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Growth and reproduction by young urban and rural black bears

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Human-dominated landscapes contain fragmented natural land cover interspersed throughout an urban matrix. Animals that occupy human-dominated landscapes often grow and reproduce differently than conspecifics. Female American black bears (*Ursus americanus*) produce litters for the first time usually at age 4 years; 2-year-olds rarely give birth. We visited winter bear dens and trapped bears in spring and summer to compare the reproductive output and weight of female black bears within the city limits of Asheville, North Carolina, and three forested rural sites in North Carolina and Virginia representative of the undeveloped habitat of Asheville. Urban yearling females weighed nearly double (45.0 kg ± 8.1 [± *SD*]; $n = 36$) that of yearling females from the three rural study sites (23.2 ± 8.5 [Pisgah], 23.6 ± 8.3 [Virginia SW], and 23.9 ± 9.7 [Virginia NW]; $n = 95$). Across all sites, hard mast production during the autumn, when females were cubs, did not affect their weights as yearlings. Seven of 12 (58%) 2-year-old urban bears produced 11 cubs (mean litter size = 1.6 ± 0.8), but no 2-year-old rural females produced cubs. Production of hard mast in the autumn, when females were yearlings, did not influence cub production by 2-year-old female bears at the urban site. We hypothesize that reproduction by 2-year-old bears is linked to the availability of anthropogenic food sources associated with urban environments. To inform population level management decisions, managers and researchers should quantify urban food sources and the effects on black bear life history. If high fecundity allows urban populations to sustain relatively high mortality rates, then urban bear populations may be source populations for surrounding, rural areas. Alternately, if reproduction in urban populations cannot match high time-specific or age-specific urban mortality rates, then urban populations may be sinks for the surrounding areas.

Key words: black bears, litter size, mast production, primiparity, reproductive ecology, urban wildlife, *Ursus americanus*

Wildlife that exhibit the behavioral flexibility to take advantage of resources in urban areas can have high reproductive output and survival (Prange et al. 2003; Gosselink et al. 2007; Beckmann and Lackey 2008; Cypher 2010; Ghalambor et al. 2010; Gould and Andelt 2011; Sih et al. 2011; Lowry et al. 2013; Sih 2013; Fehlmann et al. 2017). Although adaptations to live in urban settings are not well understood, wildlife that use urban areas generally share common characteristics such as flexible diets (McKinney 2002; Ryan and Partan 2014), small- to medium-sized bodies (Baker and Harris 2007), and flexible activity patterns (Lowry et al. 2013; Lendrum et al. 2017). For instance, red foxes (*Vulpes fulva*), coyotes (*Canis latrans*), raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), and striped skunks (*Mephitis mephitis*) commonly occur in urban areas; some since the beginning of the 20th century (Bateman and Fleming 2012) have flexible diets and circadian patterns (Beckmann and Berger 2003; Riley et al. 2003), and mostly weigh < 10 kg (Baker and Harris 2007). Being omnivorous in urban areas includes eating garden foods, urban rodents and birds, and pets, as well as refuse (Bateman and Fleming 2012).

American black bears (*Ursus americanus*) are behaviorally flexible omnivores highly adapted to find and secure high-calorie foods and, thus, benefit from a variety of urban resources (Beckmann and Berger 2003; Beckmann and Lackey 2008). Although generally diurnal, black bears exhibit flexible circadian patterns in urban (Baruch-Mordo et al. 2014; Johnson et al. 2015; Zeller et al. 2019) and forested areas (Powell et al. 1997). Being able to exploit a wide variety of urban foods, including garden plants, fruit trees, bird seed, and refuse, provide black bears the calories to gain weight earlier in life than rural bears. As such, consistent and abundant resources in urban environments may influence reproduction by black bears. In contrast to other urban wildlife, however, black bears are large, which reduces their abilities to avoid humans in urban areas.

In most areas across their range, female black bears breed for the first time when they are 3 years old or older (Alt 1989; Powell et al. 1997; Garshelis et al. 2016). At any age, breeding, implantation and gestation, parturition, and lactation often are correlated with the body condition of females (Elowe and Dodge 1989; Noyce and Garshelis 1994; Powell et al. 1997; Belant et al. 2006). In addition, summer and autumn food production affects individual condition and whether a female produces and raises cubs the following winter (Rogers 1976, 1987; Eagle and Pelton 1983; Eiler et al. 1989; Elowe and Dodge 1989; Costello et al. 2003; Laufenberg et al. 2018). Elowe and Dodge (1989) found that in western Massachusetts, 93% of females produced cubs when they had access to hard mast, whereas female bears with access only to lower quality diets did not produce cubs. Similarly, Costello et al. (2003) found that bear litter size in New Mexico increased with acorn production during the previous autumn.

