.98	0.19	0.00
232	Female	Suburban	-0.30	0.01	0.29	-8.90	0.17	0.00	-7.69	0.12	0.00	-0.76	0.02	0.17
300	Female	Wild	-8.96	0.15	0.00	-2.97	0.05	0.02	-8.45	0.20	0.00	-7.82	0.20	0.00
311	Female	Wild	-3.01	0.05	0.02	-15.98	0.27	0.00	-1.67	0.03	0.07	-6.94	0.13	0.00
321	Female	Wild	-5.53	0.13	0.00	-22.09	0.72	0.00	-22.01	0.70	0.00	-3.67	0.06	0.01
352	Female	Suburban	-18.34	0.52	0.00	0.05	0.00	0.38	-3.38	0.06	0.01	-13.40	0.25	0.00
361	Female	Wild	-7.43	0.27	0.00	-7.48	0.20	0.00	0.13	0.00	0.38	-3.35	0.10	0.02
371	Male	Suburban	-18.39	0.51	0.00	-4.85	0.13	0.00	-0.41	0.01	0.22	-12.76	0.28	0.00
391	Male	Wild	-23.05	0.52	0.00	-2.83	0.05	0.02	3.92	0.09	0.01	-16.27	0.32	0.00
401	Male	Wild	-4.57	0.16	0.01	-3.90	0.08	0.01	-5.44	0.11	0.00	-9.32	0.28	0.00
411	Female	Suburban	-6.86	0.16	0.00	-1.57	0.03	0.08	-3.87	0.09	0.01	-3.05	0.06	0.02
431	Female	Suburban	-1.38	0.02	0.09	-1.72	0.03	0.07	-2.09	0.05	0.04	-4.37	0.09	0.00
462	Male	Wild	-18.33	0.59	0.00	-9.61	0.31	0.00	-14.32	0.55	0.00	-22.66	0.82	0.00

Appendix 1.8. Continued

471	Female	Wild	-2.42	0.07	0.03	-4.89	0.13	0.00	-4.82	0.10	0.00	0.22	-0.01	0.43
481	Female	Wild	0.01	0.00	0.38	-3.40	0.09	0.01	-2.69	0.06	0.02	-2.63	0.06	0.02
1042	Male	Suburban	-13.89	0.39	0.00	-6.90	0.14	0.00	-10.66	0.20	0.00	-19.28	0.50	0.00
1051	Male	Suburban	-11.51	0.58	0.00									
1061	Male	Wild	-2.64	0.06	0.03	-6.23	0.13	0.00	3.51	0.06	0.01	-7.64	0.15	0.00
1072	Male	Wild	-14.76	0.42	0.00	-16.85	0.36	0.00	-17.92	0.59	0.00	-8.80	0.28	0.00
1092	Male	Suburban	-15.12	0.29	0.00	-2.39	0.04	0.03	-13.67	0.21	0.00	6.06	0.10	0.00
number significant shifts			11			10			10			9		
number non-significant shifts			23			22			22			23		
% significant shifts			65%			69%			69%			72%		

Appendix 2.1. Annual use, availability, and selection ^a of grassland cover types by 32 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	No. locations	% use	available area (ha)	% available	Lower CI	Upper CI	Selection
22	19	14.7%	42.4	11.7%	6.2%	23.3%	neutral
51	10	6.5%	15.5	9.2%	1.2%	11.8%	neutral
62	22	12.9%	22.3	29.2%	6.0%	19.8%	avoid
71	20	12.7%	114.9	46.5%	5.7%	19.6%	avoid
82	8	5.7%	10.8	10.9%	0.3%	11.1%	neutral
90	27	18.9%	23.1	17.1%	10.1%	27.7%	neutral
132	9	5.4%	9.5	14.1%	0.7%	10.1%	avoid
151	9	6.4%	4.6	9.8%	0.7%	12.0%	neutral
171	0	0.0%	--	--	--	--	--
181	4	2.7%	3.4	3.3%	-0.9%	6.3%	neutral
201	14	9.0%	22.7	8.9%	2.8%	15.2%	neutral
212	51	35.7%	14.7	15.4%	24.9%	46.4%	prefer
221	17	10.6%	15.7	3.3%	4.0%	17.1%	prefer
232	4	2.5%	0.2	1.5%	-0.8%	5.7%	neutral
290	33	23.6%	13.7	11.1%	14.3%	32.8%	prefer
300	33	23.7%	20.2	16.1%	14.0%	33.4%	neutral
311	29	20.7%	22.3	19.6%	11.5%	29.9%	neutral
321	5	3.5%	24.0	11.5%	-0.6%	7.6%	avoid
352	18	13.3%	13.6	22.4%	5.5%	21.2%	avoid
361	56	32.9%	26.9	25.7%	23.4%	42.4%	neutral
371	4	2.7%	15.5	19.2%	-0.9%	6.3%	avoid
391	14	9.1%	58.7	19.4%	2.9%	15.3%	avoid
401	28	18.3%	55.0	18.5%	9.7%	26.9%	neutral
411	2	1.3%	2.9	18.3%	-1.2%	3.8%	avoid
431	5	3.5%	2.5	17.1%	-0.6%	7.6%	avoid
462	25	18.1%	47.4	19.6%	9.3%	26.9%	neutral
471	7	4.9%	14.7	24.2%	0.1%	9.6%	avoid
481	10	7.4%	10.5	8.6%	1.5%	13.3%	neutral
1042	23	15.4%	34.6	29.9%	7.3%	23.5%	avoid
1061	40	25.8%	24.9	37.6%	16.4%	35.3%	avoid
1072	30	21.6%	61.9	21.5%	12.0%	31.1%	neutral
1092	28	17.7%	6.9	21.3%	9.7%	25.7%	neutral

