JOB PROGRESS REPORT

FEDERAL AID IN WILDLIFE RESTORATION

Large Carnivore Ecology and Populations Status

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Objectives

The objectives of this proposal is to obtain a better understanding of the status, ecological role, and relationships to human populations of large carnivores in the state. Studies of lynx will define how lynx use landscape features and micro-habitat types. Investigations on cougars will identify cougar populations characteristics and define environmental and human social parameters in areas where cougar-human interactions occur, whereas the objectives for predation study is to assess the effects of predation on elk and deer population recruitment by bear and cougars.

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Job 1. Conduct habitat selection studies of lynx in Okanogan County.

In 2000 we began studies of lynx use of habitat in North Central Washington and a survey to help define the east-west distribution of lynx in the North Cascades. The lynx was classified a Threatened Species in the contiguous United States under the Endangered Species Act in 2000. Information on lynx use of habitats and the effects that wild fires, timber harvesting and roads have on lynx is needed to manage lynx populations.

We are snowtracking lynx in winter and plotting their movements using Pathfinder GPS units and overlaying travel patterns onto forest stand conditions identified on a GIS. We are comparing forest stand use patterns to that available obtained from randomly placed transects. Along travel routes and random transects we collect information on snow density, tallies of tracks of snowshoe hares, red squirrel, other prey, as well as coyotes and other potential competing carnivores.

In addition we record overstory and understory tree species, diameter and stem density and topographic data. We will correlate lynx travel and habitat use patterns to those of potential carnivore competitors, snow conditions, prey and habitat conditions. We will use this data to construct a model of habitat use patterns for lynx and to assess the influence of wild fires and timber harvesting on lynx. This phase of the project will be completed in 2002 and we will conduct similar studies in more highly fragmented stands in an adjacent area to investigate lynx use of these environmental parameters where habitats are more fragmented due to natural and man-made causes.

Results

The Master of Science graduate student from the University of Washington, and three field assistants conducted lynx field work from Dec. 15, 2000, to March 15, 2001, when spring thaws and poor snow conditions prevented further snowtracking investigations. We followed 46.7 kilometers of lynx trails, surveyed 31 transects, and recorded data from 294 vegetation and prey availability plots.

We recorded four kills by lynx while snowtracking. Snowshoe hares were identified as the prey on three occasions and possibly grouse on another occasion. We recorded 15 chases of prey by lynx. Of the unsuccessful chases, nine targeted snowshoe hares, three chased red squirrels, and the objects of two pursuits were undetermined because of poor snow conditions.

In addition to these observations, we also recorded general lynx behavioral activities including 103 urine-marking sites, 21 fecal deposits, 28 resting sites, one female playing with kittens, 34 hunting ambush locations, and a variety of other behavioral activities. While conducting surveys and snowtracking, we documented tracks of other carnivores associated with lynx tracks: 12 coyotes, 26 with other lynx, 14 weasel, and 21 marten. These observations included a single coyote followed by a lynx, four instances of lynx followed by coyotes and four instances of lynx following lynx tracks.

We tallied tracks of prey species encountered within 20-meter transects along survey transects and lynx trails. They standardized these tallies by dividing the number of tracks by the hours since last snowfall times 24 hours to provide units of measure of tracks/24 hrs/20 meters. Snowshoe hares were the most numerous prey tracks encountered with 2.03 tracks/24 hrs/20 m recorded along lynx trails compared to 0.96 snowshoe hare tracks within availability plots. Tallies of grouse also were more common along trails (0.003 vs. 0.0006 within plots), while tallies of red squirrel tracks were similar for lynx trails and within availability plots (0.35 vs. 0.32 respectively).

With funding from the Washington Department of Transportation, we are conducting surveys for lynx using hair snag pads along State Highway 20 from Ross Lake in Whatcom County to Mazama in Okanogan County. Their objectives are to document the presence of lynx along the highway corridor, to determine whether individual animals cross the highway when vehicular traffic is present, and to assess the east-west distribution of lynx in the North Cascades.

From DNA analysis of hair samples collected last fall, 3 samples along Highway 20 were determined to contain lynx hair: on Granite Creek, a tributary to Ruby Creek on Ross Lake, on Early Winters Creek along the eastern summit of Washington Pass, and near Pine Creek in western Okanogan County. We continued the survey during 2001 and samples are currently being analyzed for DNA profiles.

