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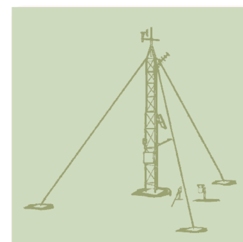

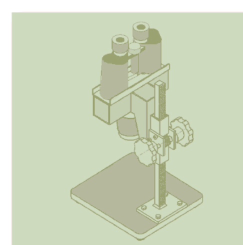

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Sierra Pacific Industries
Post Office Box 496014
Redding, California 96049-6014

Abstract

Between 1990 and 1995, a study of habitat change and subsequent use by the Pacific fisher (*Martes pennanti*) in a Northern California managed forest environment was conducted. By interpreting aerial photos flown in 1944 and 1994, the study documented substantial changes in the availability of habitat conditions used by fishers within the study. We tested telemetry accuracy using two methodologies and found large differences by methodology. Telemetry data from three male fishers demonstrated selective habitat use by fishers, preference for lower elevation forest types, and seasonal and yearly variations in use patterns. Thirty-four fisher rest sites were described. The study area's past history of use by fisher combined with the capture of adult males, adult females, and juveniles and the documentation of stable home ranges suggest that the area's habitat capability is at least sufficient to allow reproduction by the local fisher population. We calculated a preference index from our data and found a significant positive correlation with the U.S. Fish and Wildlife Service Fisher Habitat Suitability Index (USFSW HSI) model. We did not find a significant correlation between our data and predictions by the California Wildlife Habitat Relationships system. We discuss changes to both the USFWS HSI model and the California WHR system to improve their performance. We recommend that use of the USFWS HSI model will provide reasonable predictions of the potential effects of habitat management activities on fisher habitat suitability in Northern California.

Key Words: Pacific fisher, Northern California

Introduction

Sierra Pacific Industries (SPI) manages over 1.5 million acres of forestland in northern and central California. In 1990, Sierra Pacific Industries contracted with Wildland Resource Managers to conduct a systematic survey of several tracts of land for the presence of Pacific fisher (*Martes pennanti*) and pine marten (*M. americana*). This was the beginning of a three-phase study to determine the occurrence, status, and habitat use of managed forest landscapes by these two species. Phase 1 documented the presence of fisher and marten on SPI lands and developed new inventory techniques for these species (Criss and Kerns 1990). Phase2, a pilot study to assess habitat typing and telemetry techniques for determining landscape and stand attributes important to fisher and marten, was completed in winter 1991. Telemetry techniques were successfully used to define home range areas, locate areas of use and non-use, and to locate within-stand features that are used by these species (Self and Kerns 1992). This report presents the findings of Phase 3 of the study as they relate to fisher use of managed forest habitats at stand and landscape scales.

The Pacific fisher is a medium-sized terrestrial carnivore in the Mustelidae family. In California, fisher have been historically found in the Sierra Nevada south to northern Kern County, in the northern Coast Range and in the Klamath, Trinity, and Cascade Mountains (Grinnell et al. 1937). Fisher abundance does not appear to have been equal across this historical range, at least since the early 1900s, with many more sightings recorded for the southern Sierra Nevada and northwestern California than elsewhere in the published range (from Gould 1987). The reasons for this unequal distribution are not clear, although excessive trapping and habitat alteration and fragmentation by timber harvest have been suggested (Gould 1987). However, the ecology of the fisher is poorly understood and the relationships between forest structure and habitat use by fisher are largely unknown.

Historically, fisher were trapped for commercial use in California (USDI 1990). In response to the belief that fisher populations were being negatively impacted by trapping pressure, legal commercial trapping was stopped after the 1945–1946 season (Burkett 1994). Since the cessation of legal trapping, little new information has been gathered in California on this species. The fisher has been identified as a sensitive species by the U.S. Forest Service, as a species of special concern by the state of California, and as a candidate species by the U.S. Fish and Wildlife Service. As such, this species is often specifically considered in forest management planning.

Authors of the only completed study of fisher habitat use in the Pacific states (Buck et al. 1983) advised caution when using their data in formulating management strategies for fisher. In an apparent re-examination of this study, the authors have significantly revised their previous analyses and interpretations (Buck et al. 1994). This re-interpretation calls into question the conclusions originally reached in this study.

In response to a petition to list the fisher as an endangered species in California, Oregon, and Washington, the USDI Fish and Wildlife Service (Service) found that there was insufficient information to determine whether a listing may be warranted (USDI 1990). The

Service stated that, among other data, better information on the habitat needs of the fisher was needed. In summary, the Service noted that insufficient information exists in the literature to draw reliable conclusions regarding habitat preferences by fisher, or to determine population status or trends. The Service is currently conducting a status review in response to another petition to list the fisher.

Study Area

The Castle Creek watershed is located in Northern California and comprises the entire study area (Figure 1). It is a high-energy fourth-order watershed encompassing approximately 23,700 acres. The watershed lies immediately south of and partially includes Castle Crags State Park. Elevations range from 2,000 to 7,000 ft.. Annual precipitation in the watershed averages 60 to 70 in. per year, with the majority falling as snow (USDA 1993). Upper elevations (>4,000 ft.) generally have several feet of snow from mid-November through March. Lower elevation areas receive only an intermittent snow cover through winter and are generally snow-free at least 7 months per year.

As classified by the California Wildlife Habitat Relationships (WHR) system (Mayer and Laudenslayer 1988), the vegetation is primarily Klamath mixed conifer (KMC) with a high component of ponderosa pine (*Pinus ponderosa*) and sugar pine (*P. lambertiana*). Other WHR habitat types include ponderosa pine, white fir (*Abies concolor*) montane hardwood-conifer (MHC) and montane chaparral. The watershed has little ground not covered by timber or brush vegetation. Open timber stands in our study area generally have a significant brush component, between 2 and 5 ft. high, which would provide considerable overhead ground cover for a fisher. Dominant brush species in the study area are tan oak (*Lithocarpus densiflorus*) and bush chinquapin (*Chrysolepis sempervirens*).

The study area has a long history of management. The area was entered in the 1880s for mill construction and railroad logging (Signor 1982). Through the mid-1920s, several mills were operated within the watershed and were serviced by 16 miles of railroad lines within the study area. Logging was accomplished using steam donkeys and locomotives to haul timber. The lower portions of the watershed were harvested by this equipment, removing the majority of the standing timber for commercial use, construction and maintenance of track, trestles, buildings and other structures, and fuel wood.

In the mid-1920s, two large fires burned the mills, structures, decks and major portions of the watershed (Solinski 1992). As a result of the fires, the remaining equipment was sold, and harvest activities ceased until the late 1940s. Portions of the harvested land eventually were included in Castle Crags State Park. Except within the Park and for a few small (< 20 acres) clearcuts, selection harvests (overstory removal, sanitation, and thinning) have been the principal harvest methods used in the watershed since 1950. With some harvesting occurring each decade, these practices continue today.

Methods

Habitat Classification

The vegetation of the Castle Creek Study Area was classified using the California Wildlife Habitat Relationships system. Typing was interpreted from 1991 color and 1992 infrared aerial photographs using a minimum polygon size of 5 acres. Over 60% of the delineated WHR habitat stages were visually ground-checked for accuracy, with emphasis on those stands that were used by fisher. Groundchecking was conducted by individuals with experience in collecting forest inventory data and in calculating WHR stages from forest inventory data. The area was also classified to WHR stages using 1944 black-and-white aerial photographs loaned to SPI by the Mount Shasta District of the U.S. Forest Service. Since no measurable change has occurred to habitats in the study area since 1992, we used 50 years (1944-1994) as the time interval between classifications. Changes in forest landscape conditions over the last 50 years were calculated from the 2 WHR habitat mapping time periods (1944 and 1992).

Animal Capture and Handling

Fisher were captured using Hav-A-Hart 12 by 10 by 32-in. live traps (with attached wooden boxes). Canned cat food was used as bait, and open traps were checked at least once daily. Traps were closed on most weekends. Field crews moved traps as deemed necessary to facilitate trapping success. Some trap movement was dependent on snow conditions, but most traps were moved based on the field crew's determination of habitat conditions or identified animal tracks.

Captured animals were moved from live traps into restraining cones made of 1/4- or 1/8-in. steel rod, similar to those described by Seglund and Golightly (1993). The animals were anesthetized by administering between 0.17 and 0.60 cc of a solution comprised of 10 parts ketamine to 1 part valium. Dosage varied by animal weight, with the target dosage being 0.05 cc per pound. Dosages were administered using a 25-gauge insulin needle on a 1.0-cc syringe to the thigh of a hind leg.

Once sedated, each animal was removed from the cone, sexed, weighed, measured for total length, girth behind shoulders and around the neck, and leg length from hip to toe. A tissue sample was taken from each animal's ear using a 2-mm biopsy punch, and a uniquely colored plastic ear tag (Nasco standard-sized rototag) was inserted in the hole created by the biopsy punch. Tissue samples were sent to the USDA Forest Service Pacific Southwest Forest and Range Experiment Station for storage and eventual genetic analysis. Radio transmitter collars made by Telonics (model 205 transmitter on CMM collar, 115-120 grams actual weight) were attached to adult animals for tracking. Upon completion of handling, each animal was placed in a wooden box with a Plexiglas door to monitor recovery. Upon complete recovery, each animal was released at its capture site.

The radio transmitter batteries were designed to last approximately 1 year. We attempted to recapture and recollar each animal before the radio transmitter batteries lost power. We attempted to obtain 2 years of telemetry data for each animal.

Telemetry

Collared animals were located utilizing Telonics receivers (Model TR-2 receiver fitted with a TS-1 scanner) and a Telonics RA-2A directional handheld 2-element H antenna. Field researchers utilized 4-by-4s, ATVs, and snowmobiles to access the study area. Telemetry stations were marked in the field with numbered wooden stakes, pricked on aerial photographs, and plotted on 1:24,000-scale topographic maps from orthophotographs. These stations were placed at obvious physical locations, such as on prominent points, road intersections, and stream crossings. Other stations were placed between these fixed points using measured distances between known points to achieve a set of known stations approximately 1/8 to 1/4 mile apart. Maps containing these station locations were used to triangulate locations for the animals. For each collared animal, one to three locations were determined per week, with multiple locations obtained as possible. Locations were determined using a triangulation of three or more bearings. Attempts were made to gather locations during various periods of day and night, but at least 85% of locations were between 6 a.m. and 7 p.m. Efforts were made to approach as close as possible to the animals without disturbing them to minimize the error associated with triangulations.