^a Selection based on Bonferonni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984)

Appendix 2.2. Annual use, availability, and selection ^a of grass-shrub cover types by 32 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	No. locations	% use	available area (ha)	% available	Lower CI	Upper CI	Selection
22	0	0.0%	3.0	0.8%	0.0%	0.0%	avoid
51	0	0.0%	--	--	--	--	--
62	15	8.8%	9.1	11.9%	3.0%	14.6%	neutral
71	0	0.0%	12.5	5.0%	0.0%	0.0%	avoid
82	35	25.0%	14.4	14.5%	15.0%	35.0%	prefer
90	11	7.7%	14.0	10.4%	1.7%	13.7%	neutral
132	32	19.3%	9.2	13.8%	11.0%	27.5%	neutral
151	21	14.9%	9.5	20.2%	6.7%	23.1%	neutral
171	0	0.0%	--	--	--	--	--
181	0	0.0%	1.4	1.3%	0.0%	0.0%	avoid
201	0	0.0%	0.1	0.0%	0.0%	0.0%	avoid
212	8	5.6%	8.2	8.7%	0.4%	10.8%	neutral
221	8	5.0%	37.0	7.8%	0.4%	9.6%	neutral
232	7	4.3%	0.9	6.7%	0.0%	8.6%	neutral
290	0	0.0%	2.2	1.8%	0.0%	0.0%	avoid
300	11	7.9%	7.9	6.3%	1.8%	14.1%	neutral
311	4	2.9%	1.2	1.0%	-0.9%	6.6%	neutral
321	0	0.0%	3.2	1.5%	0.0%	0.0%	avoid
352	6	4.4%	4.9	8.0%	-0.3%	9.2%	neutral
361	13	7.6%	8.9	8.5%	2.3%	13.0%	neutral
371	0	0.0%	--	--	--	--	--
391	5	3.2%	26.6	8.8%	-0.6%	7.1%	avoid
401	10	6.5%	33.3	11.2%	1.1%	12.0%	neutral
411	0	0.0%	--	--	--	--	--
431	0	0.0%	--	--	--	--	--
462	2	1.4%	13.1	5.4%	-1.3%	4.2%	avoid
471	1	0.7%	1.3	2.1%	-1.1%	2.5%	neutral
481	0	0.0%	3.2	2.7%	0.0%	0.0%	avoid
1042	0	0.0%	4.4	3.8%	0.0%	0.0%	avoid
1061	1	0.6%	1.2	1.8%	-1.1%	2.4%	neutral
1072	19	13.7%	31.8	11.0%	5.7%	21.7%	neutral
1092	0	0.0%	--	--	--	--	--

^a Selection based on Bonferonni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984)

Appendix 2.3. Annual use, availability, and selection ^a of oak-hardwood savanna cover types by 32 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	No. locations	% use	available area (ha)	% available	Lower CI	Upper CI	Selection
22	2	1.6%	1.1	0.3%	-1.4%	4.5%	neutral
51	33	21.4%	29.7	17.6%	12.5%	30.3%	neutral
62	3	1.8%	7.0	9.2%	-0.9%	4.5%	avoid
71	0	0.0%	33.2	13.4%	0.0%	0.0%	avoid
82	0	0.0%	--	--	--	--	--
90	0	0.0%	1.0	0.8%	0.0%	0.0%	avoid
132	4	2.4%	5.1	7.7%	-0.8%	5.6%	avoid
151	0	0.0%	--	--	--	--	--
171	3	1.9%	0.9	10.3%	-0.7%	4.6%	avoid
181	0	0.0%	3.3	3.1%	0.0%	0.0%	avoid
201	33	21.3%	33.7	13.2%	12.4%	30.1%	neutral
212	0	0.0%	--	--	--	--	--
221	5	3.1%	36.0	7.6%	-0.6%	6.8%	avoid
232	0	0.0%	--	--	--	--	--
290	0	0.0%	1.1	0.9%	0.0%	0.0%	avoid
300	0	0.0%	1.1	0.8%	0.0%	0.0%	avoid
311	0	0.0%	--	--	--	--	--
321	0	0.0%	--	--	--	--	--
352	9	6.7%	5.4	8.9%	0.9%	12.4%	neutral
361	52	30.6%	18.7	17.9%	21.3%	39.9%	prefer
371	0	0.0%	2.0	2.5%	0.0%	0.0%	avoid
391	14	9.1%	30.9	10.2%	2.9%	15.3%	neutral
401	18	11.8%	23.7	8.0%	4.6%	18.9%	neutral
411	27	17.8%	3.3	20.3%	9.4%	26.1%	neutral
431	27	18.9%	3.8	25.9%	10.1%	27.7%	neutral
462	6	4.3%	50.2	20.7%	-0.3%	9.0%	avoid
471	16	11.2%	10.5	17.3%	4.2%	18.1%	neutral
481	1	0.7%	3.0	2.4%	-1.2%	2.7%	neutral
1042	2	1.3%	1.9	1.6%	-1.2%	3.9%	neutral
1061	0	0.0%	2.7	4.1%	0.0%	0.0%	avoid
1072	6	4.3%	25.8	9.0%	-0.4%	9.0%	neutral
1092	0	0.0%	0.0	0.1%	0.0%	0.0%	avoid