Job 2. Conduct radio-telemetry studies to investigate cougar-human interactions.

In 2001 Washington Department of Fish and Wildlife began a study of cougars called Project C.A.T. (Cougars and Teaching) which integrates public school districts, University teacher training programs, and community members with a scientific investigation of cougar use of space and habitats in relation to human residence and activity centers. The objectives are to identify characteristics of cougar populations, environmental parameters, and human development that may potentially result in human-cougar conflicts. This project is anticipated to be a long-term investigation which will include 2 or 3 study areas in different environmental and human density areas and will span 8 years. A detailed study plan is provided in Appendix A.

Capture of cougars and marking them with GPS collars began in December 2001. GPS locations will be collected at monthly intervals and data overlaid onto GIS databases. Students will analyze home range and habitat use patterns with the use of GIS. Curriculum development for the Roslyn-Cle Elum School District began in spring 2001 and *Nature Mapping* Program of the Department of Fish and Wildlife and University of Washington was instituted into the School District during fall. Senior level students well participate in capture efforts and data collection and analysis early in 2002.

Job 3. Investigate cougar and black bear predation on deer and elk populations.

Dr. Rob Weilgus at the Washington State University was contracted to write a report on the potential interactions between white-tailed deer, mule deer and mountain lions. The report titled “An Examination Of Compensatory, Additive, And Depensatory Mortality On Mule Deer Population Growth And Regulation” by Dr. Robert Wielgus amd Hugh Robinson is provided under separate enclosure.

Job 4. Conduct manuscript composition of peer-reviewed publications, technical bulletins, progress/completion report, and symposia presentations.

In 1994 the Washington Department of Fish and Wildlife began a 6 year field investigation of black bears to 1) determine sex and age characteristics, productivity and mortality of study populations and compare these factors to harvest statistics, 2) assess use of habitat and space by bears to provide relative population estimates and extrapolate findings to ecoregions, 3) develop a non-invasive population estimator utilizing DNA "fingerprinting", and 5) and provide management prescriptions to address damage caused by bears to forest plantations. Field studies were conducted at 3 study sites representing 3 ecoregions with different vegetation and mean annual precipitation ranging from 52 to 380 cm.

Results from this study were captured in the following peer reviewed publications and *In Press* manuscripts:

Collins, G. H., R. B. Wielgus, and G. M. Koehler. (*In press*). Effects of sex and age on black bear conifer damage and control. Ursus.

Koehler, G.M., P.B. Hall, M.H. Norton, and D.J. Pierce. 2001. Implant versus collar transmitter use on black bears. Wildlife Society Bulletin. 29(2): 600-605.

Koehler, G. M., and D. J. Pierce. (*In review*). Black bear home range size and forest cover type use relationship in Washington. Journal of Mammalogy.

Koehler, G. M. and D. J. Pierce. *(In review*). Survival and cause-specific mortality of black bears in Washington. Journal of Wildlife Management.

Stewart, W. B., G.W. Witmer, and G. M. Koehler. 1999. Black bear damage to forest stands in Western Washington. Western Journal of Applied Forestry. 14(3): 128-131.

Stewart, W. B., G.W. Witmer, and G. M. Koehler. (*In press*). Incisor analysis technique to identify black bears damaging trees. International Biodeterioration and Biodegradation.

Nyland, P. D., G. M. Koehler, and D. J. Pierce. (*In preparation*). Black bear use of intensively managed forest stands in Western Washington.

APPENDIX A.

COUGARS ECOLOGY AND BIOLOGY IN RURAL AND SUBURBAN ENVIRONMENTS OF WASHINGTON

STUDY PLAN

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE,

HORNOCKER WILDLIFE INSTITUTE,

2001-2009

At the pinnacle of the ecological community in the Pacific Northwest cougars (*Puma concolor*) are a management enigma, revered by some and reviled by others. Once associated with remote wilderness areas they now frequent suburban communities. Development and urban sprawl has usurped rural environments with more than 70,000 acres of habitat lost each year as a result of human population growth (1 million people in the past decade). Healthy cougar and the likelihood of cougars dispersing from surrounding wild areas has increased probabilities of incidents between humans and cougars. Human-cougar interactions have increased significantly in Washington in the past decade, with more than 600 complaint reports filed each year with Washington Department of Fish and Wildlife (Washington Department of Fish and Wildlife 2000). .

