Population Ecology of Black Bears in the Starkey Wildlife Management Unit of Northeastern Oregon, 1993-2000

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Abstract: Black bear *(Ursus americanus)* is an iconic species throughout Oregon because of its relative scarcity, size, and stature. From 1993 to 2000 Oregon Department of Fish and Wildlife lead an interagency effort to gather baseline population and life history information of this species within the Starkey Wildlife Management Unit in the Blue Mountains of Northeastern Oregon to complement concurrent work occurring in the Cascades of southwest Oregon. This 889 km^2 study area was representative of much of the physiographic and climatic conditions east of the Cascade Mountains. Our intent is to highlight information obtained from published and unpublished work of survival, productivity, habitat selection, and home ranges of 65 radiocollared black bears from 1993 – 2000 and to describe its relevance to current bear management in Oregon. The study spanned when Ballot Measure 18 was implemented, so survival estimates for bears pre- and post-Measure 18 are discussed, as well as before spring bear hunts became popular. Because data collection started 2 decades ago, results summarized here provide a reference for managers to compare current and future information describing bear management in Oregon.

Key words: harvest, habitat, home range, management, Oregon, population, reproduction, survival, *Ursus americanus*

Understanding black bear ecology is critical for making sound decisions regarding the management and conservation of this species. This report provides a summary of findings made over an 8 year period when several studies were conducted on black bear in northeastern Oregon. It is our goal to provide a broad overview of these findings and, if additional information is needed, to provide references and access to those data and studies. We want district biologists and managers to be able to readily access specific findings and incorporate them into management actions. All electronic files are housed at the ODFW office at the USDA Forest Service, Pacific Northwest Research Station in La Grande, Oregon (see Appendix 1).

STUDY AREA

The Starkey black bear study occurred within the Grande Ronde River Watershed in the Starkey Wildlife Management Unit (WMU) in Blue Mountains ecoregion (Franklin and Dyrness 1973) of northeastern Oregon. The original capture area in 1993 encompassed 570 km^2 and ranged in elevation from 840 to 2,640 m. Approximately 75% of the area was mixed conifer stands of

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Douglas-fir *(Pseudotsuga menziesii)*, grand fir *(Abies grandis)*, western larch *(Larix occidentalis)*, lodgepole pine *(Pinus contorta)*, ponderosa pine *(P. ponderosa)*, and Englemann spruce *(Picea englmannii)*. Douglas-fir predominated at mid-elevations, ponderosa pine at low elevations, and lodgepole pine and Englemann spruce at high elevations. Approximately 25% of the area was bunchgrass rangeland. Land ownership was 60% U.S. Forest Service and 40% private timber company lands and cattle ranches. Most of the area has been intensively managed for timber harvest, although approximately 10% of the total study area was in a roadless area associated with the municipal watershed for La Grande. Within this area, population estimates based on hound-scenting transects were conducted in a 234 km^2 area.

Management of black bear in the study area was representative of WMUs in the Blue Mountains with a controlled spring season and a general fall bear hunting season running September through November. The first spring bear season started in 1998. Prior to passage of Ballot Measure 18 that banned the use of dogs for hunting bears after 1994, most harvest was accomplished using tracking hounds, or bait stations and tree-stands. After passage of Measure 18, most bear hunting occurred concurrently during other big game seasons. A spring bear hunting season was initiated in 1998 with 50 tags available for the entire Starkey Unit. Tag numbers doubled in 2000. As examples of hunting pressure, in the 1999 fall general season, 20 bears were harvested for a 2% success rate (1,032 hunters), and during the 2000 spring controlled hunt, one bear was harvested for a 1% success rate (100 tags available with 84 hunters). Bear check-in after harvest was not mandatory but was strongly encouraged during the study with notices put into the game regulations and signs posted at road access points.

METHODS

Black Bear Capture

We captured black bears during 1 April - 1 August, 1993-97 (Table 1). During 1993 and 1994, we used trained pursuit dogs (Willey 1980, Akenson et al. 2000), Aldrich foot snares (Flowers 1977), culvert traps, and darting over bait stations to capture black bears. We found use of pursuit dogs the most effective capture method during 1993-94 and became the primary method of capture during 1995-99. Methods other than dog-supported capture accounted for < 5% of total bear captures.

During 1993-94, we searched the entire study area for bears throughout each capture period to minimize seasonal and annual variation in gender and age of captured bears. In contrast, we directed capture efforts to capture unmarked bears in 1995 and to obtain population density estimates in 1996-97 (Akenson et al. 2001). During capture efforts dogs were primarily positioned on vehicles driven along secondary roads or occasionally dogs were walked through potential bear feeding or bedding areas. When dogs detected bear scent, they were released to pursue the bear until the bear treed. If it was safe to immobilize the bear, we erected a net about 10 feet off the ground around the tree. The bear was then immobilized using a Palmer dart gun (Palmer Chemical & Equipment Co., Douglasville, Georgia, USA) with Telazol (Fort Dodge Telazol, Fort Dodge, IA) as the immobilizing agent. If using a net was unsafe to the bear or capture personnel, a blind was constructed and the bear was darted as it left the tree. Radio-tracking equipment was used to find immobilized radiocollared and leashed dogs to find uncollared bears. Radiocollars were fitted on all immobilized bears during 1993-95. During 1996 we did not radiocollar subadult males due to concerns regarding bear neck-growth and dispersal. In 1997 through 1999, several bears were uncollared if not needed to document age at first breeding or for completing diet, habitat use, and denning studies.

