



11-4-2014

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Recommended Citation

Immell, Dave; Jackson, DeWaine H.; and Boulay, Margaret C. (2014) "Home-range size and subadult dispersal of black bears in the Cascade Range of western Oregon," *Western North American Naturalist*. Vol. 74 : No. 3 , Article 8.

Available at: <https://scholarsarchive.byu.edu/wnan/vol74/iss3/8>

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HOME-RANGE SIZE AND SUBADULT DISPERSAL OF BLACK BEARS IN THE CASCADE RANGE OF WESTERN OREGON

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ABSTRACT.—Knowledge of home-range size and subadult dispersal activity of American black bears (*Ursus americanus*) is essential for understanding the complexity of how bears interact within populations and the environment. During 1993–1998, we monitored 95 radio-collared black bears in the Cascade Range of western Oregon to estimate home-range sizes and dispersal movements. Composite fixed-kernel home ranges were calculated for 37 bears. Mean home-range size differed between genders (189.7 km² for males and 33.6 km² for females); however, there was no difference in mean home-range size between subadult and adult males or subadult and adult females. We monitored 40 subadult bears (29 M, 11 F) to detect dispersal activity. We did not detect any dispersal of subadult females. One subadult male dispersed as a 2 year old, one dispersed as a 3 year old, and one as a 4 year old. The greatest dispersal distance of any subadult was 34 km by a 2-year-old male.

RESUMEN.—Conocer el tamaño ámbito hogareño y la actividad de dispersión de especímenes jóvenes de oso negro americano (*Ursus americanus*) es esencial para comprender la complejidad de la interacción de los osos dentro de las poblaciones y con el medio ambiente. Durante 1993–1998, monitoreamos 95 osos negros con collares de rastreo en las montañas Cascade Range al oeste de Oregon, para calcular el ámbito hogareño y los movimientos de dispersión. Se calculó el área del ámbito hogareño de 37 osos con el método kernel fijo. El tamaño promedio del ámbito hogareño difería entre sexos (189.7 km² para los machos y 33.6 km² para las hembras); sin embargo, no se encontraron diferencias entre el tamaño del área del ámbito hogareño de los adultos y jóvenes machos, o entre los adultos y jóvenes hembras. Monitoreamos 40 osos jóvenes (29 M, 11 H) para detectar la actividad de dispersión. No detectamos dispersión de las hembras jóvenes. Un macho joven se movió a los 2 años de edad, otro a los 3 años y otro a los 4 años de edad. La mayor distancia de dispersión de cualquier espécimen joven fue la de un macho de 2 años de edad a 34 km.

Home-range size of American black bears (*Ursus americanus*) in North America is believed to be directly related to availability of resources such as food, water, and shelter (Jonkel and Cowan 1971, Lindzey and Meslow 1977, Kolenosky and Strathearn 1987). In addition, number and distribution of females in estrous can also affect size of male home ranges (Powell et al. 1997). Because habitat quality affects reproduction, survival, and ultimately the density of bears (Beecham 1983), managers may be able to use home-range size as a proxy when evaluating habitat quality for black bears.

Information on dispersal of subadult black bears is difficult to obtain and is not well understood in North America (Rogers 1987, Clevenger and Pelton 1990, Schwartz and Franzmann 1992, Costello 2010). Once they disperse, subadults may take several years to establish home ranges. Although dispersal is important for maintenance of genetic diversity

(Clevenger and Pelton 1990) and for establishment and maintenance of bear populations (Alt 1978), the transition from dependency to adulthood can increase bears' exposure to some forms of mortality (Clevenger and Pelton 1990).

In 1993, the Oregon Department of Fish and Wildlife (ODFW) initiated a comprehensive study of black bears. The primary objectives of this study were to estimate bear survival and document reproductive parameters and denning ecology. For this paper, we used telemetry data to estimate home-range size of radio-marked male and female bears, determine the proportion of subadult bears that dispersed, and calculate the distance dispersed bears moved.