Management of cougars in Washington has a history checkered with controversy. Once perceived as a predator and bounties paid for their capture, in 1967 cougars were classified as game animals and in 1976 permits were required for their harvest. In 1996 a voter Initiative prohibited the use of hounds for hunting cougars. Following 2 children being mauled and a number of threats on livestock and pets, in 2000 the Washington State Legislature passed a law permitting the use of hounds to hunt cougars in areas where there is a documented recent history of cougar conflicts.

The controversy over cougars and cougar management is fueled by a lack of knowledge of their role in the ecological community, of which humans are increasing usurping a place. Information on cougar populations in rural and suburban areas of Washington is needed if we are to tailor management for maintaining viable populations of cougars, while mitigating human safety concerns.

To address management issues concerning human-cougar interactions it is important to understand the demographic and behavioral characteristics of individuals and populations subject to interactions. For example, if as hypothesized for cougars, social organization regulates cougar numbers (Seidensticker et al. 1973, but see Pierce et al. 2000), then it is important to understand the social characteristics of a populations; the land tenure system and demographic relationships within the population.

In this light, it may be important to understand whether areas near high human densities, residence and activities serve as “population sinks”, to where cougars immigrate, while outlying areas serve as “populations sources”, or areas from where cougars immigrate. If such areas serve as “population sinks” then we may anticipate that juvenile males, in particular, to predominate among these populations, as well as predominate among animals removed or translocated by WDFW personnel from complaint reports. For “population sinks” we would expect mortality to exceed natality and immigration. The demographic instability of “populations sinks” may result in greater frequencies of human-cougar interactions.

We may also anticipate that juvenile males, the gender and age class known to have the highest rate and distance for dispersing individuals (Logan et al. 1996, Spenser et al. In preparation), will dominate harvest data for cougars killed in “special hound hunter cougar management units”. As a result, these areas, too, may function as “population sinks”. This is in contrast to cougar populations occupying areas adjacent to “special hound hunter cougar management units”. Here we would expect populations to be dominated by adult resident animals, kittens, and pre-dispersal subadults. These adjacent areas are anticipated to serve as “populations sources”, where productivity exceeds mortality and subadults emigrate from these areas to establish home ranges in vacated areas within adjacent “population sinks”.

We might also anticipate that for cougar populations in proximity to human residence and activity that they may occupy low quality foraging habitats and/or areas of low ungulate densities. For these areas we may anticipate that diets of cougars will be comprised primarily of small or low biomass mammals and biomass consumption by cougars will be lower than for adjacent areas of low human density where deer and other large ungulates would be the primary prey of cougars. On the converse, residential areas may attract cougars because such areas are attractive to ungulates due to the forage provided by gardens and landscaping and the security provided by non-hunting zones near residential areas.

Comparative data on cougar demographics, prey species, rates of prey consumption, forest cover types and physiographic features used, and proximity to human residences and activities for rural and suburban environments can be used to construct resource use models for cougars. This information may help to define and possibly predict high potential human-cougar interaction zones, that may require special cougar management and community planning considerations.

We will compare and test for differences among population and behavioral characteristics for cougars occupying areas of high human density, residence, and activity and high incidences of human-cougar interactions to populations occupying areas where these human parameters are comparatively low. Each study area will be of adequate size to incorporate areas of both relatively high and low human residence and activity. This will permit us to test study hypotheses both between and within study areas.

Study areas

We will conduct studies within three areas: 1) Central Washington (47°N, 121°W), Kittitas county, 2) Puget Sound (48°N, 122°W), King and Snohomish counties, and possibly in 3) eastern Washington within Spokane, Stevens and Pend Orielle counties (48°N, 117°W). Investigations will begin in Kittitas county in GMU's 335, 336, 328, 329,340, and 334. The Puget Sound study area will include GMU's 448 and 460 and the Eastern study area may include GMU's 117, 121, and 124. These study areas were selected based on prior reports of human-cougar encounters and complaints. The Puget Sound study area is located approximately 60 miles west of the Kittitas study area which is approximately 120 miles west of the Eastern study area.