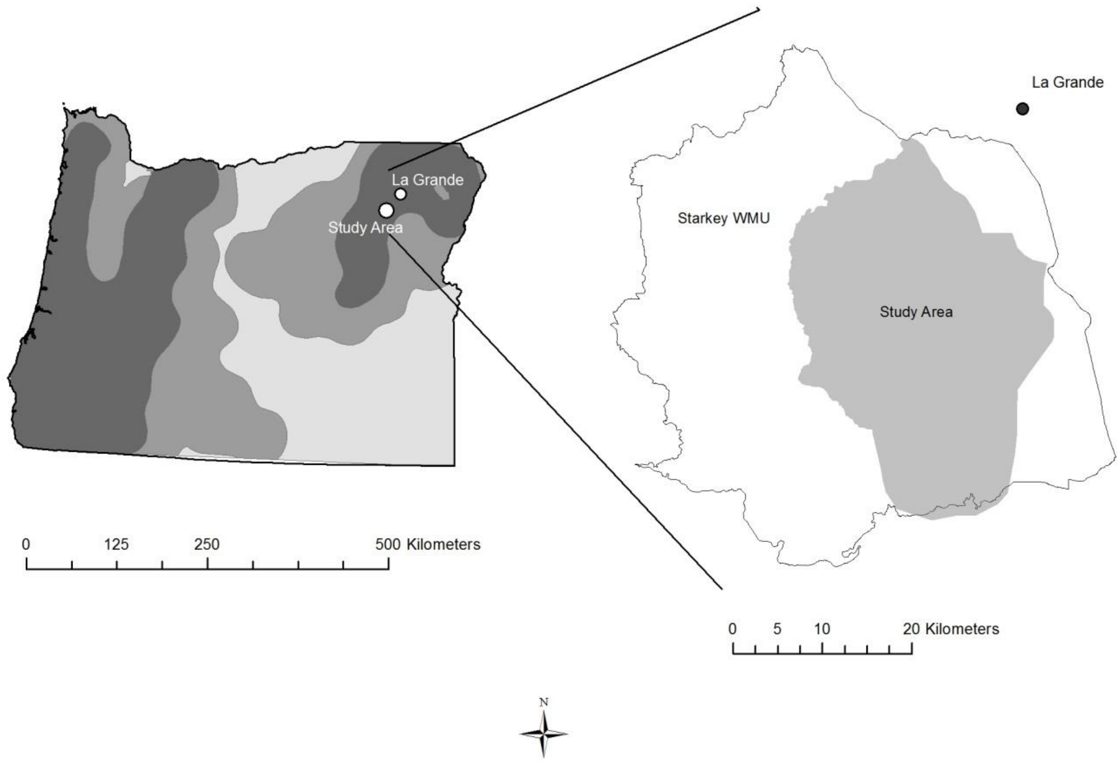

Figure 1. Map of Oregon with shading indicating highest black bear presence (dark gray) to lowest presence (light gray) from the 2012 Oregon Black Bear Management Plan. The pull-out displays the study area (889 km^2) within the Starkey WMU.

Monitoring

Over 2,000 aerial or ground locations were obtained to estimate survival, home range size and relationship to other bears, monitor dispersal of subadults, locate den sites, produce population density estimates, and for habitat use and diet documentation. The majority (70%) of aerial locations were done with the support of Oregon State Police and a Cessna 180 aircraft. Locations were made with global position systems (GPS) mounted in the aircraft when the aircraft was above the estimated location of the animal, based on VHF radio signals from the collar. We followed standard protocols for locating VHF radios during flights. We placed collars in the field to test telemetry accuracy and estimated precision of the location to be within

800 m of the true location and have no consistent directional bias. We determined ground locations by triangulation or direct observation.

Population Estimation

In 1996 and 1997, we conducted surveys to locate bears along 4 transect routes (hound transects) and used mark-recapture methods to estimate a black bear population. Transect routes averaged 21 km in length and bisected representative habitat types with a variety of forest management practices, open road densities, and food resources found within our study area. We conducted surveys from May 8 to July 31 each year to maximize efficiency of scent detection as influenced by weather and to minimize bias caused by dispersing subadult bears (Akenson et al 2001).

We used trained pursuit dogs to locate bear scent during surveys (Akenson et al. 2001). Dogs were leashed on a front hood platform of a pickup truck which was driven slowly (≤ 10 kph) along transect routes. When dogs detected bear scent, they barked excitedly, which was considered a "strike." If recent presence of a bear was verified through bear tracks and/or other sign, dogs were released to chase and tree the bear. Strike locations were documented with an odometer reading, and the route of bear pursuit was drawn on the transect map to document any re-crossing of transects ahead of the strike location. We determined mean chase distances and duration, and treeing success. Distances traveled per strike (km/scent detection) were compared between years using the Wilcoxon rank sum test. Bears treed by dogs during transects were individually identified by radio frequency for radiocollared bears, eartag number for eartag-only bears, or distinguishing features, such as color, markings, and size for unmarked bears.

Home Range

We attempted to locate radiocollared bears at least twice a month from April through October to monitor bear movements and survival. Monitoring began with emergence from the den and ended with den entry. We calculated and mapped in a GIS home ranges using four methods: Minimum Convex Polygon (MCP), 95% contour adaptive kernel (Worton 1989), and 50% and 95% volume isopleth fixed kernel with least squares cross-validation smoothing parameter (Beyer 2012), R Core Team (2012) for bears with > 30 locations. We mapped home ranges using the fixed kernel method with 50% volume isopleth.