Black bear primiparity, or age of first litter, occurs almost universally at 4 years of age or older in rural settings (Alt 1989; Eiler et al. 1989; Elowe and Dodge 1989; Costello et al. 2003; Obbard and Howe 2008; Bridges et al. 2011a). In a 10-year study around Lake Tahoe, California, Beckmann and Lackey (2008) documented that female bears with access to garbage in a developed area weighed more and first gave birth at 4 years old compared to 7 years old for their wildland counterparts. In a 33-year-study, however, the North Carolina Wildlife Resources Commission counted corpora lutea and placental scars in reproductive tracts of vehicle-killed and hunter-harvested black bears, documenting that 1.5-year-old black bears were capable of breeding, but rarely had the nutritional reserves to become pregnant: only two individual bears in the 1.5-year-old age group had placental scars (North Carolina Wildlife Resources Commission, unpubl. data). In addition, earlier work in North Carolina documented five instances (out of 58) of primiparity at age 3 in a forested, nonurban site with high food productivity (R. Powell, pers. comm.), and Garrison et al. (2007) documented that 3 of 12 2-year-old female black bears in Florida produced cubs.

The literature for captive and zoo mammals shows a trend toward early reproduction, suggesting diet is a factor contributing to successful breeding. Captive female black bears and orcas (*Orcinus orca*) mature and reproduce at younger ages than do their wild counterparts (Rogers 1976; Robeck et al. 2015). Good nutrition was associated with breeding at 10 months of age by captive wolves, half the typical age for wild wolves (Medjo and Mech 1976). Captive deer have faster growth rates, higher fecundity, and breed at younger ages when fed highly nutritious diets (Verme 1969; Robinette et al. 1973; Ozoga and Verme 1982; Ozoga 1987). The effects of consistently available high-calorie foods in captive settings may mirror those in urban environments.

Early primiparity can lead to faster population growth, assuming that cubs recruit into the adult population. High densities of bears in urban areas often lead to frequent human–bear interactions (Garshelis et al. 2020). In this study, we compared cub production by 2-year-old female black bears living in an urban environment to that of female bears living in rural environments. We hypothesized 1) that black bear cubs that gain sufficient weight in their first year and grow large (defined as > 40 kg) can breed as yearlings and produce cubs at age 2 and 2) that abundant natural food facilitates rapid growth of young bears in urban habitats.

Materials and Methods

Study areas.—Our urban study area was in and around the city of Asheville, North Carolina, United States, a 117-km^2 city with a population density of 760 people/km^2 (Kirk et al. 2012; Fig. 1). We defined "urban" to be land covers that have high densities of commercial buildings and human housing (Gehrt 2010). In addition, we studied bears in three rural, forested areas that lacked commercial buildings and human housing (Fig. 1). One rural site was located in the Pisgah National Forest, adjacent to the southwest boundary of our urban study site (Powell et al. 1997; Mitchell et al. 2002). The other two study areas were on the George Washington and Jefferson National Forest in western Virginia: one 260 km northeast of Asheville, the other 430 km north of Asheville (Bridges 2005; Bridges et al. 2011a, 2011b). All four study areas were in the southern Appalachian Mountains, with a climate characterized by mild winters, cool summers, and annual precipitation of 130 – 250 cm/year, which was mostly rain. Forests were predominantly mixed hardwoods with scattered pine (*Pinus* spp.—Kirk et al. 2012) and pine-hardwood mixes (Mitchell et al. 2002).