METHODS

Study Area

The 1800-km² study area was located in the Willamette National Forest on the west slope

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of the Cascade Mountains, approximately 80 km southeast of Eugene, Oregon, and adjacent to the community of Oakridge. Land ownership within the study area was primarily federal (Middle Fork Ranger District, Willamette National Forest) with some private in-holdings. Most of the study area was managed for timber except 2 wilderness areas: Diamond Peak (211 km²) on the east and Boulder Creek (77 km²) on the south. The middle fork of the Willamette River bisected the study area, with the headwaters at the southeastern edge and Hills Creek Reservoir on the northern end. The landscape was highly fragmented with road densities of 2.01 km · km⁻² (J. Lloyd personal communication).

Elevation within the study area ranged from 460 to 2460 m, the highest point being an inactive volcano (Diamond Peak) on the eastern border. The study area fell within the western hemlock (*Tsuga heterophylla*) zone of the Cascade physiographic province (Franklin and Dyrness 1973). The climax association was the western hemlock–western red cedar (*Thuja plicata*) series; however, the lower elevations were dominated by the seral species Douglas-fir (*Pseudotsuga menziesii*), with common understory vegetation including vine maple (*Acer circinatum*), salal (*Gaultheria shallon*), rhododendron (*Rhododendron macrophyllum*), swordfern (*Polystichum munitum*), vanilla leaf (*Achlys triphylla*), Oregon oxalis (*Oxalis oregana*), and twin flower (*Linnaea borealis*). Higher elevations (≥ 1220 m) were dominated by the Pacific silver fir (*Abies amabilis*) series and herbaceous species including big huckleberry (*Vaccinium membranaceum*), Alaska huckleberry (*Vaccinium alaskaense*), rhododendron, grouse huckleberry (*Vaccinium scoparium*), coolwort foamflower (*Tiarella trifoliata*), false solomonseal (*Smilacina racemosa*), queenscup beadlily (*Clintonia uniflora*), dogwood bunchberry (*Cornus canadensis*), sidebells pryrola (*Pyrola secunda*), and beargrass (*Xerophyllum tenax*).

The mild maritime climate of the study area was characterized by cool, wet winters and hot, dry summers. Historical annual precipitation was 120 cm (1961–1998; Oregon Climatic Service, unpublished data), occurring primarily from November to May. Annual precipitation during the 6 years of the study averaged 132 cm, with a low of 93 cm in 1994 to a high of 185 cm in 1996. Historical average

daily temperatures ranged from 3 °C in January to 18 °C in July (1961–1998, Oregon Climatic Service, unpublished data). Average daily temperatures during the 6 years of the study ranged from 0.5 °C in January to 26 °C in August. The cooler, wetter-than-normal winters and hotter-than-normal summers we observed during the study possibly reflect El Niño events from January 1994 to July 1995 and January 1997 to July 1998 and La Niña events from January 1995 to July 1996 and January 1998 to July 1999 (National Oceanic and Atmospheric Administration, www.noaa.gov).

Black bears in Oregon are managed with a statewide general fall season and a limited-entry spring season in western and northeastern Oregon; there are also statutes and rules regarding bears that cause damage, threaten human safety, or constitute a public nuisance (Oregon Department of Fish and Wildlife 2012).

Capture, Monitoring, and Error Trials

Bears were captured in modified Aldrich foot snares (Flowers 1977, Johnson and Pelton 1980). Captured bears were immobilized with a combination of tiletamine and zolazepam (Telazol, Fort Dodge Labs, Fort Dodge, IA) delivered using a Zoolu[®] Pole Syringe. Morphometric measurements were taken and bears were sexed, weighed, and eartagged. A premolar tooth (P1 or P3) was removed for aging by laboratory analysis of cementum annuli (Willey 1974). Males and females were considered adult at ≥ 4.5 years of age. Captured males ≥ 2 years old were fitted with MOD-500 VHF radio-collars (Telonics Inc., Mesa, Arizona) with 4.7-h mortality switches. Captured females ≥ 2 years were fitted with MOD-400 or MOD-500 radio-collars with 4.9-min mortality switches. MOD 400 transmitters with 4.7-h mortality switches and expandable collars (Telonics CB-3) were placed on all yearlings. All collars were fitted with leather breakaway spacers designed to rot and fall off in approximately 1.5 years if bears could not be recaptured for collar adjustment.