Telemetry data were entered into SPI’s geographic information system (GIS). The positional accuracy of the GIS is to the nearest 0.01 ft. This positional accuracy is far greater than any available field data, but would allow use of global positioning system (GPS) data in the future. Locations of the telemetry stations were first digitized into the GIS from orthophotographs. Field bearings from the fixed stations to the animal locations were entered into the system to the nearest degree. For each animal location, the three strongest signals were extended at the given bearing from the mapped station locations. Locations were written into the database. The estimated point location was mapped by intersecting two angle bisectors, and the geographic location (X and Y coordinates, in feet, based on the California Coordinate System [Lambert], Zone 1) was added to the database. The animal, date, and time period were added to the database for each location.

We examined two methods to determine the accuracy of our predicted locations: 1) calculated triangulation error polygons from the GIS, and 2) measured error distances. Our desired minimum accuracy was to have the error associated with >80% of the locations be less than the size of 80% of the habitat polygons. Triangulation error polygons were calculated by the GIS from the triangle created by the three directions used to predict the location. Measured error distances were found by obtaining by a predicted location for a nonmoving animal (telemetry location) and then walking in to determine the actual location of the animal. The distance between these two locations provides an estimate of the accuracy of the initial telemetry location. This distance was then used as a radius for a circle whose total area was called the measured error polygon.

Habitat Use

Minimum convex polygon (MCP) home range areas were delineated for each animal by connecting its outermost locations. The entire area within each MCP was initially considered available to the fisher. Final availability for use versus availability analyses was determined by meeting the minimum accuracy requirements as described above and by having at least 5 locations within the polygon type or by the polygon type comprising at least 5% of the MCP. Analyses of use versus availability were developed for individual WHR types. Analyses were conducted by individual animal to determine the variance of use and by grouping animals together to determine the average use. To increase the independence of data, all analyses were restricted to using only 1 location per animal per 3 days, using the first location received in any one day.

Distance to Water

Using the GIS, we divided the study area into 3 zones of approximately equal areas that varied by distance to water sources having surface water available at least 6 months per year. These zones were created without regard to the presence or absence of riparian vegetation. Zone 1 was land within 500 ft. of a water source, zone 2 was land between 501 and 1,100 ft. of a water source, and zone 3 was land more than 1,101 ft. from a water source. Wildlife habitat relationships polygons were coded by their appropriate distance zone. Analyses were conducted by comparing expected use by habitat type by distance zone to measured use.

Rest Sites

If during telemetry monitoring the transmitter signal strength was nonvariable, it was interpreted to mean that the monitored animal was not moving and a walk-in was then attempted to determine the specific location of the animal. The transmitter signal strength was monitored during the walk-in attempt to ensure that the animal did not move. If the animal's stationary location was found and a visual on the animal obtained, the walk-in was considered successful, and the site was marked in the field and on a field map and termed a rest site. These rest sites were revisited and habitat measures were recorded using a plot centered on the rest structure (Pious 1990) (Appendix B). The rest structure was measured as well as habitat variables within 115 ft. such as tree canopy closure (average of 48 spherical densiometer measurements) basal area (100% sample of plot area), cored age of rest tree, age of rest site stand (average cored age of 3–5 dominant and codominant trees), and quadratic mean diameter of all trees greater than 5 in. diameter at breast height (dbh).

Habitat Capability Model Comparisons

Habitats within the study area were assigned 2 habitat suitability values (ranging from 0.0 to 1.0) using the WHR system for one and the Service's fisher habitat suitability index model (Allen 1983) for the other. From the WHR habitat use matrix for fisher, habitat suitability values were developed by averaging the predicted values for feeding, reproduction, and cover for each WHR habitat stage. WHR size and density class midpoint values were used with the HSI model to determine appropriate habitat suitability values. A Preference Index (PI) was calculated from our data for each WHR habitat stage. The PI was calculated as in Thomasma, et al. (1991) by dividing the percent use by the percent available. All stand structure classes that were expected to receive 5% of total use or had a minimum of 5 recorded locations were assigned a WHR habitat value and an HSI value. A PI was calculated for each of these WHR habitat stages for winter use and full-year use. The PI was compared to the WHR habitat suitability values and the fisher habitat suitability values for similarity using correlation analyses.

Analyses

Statistical analyses regarding habitat selection were conducted according to the methodology presented by Manly et al. (1993) (chap. 4). We used equation 4.27 (log-likelihood chi-squared test statistic) to determine if there was evidence of selection. Equations 4.29, 4.30, and 4.31 were used to estimate the selection ratio and simultaneous Bonferroni confidence intervals for each WHR habitat type. These calculations were conducted on a microcomputer. The relationships between observed habitat use and habitat-use predictions from HSI and WHR models were evaluated using simple correlation analyses.

Results

Habitat Changes Over Time

From 1944 to the present, substantial changes have occurred in the habitat conditions within the study area. Although the amount of area by forest type has remained fairly stable, changes in the percent occurrence by WHR size and density classes have taken place. In 1944, WHR size classes 1–3 dominated the watershed, comprising over 80% of the entire area (Figure 2a). Currently, the watershed is dominated by WHR classes 4–6, which exist over approximately 79% of the area.

In 1944, the watershed was dominated by stands in WHR density classes S and P (10–39% total canopy closure), with nearly 50% of the area occurring in WHR S canopy closure class (10–24% total canopy closure) (Figure 2b). Currently, stand densities are relatively evenly distributed across the 4 WHR density categories, with about 50% of the watershed in WHR canopy closure classes M and D (canopy closures greater than 40%). Stands in the

S canopy closure class occur on less than 25% of the area.

Over the last 50 years, the watershed has generally changed from early-seral open-forest conditions to mid-seral size classes with a relatively even distribution of WHR canopy closure classes.

Effect of Telemetry Error

The error polygons formed by telemetry location bearings averaged about 1 acre in size. The size of the triangulation error polygons decreased as the distance between the observer and the animal decreased. However, when we walked in to verify the assumption that the animal's actual location would lie within this error polygon, we found it to be incorrect and thus an unreliable method for telemetry accuracy estimation.

Nineteen recorded rest-site locations also had estimated locations based on telemetry data. Error distance (distance between estimated and actual location) ranged from 72 to 2,366 ft. Assuming random error direction, we use the error distance as a radius to calculate a measured error polygon. Our median error polygon was 9.1 acres, with an average of 22.5 acres. Eighty percent of the error polygons were less than 37 acres (Figure 3).

Within the Castle Creek watershed, groundchecked photointerpretation designated 152 separate WHR polygons. Sixty-three percent of the WHR polygons were greater than 40 acres in size, which, when compared to the measured error polygons, did not meet our accuracy criteria. However, within the KMC/MHC forest types (which received 95% of recorded fisher use), the majority of WHR types had at least 80% of the polygons greater than 40 acres in size (Figure 4). The KMC and MHC 3D, 4P, 4M, 4D, 5P, 3S, and 4S types met our accuracy criteria. The combination of measured error polygons and polygon sizes for the KMC 5M and 6 types did not meet the minimum accuracy level.

Habitat Use

From 1991 to 1993, 9 individual fisher were captured within the Castle Creek watershed, 7 adults (5 males, 2 females), and 2 juveniles (both male) (Table 1). Three adult males were fitted with radio transmitters and ear tags, and the others were fitted only with ear tags. (Juveniles were not fitted with transmitters and the other adult males and females were captured during final collar removals at the end of the study period.) Between 1991 and 1993, a total of 714 telemetry locations were recorded (550 in summer, 164 in winter). A total of 482 locations were recorded for 2 males from 1991 to 1992, and 232 locations were recorded for 3 males (2 recollared and 1 initially captured at the end of 1992) in 1992–1993 (Table 2). MCP annual home ranges averaged 7,039 acres and ranged from 5,827 to 8,610 acres.

Ten WHR habitat types exist within the study area (Table 3). Fisher selectively used these types. Two types, Klamath mixed conifer (KMC) and montane hardwood conifer (MHC), comprise approximately 63% of the watershed and received over 95% of total fisher use (Table 3). Two other types, montane chaparral (MCP) and white fir (WFR), comprise approximately 29% of the watershed and received less than 4% of total fisher use.

Fisher selectively used habitats by WHR density class (X2 = 381.71, P < .001) and size class (X2 = 439.99, P < .001). Within the KMC/MHC habitat types and WHR 3–6 size classes, use of WHR canopy closure classes P and D was significantly greater than expected (95% Bonferroni confidence intervals) (Figure 5). Within the KMC/MHC habitat types and WHR P, M, and D density classes, use of WHR size classes 3, 4, 5, and 6 was significantly greater than expected (95% Bonferroni confidence intervals) (Figure 6). Within these two forest types, fisher were found to significantly select for the WHR 3D, 4D, 5P, and 5M size/canopy closure combinations, significantly select against 3S and 4S, and use 4P, 4M, and 6 as expected (X2 = 530.58, P < .001) (Figure 6 and Table 4).

Use of Habitat by Distance to Water

Fisher selectively used the watershed in relation to distance zones from water (X2 = 169.69, P < .001) (Figures 7, 8, and 9). Fisher selected positively for use within 500 ft., used areas between 500-1,100 ft. as expected and selected against use of areas greater than 1,100 ft. from water (95% Bonferroni confidence intervals).

For WHR habitat stages significantly selected for or against, the preferences (and their significance) generally held true at different distances from water (Figures 10a,b). Exceptions were the nonselective use of 3D and 5P stands, except at distances far from water, and nonselective use of 5M stands far from water.

Generally, although the availability of habitats varied by distance from water, fisher were found to make significant use of preferred habitat types, regardless of distance from water.

Seasonal Use of Habitat

Within the KMC/MHC habitat types, fisher used open stands (WHR P) substantially more in summer than in winter (39% of summer locations, n= 217 v. 13% of winter locations, n= 21) (Figure 11). Dense stands (WHR D) predominated in winter use (60% of winter locations, n=99). Moderate density (WHR M) stands were used similarly in summer and winter. Large-tree (WHR 5 and 6) and pole (WHR 3) stand use increased in summer, while a strong shift to use of small-tree stands (WHR 4) was found in winter (Figure 12). In general, fisher significantly selected for WHR 4D stands in winter and WHR 3D, 4D, 4P, 5P, and 5M stands in summer (95% Bonferroni confidence intervals) (Figures 13, 14).

Yearly Use of Habitat

Within the KMC/MHC habitat types, fisher selection of habitat stages varied by year.

