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Caloric Production of Black Bear Foods in Great Smoky Mountains National Park

Robert Michael Inman
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Robert Michael Inman entitled "Caloric Production of Black Bear Foods in Great Smoky Mountains National Park." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

David A. Buehler, John C. Waller, Edward R. Buckner

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Caloric Production of Black Bear Foods

in Great Smoky Mountains National Park

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Robert Michael Inman

December 1997

DEDICATION

To that most glorious symphony of sound, light, motion, and drama which takes place every minute of every day.

To those who perceive this beauty, take the time to share this beauty, and protect this most miraculous way.

To Robert and Helen. You have shown me the beauty of America and of the human heart. I will always love you.

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I am deeply appreciative of the dedication exhibited during some of the toughest work of this project by Greg Baily, Becky Mills, and Jeff Pearce. I thank Thomas Eason for his help with the vegetation sampling and den work. I greatly appreciate the superb effort given by Greg Batts, Rick Eastridge, Laura Heiser, Vebjorn Knarrum, Kai-Eerik Nyholm, Jeff Pearce, Chad Pelton, and Heath Smith during the summer trapping of 1994, 1995, and 1996. For their support, encouragement, occasional help grading papers, and all the good laughs, I would like to thank all of my friends!!

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ABSTRACT

Understanding energetic potential of habitat patches is important for management designed to provide adequate habitat for wildlife species. Great Smoky Mountains National Park (GSMNP) has a high density of black bears that have been studied intensively from 1968-1997; habitats within the Park are relatively undisturbed, and similar vegetative cover types can be found throughout the southern Appalachian mountains. Black bear reproduction in the Park has been correlated to hard mast production, however little work has been done to assess the importance of soft mast. Geographic Information System (GIS) based habitat use models have been developed for bears in the Park, yet the importance of foods in determining habitat selection, and the possibility of sexual habitat segregation due to food availability have not yet been determined. The primary objectives of the study included estimation of the location, timing, and amount of caloric production by 19 important black bear foods and determination of the significance of caloric production by mast type, season, overstory vegetation type, and plant species. Secondary objectives were to test for correlation of bear habitat use with estimated caloric production from mast, and to test for sexual segregation of habitats based on caloric production. This study was limited to the northwest quadrant of GSMNP during 1995.

For each bear food, I measured mean square meters of shrub coverage or cubic meters of tree crown volume per hectare within each of 9 vegetation types. I also measured the mean number of fruits produced per square meter of shrub coverage or per cubic meter of tree crown volume, and I measured the mean dry weight of 1 fruit and the

gross energetic content (calories per gram, dry matter basis) for each species. Finally, I calculated the caloric production per square meter of shrub coverage or per cubic meter of tree crown volume for each species.

During 1995, total caloric production in the northwest quadrant of GSMNP for all species was 21.5 billion Cal (SE = 3.0 billion Cal). The mean number of calories produced annually per hectare was 351,209 Cal/ha (SE = 49,834 Cal/ha).

Northern red oak (*Quercus rubra*) produced 65.7% of all calories; squawroot (*Conopholis americana*) produced 15.8%, and huckleberries (*Gaylussacia spp.*) produced 5.1%. A white oak (*Quercus alba* and *Quercus prinus*) mast failure occurred on the study area during 1995; red oaks (*Quercus rubra* and *Quercus coccinea*) yielded 69.4% of all calories, whereas white oaks yielded only 5.1%. Oaks are likely the single most influential genera affecting bear ecology in the southern Appalachians. However, adequate sources of squawroot and berries, along with a diversity of food sources, are also likely to influence population dynamics.

Caloric production per hectare differed among seasons (F = 284.92, df = 2, P = 0.0001). Fall composed 59.3 % (12.8 billion Cal, SE = 1.3 billion Cal) of all calories produced. Mid-summer was the lowest period of production, excluding winter. Availability of plants and habitats that produce spring and summer foods likely has significant impacts on bear recruitment and carrying capacity.

Caloric production per hectare differed between mast types (F = 32.16, df = 1, P = 0.0001). Total production by mast types also differed (t = 3.65, df = 532, $Pr > |t|$ = 0.0003). Hard mast produced 74.5% (16.0 billion Cal, SE = 2.0 billion Cal) of all

calories; soft mast produced 25.5% (5.5 billion Cal, SE = 2.0 billion Cal). Gross energetic contents of soft and hard masts did not differ ($P = 0.536$, $n = 20$), indicating that size and number of fruits produced per unit area are determining factors for caloric production rather than mast type. Production (Cal/m^3) by soft and hard masts did not differ ($P < 0.1260$, $n = 18$); however, years of good white oak or hickory (*Carya spp.*) crops could result in differences.