The central Washington study area in Kittitas county has had a history of few human-cougar interaction reports; 7.6 ± 4.5(SD) reports/year during 1996-2000. Kittitas county is representative of much of eastern Washington rural areas with a low human density < 200 people/km^2 (<1-500 people/mile^2). The Kittitas study area, located on the east slope of the Cascade Mountains, is approximately 3075 km^2 (1200 mile^2) in size and includes the upper Yakima River drainage, with elevations ranging from 480-2400 m (1590-7900 feet). Ponderosa pine *(Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*) forest associations and shrub-steppe habitats are dominant at lower elevations. Upper elevations are comprised of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) forest associations. Potential prey species include mule deer (*Odocoileus hemionus hemionus*) and elk (*Cervus elaphus*).

Puget Sound represents a high human density and high incidences of human-cougar interactions; 138 ± 54.6 reports/year during 1996-2000. This area represents relatively high human densities with > 200 people/km^2 (>500 people/mile^2). This study area is approximately 3800 km^2 (1500 miles^2) in size and includes tributaries of the Snohomish, Snoqualmie, Tolt, and Skykomish Rivers, with elevations ranging from 30-240 m (100-7900 feet). Forest associations include western hemlock (*Tsuga heterophylla*) at lower elevations and mountain hemlock (*Tsuga mertensiana*) and Pacific silver fir (*Abies amabilis*) at higher elevations. Prey species are likely to include

Columbia black tailed deer (*Odocoileus hemionus columbianus)* and a variety of smaller mammals.

The eastern study area, including portions of Stevens, Pend Orielle, and Spokane counties, represents relatively high human density and activity, with 200 people/km^2 (1-500 people/mile^2, and 168 ± 58.6 human-cougar interaction reports/year during 1996-2000. This study area is approximately 2500 km^2 (1000 miles^2) in size and includes a portion of the Spokane River with elevations ranging from 66-175 m (2188 to 5800 feet). Lower elevations consist primarily of Ponderosa pine, Douglas fir forest, and grand fir (*Abies grandis*) associations and shrub-steppe habitats with upper elevations comprised of Engelmann spruce and subalpine fir associations. Potential prey species include mule deer, white tailed deer (*Odocoileus virginianus*), elk, and moose (*Alces alces andersonii*).

Objectives

The objectives of this investigation is to define and compare population and behavioral characteristics of cougars occupying areas of high and relatively low human density, residence, and activity. With information on cougar behavior and ecology in these contrasting environments we can develop strategies for managing human-cougar encounters.

The objectives of this research are to:

1.) describe cougar population characteristics in areas of low and high human activity in the Kittitas Valley and Puget Sound, and determine if there are demographic segments of these populations that are more likely to be associated in interactions with people;

2.) document cougar population demographics, including: population size, survival, mortality, and natality rates in the Kittitas Valley and Puget Sound;

3.) assess spatial and temporal habitat use, movements, and activity patterns of cougars relative to human activities and behavioral patterns;

4.) investigate cougar food habits and prey utilization characteristics;

5.) conduct a survey of infectious disease of cougars throughout Washington,

6.) compare cougar harvest data from statewide harvests and special cougar management units with cougar population demographics within the Kittitas and Puget Sound study areas,

7.) develop predictive models describing potential human-cougar interactions zones in the Kittitas Valley and Puget Sound, and determine the most effective measure for reducing the probability of human-cougar interactions;

8.) develop specific management recommendations designed to reduce human-cougar interactions, while insuring the long-term survival of wild cougar populations in the Kittitas Valley and Puget Sound; and

9.) communicate research findings to state and federal agencies and the public through annual technical reports, research updates, presentations, and the Internet.

10.) and describe human attitudes and perceptions about cougars in urban and rural environments.

Hypotheses:

1. Document cougar demographics.

Within study areas

Ho: Cougar gender ratios do not significantly differ from 1F:1M.

Ho: Adult cougar survival is not significantly reduced by human caused mortality factors.

Ho: Mortality of adult male cougars does not exceed 30%.

Ho: Mortality of adult female cougars does not exceed 15%.

Between study areas

Ho: Cougar mortality rates do not differ between rural and suburban environments.

Ho: Primary cougar mortality factors do not differ between rural and suburban environments.

Ho: Cougar age structure does not significantly differ between rural and suburban environments.

Ho: Cougar gender ratios do not significantly differ between rural and suburban environments.

Ho: Cougar birth rates do not significantly differ between rural and suburban environments.

2. Evaluate home range characteristics of cougars.

Within study areas

Ho: Adult cougar exhibit stable home ranges.