Habitat stages that were found to be selected for by all fisher over all years were found to be used only as available or even selected against when only 1 year's data were analyzed. For instance, the WHR 4D habitat stage was significantly selected for in winter 1992 and significantly selected against in summer 1992 (Figures 13, 14).

Rest Sites

Thirty-four rest sites were determined by walking in on collared fisher. Over 77% of the rest sites were located in WHR 4 size class stands, with 39% found in KMC and MHC 4D stand types (Table 4). Rest sites were generally distributed within the WHR habitat stages in the same proportions as telemetry locations. One rest site was used by more than 1 male, 2 rest sites were used twice by the same male, and one was used three times by the same male. Rest sites with repeated use or use by more than one animal were not counted as multiple rest sites.

Twenty-seven (79%) of the rest sites were in green trees, 5 (15%) were in snags, and 2 (6%) were in logs on the ground (Table 5). Green-tree rest sites were found in 4 species: Douglas-fir (*Pseudotsuga menziesii*)(74%), ponderosa pine (15%), black oak (7%), and incense-cedar (*Calocedrus decurrens*) (4%). The structure used in one of the green-tree rest sites was not determined. Mistletoe brooms (81%), cavities (8%), squirrel or bird nests (8%), and forked-topped trees (4%) comprised the known green-tree rest structures. Species of snags used for rest sites were Douglas-fir, sugar pine, white fir, and incense-cedar. Fisher at 4 of the 5 snag rest sites were in cavities, and the fifth snag rest structure appeared to be either a platform on top of the snag or a cavity. One log structure was a natural log (well decayed, 19-in. diameter at large end, 15 ft. long) and the other was a cull log left in the stand from an earlier selection harvest logging operation (well decayed, 58-in. diameter at large end, 33 ft. long).

Approximately 30% of the rest sites had at least 1 tree > 40 in. dbh and 50% had at least one tree > 30 in. dbh. Approximately 18% of the rest sites had at least one tree > 150 ft. tall and 78% had at least 1 tree > 110 ft. tall. Thirty-seven percent of the rest trees were the largest-diameter tree measured in the plot, and 30% were the tallest tree measured in the plot. Twenty-six percent of the rest trees were both the largest-diameter tree and the tallest tree measured in the plot. Rest trees averaged 85% of both the height and diameter of the tallest and largest-diameter trees measured in the plots.

Although over 48% of the rest sites were in stands of WHR S and P canopy closure classes, only about 10% of the rest sites had measured canopy closures of less than 40%. This was possible because of the patchy nature of the stands. Most rest sites were found in small aggregations of trees, less than 5 acres in size, that had canopy closures greater than the stand on average. Nine of the rest sites (26%) were found in small stringers of trees between small and large open or brushy areas. These stringers ranged from 50 to 300 ft. in forested width. Three of these stringer rest sites were found in a streamside management zone between two 1989 regeneration harvests. The other stringer rest sites were generally in areas where one or more trees survived the fires of the 1920s. These stringers of timber were also used for travel. One such stringer of timber was used by 1 fisher repeatedly to move from one drainage to another through a saddle. The saddle portion of this travel-way was composed of dense brush with a few scattered individual white fir and knobcone pine (*Pinus attenuata*). Both of the other fisher used similar residual stringers of timber and brush to travel over ridges.

Comparison with WHR and HSI Models

The winter PI was positively correlated with the HSI model ($r2 = .615$, $p = .004$). The full-year PI was not as strongly correlated with the HSI ($r2 = .370$, $p = .047$). We did not find a significant correlation between the PI and the assigned WHR habitat value ($r2 = .251$, $p = .117$).

Discussion

We found significant nonrandom use of the habitat types within the study area. Our findings generally agree with other studies. We found fisher to prefer forested habitats (Kelly 1977; Buck et al. 1994), habitats containing a significant hardwood component (Thomasma et al. 1991; Buskirk and Powell 1994), and lower-elevation forest types (Buck et al 1983; Raphael 1994). In our study area, lower elevations have a thin, intermittent snow cover in winter. Others have suggested that fisher avoid areas of deep, soft snow (Raine 1983). We believe that fisher in California prefer the lower elevations of the conifer forest zone for several reasons. In California, these lower elevations not only have less snow but also support a significant hardwood component. Hardwoods are largely absent in higher-elevation forest types. The WHR system suggests that conifer forest types with hardwood inclusions support a higher vertebrate species richness than conifer forests without a hardwood component. This suggests that prey diversity may be greater at lower elevations and could be a determining factor in fisher selection for lower-elevation forest types. In addition, prey are likely to be more available to fisher in areas with relatively less snow.

Our finding that fisher selected for areas close to water is supported by others (Buck et al. 1983; Seglund and Golightly 1993). However, we cannot say that fisher are choosing to use the landscape in this manner solely because of a desire to be close to water sources, riparian vegetation, or special microhabitat conditions. Habitats that we detected fisher selecting for were not evenly distributed in our study area but were more abundant close to water than far from water. This unequal distribution of selected habitats appears to be the simplest explanation for this landscape use pattern as these habitats were selected for regardless of their distance from water.

We found use to vary by year and by season. Jones and Garton (1994) described their study area by age of forest and found differences in use by season. They found fisher to be more selective in summer and to use a wider array of stand ages in winter than summer. In a review of a number of studies (which varied in how the study areas were described), Buskirk and Powell (1994) noted fisher were generally less selective in summer and used a more narrow range of habitats in winter. We described our study area by stand structural condition and found differences in use by season. In general, we found fisher to use a wider variety of stand conditions in summer than winter. However, we found fisher to be selective in their use of habitats in both seasons.

It has been hypothesized that fisher find optimal or preferred habitat in mature and old growth forest stands (Allen 1983; Rosenberg and Raphael 1986). Less than 10% of our study area is composed of stands that meet the WHR canopy cover and tree size classes of this stand structural condition (WHR 5M, 5D, 6). Fisher in our study did appear to select for these stand types, but we found equally strong selection for other stand types. Our study, as well as others, indicates that a variety of forest habitat conditions can be selected for by fisher and that these selection patterns vary by season, and from year to year. Because fisher appear to regularly change their use patterns by season and year, interpretations of past studies of habitat use must be sensitive to this. If future habitat use studies are to account for seasonal and yearly variation in use patterns, they should be conducted across seasons and for more than one year.

We found significant selection for use of timber stands within the WHR canopy closure class P (25–40% total canopy closure). This selection for use of open-forest stands was supported by our rest site data, with the caveat that rest sites were most often located in small areas (between 0.1 and 5 acres in size) of higher -than-average canopy closure. It must also be remembered that open stands in our study area generally have a heavy brush component, which would provide a high level of overhead cover for a fisher traveling on the ground. Several other researchers have reported fisher using brushy or open-forest areas (Buck et al. 1983; Raphael 1988). This high-brush-ground-cover, open-forest condition is relatively common in some portions of lower elevation California forests, particularly in high rainfall areas (pers. observation). Where this condition exists, it should not be discounted as an important habitat condition for fisher.

Although we found fisher using a wide range of tree sizes (mean + 1 SD = 18–42 in. dbh) for rest sites, the majority of the rest trees were of the larger diameters available within 100 ft. of the rest site. These fisher rest trees contained structures (mistletoe brooms, reformed or forked tops, cavities, squirrel nests) that are more commonly found in larger or older trees. This suggests that it may be important to maintain some number of larger or older trees within landscapes managed to maintain fisher habitat capability. These trees would appear to be of most use if they are in relatively dense aggregations of conifers and hardwoods (0.1–5 acres or larger in size) and within several hundred feet of permanent surface water. Fifty percent of our recorded fisher rest sites were within 150 ft. of water and 85% were within 500 ft. of water. Taking a conservative approach, if each fisher used 2 separate rest sites a day with no reuse, then 730 separate rest sites would be used within a year. The Castle Creek watershed has about 8,000 acres within 500 ft. of water. If all 730 rest sites were located within 500 ft. of water, there would be one rest site per every 11 acres, or 0.09 rest sites per acre. This is likely to be more rest sites than would be used by fisher in any particular area.

Historic and recent studies of the noncoastal forests in California have found that fire has always been a significant factor in the creation and maintenance of stand and landscape conditions (Sudworth 1900; Verner et al. 1992; USDI 1992; USDA 1993). These studies and others have led to the belief that the frequent fire cycles of presettlement forests kept the forest matrix in an open-forest condition dominated by large trees (with a variable brush layer), with inclusions of dense, multistoried forest conditions likely to be found only in protected areas such as riparian zones and on north slopes. Seventy to ninety years of fire suppression management has generally reversed this landscape condition such that the matrix is now composed of dense forest dominated by smaller trees with little to no brush component, where large-tree, open-forest conditions now occur only as small, isolated inclusions.

Although conclusions may need to be tempered by the specific history of our study area, the changes we found in the landscape conditions of the Castle Creek watershed over the last 50 years support this historical perspective. In addition, the use of open-forest stands by fisher supports the idea that this condition existed as an important component of historic and prehistoric forest landscapes. If our data are correct and these open-forest conditions are important to fisher (as indicated by selection), the current density and distribution of fisher may have been negatively affected by the major reduction in the amount and distribution of this open-forest habitat condition.

We compared two methods of estimating telemetry error: 1) a triangulation error estimate, and 2) a measured error estimate. Our triangulation error estimate assumes that the actual location of the animal is within the calculated error polygon and that smaller error polygons lead to more-accurate location predictions. Although we were able to triangulate to a very small area (about 1 acre), we found that the animal's actual location was often not within the predicted area. Therefore, we believe that comparing estimated locations to actual locations is a more accurate method of telemetry location error estimation.

As reported above, in our study several WHR habitat stages could not be evaluated for selection by fisher because of the relationship between average patch size and our estimated error. Many past and recent telemetry studies have not presented an estimate of the error associated with their predicted locations. Most studies have not discussed the significance of this error to the conditions of the study area or how the error affects the reliability of results and conclusions. We feel that this is a significant omission and must be considered in evaluating any telemetry study: past, present, or future.
The HSI model for fisher habitat use performed well in predicting winter habitat use by fisher in our study area. For annual use, the model, though significantly correlated, performed less well. The weak annual performance of the model is best explained by its underprediction of the use of open-forest conditions. This underprediction was apparently also found by Thomasma et al. (1991) in their field test of the model. Our data suggest that these open-forest stand conditions provide better fisher habitat than the model predicts, though a significant ground cover of brush may be required.

The WHR model for fisher habitat use did not perform well in predicting habitat use by fisher in our study area. Although fisher used stand conditions predicted, the model was too conservative and did not account for the significant use by fishers we found in KMC/MHC 3D, 4P, and 5P stands. Inclusion of these stand-structure conditions with others deemed suitable for use by fisher would improve this model.

