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# PRODUCTION OF IMPORTANT BLACK BEAR FOODS IN THE SOUTHERN APPALACHIANS

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**Abstract:** Production of foods has been linked to population sizes, social organization and mating strategies of many vertebrates, yet few studies of bears have quantified food production. In the Southern Appalachian Mountains of North Carolina, we quantified production of 2 important foods for black bears (*Ursus americanus*) during 1986-1988 and the U.S Forest Service quantified a third between 1962 and 1973. Annual production of squaw root (*Conopholis americana*) averaged 4.14 kg/ha whereas annual production of berries (*Vaccinium* spp., *Gaylussacia* spp., *Rubus* spp.) averaged 52 kg/ha in areas with berry bush cover, which translates to 2.6 kg/ha over the whole forest (including areas without berry cover). Mean gross energy production by squaw root was  $4.97 \times 10^3$  kcal/ha and by berries,  $1.64 \times 10^3$  kcal/ha. Current mean acorn (*Quercus* spp.) production in the study area is expected to be similar to the 58.1 kg/ha measured between 1962 and 1973. This production of food is significantly higher than that reported for black bears in northern Minnesota.

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Production of foods has been linked to population sizes, home range sizes, and social organization of many vertebrates. Mating patterns of many mammals appear affected not only by productivity of food but also by the variance in that productivity (Powell 1989). Production of berries (*Vaccinium* spp. and other berries) and other foods affect reproduction and mortality and hence population dynamics of black bears (Rogers 1976). As part of our ongoing research project on black bears in the Southern Appalachian Mountains (Warburton and Powell 1985, Powell 1987, Seaman and Powell 1990, Zimmerman 1990, Horner and Powell in press) we documented the productivity of certain foods important for black bears (Beeman and Pelton 1980).

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## METHODS

The 220-km<sup>2</sup> study area was located approximately 25 km southwest of Asheville, North Carolina, within the Pisgah Bear Sanctuary and the surrounding Pisgah National Forest (Fig. 1). The Blue Ridge Parkway, administered by the National Park Service, bisected the study

area from west central to northeast. Elevations in the study area ranged from 650 m to 1750 m. Precipitation averages over 165 cm per year at low elevations in the study area and over 230 cm rainfall per year in nearby mountains (National Climatic Data Center). The forest was predominantly oak (*Quercus* spp.) associations with other hardwoods or conifers and mean stand age was approximately 80 years (Betton 1982, Warburton 1985).

In 1983-1984, 60 vegetation sample sites were established in a 2 x 2 km grid pattern. Five circular subsites of 10-m radius were established at each site: 1 at the site center (as best as it could be determined on the ground in the woods using map, compass and altimeter), and 4 more 100 m due north, south, east and west of the center subsite. At each subsite the percent ground covered by the canopies of berry-producing plants (*Vaccinium* spp., *Gaylussacia* spp., *Rubus* spp., *Prunus* spp.) was determined.

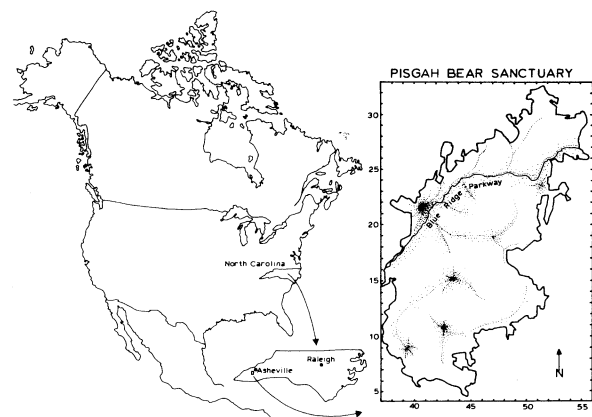


Fig. 1. Study area, the Pisgah Bear Sanctuary; the stippling represents major mountains and ridges and the units on the map are in kilometers using the Universal Transverse Mercator system.

In 1986 through 1988, 15 sites within approximately 0.5 km of a road or major trail were revisited to determine forest production of squaw root and berries. Sites sampled included all major forest types in the study area with slopes ranging  $0^\circ$  -  $>45^\circ$  and elevation ranging approximately 700 - 1,600 m, producing an apparently unbiased sample.

Squaw root was sampled in late May and early June when fruits were ripe; thus low elevation sites were sampled earlier. Stalks with fruits were broken just below the ground where the stalk broke easily and all within the subsite were weighed to the nearest g. Percent of sample that was fruit was also determined because black bears eat only berries (Powell and Seaman, pers. observ.; J Collins, pers. commun.). Tests for independence of squaw root production (kg/ha) at subsites within sites showed lack of independence in 2 of the 3 years (ANOVA,  $p < 0.05$ ), therefore annual production was estimated by averaging production over subsites at each site and then averaging over sites each year.