Dispersal

Monitoring the movement patterns of subadult bears has been avoided by other studies due to the difficulty of adjusting collars to account for growth of bears. Because we used tracking dogs to capture specific individuals to maintain radiocollars, we were able to document dispersal and age-at-first-litter. We radiocollared subadult females in 1993-1998 and subadult males in 1993-1995. We focused capture efforts on subadult females every year because they did not show a tendency for long-distance dispersal, and we were completing age-at-first-litter documentation whereas monitoring dispersing males was time consuming.

Reproduction

We estimated reproduction during 1993-95 from the number of cubs treed with radiocollared females. In 1996, 12 hibernating females were immobilized so cubs could be marked, sexed, weighed, and measured. Immobilizations in dens were performed with Telazol administered by a syringe-mounted jabstick. We inserted AVID microchips (Norco, CA) under the skin behind an ear of all newborn cubs to associate offspring with radiocollared females during subsequent captures. All subadult bears captured after 1996 were scanned for microchips. We used a goodness of fit test for bias in sex ratio and pelage color of cubs (SPSS Incorporated 1993). We used a Student's t-test to compare average weights between male and female cubs and between cubs from litters of 2 and 3. During 1997, 9 radiocollared females were treed to determine survival of cubs born in 1996. Six subadult female bears were monitored until studies ended in 2000 to document age for having first litter of cubs.

Age

We removed a premolar from all immobilized, adult bears with a tooth elevator. Bear teeth were sectioned and aged using the cementum annuli method (Willey 1974) at Matson's Laboratory at Milltown, Montana. A three way comparison was made between study bears, bears harvested within the Starkey WMU, and bears harvested in the Blue Mountains ecoregion.

Habitat Use and Diet

Habitat use and availability by forest type was estimated using GIS (Bull et al. 2001). Utilization of these areas was determined from 12 radiocollared bears representing 3 sex/age classes: adult male, adult female, and subadult female. Habitat use was documented in the field by locating each bear weekly through ground-tracking with telemetry to either directly observe the bear's activities or identify evidence of use such as beds, tracks, and sign of foraging. At each confirmed bear location, two levels of evaluation took place. A circular 0.05 ha plot evaluated small-scale habitat features, and then a 200 m radius search for foraging in dead wood. Besides identifying and describing the forest type, canopy cover, and forest management status, efforts were focused on identifying what the bear was feeding on, whether animal carcass, ungulate neonates, insects, or plant matter (Bull and Torgersen 2001).

Den Sites

From 1993 to 1999 165 black bear dens were located and described (Bull et al. 2000, 2001). Dens were located using a combination of air and ground telemetry during fall and early winter months. Den characteristics were quantified at the time of discovery or during the following summer after the bear had left the den site. A GPS was used to pinpoint den sites for future reference. Dens associated with hollow trees or logs were classified as top-entry tree, base-entry tree, or inside a hollow log. Other den types were caves, excavations under logs, or ground excavations. Dens were quantified only once although reuse was recorded.

Survival and Mortality

We used the Kaplan-Meier program to estimate survival rates for all radiocollared bears. Survival estimates were modified for staggered entry (Pollack 1989). Both monthly and annual survival estimates were calculated from 1993 to 1998, with the criteria of 10 or more individuals with active radiocollars, confirmed through aerial telemetry. Mortality was also documented through aerial telemetry and hunter harvest reporting.

RESULTS

Monitoring
During 1993-97, we observed 157 different subadult and adult bears. Eighty bear were captured, of which 65 (21 adult males, 12 subadult males, 22 adult females, 10 subadult females) were outfitted with radiocollars and 12 were given only eartags (1 adult male, 11 subadult males). Only marked bears were used for sex ratio and age structure analysis. Unmarked bears were incorporated into population density estimates derived from the hound transects. In addition, 75 cubs-of-the-year were observed during 1993-97, but these animals were not included in density estimates.

Population Estimate
As of August 1995, 52 bears were marked in the 485 km^2 capture area and determined a minimum bear density of 10.8 subadult and adult bears/100 km^2. The NOREMARK density estimates derived from the hound transects were approximately 2 times higher because they account for the unmarked segment of the population not identified in 1995. During summers of 1996 and 1997 we conducted 53 surveys along the 4 transect routes. Dogs detected 72 bear scents as strikes. Strike frequency was used as a density index, and contact frequency of strikes did not differ between years. On 55 occasions bears were treed after being pursued by dogs from transect routes; 33 were marked and 22 were unmarked. During 1996 surveys, 57% of bears contacted were marked compared to 63% marked in 1997. Applying the NOREMARK software, we estimated 59 bears in 1996 and 48 bears for 1997 in the 234 km^2 survey area. We calculated a density of 25.2 bears/100 km^2 in 1996 and 20.5 bears/100 km for 1997 (Akenson et al. 2001) or an average of 0.23 bears per km^2, which is representative of a high presence black bear population in the Blue Mountains of northeastern Oregon (Figure 1). See Akenson et al. (2001) for full summary of results.

Home Range
Both male and female home ranges were larger than the majority reported around the West where most information available has been calculated using MCP method. Using MCP, the Starkey study mean home ranges were 39.3 km^2 for females, 39.1 km^2 for sub-adult females, and 161 km^2 for adult males (Wertz et al. 2000). Using the 50% volume isopleth fixed kernel method, home ranges were 87 km^2 for adult males and 19 km^2 for adult females. All but one of 21 adults (13 females, 8 males) had home ranges that overlapped with other radiocollared bears. Eighty-five percent of the adult females had overlap with other females with a median home range overlap of 18%. Male bears overlapped other males slightly less at 15% of their home range area. The greatest amount of overlap among adult bears was males overlapping with females. Three adult males had 100% overlap with 5 different females, and one male partially overlapped 5 different female bear home ranges (Figure 2). In cases of known parentage 3 subadult females established home ranges within their mother's home range.