Caloric production per hectare differed among vegetation types ($F = 3.36$, df = 8, $P = 0.0011$). Differences in seasonal production per hectare also occurred between vegetation types. Management that considers the food producing potential of each vegetation type, including seasonal and species specific effects, will improve the quality of bear habitat. Practices that improve the abundance of squawroot should target the cove hardwood, mixed mesic hardwood, and tulip-poplar types; these vegetation types exhibited the greatest propensity for squawroot, and would likely support the greatest abundance of this important spring food. The greatest improvement in summer foods can be made by promoting huckleberries in the mesic oak and mixed mesic hardwood types, huckleberries and blueberries in the xeric oak, pine, and pine-oak types, and blackberries in the northern hardwood and spruce-fir types. Prescribed fire programs and adjustment of logging practices to prevent loss of rootstocks and soil compaction (i.e. burn slash rather than pile with bulldozer) may lead to increased huckleberry and blueberry abundance and productivity. Blackberry abundance may be increased by providing openings in the overstory. An abundant and diverse fall food source will facilitate bear population stability; mature stands of red and white oaks along with black cherry, grape,

and hickory should be maintained within each watershed. The white oak component was found in greatest abundance within the xeric oak, mixed mesic hardwood, and pine-oak types; management that concentrates on increasing basal areas of white oaks within these vegetation types will yield improvement of food resources for bears. Management for the red oak component should be concentrated in the mesic oak, mixed mesic hardwood, and cove hardwood types. Maintenance of a mature black cherry component on northern hardwood, mesic oak, and cove hardwood sites is recommended.

There was not a strong relationship between any measured caloric production during 1995 and any bear relative probability of habitat use (RPHU) model (Calories: all calories, soft mast calories only, hard mast calories only; Bear RPHU: male annual, female annual, female spring, female summer, female fall). Factors such as road density and proximity to human activity may affect habitat use more than food production. Also, multiple years of data or simultaneous studies of habitat use and caloric production are needed to address this question more accurately.

Although there were no strong relationships between caloric production and bear habitat use, results suggest sexual habitat segregation and the importance of soft mast for female bears. These trends are likely more important than data prove because of the high variation in caloric production from plot to plot within a vegetation type and the lack of ability of habitat use models to discern areas of a vegetation type that contain high or low caloric value.

Fruits produced per unit area combined with the mean dry weight of a fruit are measures that should provide an accurate and useful index of nutrition available to bears

from year to year. Data from this study can be used as a basis for designing experiments to research the effects of forest management practices on bear habitat. Results will allow land managers to assess the impacts forest management plans on bear populations.

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I. INTRODUCTION

Black bears exist at low densities and their reproductive rate is one of the lowest for any North American land animal (Pelton 1982). Population regulation of black bears is considered largely density-independent (Garshelis 1994), with food availability having the greatest influence (Rogers 1976, Young and Ruff 1982, Eiler et al. 1989). Managing bear habitats requires identification of important habitat components and determination of the optimal or at least minimal habitat mix necessary for maintaining populations at desired population levels (Schoen 1990). Although food is only one component of habitat, its availability may be influenced by policies regarding natural disturbances in national parks and by silvicultural practices on multiple-use lands. Misunderstanding the regulatory influences of specific foods could lead to ineffective or inappropriate management strategies. Bear habitat management in the southern Appalachians emphasizes the importance of the fall, hard mast component (oaks (*Quercus spp.*) and hickories) (Pelton 1989). Largely undocumented, however, remains the importance of soft mast (cherries, (*Prunus spp.*), huckleberries, blackberries (*Rubus spp.*), blueberries (*Vaccinium spp.*), grapes (*Vitis spp.*), greenbriers (*Smilax spp.*), blackgum (*Nyssa sylvatica*), and squawroot.