Ho: Male home ranges do not significantly overlap.

Ho: Male home ranges are significantly larger than female home ranges.

Between study areas

Ho: Home range size does not significantly differ between rural and suburban environments.

Ho: Home range stability does not significantly differ between rural and suburban environments.

Ho: Home range overlap does not significantly differ between rural and suburban environments.

3. Evaluate cougar prey characteristics and prey use-availability relationships.

Within study areas

Ho: Cougars select prey items based on biomass and vulnerability.

Ho: Cougars select prey items based on availability.

Ho: Preferred prey items are not displaced by anthropogenic activities.

Between study areas

Ho: Prey composition does not differ between rural and suburban environments.

Ho: Prey availability and selection do not differ between rural and suburban environments.

Ho: Prey capture rates do not significantly differ between rural and suburban environments.

4. Evaluate habitat use and movement patterns of cougars.

Within study areas

Ho: Cougar habitat use probabilities are not significantly influenced by anthropogenic activities.

Ho: Cougar movement patterns are not significantly influenced by anthropogenic activities.

Ho: Cougar activity patterns are not significantly influenced by anthropogenic activities.

Between study areas

Ho: Cougar habitat use does not differ between rural and suburban environments.

Ho: Cougar movement patterns do not differ between rural and suburban environments.

Ho: Cougar activity patterns do not differ between rural and suburban environments.

5. Evaluate the relationships between cougar population structure and human-cougar interactions.

Between study areas

Ho: Ages of cougars involved in human-cougar interactions do not significantly deviate from individuals not associated with human conflict.

Ho: Gender ratios of cougars involved in human-cougar interactions do not significantly deviate from individuals not associated with human conflict.

Ho: Nutritional condition of cougars involved in human-cougar interactions do not significantly deviate from individuals not associated with human conflict.

Methods

Because cougar social organization may, in part, dictate rates of human-cougar interactions and help explain the demographic and behavioral dynamics of populations within residential and remote areas it will be important to capture, mark, and monitor all individuals within a population in order to understand these relationships. To meet these objectives we will attempt to capture 20-30 cougars, of various age and social classes, within each study area during a 5-8 year period. We will capture cougars, record their physical condition, determine their age, mark them with GPS and/or VHF collar transmitters, monitor their movements, estimate survival rates, document natality and causes of mortality, investigate predation and habitat use patterns and compare these aspects of cougar ecology and behavior among high and low human use areas.

We will use trained trail hounds to tree or bay cougars (Murphy 1998, Ruth 2000) during November-April when snow conditions are suitable for tracking and trailing cougars. In addition, we will place large wire-mesh live traps (1.5 x 2.5 x 1 m) near ungulate carcasses or other cougar food cashes. Traps will be baited with the remains of cougar prey. We will anesthetize cougars with ketamine hydrochloride and xylazine hydrochloride. We will estimate weight of captured animals and administer doses of 12 mg/kg of body weight (Logan et al. 1996) by 3.0-cc dart fired from a CO_2 powered dart gun. We will administer 0.5 mg xylazine hydrochloride/kg body weight to calm animals when they have been immobilized and lowered from the tree (Logan et al. 1996). We will determine gender, weight, and take morphological measurements, ear-tag, lip tattoo, extract a premolar, and collect tissue and blood samples. Blood and tissue samples will be used to assess physical condition, test for disease, and analyze DNA profiles. Research activities will be conducted in accordance with Washington Department of Fish and Wildlife and Hornocker Wildlife Institute animal safety handling standards (Quigley 1997). Capture and processing animals will be supervised by veterinarians from WDFW and HWI.

We will mark animals with Global Positioning System (GPS) and VHF transmitter collars manufactured by Telonics (Telonics Inc., Mesa, Ariz. USA) or Televilt (Telemetry Solutions Concord, Calif. USA). Transmitter collars weigh 300 600 gms and will be fitted with cotton spacers designed to break-away (Hellgren et al. 1988). VHF frequencies will range from 149.00 to 152.00 MHz. We will use two models of GPS collars. Smaller 300 gm models, which provide approximately 4400 GPS positions and which require retrieval of collars for collecting GPS locations, will be mounted on female sized cougars. These will be retrieved during recaptures or when collars are discarded. Males weighing >70 kg will be fitted with GPS collars weighing approximately 650 gm and which provide approximately 4500 GPS fixes. These models are programmable to transmit GPS locations to a remote receiver.