Dispersal
Dispersal patterns varied greatly between subadult males and subadult females. None of the 11 subadult females left the study area. Seven subadult females did not disperse moving a mean distance of 1.7 km (0.6 km – 3.6 km) from capture site to center of their home ranges. All three subadult females with radiocollared mothers established home ranges within their mother's home

range. Seven of 18 subadult males left the study area and moved an average of 63 km (range = 33 to 96 km) from their capture site to where they were recaptured and collars removed or killed by a hunter. Four subadult males were killed by hunters before dispersing. Subadult males dispersed between 1 and 3 years of age and none of the 5 radiocollared 4-year-old males dispersed (Wertz et al. 2001).

Table 1. Age class and gender of bears captured and marked with eartags and/or radio-collars within Starkey Wildlife Management Unit, northeast Oregon, 1993-97.

	Males		**Females**			
Year	**Adult**	**Subadult**	**Adult**	**Subadult**	**Total**	**M:F**
1993	6 (4) [a, b]	6 (6)	8 (8)	3 (3)	23 (21)	1.09
1994	6 (5) [b]	6 (6)	11 (11)	5 (5)	28 (27)	0.75
1995	7 (7)	4 (0)	2 (2)	0 (0)	13 (9)	5.50
1996	5 (4)	5 (1)	1 (1)	2 (2) [b]	13 (8)	3.33
1997[c]	1 (0)	2 (0)	0 (0)	0 (0)	3 (0)	n/a
Total	25 (20)	23 (13)	22 (22)	10 (10)	80 (65)	1.50

[a] Number of captured bears with radiocollars indicated in parentheses.
[b] Includes capture-related mortalities: 2 adult males in 1993 (not radiocollared), 1 adult male in 1994 (not radiocollared), and 1 subadult female in 1996 (collared). In addition, a female cub died due to capture related causes in 1995, but is not included in this table.
[c] No new bears were radiocollared during 1997.

Reproduction

Reproductive histories were developed for 35 radiocollared female black bears from 1993-2000 focusing on cub production, cub survival, and age at first birth. We documented 42 litters by 27 females. Female bears exhibited synchronous biennial breeding cycles in which 83% of females produced cubs during even years and only 7% of radiocollared females gave birth in odd years. We have no explanation for this observation. Mean litter size of cubs in dens was 2.2 (n = 36). We did not document any females with birth intervals > 2 years. March weight of cubs did not differ by gender (males: 2.8 kg; females; 2.5 kg; t = -1.75, P = 0.09). Cubs from litters of 2 weighed more ($\bar{x}$ = 3.02 kg) than from litters of 3 ($\bar{x}$ = 2.42 kg; t = 4.56; P < 0.01). Sex ratio of cubs was 0.62 male: 1.0 female (13 males, 21 females) and was not different from parity (x^2 = 0.95, P = 0.47). Cub survival to 18 months (n = 39) was 72%. Of the 12 subadult females monitored during the study, 6 had their first litter at an average age of 4.7 yrs. One female (age 5) had not given birth by the end of the study and 5 others (ages 3, 4, 4, 5, 5) were killed or radio contact was lost by the end of the study. No bears younger than age 4 gave birth and all bears followed to age 6 had given birth.

Ages

Ages of 586 bears (62 radiocollared, 524 hunter-harvested) were determined from the Blue Mountain ecoregion collected from 1993-97. Average age did not differ between bears harvested within Starkey WMU and other WMU's in the Blue Mountains (t = -0.78, P = 0.44), so ages of harvested bears were pooled. Average age did not differ between radiocollared and hunter harvested bears for males (t = 0.13, P = 0.90), females (t = 0.14, P = 0.89) or all bears (t = 0.58, P = 0.56). Average and median ages, of radiocollared bears were 4.7 and 4.0 for males, 6.1 and 4.0 for females, and 5.4 and 4.0 years for all bears (n = 62) (Table 2).

Table 2. Mean and median (Med.) ages of captured and hunter-killed bears, based on tooth cementum annuli analysis, Starkey Wildlife Management Unit and throughout northeast Oregon, 1993-97.

	Males			**Females**			**All Bears**			
	n	**Mean ± SD**	**Med.**	***n***	**Mean ± SD**	**Med.**	***n***	**Mean ± SD**	**Med.**	**Male: female ratio[a]**
Captured [b]	31	4.7 ± 3.9	4.0	31	6.1 ± 4.6	4.0	62	5.4 ± 4.3	4.0	1.0:1.0
Starkey Harvest [c]	12	3.2 ± 2.2	2.5	11	5.7 ± 7.0	2.0	23	4.4 ± 5.2	2.0	1.1:1.0
Blue Mtns Harvest [d]	335	4.7 ± 4.0	3.0	166	6.0 ± 4.7	4.0	501	5.1 ± 4.3	4.0	2.0:1.0
Total	378	4.6 ± 3.9	3.0	208	6.0 ± 4.8	4.0	586	5.2 ± 4.3	4.0	

[a] Includes all captured bears (n = 80) because bears were selectively radiocollared.
[b] No new bears were captured in 1997, so data is from 1993-96. Ages were not obtained for eartag-only bears. Ages were not obtained for 1 adult female and 2 adult male radiocollared bears.
[c] Does not include radiocollared bears harvested within Starkey WMU.
[d] Bears harvested from WMU's in the Blue Mountains eco-region. Totals do not include radiocollared bears or those harvested within Starkey WMU.