Weekly monitoring of radio-collared bears extended from their capture until all bears had denned, then began again in April as bears emerged from dens. Bears were located aerially or via ground triangulation.

Error trials were completed during 1994 and 1995 to determine telemetry accuracy under a variety of field conditions. Ten test

transmitters were placed in locations that were representative of known bear locations. Transmitter placement addressed 3 primary variables contributing to telemetry error in the study area: position on slope, habitat type, and distance from road. The exact location of the test transmitter was determined using U.S. Geological Survey (USGS) 1:24,000 topographic and orthophoto maps. To determine the standard deviation of bearing error, 3 bearing stations were established for each collar. Four observers took bearings at each station. Linear error was measured as the linear distance between the observed (estimated) and expected (known) UTM locations (White and Garrott 1990). Areal error was estimated by using the mean linear error distance as the radius of an error circle.

Home-Range Calculation and Subadult Dispersal

Composite home ranges were calculated using the 95% fixed-kernel methods (Worton 1989) within the Animal Movement extension (Hooge and Eichenlaub 1997) in ArcView (ESRI Inc., Redlands, CA). We calculated home ranges only for bears that were monitored for ≥ 1 year and had ≥ 30 total locations (Seaman et al. 1999). In addition, only one den location per year was used. Extreme outliers (locations that were far beyond a bear's normal home range and that appeared to be erroneous) were removed from analysis. Most triangulated male locations obtained in 1993 were also removed from analysis because of inconsistent telemetry protocol. Least-squares cross validation (LSCV) was used in calculating smoothing parameters. Because Seaman et al. (1999) and Horne and Garton (2006) found that using LSCV for smoothing in calculation of fixed-kernel home-range area may overestimate home-range size for individuals with < 50 total locations, we compared mean home-range size for male and female bears with < 50 total locations to bears with ≥ 50 total locations using the Mann-Whitney U test. The Mann-Whitney U test was also used to compare mean home-range estimates by gender and age class.

We used methods described in Lee and Vaughan (2003) to determine dispersal activity for subadult bears. Dispersal distance moved was defined as a straight line between the initial location and the final location. Initial loca-

tions were defined as locations where bears were collared in dens as yearlings or first captured during spring snaring operations. Final locations were sites where bears had either lost transmitters or were harvested. Bears were considered dispersed when they moved to an area to establish a new home range that would not overlap their mother's. For males, this distance was calculated by adding the radius of an average female home range (3 km) to the average diameter of a male home range (15 km). For females, we added the radius of an average female home range (3 km) to the average diameter of a female home range (6 km). This meant subadult males needed to move 18 km from first to final location to be considered dispersed, and subadult females needed to move 9 km from first to final location to be considered dispersed. Bears that were not monitored through July of the year following capture were removed from analysis because they did not have time to disperse.

RESULTS

Capture, Monitoring, and Error Trials

We captured 61 male (28 subadult, 33 adult) and 34 female (13 subadult, 21 adult) bears from 1993 through 1998. We obtained a sufficient number of locations (≥ 30) on 21 males (6 subadult, 15 adult) and 16 females (4 subadult, 12 adult) to estimate home ranges. Number of locations per bear home range ranged from 30 to 183. Females had a greater average number of locations than males (86 versus 52) because of a concomitant habitat use study during which female bears were more frequently located (Vander Heyden 1997). Average linear error for home-range locations was 352 m (95% CI 0–854 m, $n = 10$). Areal error for home-range locations was 57 ha (95% CI 0–186 ha, $n = 10$).