^a Selection based on Bonferonni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984)

Appendix 2.4. Annual use, availability, and selection ^a of oak-hardwood savanna shrub cover types by 32 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	No. locations	% use	available area (ha)%	available	Lower CI	Upper CI	Selection
22	32	24.8%	72.7	20.1%	14.4%	35.2%	neutral
51	1	0.6%	12.1	7.2%	-1.1%	2.4%	avoid
62	99	57.9%	20.0	26.2%	47.7%	68.1%	prefer
71	23	14.6%	10.5	4.2%	7.2%	22.0%	prefer
82	24	17.1%	15.5	15.5%	8.4%	25.9%	neutral
90	27	18.9%	28.5	21.1%	10.1%	27.7%	neutral
132	72	43.4%	22.5	33.4%	33.0%	53.7%	neutral
151	34	24.1%	10.4	22.0%	14.2%	34.0%	neutral
171	0	0.0%	--	--	--	--	--
181	7	4.8%	19.6	18.6%	0.0%	9.5%	avoid
201	6	3.9%	28.4	11.1%	-0.3%	8.0%	avoid
212	12	8.4%	22.8	24.0%	2.2%	14.6%	avoid
221	16	9.9%	125.3	26.3%	3.6%	16.3%	avoid
232	10	6.2%	1.0	7.4%	1.1%	11.3%	neutral
290	25	17.9%	15.6	12.7%	9.5%	26.2%	neutral
300	34	24.5%	22.1	17.7%	14.7%	34.3%	neutral
311	6	4.3%	15.9	14.0%	-0.3%	8.9%	avoid
321	22	15.5%	28.6	13.7%	7.5%	23.5%	neutral
352	53	39.3%	10.2	16.8%	28.0%	50.6%	prefer
361	6	3.5%	19.8	18.9%	-0.2%	7.3%	avoid
371	1	0.7%	4.5	5.6%	-1.1%	2.5%	avoid
391	27	17.5%	79.7	26.3%	9.3%	25.8%	avoid
401	34	22.2%	93.1	31.3%	13.0%	31.4%	neutral
411	5	3.3%	1.3	8.3%	-0.6%	7.2%	avoid
431	6	4.2%	0.9	6.2%	-0.3%	8.7%	neutral
462	23	16.7%	23.5	9.7%	8.1%	25.2%	neutral
471	0	0.0%	--	--	--	--	--
481	46	33.8%	40.9	33.5%	23.1%	44.5%	neutral
1042	3	2.0%	7.9	6.8%	-1.1%	5.2%	avoid
1061	21	13.5%	5.1	7.6%	6.2%	20.9%	neutral
1072	10	7.2%	34.9	12.1%	1.2%	13.2%	neutral
1092	10	6.3%	4.3	13.4%	1.2%	11.4%	avoid

^a Selection based on Bonferonni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984)

Appendix 2.5. Annual use, availability, and selection ^a of oak-hardwood woodland cover types by 32 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	No. locations	% use	available area (ha)	% available	Lower CI	Upper CI	Selection
22	39	30.2%	127.1	35.1%	19.2%	41.3%	neutral
51	59	38.3%	80.1	47.6%	27.8%	48.8%	neutral
62	0	0.0%	1.0	1.4%	0.0%	0.0%	avoid
71	24	15.2%	35.2	14.2%	7.7%	22.7%	neutral
82	32	22.9%	24.7	24.8%	13.1%	32.6%	neutral
90	18	12.6%	33.4	24.8%	5.1%	20.0%	avoid
132	14	8.4%	6.5	9.6%	2.6%	14.2%	neutral
151	54	38.3%	12.1	25.7%	27.1%	49.5%	prefer
171	0	0.0%	0.1	0.6%	0.0%	0.0%	avoid
181	73	49.7%	44.6	42.4%	38.6%	60.8%	neutral
201	53	34.2%	110.0	43.2%	23.9%	44.4%	neutral
212	37	25.9%	27.8	29.2%	16.0%	35.7%	neutral
221	36	22.4%	115.7	24.3%	13.5%	31.2%	neutral
232	40	24.7%	3.9	29.0%	15.6%	33.8%	neutral
290	42	30.0%	55.6	45.1%	20.0%	40.0%	avoid
300	28	20.1%	43.3	34.6%	11.0%	29.3%	avoid
311	47	33.6%	40.7	35.8%	22.8%	44.3%	neutral
321	72	50.7%	68.8	33.1%	39.6%	61.8%	prefer
352	11	8.1%	14.2	23.4%	1.8%	14.5%	avoid
361	15	8.8%	17.7	16.9%	3.1%	14.6%	avoid
371	12	8.2%	13.8	17.2%	2.1%	14.2%	avoid
391	51	33.1%	71.0	23.5%	22.9%	43.3%	neutral
401	16	10.5%	39.1	13.2%	3.7%	17.2%	neutral
411	25	16.4%	2.7	16.7%	8.4%	24.5%	neutral
431	28	19.6%	2.1	14.3%	10.7%	28.5%	neutral
462	48	34.8%	68.8	28.4%	23.9%	45.7%	neutral
471	14	9.8%	20.4	33.7%	3.2%	16.3%	avoid
481	20	14.7%	37.3	30.5%	6.7%	22.7%	avoid
1042	19	12.8%	29.8	25.8%	5.3%	20.2%	avoid
1061	82	52.9%	23.8	35.9%	42.1%	63.7%	prefer
1072	57	41.0%	95.6	33.2%	29.6%	52.4%	neutral
1092	34	21.5%	7.2	22.3%	12.9%	30.1%	neutral