Habitat Use and Diet

Use of forest type, habitat structural composition, and management status varied among reproductive classes of bears (Bull et al. 2001). Adult males used the most diversified habitats while adult females consistently used grand fir stands that were old with closed canopy and multiple canopy layers. These habitats were typically unlogged (Figure 3). Bull et al. (2001) also found bedding sites and movement corridors had a high degree of security cover and dense canopy closure. Sites used for foraging on logs were in more harvested stands and higher on the slope. Sites used for foraging on fruit (wild berries) were in more open stands, lower on the slope and closer to roads and water. Bears selected for downed logs large in diameter (>38 cm in diameter) with either partial or advanced decay. The dead wood was comprised of 82% logs, 17% stumps, and 1% snags. Logs with partial or advanced decay comprised 99% of logs with foraging activity. Of logs used for foraging, 50% contained ant galleries, 21% freely moving ants, 4% yellow jackets, 2% wood boring larvae, and 23% undetermined type of insect.

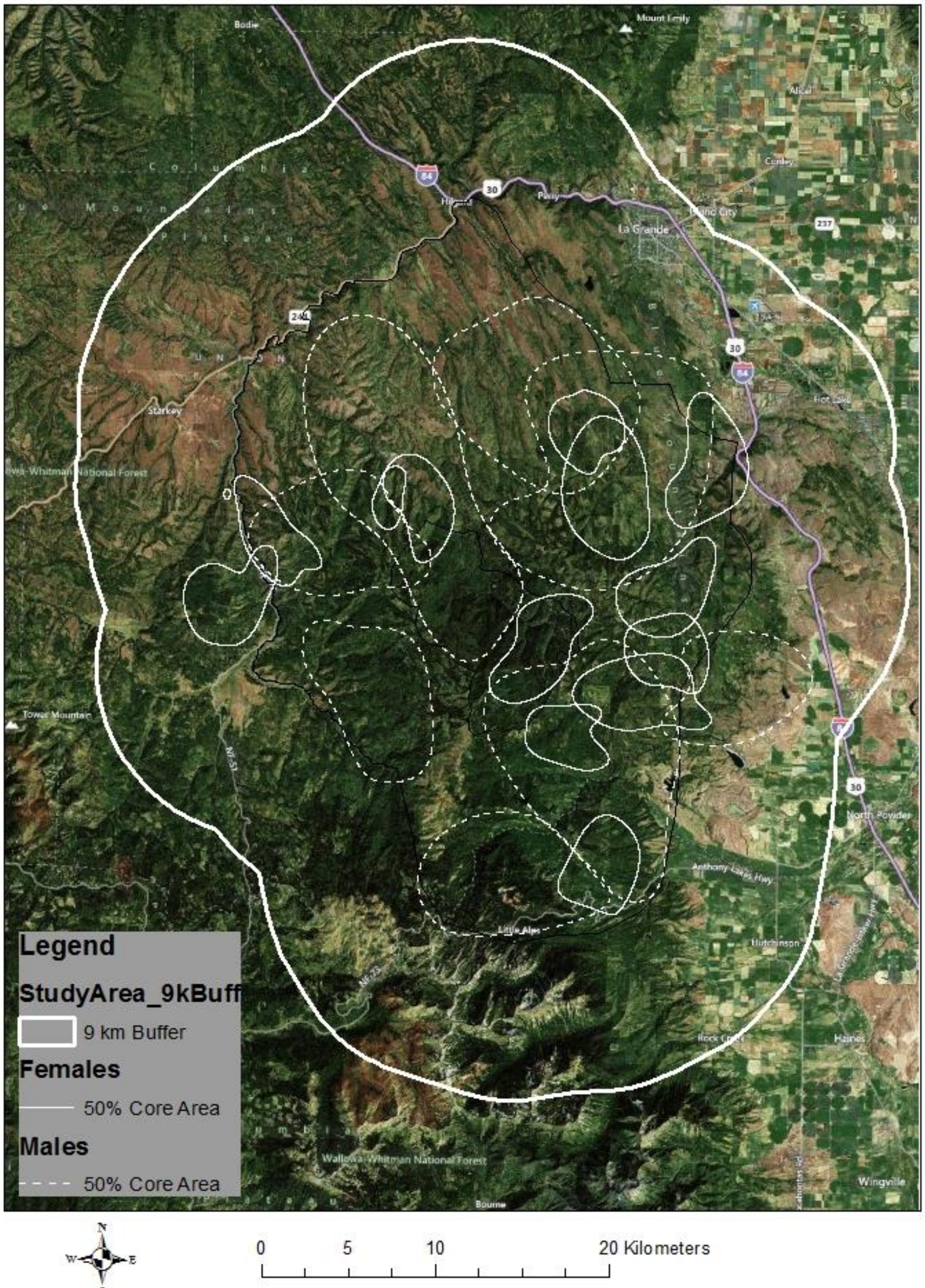

Figure 2. Male and female home range overlap calculated at 50% kernel density estimate. Outside boundary is a 9 km buffer around the study area in Figure 1.

Bull and Torgersen (2001) reported the mean volume of foods from 621 scat samples. They found grasses comprised 35%, insects 24%, soil and wood 11%, animal remains 10%, and leaves and stems 4% of the scats. These proportions varied seasonally, and during early summer mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) remains occurred in 44% of the scats in 1998 and 25% in 1999.