Berries were sampled as they ripened from late June through early September. Once berry production began, the 19 subsites with  $>25\%$  berry cover were visited approximately weekly until production ceased. Limiting sampling was necessary to allow weekly visitation; we believe that the sampling represented areas with less berry cover as well. All ripe berries were picked at each visit and production was weighed to the nearest 0.1 g. Berries did not differ by species in percent dry weight or energy content, therefore all berries at each subsite were combined for measurement. Tests for independence of subsites within sites showed lack of independence in 2 of the 3 years (ANOVA,  $p < 0.05$ ), therefore annual berry production (kg/ha) was estimated as was production of squaw root. This was then multiplied by the total proportion of forest covered by berry-producing plants as determined from the 1983-1984 vegetation samples.

Gross energy content of berries and squaw root stalks and fruits was determined by bomb calorimetry from samples dried to constant weight at approximately 65 C.

Production during each year is presented as mean  $\pm$  standard deviation to make spatial variance (patchiness) clear. Production averaged over all years is presented as mean  $\pm$  standard error of the mean. Because in a Poisson distribution the variance ( $s^2$ ) equals the mean ( $x$ ), the ratio  $s^2/x$  is a measure of randomness. If  $s^2/x \approx 1$  for a distribution, it approximates random; if  $s^2/x < 1$ , it approaches even; and if  $s^2/x > 1$ , it is patchy (or clumped). Distribution patterns for squaw root and berries were quantified by  $s^2/x$  ratios.

For comparison, production of berries (*Vaccinium*

spp., *Rubus* spp., *Prunus* spp.) in Rogers' (1987) study area in Superior National Forest in northeastern Minnesota was calculated from Arimond's (1979) work. Because her data were given in kg/ha for each stand type, we determined the relative area in each type from data collected by Peek et al. (1976) in the same study area. To do this, we assumed that berry production was similar in blowdowns, clearcuts and forest areas called "clear", and was similar in birch plantations and birch forest. We also assumed that berry percent dry matter was the same in northern Superior National Forest as in the Pisgah Bear Sanctuary because Arimond (1979) did not provide data on percent dry matter.

## RESULTS

Production of squaw root and berries in the Pisgah Bear Sanctuary are given in Table 1, as is production of berries in Superior National Forest (Arimond 1979). Mean squaw root fruit production in the Pisgah Bear Sanctuary was  $2.3 \pm 0.05$  kg/ha. The  $s^2/x$  ratio ranged from 6.4 to 9.2 over the 3 years and averaged 8.1, which is significantly  $>1$  ( $X^2$ ,  $p < 0.01$ ). Thus the annual production of squaw root was significantly patchy. Proportion dry weight was  $0.27 \pm 0.03$ ; gross energy content was  $4.6 \pm 0.06$  kcal/dry g; thus mean gross energy production of squaw root in the forest was  $2.8 \cdot 10^3$  kcal/ha/yr. The proportion of the above ground plant that was fruit was  $0.55 \pm 0.101$ . Energy content of squaw root fruit ( $4.6 \pm 0.06$  kcal/dry g) did not differ from that of stalks ( $4.4 \pm 0.07$  kcal/dry g;  $t$ -test,  $p > 0.05$ ).

Berry production was highly variable both in space and time regardless of percent cover of a subsite by berry-producing bushes. The  $s^2/x$  ratios over the 3 years ranged from 0.84 to 14.8 and averaged 6.8, which is significantly  $>1$  ( $X^2$ ,  $p < 0.01$ ). In the year with little berry production, production was evenly distributed because there was little production anywhere. In the other 2 years, production was very patchy.

Berry production was so predominantly blueberries (*Vaccinium* spp.) and huckleberries (*Gaylussacia* spp.) (only 2 subsites produced blackberries [*Rubus* spp.] in 1 year only) that dry weights and energy content were determined for these berries only. Proportion dry weight and energy content of these berries were nearly identical and are therefore given together. Annual production of berries in areas with  $>25\%$  berry bush cover averaged  $52 \pm 24$  kg/ha (wet weight) over all 3 years; annual means ranged from  $6.5 \pm 11$  to  $85 \pm 92$  kg/ha. Proportion dry weight was  $0.15 \pm 0.03$  and energy content was  $4.4 \pm 0.07$  kcal/dry g. Mean percent cover by berry plants over the 60 vegetation sampling sites was  $4.9 \pm 7.9$ .