Because our sample size is small and restricted to males, we suggest that others view our study within the context of other available information. We believe that, for the most part, habitat use by male fishers may reflect habitat use by females. Other studies have not found female fishers to use habitats or rest sites differently than males (Jones and Garton 1994; Powell and Zielinski 1994) and anatomical analyses suggest that dietary specialization between sexes is unlikely (Powell and Zielinski 1994). Although female fisher may require specialized structures for whelping and raising young, few natal dens have been found in the West. The majority of those found in the East have been in cavities in living and dead trees, mostly in hardwoods, and a few have been found in logs on the ground (Powell and Zielinski 1994). Structures used for natal dens have generally been of large size (89 cm dbh, 35 in.) (Buck et al. 1983). The descriptions of these known natal dens are notoutside the range of parameters we measured at male fisher rest sites. This suggests that the variability of male fisher rest sites may be sufficient to include those required by females for whelping and raising their young. However, developing additional insight into the needs of female fisher while raising young must be considered a high priority for future research.

Fisher are known to have used our study area since at least the 1970s (Gould 1987; Benkowski 1991), and the capture of adult males, adult females, and juveniles in the study area suggests that habitat is of at least sufficient quality to allow for reproduction to occur. Our study area is also within a region of California where others have described the fisher population as having been stable or increasing for at least the last 20–25 years (Yocum and MCCollum 1973; Schempf and White 1977; Gould 1987).

One other study has been completed on fisher in California. The data from this study have been reported in the literature at least twice (Buck et al. 1983; Buck et al. 1994) with quite different interpretations presented in these respective reports. The 1983 analysis hypothesized that adult male fisher were influencing habitat use by females and juveniles by causing them to occupy areas of less suitable habitat. If this were true, it would violate one of the assumptions required in habitat selection studies, that study organisms have free and equal access to all available resource units (Manly et al. 1993). Furthermore, then maintenance of nonselected habitats may be important for maintaining the overall population by allowing the continued existence of females and juveniles in the study area. In characterizing optimum fisher habitat, Buck et al. (1983) used data from one of their study areas, the HBSA, which they characterized as the area of best habitat for fisher. The HBSA had data from 2 males tracked over approximately 1 year (65 total locations). Selection by females and juveniles in the HBSA was not detected. In addition, we question whether their data support the conclusion that the HBSA was the area of better habitat. Other researchers have suggested that home range size will increase when the percentage of suitable or preferred habitat decreases (Forsman et al. 1984; Thomas et al. 1990; Herrmann 1994). Fisher in the HBSA consistently had larger average home ranges than fisher in the “less suitable” CBSA. It may be that the most logical interpretation of these data is that the CBSA was the area that was most suitable for use by fisher.

A further complication with the Buck et al. (1983) study is that the 1994 reanalysis found that adult female fisher exhibited stronger selection than males, a reversal from the 1983 interpretation. There were a total of 4 adult females in the Buck et al. study (2 in each study area), which were tracked for 3to 5 months (61 total locations).

The Buck et al. study provided useful information and explored new methodologies in dealing with detection, capture, handling, and analysis techniques. However, we believe that the correlation we found between our data and the HSI model is of further importance. This model has been field tested on at least one other occasion (Thomasma et al. 1991) and found to be generally accurate in its predictions. We found an equally strong correlation between the model’s predictions and our winter actual use data. as was found by Thomasma et al.

Management Implications

We agree with Jones and Garton (1994) that management for fisher should be conducted on a landscape scale and provide for a variety of forest habitat conditions across the landscape. Lower-elevation areas within several hundred ft. of water should be an area of focus for the creation and maintenance of these varied forest conditions, with an emphasis on stands with both relatively open and closed canopy closures. Forest stands managed to allow use by fisher should not be uniform in structure but should contain at least a few small aggregations (0.1 – 5.0 acres in size) of relatively dense canopy with one or more trees of larger-than-average size and/or trees that contain obvious platforms usable by fisher for rest structures. The conditions provided within streamside management zones are useful for this purpose. Approximately 34% of the area within 500 ft. of water in our study area was composed of stand conditions that fisher selected for. This selected habitat was composed of approximately 5% WHR 3, 45% WHR 4, and 50% WHR 5 size classes. Sixty percent of this selected habitat was within the WHR D density class and 33% was in the WHR P density class. Higher-elevation areas and areas away from water could emphasize more diverse forest conditions. Approximately 19% of the area more than 1,100 ft. from water in our study area was composed of stand conditions that fisher selected for. This selected habitat was composed of approximately 20% WHR 3, 50% WHR 4, and 30% WHR 5 size classes, and 65% of it was in the WHR D density class.

Open-forest stands that lack a significant brush or hardwood ground cover component and other openings without overhead cover should not be considered suitable habitat for fisher. Although we found nearly 60% of fisher use to occur within 500 ft. of water, fisher do not appear to be restricted to areas close to water. We found significant selection for habitat types even though they were at least 2,500 ft. from water.

We believe the U.S. Fish and Wildlife Service's habitat capability index model for fisher (Allen 1983) will work reasonably well in predicting changes to fisher habitat capability in Northern California. However, the model does not account for the use of open-forest conditions. Our finding of significant use of high-brush-cover open-forest conditions (25–40% tree canopy closure) by fisher in summer should be accounted for in future habitat evaluations. In addition, managing for some timber stands with an irregular distribution of trees may be of more use to fisher than managing all stands to have an even distribution of trees. Also, care must be taken to continue to provide trees with rest structures such as mistletoe brooms, forked-topped trees, platforms, cavities, and large snags and logs. To be of most use, these within-stand features should be provided within close proximity to permanent water.

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Tables

Table 1: Fisher Capture Information

Animal	Date Captured	Sex	Age	Weight (lb.)	Body Length (in)	Total Length (in)
Wilbur	**11/91**	**Male**	**Adult**	**8.5**	**27.2**	**41.4**
Rocky	**1/92**	**Male**	**Adult**	**9.9**	**25.8**	**39.0**
F-3	**11/92**	**Male**	**Juvenile**	**4.4**	**24.4**	**37.8**
F-4	**12/92**	**Male**	**Juvenile**	**6.6**	**23.4**	**39.0**
Odie	**11/92**	**Male**	**Adult**	**8.8**	**25.6**	**41.2**
F-6	**6/94**	**Female**	**Adult**	**3.9**	**20.9**	**35.5**
F-7	**7/94**	**Male**	**Adult**	**8.8**	**25.2**	**39.8**
F-8	**7/94**	**Female**	**Adult**	**3.3**	**22.1**	**35.1**
F-9	**7/94**	**Male**	**Adult**	**8.8**	**24.8**	**39.0**

Table 2: Fisher Telemetry Data

Animal	Sex	Periods Tracked	Number of Locations	MCP Home Range (Ac)
Wilbur	**Male**	**11/91 to 11/92** **11/92 to 10/93**	**209** **94**	**6536** **6719**
Subtotal		11/91 to 10/93	303	10067
Rocky	**Male**	**1/92 to 11-92** **11/92 to 11/93**	**273** **76**	**5827** **7504**
Subtotal		1/92 to 11/93	349	7705
Odie	**Male**	**11/92 to 10-93**	**62**	**8610**
Overall Total			**714**	

Table 3: WHR Habitat Types and Use by Fisher in the Castle Creek Watershed

WHR Label	Habitat Type	Percent of Watershed	Percent Use
AGS	**Annual Grassland**	**0.9**	**0.0**
CPC	**Closed-Cone Pine-Cypress**	**1.5**	**1.0**
KMC	**Klamath Mixed Conifer**	**57.5**	**83.0**
MCH	**Mixed Chaparral**	**3.7**	**0.0**
MCP	**Montane Chaparral**	**16.2**	**2.0**
MHC	**Mixed Hardwood Conifer**	**5.5**	**12.0**
MHW	**Montane Hardwood**	**0.7**	**0.0**
RFR	**Red Fir**	**0.7**	**0.0**
SCN	**Sub-Alpine Conifer**	**0.6**	**0.0**
WFR	**White Fir**	**12.7**	**2.0**

Table 4: Available WHR Structure Stages and Associated Fisher Use

WHR Structure Stage	% of MCP	% of Fisher Locations (n=714)	Selection[1]	% of Fisher Rest Sites (n=34)
KMC4D	17.61	31.23	+	29.0
KMC4P	9.18	11.06	0	22.6
KMC4M	9.06	2.66	-	3.2
KMC4S	9.06	2.38	-	3.2
KMC5P	8.58	21.01	+	19.3
WFR3S	7.16	0.14	N	0.0
KMC5M	4.97	11.90	+[2]	0.0
KMC3S	4.73	0.70	-	3.2
MCP4P	4.53	0.00	N	0.0
MHC4D	3.78	4.20	0	9.7
MCP4S	3.32	1.54	N	0.0
WFR4M	2.52	1.12	N	9.7
MHC3D	1.86	5.18	+	0.0
MCH3D	1.58	0.00	N	0.0
KMC6	1.44	2.24	0	0.0
WFR3P	1.19	0.14	N	0.0
MHC4P	0.96	1.12	N	0.0
KMC3D	0.90	0.00	N	0.0
MCP4M	0.89	0.14	N	0.0
AGS2D	0.70	0.00	N	0.0
CPC3D	0.64	0.00	N	0.0
MHC4M	0.62	2.24	0	0.0
OTHER	4.72	1.00	N	0.0

1. Selection is for telemetry locations and was measured using simultaneous 95% Bonferroni confidence intervals. "+" = Selected For; "-" = Selected Against; "0" = Used as Expected; "N" = Not testable due to accuracy requirements not met, actual locations being less than 5, or did not comprise at least 5% of Study Area.

2. The reader should note that KMC5M did not meet the accuracy requirement but was interpreted to be "selected for" by fisher.