Den Sites

Bull et al. (2000) summarized characteristics of winter dens of bears. Between 1993 and 1999 165 dens for 51 different radiocollared bears were identified for 23 adults, 19 subadults, and 9 bears monitored as both subadults and adults. Forty-one percent of all dens were in hollow trees or logs followed by ground excavations (37%) and caves and rock structures (22%). The distribution by specific den types included: 24.7% excavations under logs, 21.7% in caves, 19.3% in top-entry trees, 12.1% in ground excavations, 10.8% in hollow logs, 10.8% in base-entry trees, and 0.6% on the snow surface in a tree well. Bears in the Starkey WMU reused dens from year to year in structure types involving trees. Twenty-three percent of top-entry trees were used by the same bear for 2 or 3 years. Thirteen percent of hollow logs, 12% of ground excavations, and 9% of caves were used at least 2 years. Four bears used dens under logs for 3 successive years. Eighty-eight percent of dens were in grand fir forest types, 8% in Douglas-fir, 3% in lodgepole pine, and 1% in subalpine fir. Slope gradient averaged 30% and aspect was highly variable with 30% west, 29% north, 21% east, and 21% south. Distance from a den to an open road averaged 3.1 km (SD = 4.8). Eighty-nine percent of dens had 2 or more canopy layers (Bull et al. 2000).

Survival

Average annual survival rates were 0.82 for males, 0.88 for females, and 0.84 for all bears (Table 3). These survival rates were comparable to a study conducted in the Okanogan region of Washington where survival from 1994-98 was 0.77 for males and 0.95 for females (Koehler and Pierce 2005). Survival rates of bears on the west slope of the Cascades were similar for both males (0.85) and females (0.83) (D. Immell, pers. comm. 2012). Hunting was the primary form of mortality in our study accounting for 70% of all bear mortality, 1993-98 (Table 4).

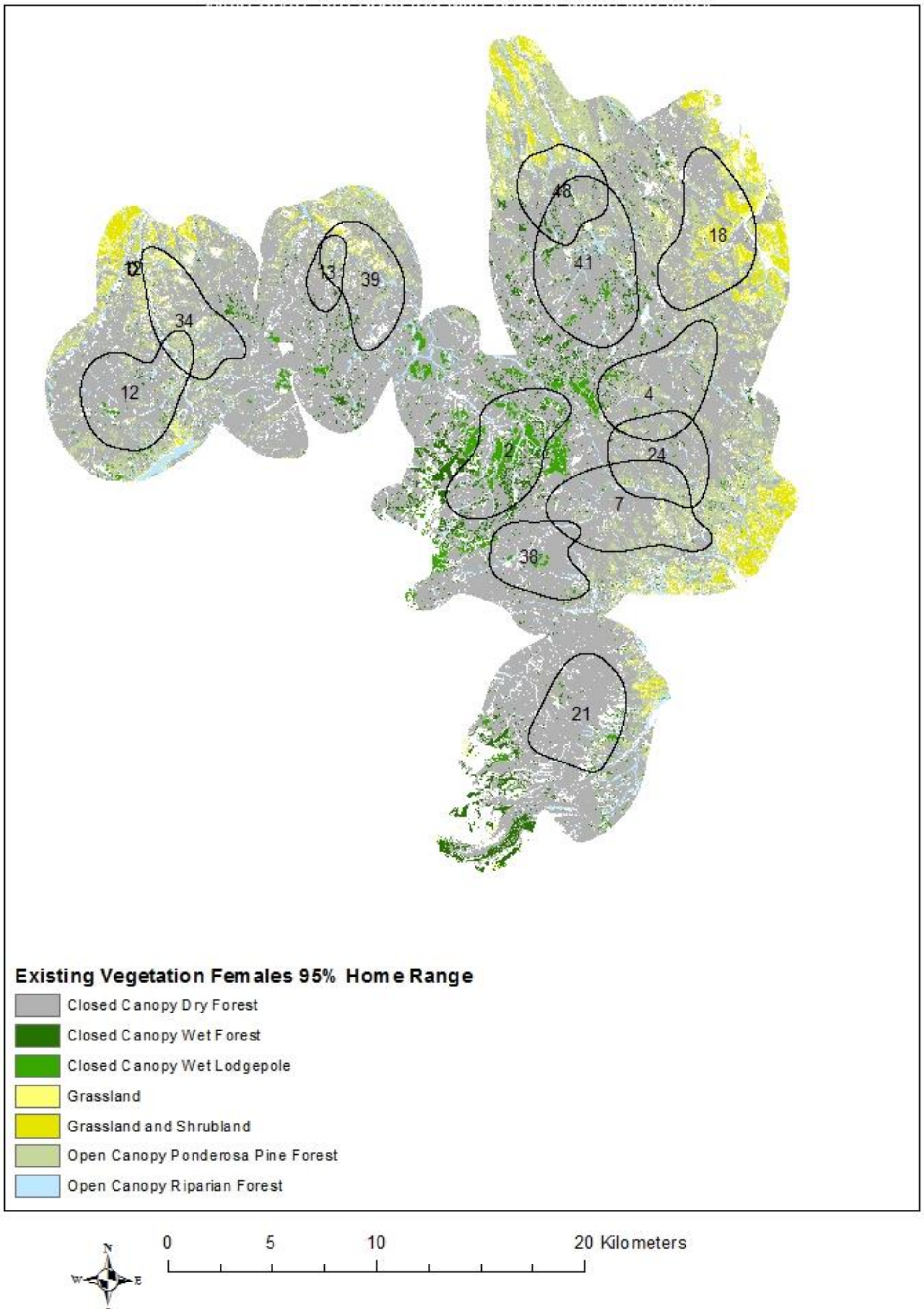

Figure 3. Major habitat types and home ranges of adult female black bears within the Starkey Wildlife Management Unit, northeast Oregon. Black lines represent 50% kernel density estimates of individual bears and total mapped area represents 95% kernel density estimates of adult female bears. Habitat types were derived from LANDFIRE (2001).