Bear captures.—From April 2014 through September 2018, we captured black bears using culvert-style live traps on private properties across the urban study area. We baited traps with day-old pastries and checked them twice a day. We immobilized bears with a combination of telazol (50 mg/cc), ketamine hydrochloride (40 mg/cc), and xylazine hydrochloride (10 mg/cc), at a dose of 1 cc per 45 kg. For bears ≥ 12 months old, we recorded date and capture location, weight, sex, morphological measurements, body condition, reproductive condition; we also inserted a uniquely numbered ear tag in each ear, applied a tattoo to the inside of the upper lip, and removed an upper first premolar to estimate age at Matson's Laboratory in Manhattan, Montana (Willey 1974). We fitted each bear with a GPS transmitter-collar that did not exceed 3% of the bear's weight (Vectronic, Berlin, Germany—Samuel and Fuller 1996; Cattet 2011). We administered a long-lasting analgesic and an antibiotic. We reversed the effects of xylazine hydrochloride with yohimbine hydrochloride (0.15 mg/kg) within approximately 60 min of immobilization. Due to their large sizes (> 45 kg), we outfitted a sample of yearling bears (1 to < 2 years old) with GPS collars to investigate the social dynamics of bears as well as their dispersal, survival rates, and causes of mortality. Handling of bears was approved by the Institutional

Fig. 1.—Locations of captures for yearling urban and rural black bears (*Ursus americanus*) at four study sites in North Carolina and Virginia, United States.

Animal Care and Use Committee at North Carolina State University (14-019-O) and was consistent with the guidelines of the American Society of Mammalogists (Sikes et al. 2016).

In 1981–2002, from May through August, we captured black bears on the Pisgah study site in North Carolina, outside of Asheville, using homemade barrel traps and spring-activated leg-hold snares modified for bear safety (Powell et al. 1997; Powell 2005; Cattet et al. 2008). Each day, we baited traps with sardines, day-old pastries, or left them unbaited. We immobilized bears with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride or with telazol using a pole syringe or blowgun. We recorded the same data and applied the same unique identifiers as bears from other study sites. We fitted bears that would not outgrow collars with a VHF transmitter-collar that did not exceed 2% of a bear's weight (Telonics, Mesa, Arizona; SirTrack, Havelock North, New Zealand; Lotek, New Market, Ontario, Canada). We reversed the effects of xylazine hydrochloride with yohimbine hydrochloride within approximately 45 min of immobilization.

From January through August in 1994–2002, we captured black bears on the Virginia study sites using culvert traps and spring-activated Aldrich leg-hold snares. We immobilized bears with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride (concentration of 300 mg/ml) at a dosage of 1 cc/45 kg, using dart pistol, pole syringe, or blowgun. We recorded the same data and applied the same unique identifiers as bears from other study sites. We collared cubs (Advanced Telemetry Systems, Inc., Isanti, Minnesota) and either affixed VHF radiocollars (Telonics, Mesa, Arizona) or eartag transmitters to young study bears (Advanced Telemetry Systems, Inc., Isanti, Minnesota). We reversed the effects of xylazine hydrochloride with yohimbine hydrochloride (0.15 mg/kg) within approximately 60 min of immobilization.

At all sites, we located female bears with active transmitters in their den sites from October through February. We entered dens from mid-January through mid-March to undertake physical examinations of the females and change collars if necessary. We documented reproduction by the presence of cubs and, during spring and summer trapping, documented reproduction by the presence of cubs in culvert traps or in trees above trap sites when females were captured.

Mast surveys.—For the two study sites in North Carolina, the Wildlife Resources Commission surveyed hard mast annually from August through September and based indices on visual estimates of the percentage of oak crowns with acorns (Greenberg and Warburton 2007). Post data collection, we converted these indices into hard mast categories: failure (0–19.4% with acorns), poor (19.5–39.4%), average (39.5–59.4%), good (59.5–79.4%), and bumper (79.5–100%; Virginia Department of Game and Inland Fisheries). For the two study sites in Virginia, the Virginia Department of Game and Inland Fisheries used the average number of acorns per 10 limbs on each tree as an index of annual hard mast production from August to September (Fearer et al. 2002; Bridges 2005). Due to small sample sizes in some mast categories and to increase statistical power, we combined the "failure" and "poor" categories into one "poor" category and the "good" and "average" categories into one "average" category for all study areas. The North Carolina study sites had no "bumper" crop years. We did not combine "good" and "average" categories at the Virginia sites because they had sufficient sample sizes.

Weight comparisons: urban versus rural bears.—We used the *lsmeans* package (Lenth 2016) in R (v. 3.3.1; R Development Core Team 2016) and an additive factorial analysis of variance (ANOVA) to test for differences in yearling weights at capture by study area and by hard mast index for the autumn before each bear was captured and weighed; the timing of captures and collection of data across study sites was similar (Figs. 2 and 3). We included an interaction term between study area and the hard mast index to determine if the effect of hard mast varied by study area. We examined the QQ plots and the Shapiro–Wilk test for normality prior to analysis and found evidence of non-normality. Prior to our analyses investigating the distribution of yearling weights, we log-transformed the data to meet the assumptions of normality associated with an ANOVA. We used logistic regression in program R to ascertain the effect of the previous falls' hard mast index and weight at capture on whether or not a 2-year-old bear reproduced. Our model set included one a priori model with both main effects and an interaction term.