^a Selection based on Bonferonni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984)

Appendix 2.6. Annual use, availability, and selection ^a of oak-hardwood conifer cover types by 32 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	No. locations	% use	available area (ha)	% available	Lower CI	Upper CI	Selection
22	15	11.6%	53.2	14.7%	3.9%	19.4%	neutral
51	19	12.3%	13.9	8.3%	5.2%	19.5%	neutral
62	2	1.2%	2.5	3.3%	-1.0%	3.4%	neutral
71	43	27.2%	9.8	4.0%	17.9%	36.5%	prefer
82	13	9.3%	19.1	19.2%	2.6%	16.0%	avoid
90	12	8.4%	10.9	8.1%	2.2%	14.6%	neutral
132	0	0.0%	1.0	1.5%	0.0%	0.0%	avoid
151	7	5.0%	2.7	5.6%	0.0%	10.0%	neutral
171	0	0.0%	0.0	0.1%	0.0%	0.0%	avoid
181	10	6.8%	15.5	14.7%	1.2%	12.4%	avoid
201	21	13.5%	27.4	10.8%	6.2%	20.9%	neutral
212	8	5.6%	10.1	10.7%	0.4%	10.8%	neutral
221	11	6.8%	82.7	17.3%	1.5%	12.2%	avoid
232	58	35.8%	5.0	36.8%	25.7%	45.9%	neutral
290	9	6.4%	23.7	19.3%	1.1%	11.8%	avoid
300	12	8.6%	18.0	14.4%	2.2%	15.0%	neutral
311	40	28.6%	20.2	17.8%	18.3%	38.8%	prefer
321	22	15.5%	52.9	25.4%	7.5%	23.5%	avoid
352	0	0.0%	0.3	0.4%	0.0%	0.0%	avoid
361	0	0.0%	--	--	--	--	--
371	2	1.4%	6.5	8.1%	-1.2%	3.9%	avoid
391	1	0.6%	5.4	1.8%	-1.1%	2.4%	neutral
401	5	3.3%	19.3	6.5%	-0.7%	7.2%	neutral
411	58	38.2%	2.5	15.7%	27.6%	48.8%	prefer
431	53	37.1%	2.5	16.9%	26.2%	47.9%	prefer
462	8	5.8%	12.4	5.1%	0.4%	11.1%	neutral
471	1	0.7%	2.5	4.1%	-1.1%	2.5%	avoid
481	2	1.5%	9.3	7.6%	-1.2%	4.2%	avoid
1042	24	16.1%	14.2	12.3%	7.9%	24.4%	neutral
1061	9	5.8%	3.8	5.7%	0.8%	10.9%	neutral
1072	3	2.2%	9.2	3.2%	-1.2%	5.5%	neutral
1092	12	7.6%	4.7	14.4%	2.0%	13.1%	avoid

^a Selection based on Bonferonni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984)

Appendix 2.7. Annual use, availability, and selection ^a of conifer cover types by 32 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	No. locations	% use	available area (ha)	% available	Lower CI	Upper CI	Selection
22	1	0.8%	11.0	3.0%	-1.3%	2.9%	avoid
51	1	0.6%	0.3	0.2%	-1.1%	2.4%	neutral
62	4	2.3%	7.7	10.0%	-0.8%	5.4%	avoid
71	24	15.2%	5.4	2.2%	7.7%	22.7%	prefer
82	0	0.0%	--	--	--	--	--
90	0	0.0%	--	--	--	--	--
132	1	0.6%	1.8	2.7%	-1.0%	2.2%	avoid
151	0	0.0%	--	--	--	--	--
171	0	0.0%	--	--	--	--	--
181	3	2.0%	3.4	3.3%	-1.1%	5.2%	neutral
201	1	0.6%	3.6	1.4%	-1.1%	2.4%	neutral
212	0	0.0%	--	--	--	--	--
221	0	0.0%	14.4	3.0%	0.0%	0.0%	avoid
232	0	0.0%	--	--	--	--	--
290	0	0.0%	--	--	--	--	--
300	0	0.0%	--	--	--	--	--
311	1	0.7%	0.8	0.7%	-1.2%	2.6%	neutral
321	0	0.0%	4.8	2.3%	0.0%	0.0%	avoid
352	0	0.0%	--	--	--	--	--
361	0	0.0%	--	--	--	--	--
371	4	2.7%	6.4	7.9%	-0.9%	6.3%	avoid
391	0	0.0%	0.5	0.2%	0.0%	0.0%	avoid
401	21	13.7%	12.4	4.2%	6.1%	21.3%	prefer
411	0	0.0%	--	--	--	--	--
431	0	0.0%	--	--	--	--	--
462	0	0.0%	--	--	--	--	--
471	0	0.0%	--	--	--	--	--
481	0	0.0%	0.6	0.5%	0.0%	0.0%	avoid
1042	24	16.1%	1.0	0.8%	7.9%	24.4%	prefer
1061	0	0.0%	--	--	--	--	--
1072	0	0.0%	3.5	1.2%	0.0%	0.0%	avoid
1092	35	22.2%	6.0	18.5%	13.4%	30.9%	neutral

^a Selection based on Bonferonni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984)

Appendix 2.8. Annual use, availability, and selection ^a of riparian cover types by 32 adult Columbian white-tailed deer, Douglas County, Oregon, 1996 – 97.