Table 3. Survival rates for radiocollared bears (pooled by age/sex class) in the Starkey Wildlife Management Unit, northeast Oregon, 1993-98. We used a minimum of 10 bears per category for estimating survival.

	N	S(x)	SE	Lower 95% CI	Upper 95% CI		Deaths
Males							
Jul 93-Mar 94	10	0.90	0.09	0.71	1.00		1
Apr 94-Mar 95	18	0.67	0.11	0.45	0.88		6
Apr 95-Mar 96	16	0.75	0.11	0.54	0.96		4
Apr 96-Mar 97	13	0.77	0.12	0.54	1.00		3
Apr 97-Mar 98	10	1.00		1.00	1.00		0
Average		**0.82**				**Total**	**14**
Females							
Jul 93-Mar 94	10	0.80	0.13	0.55	1.00		2
Apr 94-Mar 95	24	0.88	0.07	0.74	1.00		3
Apr 95-Mar 96	23	0.91	0.06	0.80	1.00		2
Apr 96-Mar 97	22	0.91	0.06	0.79	1.00		2
Apr 97-Mar 98	19	0.89	0.07	0.76	1.00		2
Average		**0.88**				**Total**	**11**
All Bears							
Jul 93-Mar 94	20	0.85	0.08	0.69	1.00		3
Apr 94-Mar 95	42	0.79	0.06	0.66	0.91		9
Apr 95-Mar 96	39	0.85	0.06	0.73	0.96		6
Apr 96-Mar 97	35	0.86	0.06	0.74	0.97		5
Apr 97-Mar 98	29	0.86	0.06	0.74	0.99		4
Average for All		**0.84**				**Grand Total**	**25**[a]

[a] Does not include 4 bears that died due to capture-related causes and 1 female bear harvested in the 1998.

DISCUSSION

Developing a reliable method to estimate black bear populations is critical for species management; however, methods currently used have some degree of detection bias and vary in cost and efficiency. The initial work by Akenson et al. (2001) addressed one of the primary biases in sampling bears; bears were detected within their normal range rather than attracted to a bait or scent thus minimizing behavioral responses caused by the attractant. This capture work was conducted from June – early July when the widest range of sex and age classes of bears were encountered, because it was during the breeding season and before subadults dispersed (Akenson et al. 2001). However, additional work needs to be done to validate this method as a reliable tool to estimate bear populations. Perhaps the best application of dog scent surveys would be in conjunction with using bio-darts (Russell et al. 2012). Determining an accurate and cost-effective method of population surveys is still evolving and will only be enhanced by mandatory hunter check-in, first implemented on a state-wide basis in 2008.

Table 4. Mortality causes for all radiocollared bears, Starkey Wildlife Management Unit, northeast Oregon, 1993-98.

	Hunting	Illegal	Unknown	Vehicle	Capture	Total
Males						
Adult	4	1	0	0	3	8
Subadult	5	2[a]	2	0	0	9
Female						
Adult	5	2[a]	2	1	0	9
Subadult	2	0	0	0	1	3
Total	15	5	4	1	4	30

[a]Includes 1 adult male, 1 subadult male and 1 adult female which were not checked-in, thus were considered illegal harvests although other hunting regulations may have been observed.

In reviewing home range characteristics from many studies across the U.S., it is apparent sizes vary greatly on a regional basis. Vander Heyden (1997) compiled home range sizes from 26 studies, and in studies west-central Colorado, northeastern Washington, Idaho, and Oregon Cascades, average MCP home range for female bears was 30.4 km^2. Home ranges in this study for females averaged 39 km^2, well within the range of all studies reported.

Diet and habitat research in this study identify certain habitat types and structural components as being most important for reproductively-active female black bears. Female bears with cubs tended to stay in more remote areas with dense cover and large-diameter trees that could serve as security trees which cubs could climb to escape a threat. Beecham and Rohlman (1994) reported females with cubs favored dense tree stands, while those without cubs used more open timber during spring months in Idaho. Vander Heyden and Meslow (1999) reported in the central Cascades of Oregon, 10 of 12 female home ranges occurred in closed canopy mature timber and this structure was the most prevalent forest type for those bears. The high occurrence of top-entry tree dens reported in our study has not been documented elsewhere in the western United States, although in British Columbia all dens were in or beneath large diameter trees, root boles, and logs (n = 67, Davis 1996). Based on diet and habitat use from our study, large diameter and decaying logs, both standing and downed in a dense canopy cover are ecologically important for black bears in northeast Oregon.

The health of a black bear population is ultimately reflected through survival rates, age and sex structure, and reproductive parameters. Hebblewhite et al. (2003) determined growth rates of black bear populations were most influenced by adult female survival and reproductive rates. Survival rates we documented were very similar or slightly higher than those reported in several other western states (Koehler and Pierce 2005). Results from our study revealed human-caused mortality was the biggest source of mortality for bears. We estimated adult male: female ratios to be 0.79:1.00. Sex ratios of adults would be expected to favor males in unhunted populations and favor females in heavily exploited populations (Beecham 1983, Beck 1991). Therefore, with the high survival rates and sex ratios we found in the Starkey study area suggested a moderately hunted population in good health. Subadult males had the highest rate of morality of any sex-age classes we evaluated.