Thus mean berry production over the entire study area was estimated to be  $2.6 \pm 2.0$  kg/ha and mean annual energy production  $1.6 \times 10^3$  kcal/ha over the duration of the berry-producing season.

Berry production in Superior National Forest was not as patchy as in the Pisgah Bear Sanctuary because of low productivity.  $s^2/x$  ratios ranged from 0.26 to 3.3 and averaged 1.3, which does not differ significantly from 1 ( $X^2$ ,  $p > 0.05$ ). Total berry production was greater (SAS General Linear Model procedure [Joyner 1985],  $p = 0.0828$ ) in the Pisgah Bear Sanctuary than in Superior National Forest ( $0.44 \pm 0.26$  kg/ha, from Arimond 1979). Gross energy content of blueberries in Superior National Forest was 4.25 kcal/dry g, similar to but slightly lower than that of blueberries and huckleberries in the Pisgah Bear Sanctuary. Annual gross energy production for berries in Superior National Forest averaged  $2.8 \times 10^2 \pm 1.6 \times 10^2$  kcal/ha, 0.17 times that in the Pisgah Bear Sanctuary.

## DISCUSSION

Squaw root and berry production in the Pisgah Bear Sanctuary was very patchy (Table 1). Annual production of squaw root, however, was extremely consistent over all 3 years and was similar to mean berry production over all years. Gross energy content per dry weight was also similar to that of berries but percent dry weight was much higher than for berries. This led to higher energy production (kcal/ha) by squaw root than by berries except in good berry years. Thus squaw root may represent a high energy food of consistently high production in spring and early summer for the bears in the Pisgah Bear Sanctuary. Squaw root is potentially important for early nutrition following denning and may be important for lactating females, who have high energy demands. Digestibility (which can significantly affect food quality) of squaw root fruits is unknown, however. If much of squaw root's energy is bound in poorly digestible fiber, total energy content will overestimate its potential as a high energy food for black bears.

In contrast to squaw root, annual production (kg/ha) of berries was highly variable over the 3 years of sampling. Berries are important summer and early fall foods for bears in the Southern Appalachians (Beeman and Pelton 1980) and elsewhere, and, in northeastern Minnesota, have been shown to be important for survival of a female's cubs during the following year (Rogers 1976). In only 1 of the 3 years of sampling, however, was our berry production as low as the production documented by Arimond (1979) in northeastern Minnesota; in the other

**Table 1.** Production in kg/ha and kcal/ha of squaw root and berries in the Pisgah Bear Sanctuary in North Carolina and production of berries in Superior National Forest in Minnesota.

| Site                   | Food       | Year | N <sup>a</sup> | Production (kg/ha) | Production <sup>b</sup> (kcal/ha) |
|------------------------|------------|------|----------------|--------------------|-----------------------------------|
| Pisgah                 | Squaw root | 1986 | 12             | $2.18 \pm 4.49$    | $2.67 \times 10^3$                |
|                        |            | 1987 | 10             | $2.34 \pm 3.88$    | $2.86 \times 10^3$                |
|                        |            | 1988 | 10             | $2.24 \pm 4.36$    | $2.75 \times 10^3$                |
|                        | Berries    | 1986 | 7              | $0.32 \pm 0.52$    | $0.21 \times 10^3$                |
|                        |            | 1987 | 7              | $3.17 \pm 6.83$    | $2.03 \times 10^3$                |
|                        |            | 1988 | 7              | $4.19 \pm 4.49$    | $2.69 \times 10^3$                |
| Minnesota <sup>c</sup> | Berries    | 1974 | 30             | $0.14 \pm 0.19$    | $0.88 \times 10^2$                |
|                        |            | 1975 | 30             | $0.78 \pm 1.60$    | $4.89 \times 10^2$                |
|                        |            | 1976 | 30             | $0.43 \pm 0.58$    | $2.72 \times 10^2$                |
|                        |            | 1977 | 30             | $0.40 \pm 0.56$    | $2.53 \times 10^2$                |

<sup>a</sup> The period with ripe squaw root fruits was only long enough to allow 10-12 sites, each with 5 subsites, to be sampled each year under field conditions. The 7 berry sampling sites represented 19 subsites with >25% berry coverage.