Home Range and Subadult Dispersal

We found no difference in mean home-range size between adult males ($\bar{x} = 199$ km², SD 115, $n = 15$) and subadult males ($\bar{x} = 162$, SD 59, $n = 6$; $Z = -0.623$, $P = 0.533$) or adult females ($\bar{x} = 33$, SD 16, $n = 12$) and subadult females ($\bar{x} = 34$, SD 24, $n = 4$; $Z = -0.485$, $P = 0.628$), so age groups were combined for each gender. Mean home-range size was 189 km² (SD 102) for males and 33 km² (SD 17) for females. Male home ranges were approximately 6 times greater than those of

TABLE 1. Comparison of home-range size (km²) of black bears in Oregon and Washington.

State	Study area	Authors	Home range size (km ²)	
			Male	Female
Oregon	Oakridge	This study	189	33
Oregon	Starkey	Wertz et al. 2001	161	39
Washington	Long Island	Lindzey and Meslow 1977	5	2
Washington	Grays Harbor County	Poelker and Hartwell 1973	51	5
Washington	Olympic	Koehler and Pierce 2003	125	28
Washington	Snoqualmie	Koehler and Pierce 2003	90.8	18.0

females ($Z = -5.089$, $P < 0.001$). Considerable variation in home-range size occurred within all age and gender classes. However, adult males showed the greatest variation in home-range size (53–465 km²). We found no difference in mean home-range size between females that had ≥ 50 locations ($\bar{x} = 37$ km², SD 17, $n = 13$) and females with < 50 locations ($\bar{x} = 18$ km², SD 6, $n = 3$; $Z = -1.816$, $P = 0.069$), nor for males that had ≥ 50 locations ($\bar{x} = 217$ km², SD 124, $n = 9$) and males with < 50 locations ($\bar{x} = 169$ km², SD 82, $n = 12$; $Z = -0.782$, $P = 0.434$).

We monitored 11 yearlings (8 M, 3 F), 11 two year olds (10 M, 1 F), and 18 three year olds (11 M, 7 F) for dispersal movements. Two yearlings (1 M, 1 F), 3 two-year-old males, and 7 three year olds (4 M, 3 F) were censored from dispersal analysis because they did not meet our criterion for being followed through July of the year following their capture.

We did not document dispersal movement for any subadult females but documented dispersal for 3 subadult males. No males collared as yearlings dispersed as yearlings, but 1 bear collared as a yearling dispersed in July as a 2 year old, one bear collared as a 2 year old dispersed in July as a 3 year old, and one bear collared as a 3 year old dispersed in June as a 4 year old. In addition, one bear collared as a yearling moved 17.9 km in June as a 2 year old, nearly meeting our criteria for dispersal. Mean movement for subadult males that dispersed was 25 km ($n = 3$, SD 1.69). Mean movement for subadult bears that did not disperse was 9 km for males ($n = 18$, SD 5) and 3 km for females ($n = 7$, SD 1.69).

DISCUSSION

Home Range

The composite home-range size for bears in our study was similar to those of black bears

in northeastern Oregon but larger than reported for black bears in comparable habitats in the Pacific Northwest (Table 1). Proximate causes of variation in home-range size of black bears have been attributed to natural food quality and quantity (Armstrup and Beecham 1976, Garshelis and Pelton 1981), habitat diversity and quality (Lindzey and Meslow 1977), the immediate availability of natural food resources (Noel 1993), and availability of anthropogenic food sources (Novick and Stewart 1982). Heavy hunting pressure can also affect home-range size of bears by altering their distribution and social structure (Wielgus and Bunnell 1995) and reducing density (Oli et al. 2002). Our larger home ranges could also have been influenced by the long duration of monitoring. It is common for bear home ranges to shift annually (Reynolds and Beecham 1980). Thus, the longer an individual bear is followed, the larger its composite home range is likely to be. Moreover, some studies report composite home ranges and some report annual home ranges, but the difference is not always distinguished in publications.