Harvest records can be used to assess population health and evaluate harvest methods. We gained insight from this study on effect of changes in methods of hunting after the 1994 hunting season when Ballot Measure 18 was implemented. There was no discernible change in harvest structure (age, sex, and number) in the years before and 2 years after the change in regulation (Tables 3, 4). Akenson et al. (1997) speculated that age and sex ratios and total harvest would be reduced from less discriminating methods of spot and stalk or opportunistic hunting. The biggest changes in harvest and hunter behavior were with social factors such as hunter effort when measured at the statewide level and with larger sample sizes. In 1994, the last season that dogs and bait were legal, the statewide harvest totaled 1,250 with 13,672 hunters participating (general bear season and harvest summary, ODFW 2011). For the 2010 season, 3 times as many hunters (32,777) harvested a near identical number of bears (1,235). In 1994, the male: female ratio was 3:1 (905:280) compared with a ratio closer to 2:1 (836:380) for the 2010 hunting season. The advent of the sport-pack and reduced price bear tag has encouraged bear hunting around the state.

The reproductive potential of female bears in this study area was higher than other populations in the western United States in terms of litter size, litter frequency and cub survival (Wertz et al. 2001). Based on the importance of insect and animal remains in bear diet, Wertz et al. (2001) speculated 3 large-scale and long-term changes in the habitat of the Blue Mountains may have contributed to more optimal conditions for reproductive success. These 3 variables were increased salvage logging during the 1980's which resulted in more woody ground debris during the 1990's, an increasing elk population which led to more hunter harvest (more elk carcass remains in the fall and spring time neonates), and the return to a normal precipitation regime during the years of the study. As ecological conditions change over time, these data may provide a benchmark for future monitoring of bear populations in northeast Oregon.

MANAGEMENT IMPLICATIONS

From a state perspective, these findings tie directly to objectives 3 and 4 in Oregon's Black Bear Management Plan (Oregon Department of Fish and Wildlife 2012). Objective 3 reads: "To develop, refine, and evaluate population abundance estimation through modeling techniques." Objective 4 states: "to continue to improve basic understanding of black bear management and ecology through applied research." Regionally, this has been the only large-scale black bear study conducted in eastern Oregon. From a district and field-level perspective, these findings give managers baseline information on many aspects of black bear population ecology and identify critical habitat components to manage for protection or retention to help ensure a healthy black bear population in eastern Oregon.

Population Modeling

In order to have effective population modeling, there needs to be effective methods for estimating population size of a specific area or management unit. As Garshelis (1993) has pointed out, biases exist inherent to bear population estimation regardless of method. To help alleviate this, Garshelis suggests using a combination of trend indicators, including harvest data, nuisance activity, and visitation at bait, scent, or camera stations. Akenson et al. (2001) suggest an economical alternative through using bear dogs and strikes per kilometer to an index for referencing population trends. Immell et al. (2008) suggested using tetracycline markers in bait, as an ingestible biomarker, to deploy over large areas at relatively low cost. Immell and Anthony (2008) used increased sample sizes and systematic, bait spacing to reduce bias when collecting DNA samples. Since mandatory check-in was implemented in 2008 (Oregon Bear Plan, 2012), DNA sampling methods gain practicality with the increased samples that may be available. Kohlmann et al. (1999) warned that the collection method (stalking, bait, dogs) was a large factor influencing the age and sex structure of a bear population as determined from tooth samples collected by hunters. Kohlmann et al. (1999) suggested hunter samples need to be validated with other survey techniques. Whatever population sampling method is used, priority should be given in future surveys to WMU's which have solid baseline information on the population, such as in the Starkey WMU, or similar environmental situations and matching hunting season regulations.

Critical Habitat

Trees having both large diameter and appropriate decay type to form large hollow chambers are extremely scarce in the managed forests of the Blue Mountains and habitat evaluation from this study area support the importance of this type of woody structure. Retention of live and dead standing, large diameter grand fir, western larch, and ponderosa pine, with evidence of decay – in grand firs, usually Indian paint fungus (*Echinodontium tinctorium*), will maintain both denning and security opportunities for black bears. Maximizing the occurrence of structure suitable for den sites in hollow trees and logs will require special consideration of grand fir stands in climax stages for several hundred years to come.

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Original Project contributors:

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APPENDIX 1

Topic	Author
Black bear population characteristics, movements and denning habitat in the Starkey Wildlife Management Unit of the Blue Mountains of Oregon	Akenson et al. 2000
Use of dogs and mark-recapture techniques to estimate black bear densities in northeast Oregon	Akenson et al. 2001
Bear habitat use in northeastern Oregon	Bull et al. 2001
The importance of vegetation, insects, and neonate ungulates in black bear diet	Bull et al. 2001
Characteristics of black bear dens in trees and logs in northeastern Oregon	Bull et al. 2001
Reproductive parameters of female black bears in northeastern Oregon	Wertz et al. 2001
Home range and dispersal patterns of subadult black bears in northeastern Oregon	Wertz et al. 2000
Are hunter harvested tooth ages an accurate indicator of the age structure of a black bear population in Oregon	Akenson et al. 1997
Bear trees: And eastern Oregon landscape legacy	Parks et al. 1996

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