Deer ID	No. locations	% use	available area (ha)	% available	Lower CI	Upper CI	Selection
22	15	11.6%	20.3	5.6%	3.9%	19.4%	neutral
51	31	20.1%	16.6	9.9%	11.4%	28.8%	prefer
62	26	15.2%	6.7	8.8%	7.8%	22.6%	neutral
71	24	15.2%	25.7	10.4%	7.7%	22.7%	neutral
82	23	16.4%	9.8	9.8%	7.8%	25.0%	neutral
90	32	22.4%	17.0	12.6%	13.0%	31.8%	prefer
132	34	20.5%	11.5	17.2%	12.1%	28.9%	neutral
151	11	7.8%	4.2	8.9%	1.6%	14.0%	neutral
171	13	8.3%	0.7	7.7%	3.0%	13.6%	neutral
181	50	34.0%	13.9	13.2%	23.5%	44.5%	prefer
201	27	17.4%	28.8	11.3%	9.2%	25.6%	neutral
212	14	9.8%	7.8	8.2%	3.1%	16.5%	neutral
221	68	42.2%	50.1	10.5%	31.8%	52.7%	prefer
232	2	1.2%	1.2	8.8%	-1.1%	3.6%	avoid
290	31	22.1%	11.4	9.2%	13.1%	31.2%	prefer
300	20	14.4%	11.5	9.2%	6.4%	22.4%	neutral
311	13	9.3%	12.8	11.2%	2.7%	15.9%	neutral
321	11	7.7%	17.9	8.6%	1.8%	13.7%	neutral
352	21	15.6%	3.7	6.1%	7.2%	23.9%	prefer
361	28	16.5%	12.5	11.9%	9.0%	24.0%	neutral
371	11	7.5%	11.6	14.4%	1.6%	13.3%	avoid
391	42	27.3%	29.8	9.8%	17.6%	36.9%	prefer
401	21	13.7%	21.2	7.1%	6.1%	21.3%	neutral
411	20	13.2%	2.4	14.8%	5.8%	20.5%	neutral
431	12	8.4%	1.9	12.9%	2.2%	14.6%	neutral
462	26	18.8%	24.8	10.2%	9.9%	27.8%	neutral
471	104	72.7%	11.3	18.6%	62.9%	82.5%	prefer
481	57	41.9%	17.3	14.2%	30.8%	53.1%	prefer
1042	18	12.1%	8.5	7.3%	4.8%	19.4%	neutral
1061	1	0.6%	1.6	2.3%	-1.1%	2.4%	neutral
1072	14	10.1%	24.5	8.5%	3.1%	17.1%	neutral
1092	39	24.7%	3.2	9.9%	15.6%	33.7%	prefer

^a Selection based on Bonferonni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984)

Appendix 2.9. Annual use, availability, and selection ^a of 'yard' cover types by 32 adult Columbian white-tailed deer, Douglas County, Oregon. 1996 – 97.

Deer ID	No. locations	% use	available area (ha)	% available	Lower CI	Upper CI	Selection
22	6	4.7%	31.1	8.6%	-0.4%	9.7%	neutral
51	0	0.0%	--	--	--	--	--
62	0	0.0%	--	--	--	--	--
71	0	0.0%	0.2	0.1%	0.0%	0.0%	avoid
82	5	3.6%	5.3	5.3%	-0.7%	7.9%	neutral
90	16	11.2%	7.0	5.2%	4.1%	18.3%	neutral
132	0	0.0%	--	--	--	--	--
151	5	3.5%	3.7	7.8%	-0.7%	7.8%	neutral
171	140	89.7%	7.3	81.2%	83.9%	95.6%	prefer
181	0	0.0%	--	--	--	--	--
201	0	0.0%	--	--	--	--	--
212	13	9.1%	3.6	3.8%	2.6%	15.6%	neutral
221	0	0.0%	--	--	--	--	--
232	41	25.3%	1.3	9.9%	16.1%	34.5%	prefer
290	0	0.0%	--	--	--	--	--
300	1	0.7%	1.1	0.9%	-1.2%	2.6%	neutral
311	0	0.0%	--	--	--	--	--
321	10	7.0%	8.0	3.8%	1.4%	12.7%	neutral
352	17	12.6%	8.4	13.9%	4.9%	20.3%	neutral
361	0	0.0%	--	--	--	--	--
371	113	76.9%	20.3	25.1%	67.5%	86.2%	prefer
391	0	0.0%	--	--	--	--	--
401	0	0.0%	--	--	--	--	--
411	15	9.9%	1.0	6.0%	3.4%	16.4%	neutral
431	12	8.4%	1.0	6.7%	2.2%	14.6%	neutral
462	0	0.0%	1.9	0.8%	0.0%	0.0%	avoid
471	0	0.0%	--	--	--	--	--
481	0	0.0%	--	--	--	--	--
1042	36	24.2%	13.5	11.7%	14.6%	33.8%	prefer
1061	1	0.6%	3.2	4.9%	-1.1%	2.4%	avoid
1072	0	0.0%	0.8	0.3%	0.0%	0.0%	avoid
1092	0	0.0%	--	--	--	--	--

^a Selection based on Bonferonni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984)

Appendix 2.10. Results from logistic regression models demonstrating the effects of distance to stream and relative amount of edge on the odds of habitat use ^a for individual adult Columbian white-tailed deer, Douglas County, Oregon, 1996 - 97.