Table 5. Selected Habitat Parameters From Fisher Rest Sites (n=34)

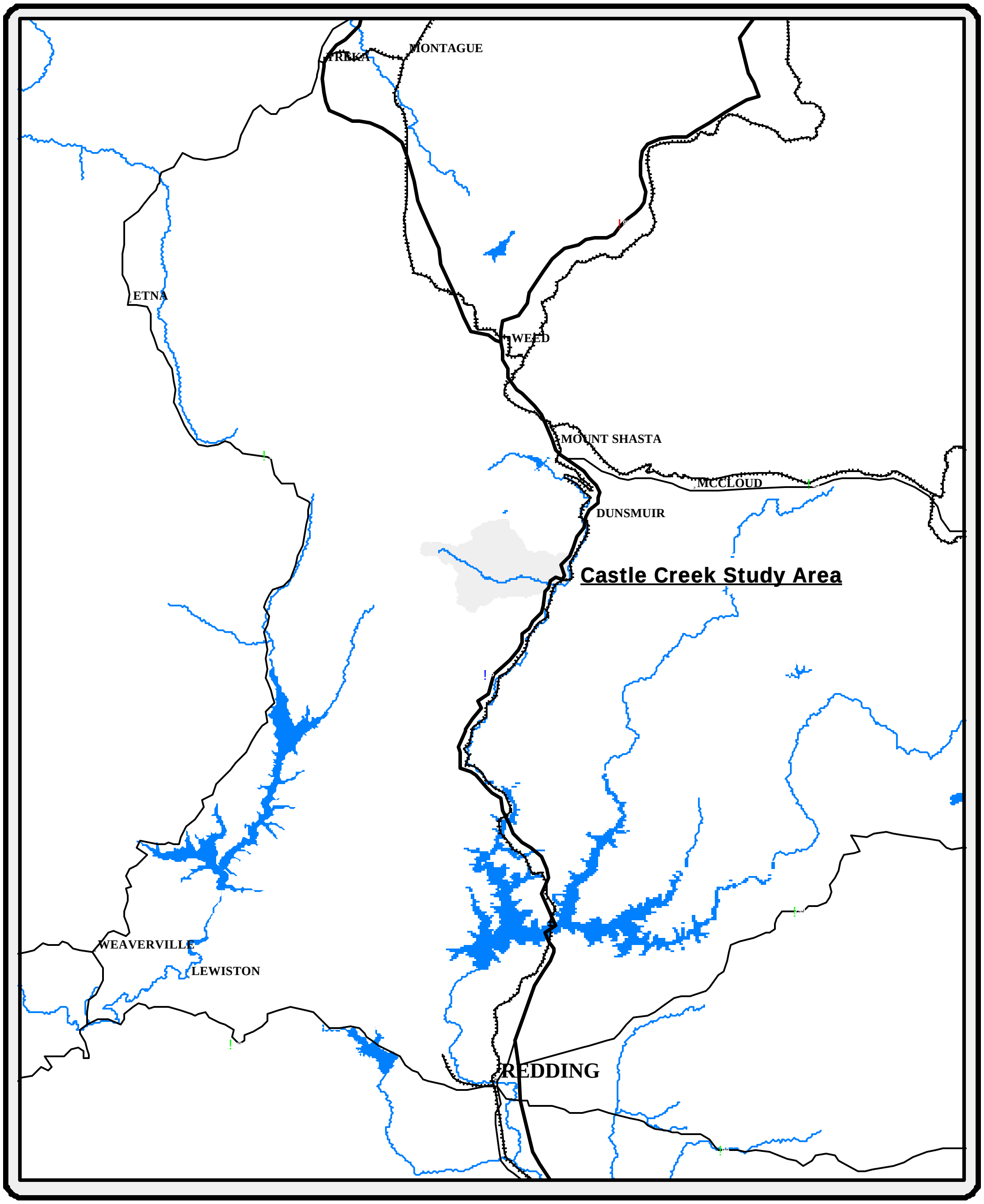
	Mean	Standard Deviation	Minimum	Maximum	Median
Canopy Closure (%)	71	20	19	100	76
Basal Area Per Acre (ft^2)	160	104	17	478	N/a
QMD[1] (in)	13.3	3.0	9.0	19.0	N/a
DBH of Rest Tree (in) (n=27)	30	12	10	58	28
Age of Conifer Rest Trees[2] (yrs) (n=19)	100	47	47	210	90
Age of Rest Site (yrs)	80	38	33	198	65
Distance to Water (ft)	442	809	3	3860	150
Distance to Human Disturbance[3] (ft)	224	332	0	1300	60
DBH of Rest Snag (in) (n=5)	42	N/A	36	48	N/A
DBH of Rest Log (in) (n=2)	38	N/A	19	58	N/A

1. Selection is for telemetry locations and was measured using simultaneous 95% Bonferroni confidence intervals. + = Selected For; - = Selected Against; 0 = Used as Expected; N = Not testable due to accuracy requirements not met, actual locations being less than 5, or did not comprise at least 5% of Study Area.

2.Ages could not be determined for 6 conifer rest trees. If a maximum age of 350 years is assigned to these 6 trees, the mean age becomes 160 years and the median age becomes 105 years.

3. Human disturbance is defined as the presence of a cut stump, road, harvest unit, or skid trail.

Figures



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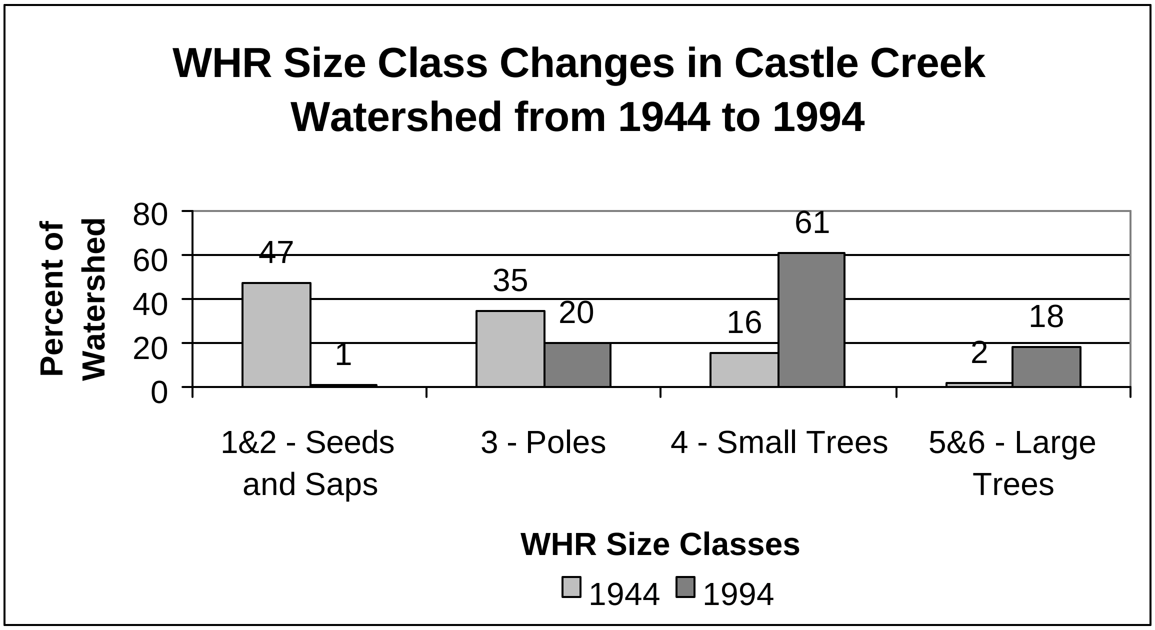

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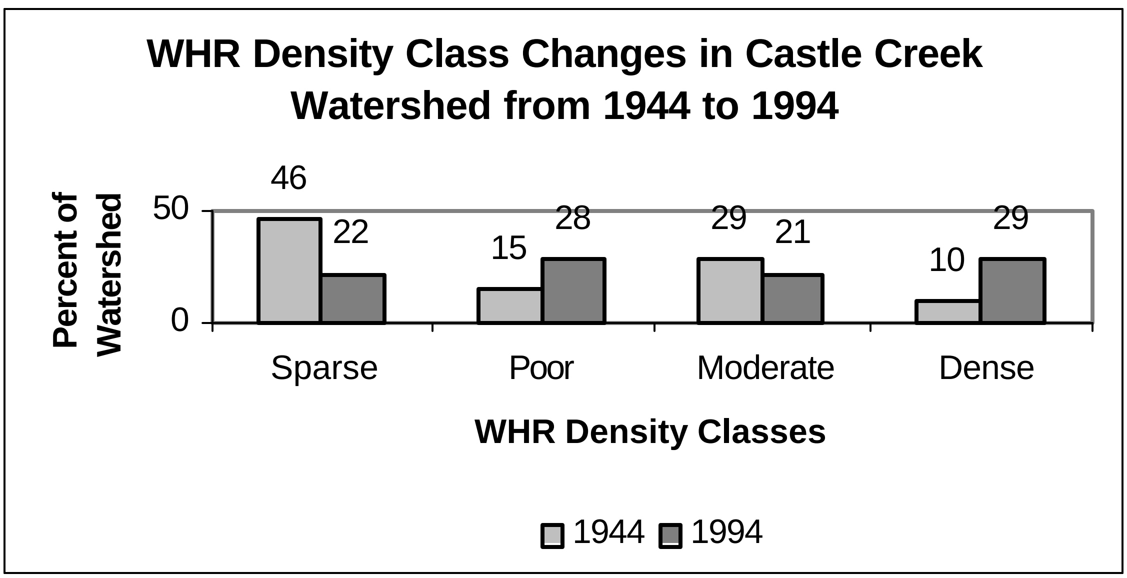

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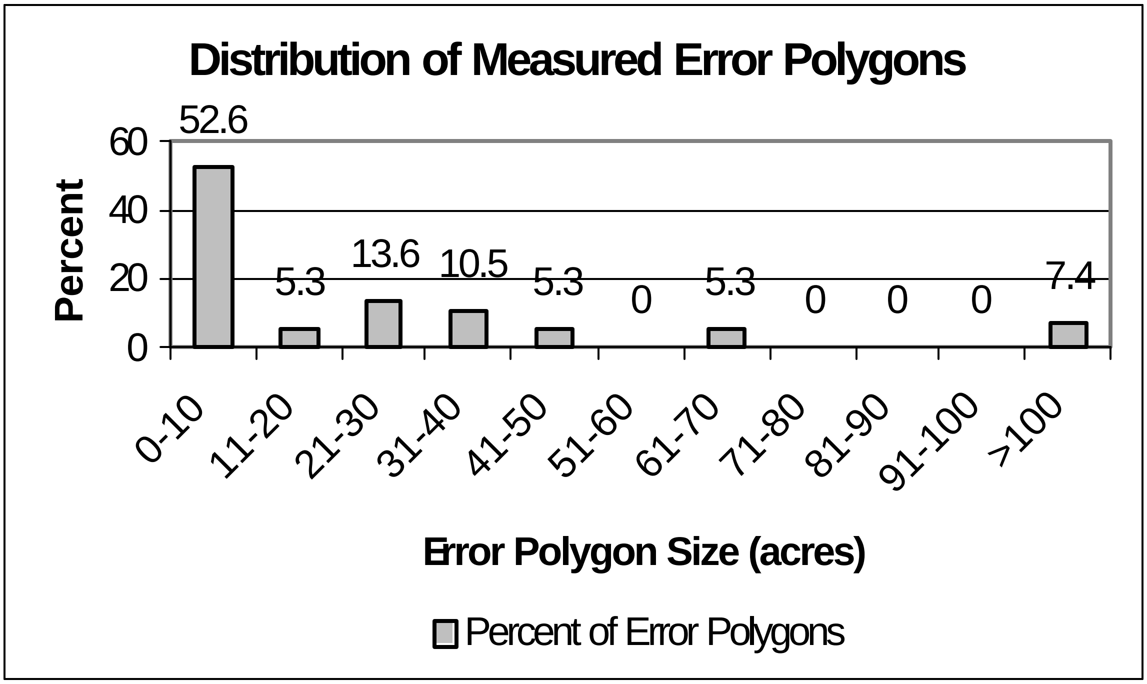