We tested whether average weights of nonreproducing yearling females differed among the four study sites using the statistical methods described above with the lsmeans package in program R; we reduced the sample size for the urban site to the four GPS-collared yearling females for this comparison because these bears did not reproduce. Finally, we tested for equal variance and used a Student's *t*-test to determine if reproducing yearling females in Asheville were heavier than the urban yearling females that did not reproduce. We added one post hoc model (Logwt ~ study * month) to examine the interaction between "study area" and the "month of year" that yearling bears were captured and subsequently weighed to ensure that differences in weights were not due to urban bears being captured, on average, slightly later in the year (e.g., July/August).

Results

We obtained data on 131 yearling female black bears, one of which was not weighed until she was 2 years old (Figs. 2 and 3). Mean weights of yearling female black bears differed significantly among the four study sites, with urban bears (n = 36) being heaviest (45.0 kg ± 8.1 [± *SD*]; $F_{3,121}$ = 46.52, P < 0.0001) but with no differences among the three rural study sites (23.2 ± 8.5 [Pisgah, n = 20], 23.6 ± 8.3 [Virginia SW, n = 30], and 23.9 ± 9.7 [Virginia NW, n = 45]; Fig. 4), failing to reject our

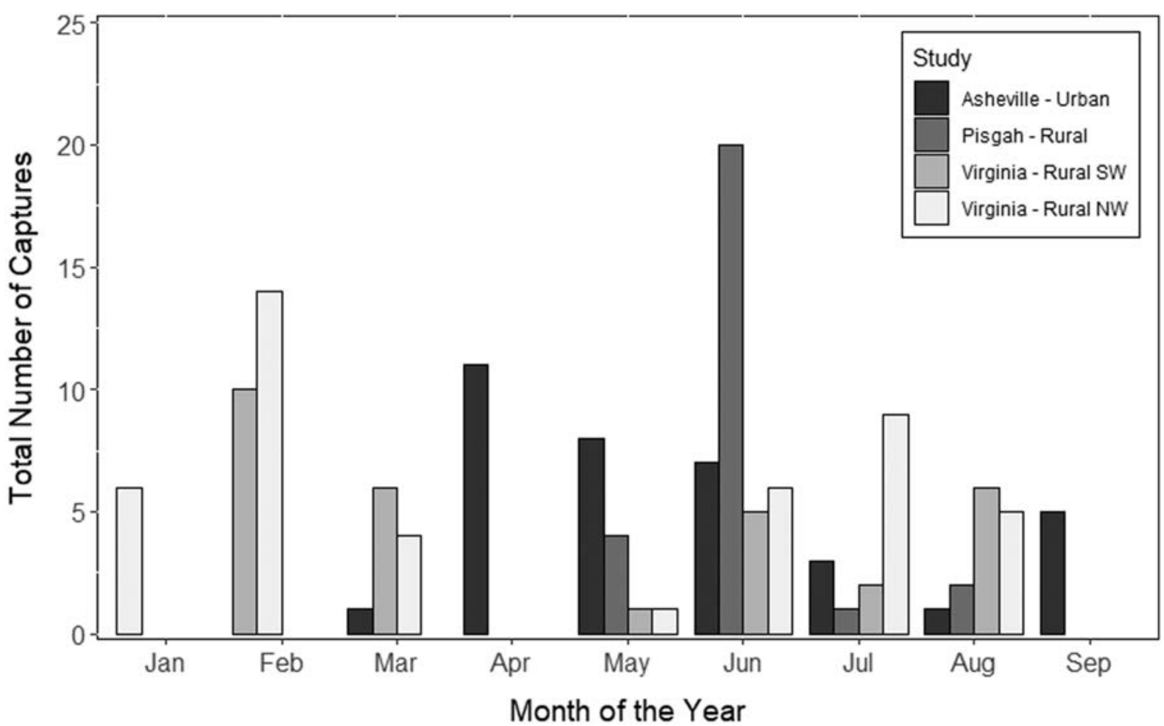

Fig. 2.—Timing of captures by month of yearling female black bears (*Ursus americanus*) in one urban (Asheville) and one rural (Pisgah Bear Sanctuary) study site in North Carolina, and two rural study sites in Virginia, United States.