Deer ID	effect ^b	coefficient	SE	Wald's X ²	P	odds ratio	lower CI ^c	upper CI ^c
1042	dts	-0.003	0.001	28.053	0.000	0.756	0.675	0.833
1042	edge	2.929	4.239	0.478	0.490	1.030	0.946	1.118
1061	dts	0.001	0.001	8.315	0.004	1.139	1.045	1.256
1061	edge	-11.746	6.964	2.845	0.092	0.889	0.763	1.005
1072	dts	0.000	0.000	0.143	0.705	1.010	0.952	1.073
1072	edge	-1.013	5.214	0.038	0.846	0.990	0.886	1.090
1092	dts	-0.001	0.001	2.398	0.122	0.887	0.760	1.032
1092	edge	7.681	3.608	4.532	0.033	1.080	1.008	1.165
132	dts	-0.002	0.001	4.045	0.044	0.803	0.649	0.991
132	edge	-18.188	7.174	6.428	0.011	0.834	0.720	0.953
151	dts	0.003	0.001	21.813	0.000	1.377	1.202	1.567
151	edge	0.873	5.117	0.029	0.865	1.009	0.909	1.111
171	dts	0.005	0.002	7.556	0.006	1.584	1.142	2.198
171	edge	-1.459	2.211	0.436	0.509	0.986	0.939	1.026
181	dts	-0.005	0.001	35.637	0.000	0.625	0.535	0.727
181	edge	-6.145	5.515	1.242	0.265	0.940	0.828	1.033
201	dts	-0.004	0.001	18.511	0.000	0.698	0.593	0.820
201	edge	3.362	4.710	0.510	0.475	1.034	0.936	1.157
212	dts	-0.006	0.001	42.297	0.000	0.543	0.448	0.648
212	edge	-33.166	7.574	19.177	0.000	0.718	0.616	0.829
22	dts	-0.001	0.001	2.760	0.097	0.923	0.840	1.013
22	edge	3.692	6.016	0.377	0.540	1.038	0.912	1.163
221	dts	-0.007	0.001	58.618	0.000	0.482	0.397	0.577
221	edge	-7.592	8.687	0.764	0.382	0.927	0.768	1.078
232	dts	0.003	0.002	2.887	0.089	1.284	0.962	1.713
232	edge	0.174	3.395	0.003	0.959	1.002	0.934	1.068

Appendix 2.10. Continued

290	dts	-0.006	0.001	28.438	0.000	0.538	0.423	0.668
290	edge	-1.769	6.756	0.069	0.794	0.982	0.856	1.117
300	dts	-0.002	0.001	3.659	0.056	0.803	0.636	1.001
300	edge	12.114	7.025	2.974	0.085	1.129	0.980	1.292
311	dts	0.000	0.001	0.007	0.933	1.010	0.861	1.173
311	edge	3.607	4.231	0.727	0.394	1.037	0.946	1.127
321	dts	0.001	0.001	2.055	0.152	1.116	0.957	1.311
321	edge	1.593	7.658	0.043	0.835	1.016	0.868	1.176
352	dts	-0.003	0.001	12.219	0.001	0.733	0.611	0.868
352	edge	-11.760	7.559	2.420	0.120	0.889	0.764	1.027
361	dts	-0.005	0.001	33.452	0.000	0.613	0.516	0.719
361	edge	7.771	6.455	1.449	0.229	1.081	0.950	1.226
371	dts	-0.006	0.001	26.554	0.000	0.560	0.447	0.693
371	edge	-35.549	6.911	26.463	0.000	0.701	0.607	0.797
391	dts	-0.004	0.001	38.432	0.000	0.657	0.575	0.748
391	edge	15.969	9.025	3.131	0.077	1.173	0.981	1.400
401	dts	-0.004	0.001	33.306	0.000	0.644	0.553	0.745
401	edge	-9.838	8.485	1.344	0.246	0.906	0.763	1.062
411	dts	0.001	0.001	0.406	0.524	1.094	0.831	1.441
411	edge	7.531	5.427	1.926	0.165	1.078	0.968	1.198
431	dts	0.001	0.001	1.156	0.282	1.150	0.892	1.482
431	edge	10.305	8.889	1.344	0.246	1.109	0.930	1.318
462	dts	0.002	0.001	6.959	0.008	1.174	1.042	1.325
462	edge	5.108	2.987	2.925	0.087	1.052	0.992	1.120
471	dts	-0.011	0.001	73.116	0.000	0.330	0.252	0.419
471	edge	2.903	10.965	0.070	0.791	1.029	0.809	1.253
481	dts	-0.005	0.001	39.614	0.000	0.613	1.000	1.000
481	edge	-3.130	6.958	0.202	0.653	0.969	1.000	1.000
51	dts	-0.002	0.001	6.278	0.012	0.803	0.678	0.951
51	edge	7.551	7.300	1.070	0.301	1.078	0.930	1.242
62	dts	-0.005	0.001	38.175	0.000	0.583	0.487	0.687
62	edge	-72.958	13.660	28.525	0.000	0.482	0.364	0.622