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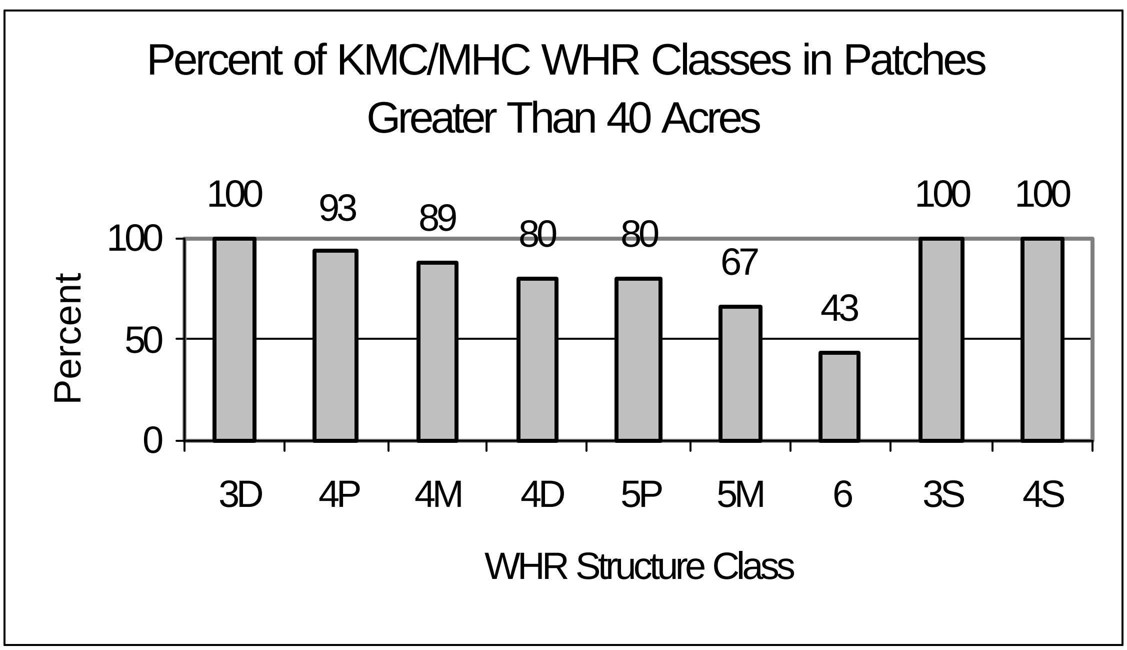

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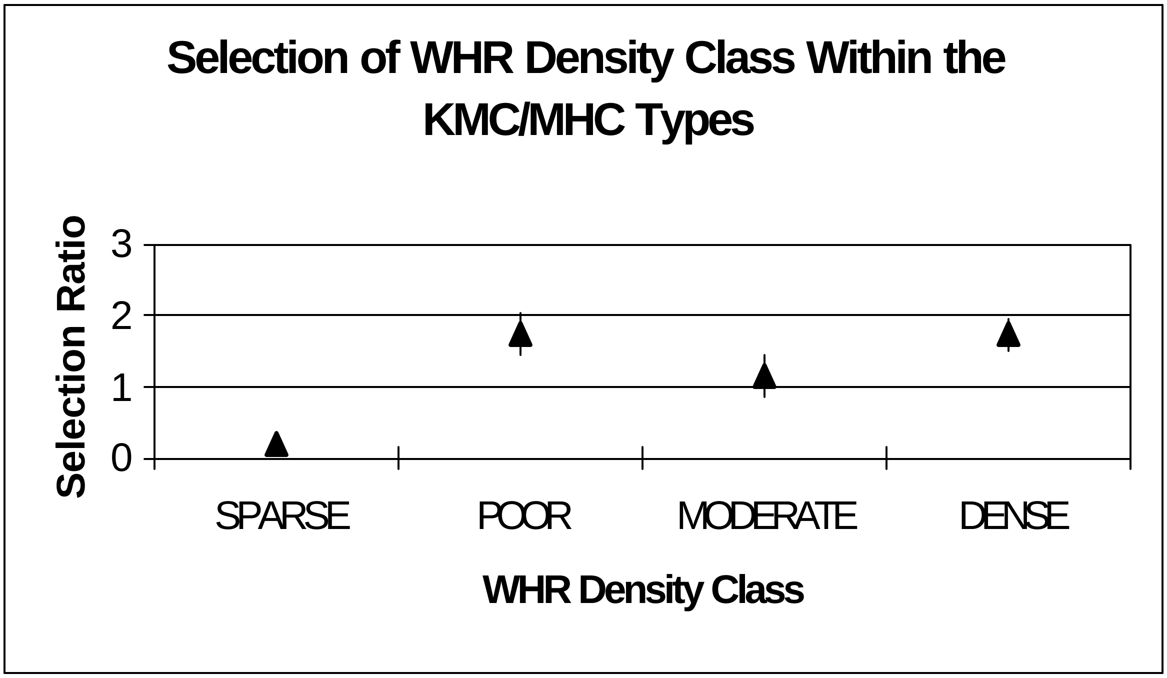

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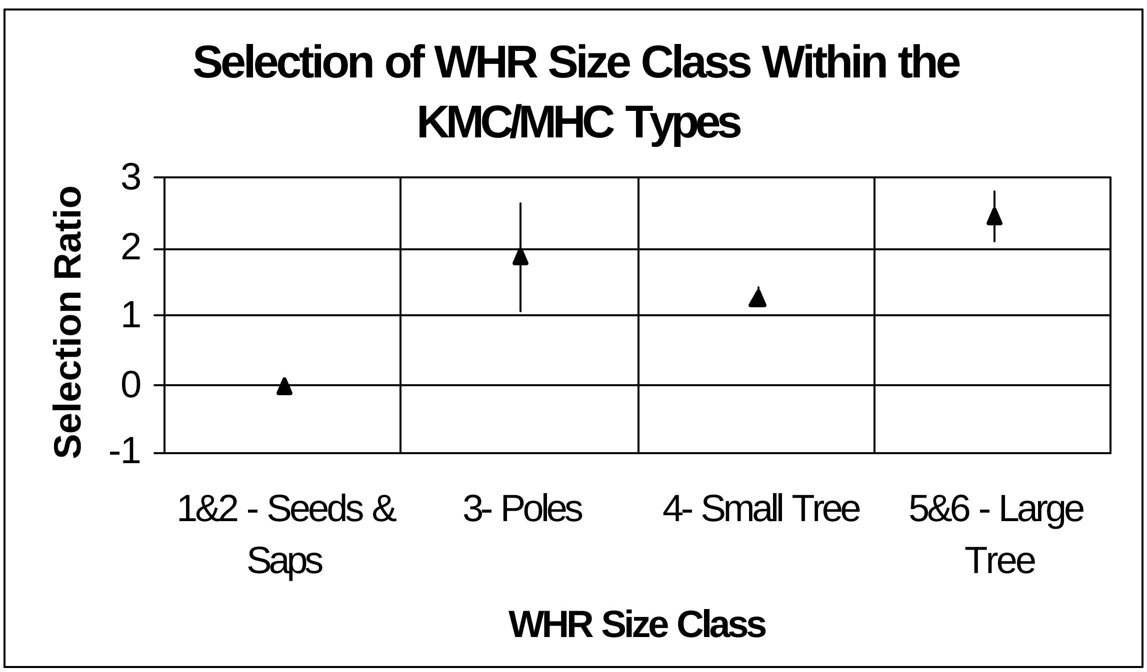

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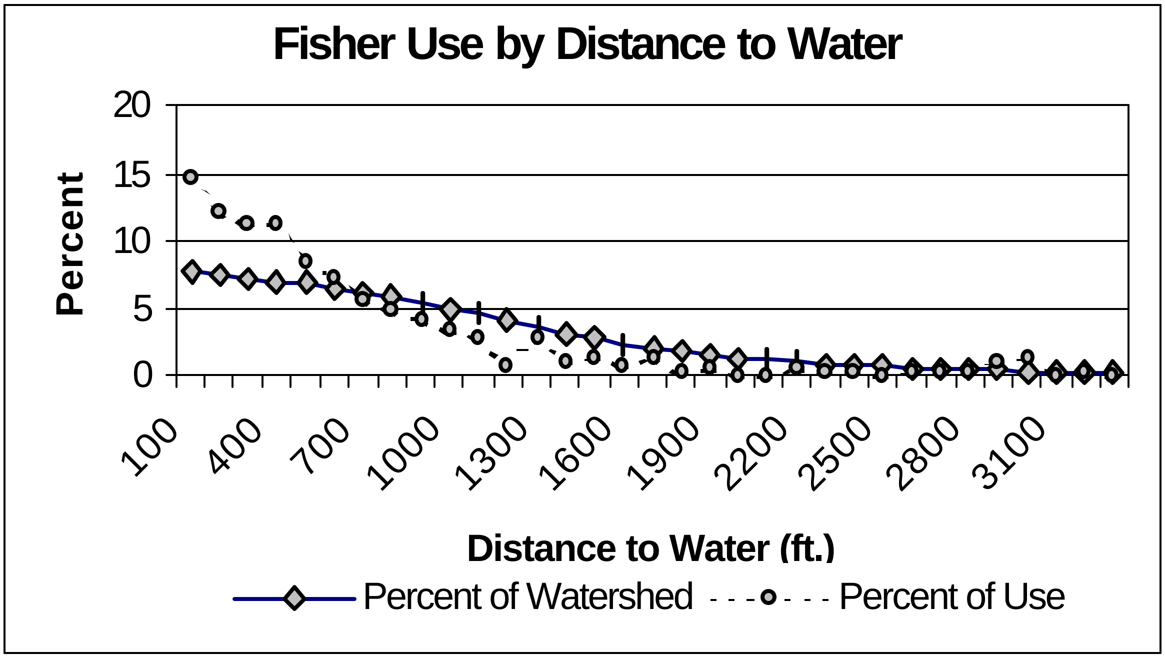