Weather permitting, we will monitor cougars from fixed wing aircraft twice weekly. We will monitor telemetry locations from a Cessna 182 or 185 on which a 2-element, 4-dBd gain “H antenna” (model RA-2A, Telonics Inc., Mesa, Ariz. USA) will be mounted on each wing strut at 45^{o} angles. We will use a programable scanner receiver (Telonics Inc., Mesa, Ariz. USA) with scan rates set at approximately 1.2 seconds. We will initially search the area where a cougar was last located and if not relocated we will conduct concentric circular searches from this location. In addition, before ending aerial telemetry sessions we will search for undetected cougars by flying a grid pattern of the study area. Telemetry flights will be conducted during daylight hours. We will plot locations of radio marked cougars on 1:24,000 United States Geological Survey topographic maps and record airplane GPS coordinates. We will determine the accuracy of radio telemetry locations by placing transmitters in the field at positions unknown to aerial telemetry observers and will calculate aerial telemetry error from differences in plotted and known locations.

We will conduct ground telemetry 24 hour monitoring sessions for selected animals and record UTM coordinates by triangulation of telemetry azimuths (White and Garrott 1990), activity patterns from documented movements and transmitter pitch changes, forest cover type association and physiographic features. Animals selected for intensive monitoring will depend on objectives (i.e. proximity to human residence or activity, or for documenting predation sequences). All telemetry and GPS data will be entered into a GIS system for analysis using ARC-INFO software.

Natality, mortality, and survival analysis

We will detect births by charting mean gestation periods of 92 days (Anderson 1983, Logan et al. 1996) subsequent to either male-female associations, female site localization for 2 weeks (indicating den establishment), or snow tracking family groups. Kittens will be captured, weighed, and instrumented with expandable drop-off transmitter collars at den sites at 4-6 weeks old or during winter tracking when 4-6 months old.

We will classify cougars as kittens, dependent subadults accompanied by mother, independent or dispersing subadults, and adult residents. We will compare ages at which subadults disperse from their mother among study areas. Ages for dispersing subadults and for resident animals may vary among study areas depending on population age and social structure and hunter management status for GMU's within each study area.

Transmitters will be equipped with activity sensors which after 6-8 hours of being stationary will change signal rates. We will document mortalities by investigating locations <1 week after transmitter signals indicate the cougar is stationary or when we detected no changes in locations during 2-3 consecutive telemetry flights.

We will classify mortalities as natural, legal hunter harvest, poaching (illegal hunter kills), hunter wounding loss, management control (cougars killed during management control activities), accident, or unknown. Mortalities identified as hunter wounding loss are animals which either a bullet or arrow wound is evident in the carcass or where carcasses are located within close proximity to known hunter positions. Mortalities identified as accidents are those from known collisions with a vehicle. Natural mortalities will be identified as being caused from intraspecific encounters or other non-human causes. Where possible we will transport cougar carcasses from the field for necropsy by a veterinarian.

We will compare survival data between study areas where human residence and activities and land management objectives, road access, vegetative types, precipitation, and geography may differ. We will estimate survival rates for kittens, dependent subadult, dispersing or independent subadults, and adult male and female resident cougars. We will also compare survival estimates between the annual hunting and non-hunting periods.

We will use the Kaplan Meier estimator, and because cougars will not be radio-marked simultaneously, we will treat the radiotracked sample as a staggered-entry design (Pollock et al. 1989). We will treat censored animals that are recaptured as new entries on the day of recapture. We will enter survival status of cougars into the Kaplan Meier model at weekly intervals (McLellan et al. 1999). We will test for differences in survival functions and survival rates among study areas, years, hunting and non-hunting seasons, gender, and age-class via the log-rank test (Pollack et al. 1989, Kasworm and Their 1994) and ANOVA (McLellan et al. 1999). Because numbers of marked cougars may differ between study areas we will weigh the analysis by number of animals at risk in each study area. We will compare censor rates among males and females and between hunting and non-hunting periods using a *t* tests of square root arcsin transformed data.

We will obtain statewide information on gender and ages of cougars harvested by hunters within GMU's from hunter harvest reports and age estimates from counts of cementum annuli (Stoneberg and Jonkel 1966) for pre-molars submitted by hunters and taxidermists. We will construct life tables from hunter harvest statistics and estimate age and gender specific survival rates. These data will be compared to survival data for study marked animals.