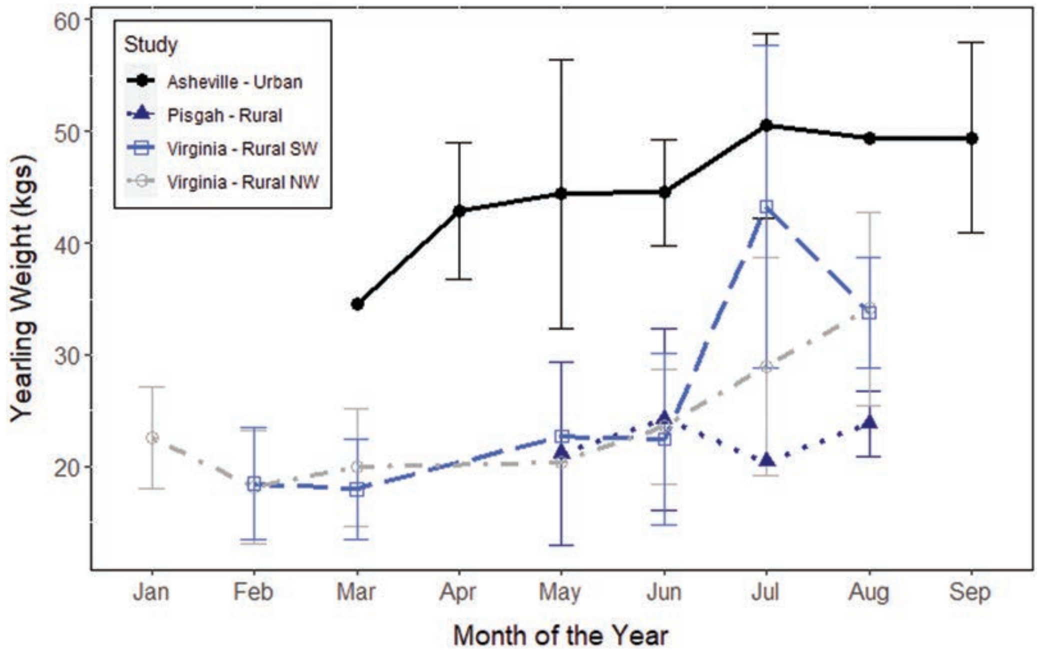

Fig. 3.—Average yearling female black bear (*Ursus americanus*) weights by month in one urban (Asheville) and one rural (Pisgah Bear Sanctuary) study site in North Carolina, and two rural study sites in Virginia, United States.