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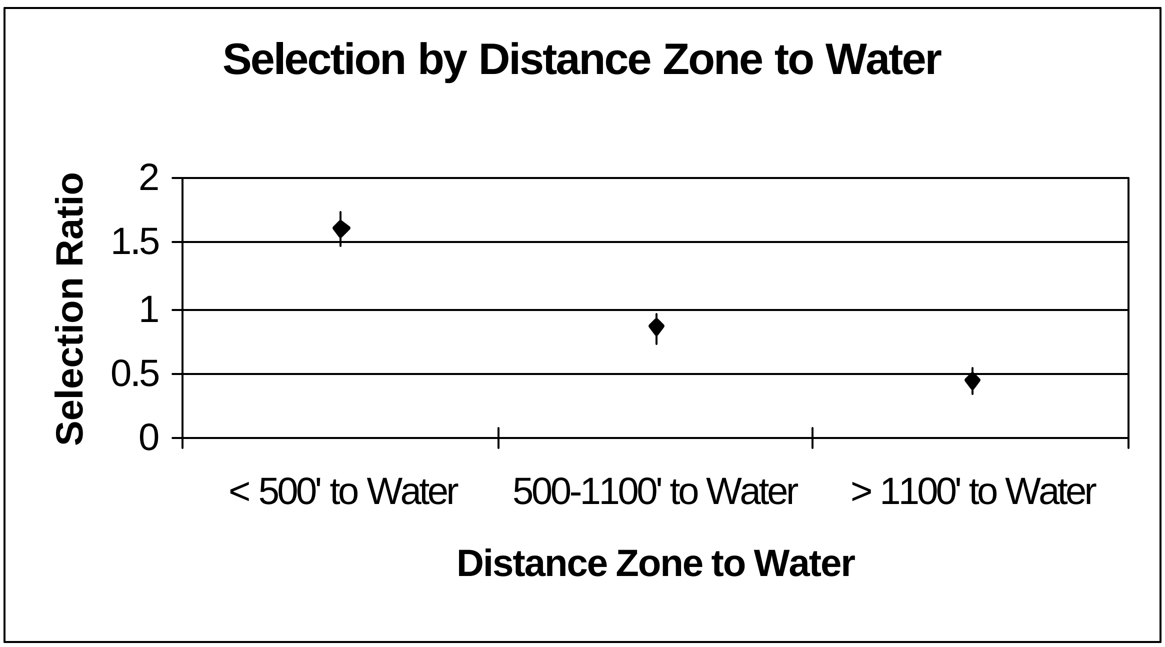

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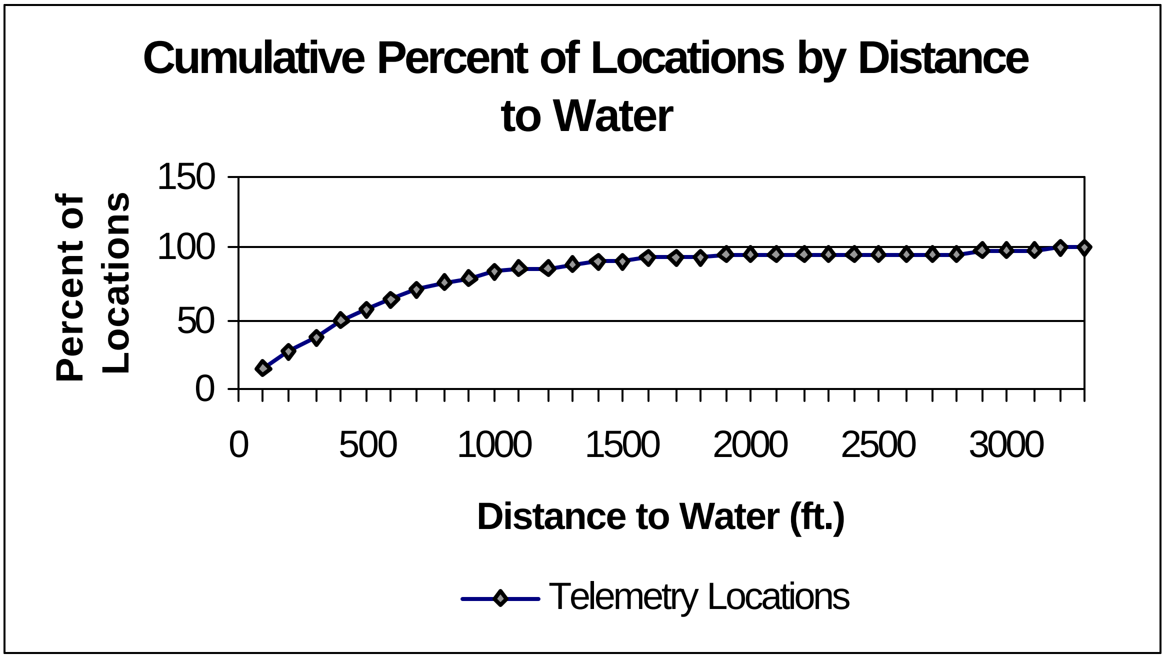

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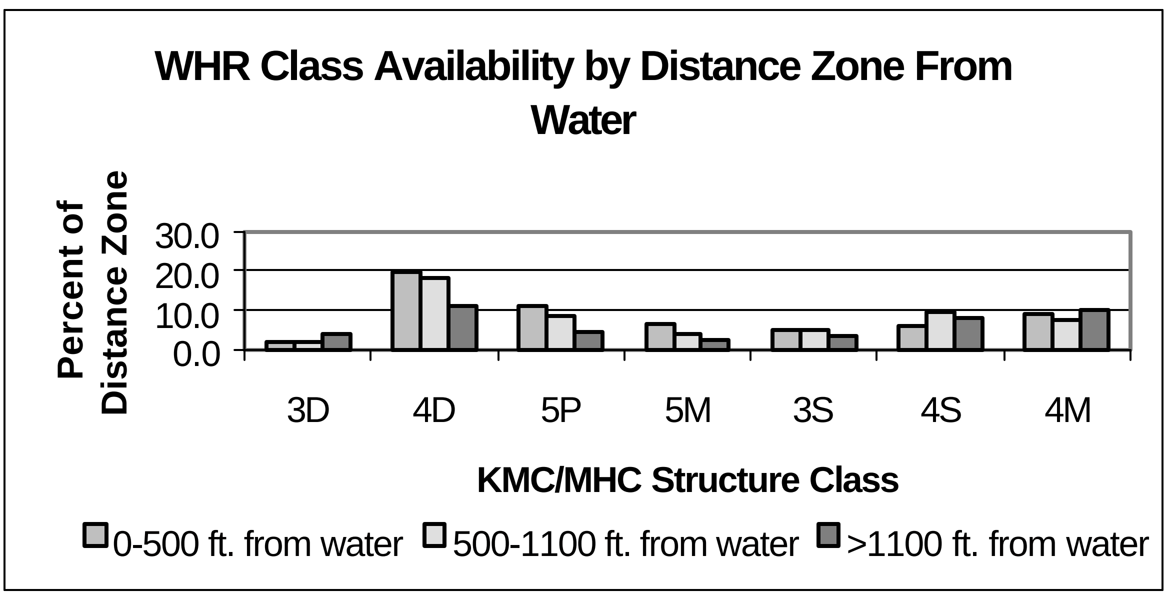

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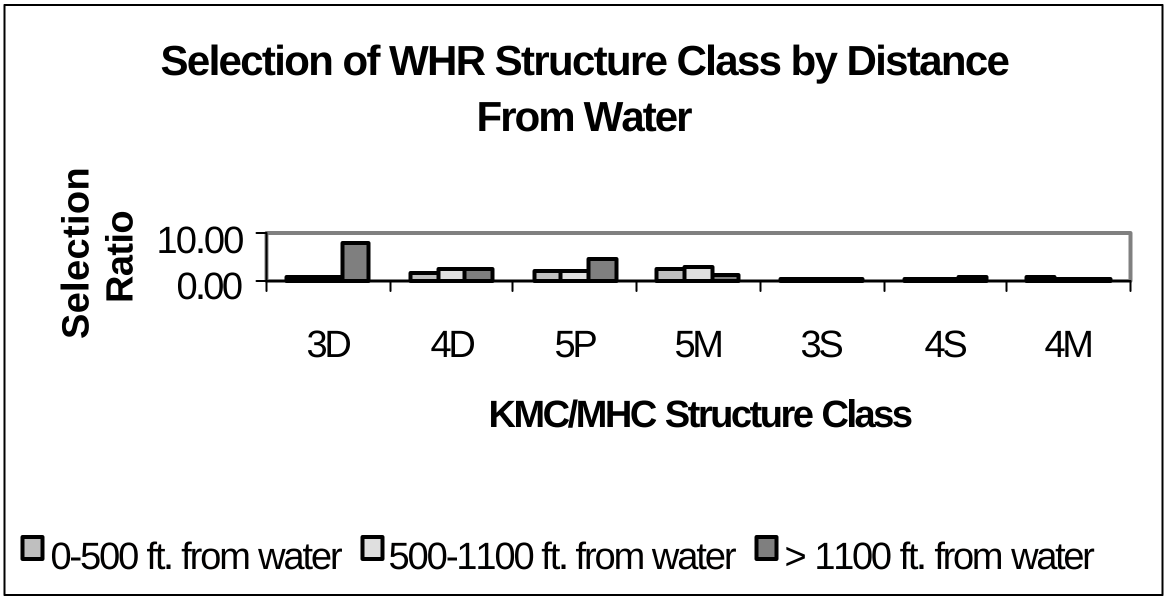