Home range size and population density

We will compare home range size and forest cover-type use patterns between genders of cougars, age classes, social status, seasons, and between study areas. We will calculate the 95% fixed kernel home range areas with least squares cross-validation (Warton 1989, Seaman et al. 1998) using the computer program KERNELHR (Seaman et al. 1998). Because weather and flight schedules may not permit us to obtain equal numbers of telemetry locations for all individuals in each of the study areas we will use transmitter GPS locations to provide location data between telemetry flights. We will include all telemetry locations but to minimize autocorrelation (Aebischer et al. 1993, Swihart and Slade 1985), we will use only those locations for females at maternal dens or for all cougars at kills that are greater distance apart than the mean aerial telemetry error.

We will use snow tracking data, populations statistics from captured animals, radio telemetry and GPS data to estimate number and the social status of individuals occupying each study area. We will use Animal Movement Extension in ArcView (ESRI, Redlands, Calif. USA) to estimate configuration and degree of overlap for home ranges of animals with different social status (kittens, dispersing subadults, resident males, resident females, breeding females, nursing females, etc.). In addition we will estimate density of animals from home range overlap and the proportion of time radio marked animals occupy core areas within each study area (Garshelis 1991).

Density estimates of resident adults and resident adults and subadults will be calculated on 1 April each year based on the minimum number present after a correction rating (CR) is applied (Logan et al. 1996) in each social class. This will include:

Resident adults 1 April = $ACyear_i * CR_i/100\ km^2$

Resident adults and subadults = $ACyear_i * CR_i + SACyear_i * CR_i/100\ km^2$

$CR = 1- (BLyear_1/BLyear_i + AD\ year_i)$,

where

$ACyear_i$ = number of adults in year i,

$SACyear_i$ = number of subadults in year i,

$BLyear_1$ = number of cougars back-logged to year 1,

$AD\ year_i$ = minimum number actually detected (radio-marked and tracks) in year i, In addition, we will develop and test techniques using hair snag pads to collect hair for DNA analysis, similar to that used for detecting presence of lynx (*Lynx canadensis*) in the western United States (K. McKelvey USDA Forest Service, Missoula Mont, USA). We will also test techniques for identifying DNA profiles from cougar scats collected in the field. We will compare these findings with DNA profiles of captured animals to derive mark-remark populations estimates.

Habitat use

We will identify GIS cover type attributes (forest cover type, physiographic features, slope, aspect, distance to road and human residence, and proximity to streams) for telemetry and GPS location points for cougars. We will examine cougar use of habitat features and other GIS parameters at two levels of use. We will compare cover-types identified at relocation points for individuals to the proportion of cover-types present within the study area (Design 2, Manly et al. 1993, Thomas and Taylor 1990). Available cover-types within each study areas will be defined by a 95% adaptive kernel composite home range for all marked cougars within each study area. We will also compare cover-types for relocation points for individuals to cover types available in the individual cougars home range (Design 3, Manly et al. 1993, Thomas and Taylor 1990).

Individual cougars will be considered the experimental unit (Aebischer et al. 1993, Alldredge et al. 1998) for use/availability analysis. We will identify use as those cover-types present within the telemetry error polygon circumscribed around each telemetry relocation point. Since the telemetry error may be greater than cover-type patch size, defining use as such may identify cover-type associations and juxtapositions that may be biologically important (Porter and Church 1987). We will use the 95% adaptive kernel estimator to define the home range boundary for cover-type availability analysis. We will use cover-types within the adaptive kernel home range boundaries to define availability only and not to identify use as inaccuracies in home range estimators may not depict accurate resource use patterns (White and Garrott 1990).

We will use compositional analysis (Aebischer et al. 1993) to compare composition of cover-types within the error polygon (use) with that available within the composite home range for all cougars in the respective study area (Design 2) and with that available in each cougars home range (Design 3, Manly et al. 1993, Taylor and Thomas 1990). To calculate compositional analysis we will use the computer program Resource Selection for Windows, Version 1 (F. Leban, University of Idaho, Moscow, Idaho, USA, 1999 unpublished).