Appendix 2.10. Continued

71	dts	0.000	0.001	0.001	0.974	1.000	0.824	1.201
71	edge	52.722	6.801	60.104	0.000	1.694	1.488	1.943
82	dts	-0.001	0.001	2.016	0.156	0.914	0.809	1.032
82	edge	6.205	7.216	0.739	0.390	1.064	0.918	1.222
90	dts	-0.004	0.001	10.544	0.001	0.677	0.533	0.852
90	edge	2.159	5.102	0.179	0.672	1.022	0.920	1.127

^a odds of use relative to decreasing distance from creek (in 100 m increments) and increasing edge ratio (in 10 ha increments).

^b dts = distance to stream, edge = edge ratio

^c likelihood ratio based 95% confidence interval for odds ratio

Appendix 2.11. Cover types where the proportion of use was significantly different, as determined from univariate analyses of variance controlling for seasonal effects, between 'suburban' and 'wild' type Columbian white-tailed deer in Douglas County, Oregon, 1996 – 97.

Cover type	mean proportion		d.f.	<i>F</i>	<i>P</i>
	wild	suburban			
grassland	0.14	0.09	1, 128	8.99	0.003
oak-hardwood savanna	0.06	0.04	1, 128	5.19	0.024
oak-hardwood woodland	0.27	0.17	1, 128	8.59	0.004
oak-hardwood conifer	0.06	0.13	1, 128	9.16	0.000
riparian	0.23	0.13	1, 128	12.17	0.000
yard	0.01	0.20	1, 128	56.33	0.000

Appendix 3.1. Summary data for age at capture, sex, site, and survival information for 36 Columbian white-tailed deer fawns in Douglas County, Oregon, 1996 – 98.

Fawn ID	Age (days)	Sex	Site	Date of capture	Date of death/censor	Fate	Cause of death or censor
1872	--	female	Ramp Canyon	06/14/96	11/17/96	dead	disease
1882	--	female	NBHMA	06/11/96	10/28/96	censored	collar drop
1892	--	female	NBHMA	06/11/96	07/14/96	dead	unknown
1902	--	female	NBHMA	06/11/96	07/10/96	dead	unknown
1861	--	Male	NBHMA	06/10/96	07/20/96	censored	premature collar slip
1872	--	Male	NBHMA	06/05/96	06/8/96	dead	predation
1911	--	Male	NBHMA	05/28/96	07/5/96	dead	predation
1881	6.4	female	NBHMA	06/03/97	06/21/97	censored	premature collar slip
1900	2.0	female	NBHMA	06/04/97	06/6/97	dead	predation
1870	2.0	female	Ramp Canyon	06/05/97	06/23/97	dead	disease
1820	--	female	Whistlers Bend	06/09/97	09/10/97	dead	unknown
1891	2.0	Male	NBHMA	06/09/97	06/10/97	dead	abandonment
1200	2.0	female	NBHMA	06/09/97	06/16/97	censored	premature collar slip
1190	6.2	female	NBHMA	06/10/97	06/19/97	censored	premature collar slip
1750	2.0	female	NBHMA	06/10/97	09/1/97	censored	premature collar slip
1790	--	Male	NBHMA	06/12/97	10/14/97	censored	collar drop
1780	8.1	Male	TJ	06/14/97	06/21/97	dead	predation
1890	8.9	female	Shorts	06/17/97		survived	
1810	7.0	Male	NBHMA	06/20/97	07/15/97	censored	premature collar slip
1130	6.8	female	NBHMA	06/20/97	08/1/97	censored	premature collar slip
1110	4.0	female	Whistlers Bend	06/24/97	06/28/97	dead	abandonment
1260	2.0	Male	Shorts	06/25/97		survived	
1250	9.5	female	Whistlers Bend	06/27/97	06/30/97	dead	abandonment
1160	8.7	Male	NBHMA	07/03/97	07/11/97	dead	predation
1231	--	Male	NBHMA	06/05/98	06/13/98	dead	unknown

Appendix 3.1. Continued

1841	--	Male	NBHMA	06/10/98	06/15/98	dead	abandonment
1150	--	female	NBHMA	06/15/98	08/24/98	dead	predation
1830	--	Male	NBHMA	06/15/98		survived	
1860	--	Male	NBHMA	06/15/98	10/12/98	censored	collar drop
1880	--	female	NBHMA	06/15/98	07/10/98	censored	premature collar slip
1770	5.1	female	NBHMA	06/16/98	07/28/98	dead	disease
1140	11.7	Male	NBHMA	06/17/98		survived	
1840	5.1	Male	Whistlers Bend	06/19/98	06/22/98	dead	abandonment
1210	--	Male	NBHMA	06/20/98	06/28/98	dead	unknown (possible predation)
1230	6.8	Male	NBHMA	06/20/98	07/18/98	dead	predation
1240	8.4	Male	Ramp Canyon	06/22/98	08/12/98	dead	predation

Appendix 3.2.

Individual areas (ha) and descriptive statistics for cover type composition within areas of concentrated use and 99% fixed kernel home ranges for 11 Columbian white-tailed deer fawns in Douglas County, June – August, 1997 – 98.