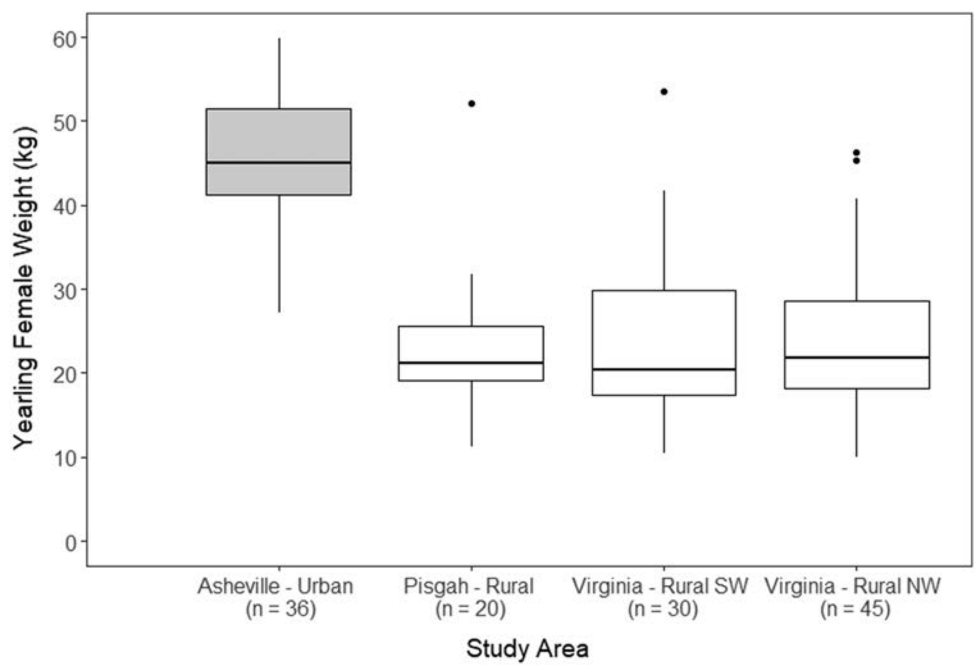

Fig. 4.—Average weights (kg) of yearling female black bears (*Ursus americanus*) in one urban (Asheville) and one rural (Pisgah Bear Sanctuary) study site in North Carolina, and two rural study sites in Virginia, United States. The horizontal line within the box indicates the median, boundaries of the box indicate the 25th and 75th percentiles, and the whiskers indicate the highest and lowest values. Black dots indicate outliers.

hypothesis that urban bears were larger than rural bears, likely because of the consistent availability of human-derived food sources.

Yearling female bears weighed more when the hard mast index was high during the previous fall (when they were cubs; $F_{2,121} = 7.64$, $P = 0.0008$; Fig. 5) but was biased by the rural site in northern Virginia, where yearlings weighed more in years with average hard mast production compared to years with poor production. Nevertheless, the interaction term between study area and hard mast index was not significant ($F_{4,121} = 1.18$, $P = 0.3223$), indicating the effect of hard mast index on weights of yearling female bears did not vary by study area. Reproduction by 2-year-old urban females was not influenced by the previous fall's hard mast index ($\beta_{\text{Hard Mast}} = -15.064$,

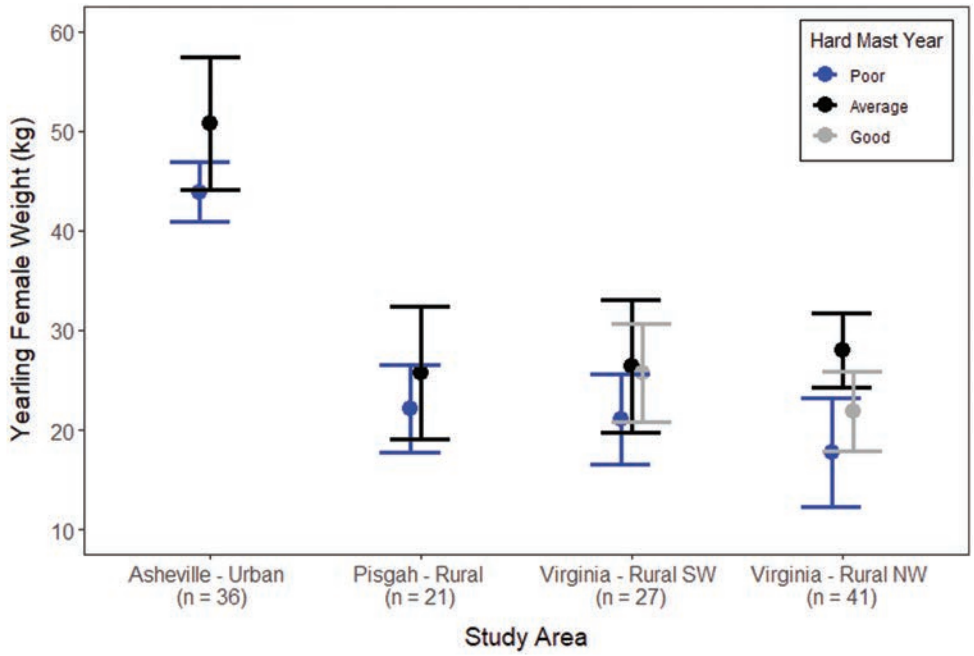

Fig. 5.—The effect of mast year (natural food production) on average weights (kg) of yearling female black bears (*Ursus americanus*) in one urban (Asheville) and one rural (Pisgah Bear Sanctuary) study site in North Carolina, and two rural study sites in Virginia, United States. The circle indicates the mean, and the vertical arms indicate the error associated with the estimates.

SE = 12.115; confidence interval [*CI*] = −48.019 to 5.356) or by the female bears' weight at first capture ($\beta_{\text{Weight at First Capture}}$ = 0.051, *SE* = 0.046; *CI* = −0.024 to 0.174); the *CI*s on the beta estimates overlapped zero.