In addition we will construct resource selection functions (Manly et al. 1993) to estimate the probability, or value proportional to the probability, that a resource unit or GIS attribute will be selected (Allredge et al. 1998). These data will be obtained from GIS cover type maps and from ground monitoring sequences for telemetry marked animals. We will evaluate all kill sites and at random locations along backtracks of individual cougars. Resource selection functions will be compared among genders, age classes, study areas, seasons, and proximity to human residence and activities. Season will be defined as winter (1 November- 14 April) and snow-free seasons (15 April-31 October). These resource functions will be used to evaluate resource use models to identify cougar demographic characteristics associated with human residences and activity centers and human-cougar interactions.

Forest cover-type classifications will be constructed from federal (United States Forest Service), state agency (Washington Department of Natural Resources), and private forest industry GIS and forest resource inventory maps. We may reclassify existing GIS cover-types into similar categories among study areas to provide categories adequate to increase power for statistical analysis.

We will classify GIS cover type classifications with consideration for security cover provisions for cougars and ungulate prey availability. We will incorporate prey distribution and abundance into home range and habitat use analysis. Maximum probability contours will be determined for cougars by graphing home range area against each probability contour (Arjo and Pletscher 1999, Shivik et al. 1996).

Predation

We will document food habits of cougars by investigating kills located either opportunistically or during predation sequences, and by analyzing cougar feces (Murphy 1998). We will classify kills as possible, probable, or positive based on telemetry, GPS locations of marked animals, and pathological evidence at kill sties (Murphy 1998, Ruth and Hornocker 1997). Causes of death for kills not associated with cougars will be determined by evidence gathered in the field. We will determine age of elk and deer killed by cougars from tooth replacement and wear patterns (Quimpy and Gaab 1957, Robinette et al. 1957). Additionally, we will determine age for elk and deer >2 years of age from analysis of cementum annuli of first permanent incisor (Mattson's Lab, Milltown, Mont. USA). We will evaluate prey condition through analysis of femur marrow fat as an index of prey vulnerability (Neiland 1970). General cougar prey selection will be determined through compositional analysis.

We will utilize a stratified random sampling design to evaluate predation patterns among 5 cougar social classes (adult male, solitary females, maternal females, subadult males, and subadult females) following Murphy (1998). We will randomly select radio marked animals from one of the social classes prior to initiating a predation sequence. During each predation sequence, the focal cougar will be located 1-4 times each day and each location site will be investigated. The sequence will continue until 3-5 large elk or deer kill sites have been located (Murphy 1998). These intensive sampling sequences will permit us to determine cougar predation rates in Washington and compare these with cougar predation rates in California, Idaho, Montana, and Wyoming (Hornocker Wildlife Institute, unpublished data).

The number of days between the first and last ungulate kill during a predation sequence will be used to calculate a daily predation rate (total days/number of kills - 1; Dale et al. 1994). Predation rates will be standardized by converting days per ungulate kill to ungulate biomass per day, with biomass estimates based on ungulate growth models (Murphy 1998). Values will be corrected for losses to scavengers including black bears (*Ursus americanus*), coyotes (*Canus latrans*), and ravens (*Corvus corax*).

Prey seasonal distribution and habitat use

We will use data provided by the Washington Department of Fish and Wildlife on seasonal distribution of deer and elk in each study area. In addition, from ground surveys we will conduct direct counts of ungulates and pellet counts to determine the distribution of deer and elk during winter (1 November -14 April) and snow-free seasons and to determine the relative abundance of ungulates in forest cover types and habitat associations. Survey will also be conducted in areas of varying densities of human residence and activity based on number of people, buildings, and roads/km^2. We will overlay ungulate seasonal distributions with GIS layers to assess influences of habitat fragmentation and corridors on ungulate travel and habitat use patterns.

Modeling human-cougar interactions

Data on cougar demographics, social status, home range size and spatial distribution, GIS cover type parameters and configuration, prey use and prey distribution, land ownership, road density, proximity to human population density, activity centers and residences will be modeled using stepwise logistic regression analysis (Mladenoff et al. 1995). This resultant multivariate model will be used to predict demographic and social status of cougars most likely associated with human interactions. In addition, we may use multi-response permutation procedures to test for spatial differences in the distribution of mountain lions of different social status and age to age and status of neighboring cougars, prey, kill locations, and proximity to human activity (Pierce et al. 2000). These tests and models will be used to predict the distribution of cougar gender and age classes in relation to potential human interactions and help define zones of human-cougar interactions. This information will be used to provide directions for management of cougars and human development.

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