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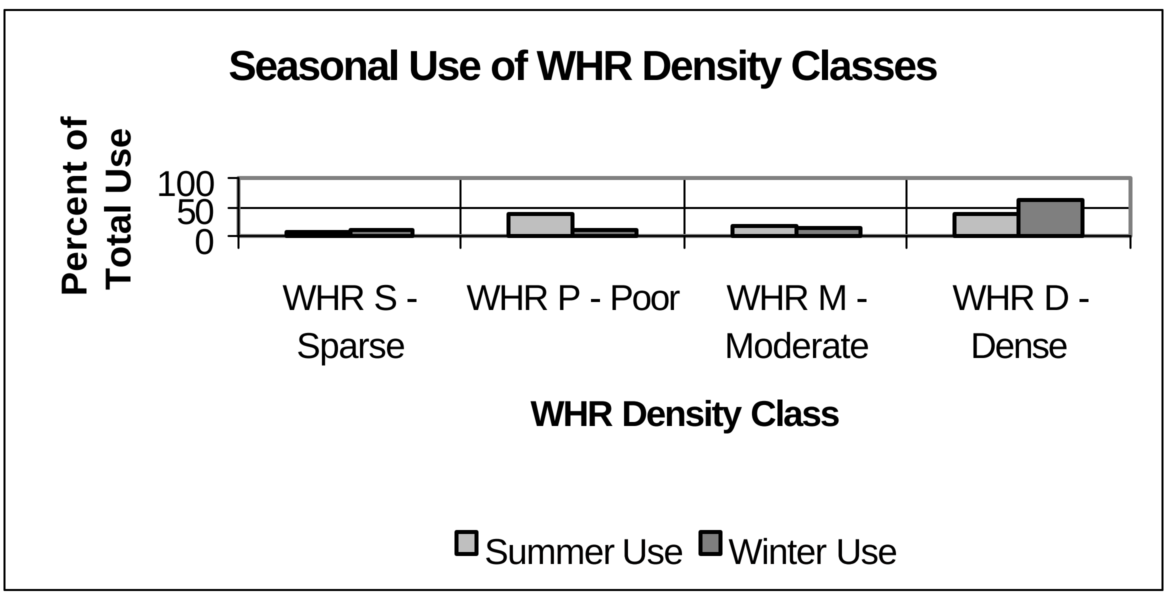

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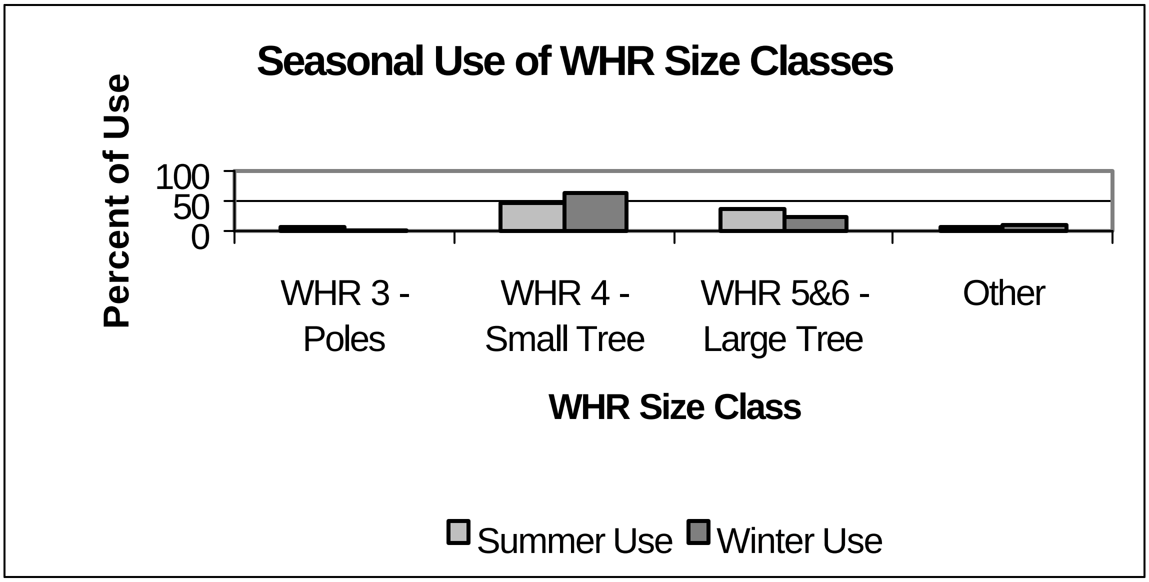

Figure 12.

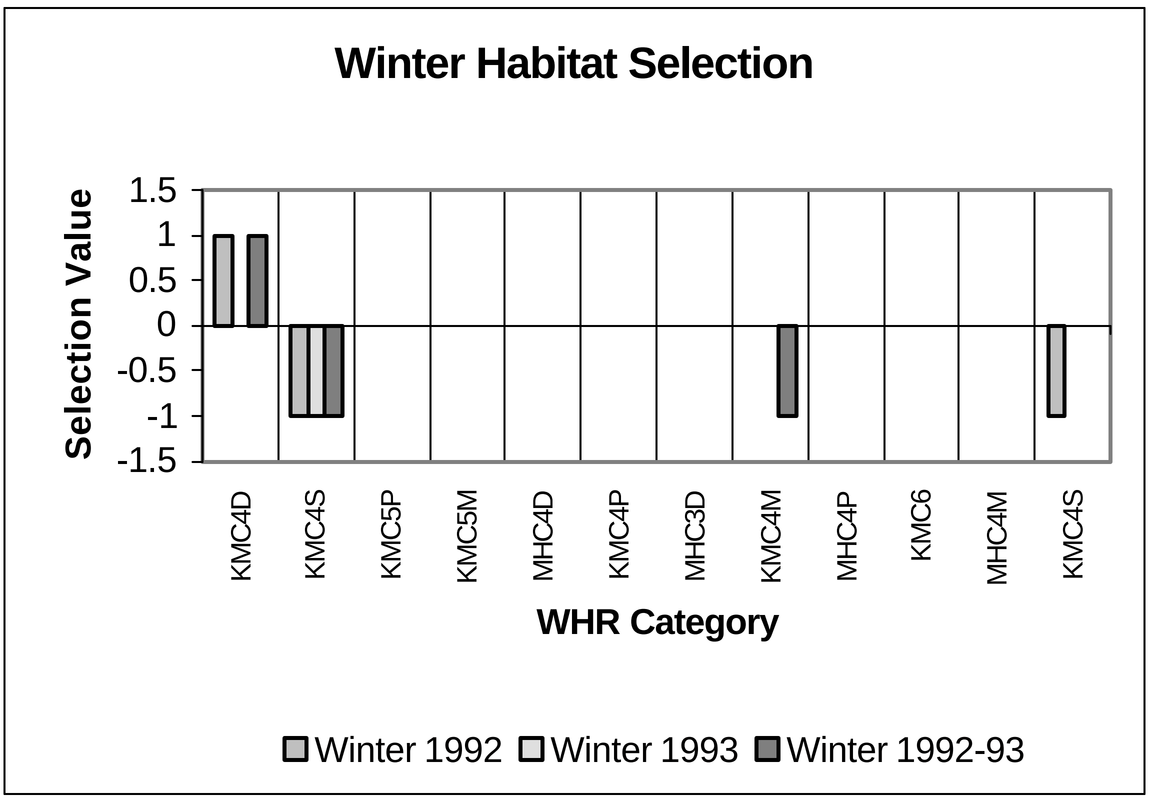

Figure 13.

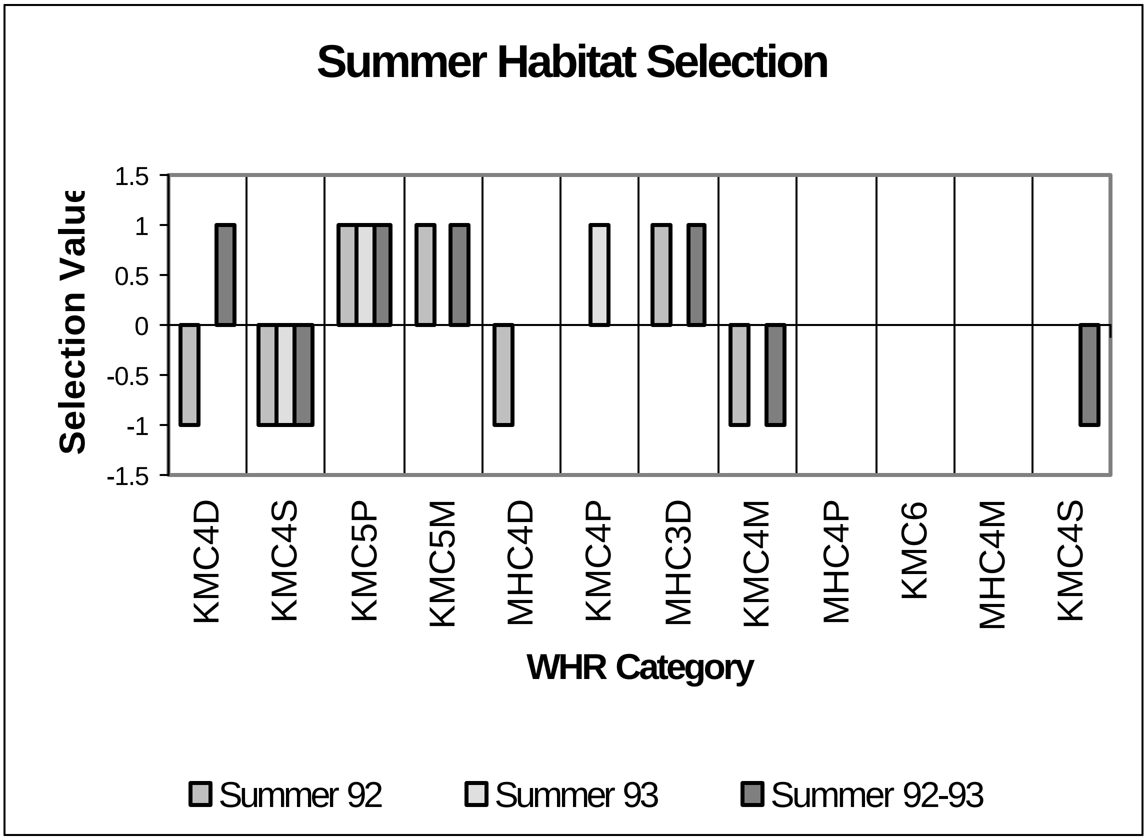
Summer Habitat Selection
Selection Value
1.5
1
0.5
0
-0.5
-1
-1.5
KMC4D
KMC4S
KMC5P
KMC5M
MHC4D
KMC4P
MHC3D
KMC4M
MHC4P
KMC6
MHC4M
KMC4S
WHR Category
Summer 92
Summer 93
Summer 92-93

Figure 14.