Comparisons of home ranges between studies and states can be misleading because of differences based on varying techniques used to calculate home-range size (Lawson and Rodgers 1997). Although Seaman et al. (1999) and Horne and Garton (2006) reported a positive bias in calculated home-range sizes when using LSCV as a smoothing parameter with sample sizes < 50 , we found no difference. In fact, our home-range sizes calculated with < 50 samples trended smaller than those calculated with ≥ 50 locations.

Similar to our results, difference in male and female home-range size has been reported in other black bear studies (Poelker and Hartwell 1973, Armstrup and Beecham 1976, Lindzey and Meslow 1977, Reynolds and Beecham 1980, Garshelis and Pelton 1981).

This variation has been attributed to breeding activity of males and distribution of receptive females (Armstrup and Beecham 1976, Powell et al. 1997).

Subadult Dispersal

Subadult females tend to establish home ranges within that of the mother (Lindzey and Meslow 1977, Schwartz and Franzmann 1992), although Rogers (1987) in Minnesota and Schwartz and Franzmann (1992) in Alaska reported that a small percentage of subadult females dispersed in their studies. As with our study area, White et al. (2000) observed no subadult female dispersal in a study in Louisiana, nor did Lee and Vaughan (2003) in a Virginia study, Wertz et al. (2001) in a north-eastern Oregon study, and Costello et al. (2008) in a New Mexico study. Klenzendorf (2002) speculated that the lack of subadult female dispersal may be related to high survival rates of adult females, which may limit availability of open spaces for females to disperse to. Conversely, low survival rates of adult females could create more open spaces nearby, therefore decreasing the need to disperse long distances. In addition, subadult females can gain competitive advantages in knowledge of available resources and cover by staying within their natal range (Rogers 1987).

Percentage of subadult males that dispersed was lower in our study area than reported for subadult bears in Pennsylvania (Alt 1978), Minnesota (Rogers 1987), Massachusetts (Elowe and Dodge 1989), Alaska (Schwartz and Franzmann 1992), Florida (Wooding and Hardisky 1994), northeastern Oregon (Wertz et al. 2001), and Virginia (Lee and Vaughan 2003). In addition, the mean dispersal distance (25 km) of male subadult bears in our study was shorter than that observed in Minnesota (61 km, Rogers 1987) and northeastern Oregon (63 km, Wertz et al. 2001) but similar to that in Florida (31 km, Wooding and Hardisky 1994). Costello et al. (2008) documented lower dispersal rates among males in low-density populations. Conversely, Roy et al. (2012) suggested that lower dispersal rates were a result of high densities. We estimated density within our habitat type to be ~ 19 bears per 100 km² (Immell and Anthony 2008), which was on the lower end of density estimates reported in North America and likely well below carrying capacity. Our low densities coupled with low dispersal rates

supports the assumptions of Costello et al. (2008).

Low dispersal rates can affect genetic diversity within bear populations (Lee and Vaughan 2003). A DNA analysis of 79 tissue samples of bears captured within our study area yielded an expected heterozygosity (H_e) value of 0.59 (Clarke et al. 2001). Although our H_e value was not as low as has been reported for more isolated bear populations (Boersen et al. 2003, Csiki et al. 2003), it may indicate that genetic flow has been or is currently being disrupted in this population. It is not clear if this disruption in gene flow is a result of low dispersal rates or some other constraining factor.

ACKNOWLEDGMENTS

This study was financed by Federal Aid in Wildlife Restoration Project W-90-R and the Oregon Department of Fish and Wildlife, with assistance from the Portland Chapter of The Safari Club International. We thank 2 anonymous reviewers for comments that greatly improved this manuscript. We also thank the numerous biologists involved with fieldwork, including M. Willis, M. Vander Heyden, K. Laudon, W. Schultz, K. Higgins, G. Mantey, J. Sagar, D. McAlister, J. Hirsch, J. Reams, and pilots J. Hunsacker, R. Granning, C. Culp, C. Haggland, and W. Moreland.

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Received 18 September 2013

Accepted 25 July 2014