<sup>b</sup> Proportion dry weight for squaw root in the Pisgah Bear Sanctuary in 1988 was  $0.268 \pm 0.029$  and for berries was  $0.148 \pm 0.026$ ; these were assumed representative for 1986 and 1987. Proportion dry weight for Minnesota berries assumed to be the same as for North Carolina berries; Arimond (1979) only provided mean dry weights of berries. Energy content of squaw root was  $4.48 \pm 0.066$ .

<sup>c</sup> Minnesota data were collected by Arimond (1979); assumptions for manipulations of data for this study are given in the text.

2 years it was approximately 10 times higher. We believe that these differences are real and biologically significant despite lack of statistical significance ( $p = 0.0828$ ) at present due to small sample sizes with high variances.

The great variability of berry production in the Southern Appalachians may have significant impact on black bear reproduction but this has not been documented. Two factors indicate that it would not be as important as in northeastern Minnesota. First, berry production in the poorest year sampled in the Pisgah Bear Sanctuary was still over twice that in the worst year sampled by Arimond (1979) in Superior National Forest. Second, berries are the major late summer and fall food for bears in Superior National Forest (Rogers 1976) whereas in the Southern Appalachians, berries are followed by acorns, other nuts and other soft mast such as grapes (*Vitis* spp.) as important fall foods (Beeman and Pelton 1980). Failure of the berry crop may be compensated in the Southern Appalachians by good production of fall nuts and grapes. Production of the major fall nut in northeastern Minnesota, beaked hazel (*Corylus cornuta*), averaged  $1.07 \pm 0.84$  kg/ha and ranged from 0.32 to 2.04 kg/ha from 1974 to 1977 (Arimond 1979), which is much less than acorn production (Beck 1977) in the Southern Appalachians.

Acorn production in a representative part of the Pisgah Bear Sanctuary was studied by Beck (1977) and by Beck

and Olson (1968) between 1962 and 1973. Production of acorns by all oak species combined averaged  $58.1 \pm 64.3$  kg/ha but was highly variable, ranging from 0.52 to 203.4 kg/ha. Years of peak production by white oak (*Q. alba*) averaged 4 years apart while those of red oak (*Q. rubra*) averaged 5 years apart. In every year at least 1 or 2 oak species produced large crops of acorns, leading to no years with complete crop failures. Bears that depend on acorns, however, would have to travel considerable distances in such years to find isolated areas with abundant acorns. An average of 35% of the acorns was infested by weevils making these nuts at least partially unavailable to bears and other wildlife. Bears may, however, treat weevils in acorns as an additional protein source. Logging within the study area has been limited and from the 1960's through the 1980's approximately 80% of the study area has been in prime mast-producing age classes (60-125 yr, Zahner in press). Thus acorn production in the study area now is expected to be similar to the production reported by Beck (1977) and Beck and Olson (1968).

Arimond (1979), Beck (1977) and Beck and Olson (1968) did not provide percent dry weight of the nuts studied and only Arimond provided data on energy content. Grodzinski and Sawicka-Kapusta (1970) determined values for European hazel (*Corylus avellana*) and oaks (*Quercus petraea*, *Q. robur*), which we use here for the missing values needed to provide a relative feeling for energy production by these nuts on the U.S. study areas discussed. Hazel nuts in northeastern Minnesota averaged 5.20 kcal/dry g; the European hazel nuts were 75.4% dry matter and contained 5.97 kcal/dry g. The European oak species averaged 70.4% dry matter and 4.46 kcal/dry g. Using these figures, we estimated hazel nut production at  $4.20 \times 10^3$  kcal/ha in northeastern Minnesota and acorn production at  $1.82 \times 10^5$  kcal/ha in the Pisgah Bear Sanctuary. The year of poorest acorn production recorded by Beck (1977) yielded an estimated  $1.62 \times 10^3$  kcal/ha, which is similar to the mean production of energy by hazel nuts in northeastern Minnesota. Clearly the productivity of the important bear foods discussed here differ greatly across the black bear's range in North America.

For animals in general, home range size is known to vary inversely with productivity of food (Hixon 1980, Schoener 1983). Thus black bears in the mountains of North Carolina are expected to have smaller home ranges than bears where food is less productive, such as in Minnesota. But, they do not. Home range size is not correlated with latitude (Warburton 1985), indicating that it is not correlated with habitat productivity. There-

fore, patchiness of food production may be equally as important as total production in analyses of effects of foods on home range and other aspects of bear biology. Productivity of a limiting resource, such as food, appears to be discounted by its patchiness and unpredictability (Powell 1989). This, in turn, affects mating and dispersal patterns, and possibly home range size. Documenting variance of food production in space and time may be as important for future research and for increasing our understanding of bear biology as determining production means.

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