We determined that urban, nonreproducing yearling females (n = 5; mean = 50.4 kg) were heavier than nonreproducing rural females (n = 89, mean = 24.2 kg, combined Pisgah and Virginia; $F_{1,89}$ = 7.865, $P < 0.001$), and the weights of reproductive (n = 6) and nonreproductive (n = 5) urban yearlings did not differ (mean = 50.4 ± 14.0; t_9 = −0.476, P = 0.646). Lastly, the post hoc model showed that yearling bears increased in weight throughout the year ($F_{8,107}$ = 7.865, $P < 0.001$) but also that the effect of the month of capture did not vary by study area ($F_{12,107}$ = 0.752, P = 0.698).

None of the 89 bears handled as yearlings on the Pisgah and Virginia study sites produced cubs by their second birthdays. Seven of the 12 yearling females captured at the urban site (58%) produced a total of 11 cubs by their second birthdays (mean litter size = 1.6 ± 0.8). We observed the cubs of urban bears at five urban dens and at two urban captures in culvert traps the following spring and summer. Two of these seven mothers weighed less than 50 kg (43 and 49 kg), and all cubs were born following autumns with mast indices of average or poor.

Discussion

Unlike rural black bears, we found that large, yearling females enter estrus, breed, and produce cubs by their second birthdays, failing to reject our hypothesis that bears in urban environments may be larger because they forage for anthropogenically derived food sources. It seems yearlings had the nutritional reserves while denning to sustain pregnancy, parturition, and lactation. The six 2-year-old bears weighed as yearlings and that produced cubs, had a mean yearling weight of 53 ± 2 kg. The flexibility to breed as yearlings preadapts black bears to have high reproductive output in food rich environments, including some urban areas.

We found only partial support for our hypothesis that mast crops from the previous autumn influenced summer yearling weights, because only one of the four study sites (Rural-Site northern Virginia) yielded this result. Spring and summer foods appear to be as important for growth of cubs as are autumn foods, which likely is not required for young urban bears that grow rapidly enough to enter estrus as yearlings. Thus, foods other than hard mast likely contribute to the weight gain and early reproduction of urban females.

Female yearlings at the urban study site weighed about double that of yearlings from the rural sites. We hypothesize that anthropogenic foods provide important calories for urban bears, as has been observed for urban flying foxes in Melbourne, Australia (Williams et al. 2006), urban herring gulls (*Larus argentatus*) in the Netherlands (van Donk et al. 2019), urban grizzly bears (*Ursus arctos*) in North America (Coogan and Raubenheimer 2016), and urban black bears in Montana (Beckmann and Berger 2003). Nevertheless, Merkle et al. (2013) concluded that although bears consumed garbage and ornamental fruits from trees, they selected wild foods over garbage when the former were available. We were unable to quantify urban foods in this study, but future studies should identify and measure these foods (including urban refuse) responsible for rapid weight gain and early reproduction by bears to further bolster our hypotheses about urban food intake. In addition, future studies should measure other vital rates (e.g., survival, litter size, recruitment) of urban and nonurban bears to determine if anthropogenic foods are affecting black bear fitness.

As often is the case, black bears are at the center of human–wildlife interactions (Merkle et al. 2013; Baruch-Mordo et al. 2014) and urban bears may suffer high mortality if they ignore the potential dangers related to humans, such as moving vehicles. Our results beg the question of whether cubs produced by young bears survive and whether recruitment into the population is similar to recruitment of cubs born to females of older age classes. As observed elsewhere in North America, efforts to manage or reduce bear population densities and interactions with people in urban areas require refined focus on educating human residents to use best practices for living responsibly with bears. Our study identified that bears can, and do, live and reproduce within urban areas. In fact, our research corroborates other past work, suggesting that, in most cases, urban bears potentially reproduce faster than bears in rural areas, which could lead to higher densities of bears, and often leads to higher levels of human–bear conflicts.

Lastly, researchers and state agencies that monitor parturition in urban bear populations need to identify environmental conditions that contribute to source or sink dynamics. If urban bears produce cubs as 2- and 3-year-olds, two alternative hypotheses obtain that need to be tested. 1) High population fecundity for urban bears exceeds mortality, allowing urban black bear populations to be source populations for surrounding, rural areas. Alternately, 2) population fecundity does not match high urban mortality rates and urban black bear populations are sinks for the surrounding areas, as suggested for black bears in the western United States (Beckman and Berger 2003; Baruch-Mordo et al. 2014).

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