Fawn ID	Area of concentrated use (used area - ha)									Total
	GSL	GSH	OHS	OHSS	OHWD	OHCN	CON	RIP	YRD	
1130	0.370	0.000	--	0.290	0.000	--	--	0.517	--	1.176
1140	0.000	--	0.650	--	1.156	0.000	--	0.000	--	1.806
1150	0.065	0.319	0.290	--	0.000	--	--	0.000	--	0.674
1240	--	--	0.002	1.187	0.179	--	0.000	--	--	1.368
1260	0.000	0.000	0.000	0.000	0.000	--	--	1.462	--	1.462
1750	0.249	1.838	0.000	0.148	0.495	--	0.000	0.867	--	3.596
1790	1.621	0.000	0.829	0.383	3.319	--	--	2.379	--	8.530
1820	0.000	0.000	0.341	0.000	0.307	0.425	--	0.047	0.021	1.141
1830	0.000	0.000	0.000	--	0.000	--	--	--	0.723	0.723
1860	0.000	0.000	0.000	--	1.755	0.000	--	0.284	0.354	2.393
1890	0.308	0.000	0.345	--	1.243	0.246	--	1.437	0.000	3.580
total area	2.612	2.157	2.456	0.823	9.461	0.850	0.000	6.993	1.098	26.449
mean %	9.9%	8.2%	9.3%	3.1%	35.8%	3.2%	0.0%	26.4%	4.2%	
SE	18.5	17.0	19.0	15.2	28.3	14.1	0.0	27.3	19.5	
n	10	10	9	5	11	6	1	10	4	
Fawn ID	99% fixed kernel home range (available area - ha)									Total
	GSL	GSH	OHS	OHSS	OHWD	OHCN	CON	RIP	YRD	
1130	2.360	1.925	--	5.910	3.807	--	--	5.503	--	19.504

1140 0.170 -- 3.369 -- 9.823 1.160 -- 2.494 -- 17.017

Appendix 3.2. Continued

1150	3.202	0.881	1.782	--	2.840	--	--	0.389	--	9.094
1240	--	--	0.844	4.432	5.426	--	0.851	--	--	11.554
1260	2.870	0.009	1.476	--	1.844	0.129	--	8.194	--	14.523
1750	7.072	5.921	0.012	8.657	1.043	--	0.072	6.950	--	29.726
1790	17.629	5.537	12.181	14.217	22.221	--	--	14.508	--	86.293
1820	0.301	--	2.816	1.616	2.192	2.663	--	1.529	0.499	11.616
1830	0.393	--	0.037	--	1.059	--	--	--	4.835	6.324
1860	0.211	--	1.225	--	13.250	0.106	--	4.174	0.948	19.914
1890	8.696	0.396	6.854	--	13.612	0.663	--	11.216	--	41.438
total area	42.904	14.669	29.753	31.243	76.124	10.149	0.072	55.807	6.282	267.002
mean %	16.1%	5.5%	11.1%	11.7%	28.5%	3.8%	0.0%	20.9%	2.4%	
SE	22.8	8.2	20.6	28.2	26.7	15.3	03.2	25.2	17.2	
n	10	6	9	5	11	6	1	10	3	

Appendix 3.3. Individual areas (ha) and descriptive statistics for distance to stream class composition within areas of concentrated use (used) and 99% fixed kernel home ranges (available) for 9 Columbian white-trailed deer fawns in Douglas County, June – August, 1997 – 98.

Area of concentrated use (used area - ha)						
Fawn ID	0 – 100 m	100 – 200 m	200 – 300 m	300 – 400 m	> 400 m	Total
1130	1.126	0.051	0.000	0.000	--	1.177
1140	0.000	0.000	--	0.000	1.806	1.806
1150	0.000	0.312	0.074	0.288	0.000	0.674
1260	1.462	0.000	0.000	--	--	1.462
1750	2.325	1.271	0.000	0.000	--	3.596
1790	4.520	1.104	2.445	0.461	0.000	8.530
1820	0.420	0.720	0.000	--	0.000	1.140
1860	1.221	1.167	0.000	0.000	--	2.388
1890	1.821	0.911	0.843	0.000	0.000	3.576
total	12.895	5.537	3.362	0.749	1.806	24.349
pooled %	0.530	0.227	0.138	0.031	0.074	
SE	0.326	0.274	0.239	0.128	0.230	
n	9	9	8	7	5	

99% fixed kernel home range (available area - ha)						
Fawn ID	0 – 100 m	100 – 200 m	200 – 300 m	300 – 400 m	> 400 m	Total
1130	11.273	5.012	3.148	0.064	--	19.498
1140	3.699	0.756	--	1.182	11.380	17.016
1150	1.205	2.188	3.204	1.697	0.804	9.097
1260	10.140	2.744	1.655	--	--	14.539
1750	16.039	8.970	4.589	0.122	--	29.719
1790	36.770	21.723	11.602	10.241	5.943	86.278
1820	6.761	4.273	0.771	--	0.675	12.480
1860	7.948	7.099	4.501	0.455	--	20.003
1890	16.377	10.626	9.321	4.182	1.656	42.163
sum	110.211	63.391	38.791	17.942	20.458	250.794
pooled %	43.9%	25.3%	15.5%	7.2%	8.2%	
SE	32.4	28.4	25.1	19.1	24.0	
n	9	9	8	7	5	