Nutrition and Population Regulation

Nutrition is an important factor affecting rate of black bear reproduction throughout North America (Jonkel and Cowan 1971, Rogers 1976, Beecham 1980,

LeCount 1982, Eiler et al. 1989, Garshelis 1994, Miller 1994). Nutritional conditions of female black bears affect age of primiparity, litter interval, and litter size (Jonkel and Cowan 1971, Rogers 1976, Beecham 1980, Elowe and Dodge 1989, McLaughlin et al. 1994). Nutritional condition may also influence fertility (Noyce and Garshelis 1994).

The survival of females and offspring is influenced by the available nutrition during the period of lactation. Females with cubs are the most active sex-age group (Garshelis and Pelton 1980, Villarrubia 1982), and this increased activity is likely in response to increased nutritional demands in support of lactation. At den entrance, weights of females with cubs are significantly lower than females without cubs (Rogers 1976, Eiler et al. 1989). However, when food supplies are abundant, females with cubs do not exhibit drastic weight losses; some females gain as much during years of lactation as in other years (Rogers 1976). Energy requirements due to lactation may place females and their offspring at greater risk of mortality, particularly during years of poor food crops.

Nutrition significantly affects survival of cubs and yearlings (Rogers 1976), and population growth can be influenced more by cub survival than by birth rate (LeCount 1987). Survival of cubs significantly varies among years in GSMNP; 1 of 8 cubs (12.5%) survived to the yearling den following a year of poor oak mast yield, whereas 14 of 16 (87.5%) survived following a year of medium oak mast yield (Eiler et al. 1989). In contrast, Elowe and Dodge (1989) reported highest cub mortality following years of good fall mast crops. Neither Eiler et al. (1989) nor Elowe and Dodge (1989) reported spring or summer food availability, which may have significantly influenced survival. As yearlings disperse, they are vulnerable because they are unfamiliar with food sources and

must compete with aggressive adults. Lighter than average yearlings have higher rates of mortality (Rogers 1976, 1987). Subadults that were thin and weak were captured without immobilization during May and June in Montana (Jonkel and Cowan 1971). Availability of spring and summer foods may significantly influence survival by aiding lactation, supplementing cub diets, and influencing yearling growth and survival.

Southern Appalachian Black Bear Studies

Because of the obvious importance of energy storage for the denning period, previous regional studies were designed to determine the relationship of fall oak mast availability and reproduction (Eiler et al. 1989, Pozzanghera 1990, McLean 1991, Coley 1995). The contribution of soft mast to the nutritional quality of bear habitat has not been quantified, but has been suggested to be of some importance.

Yields of oak mast significantly influence black bear reproduction in the southern Appalachians (Eiler et al. 1989, Pozzanghera 1990, McLean 1991). Oak mast provides a diet that is high in available fats and carbohydrates, and these materials are readily assimilated into the body fat reserves necessary for hibernation (Eagle and Pelton 1983). Fat reserves influence reproduction and cub survival because of the necessity of stored energy for the denning, gestation, and early spring negative foraging period (Eiler et al. 1989). Other southern Appalachian studies have determined that oak habitats are used extensively by bears (Villarrubia 1982, Quigley 1982, Carr 1983, Clevenger 1986).

Documented correlations of bear reproduction and yields of oak mast in the southern Appalachians are largely based on 2 methods of indexing mast crops: (1) The

Whitehead tree count survey method (Whitehead 1969), and (2) maximum potential production index (MPPI) (Pozzanghera 1990). Nicholas and White (1984) criticized the Whitehead method because there is no biological rationale for calculation of the percentage of the crown's twigs bearing acorns. The Whitehead method has never achieved a rating of 10 (highest possible score) although excellent mast years have occurred (Pozzanghera 1990); it consistently rates mast crops as fair when year to year variation is large. Pozzanghera (1990) adjusted the Whitehead method to create the MPPI. The MPPI method estimates the percentage of maximum recorded output that oaks are producing during a given year.

Coley (1995) incorporated 20 years of black bear population data to determine the influence of hard mast production on black bear population dynamics in GSMNP. Coley (1995) correlated hard mast indices from GSMNP with various population estimates for periods of up to 5 years after recorded hard mast data and found no significant positive correlations. Soft mast availability was not documented during this 20 year period; the amount of variation in population estimates and measured reproductive indices that could be explained by variation in soft mast crops is unknown.

Although hard mast is thought to be important for bears in the southern Appalachians, soft mast composed 37% of the annual volume of scats collected in GSMNP, whereas hard mast composed only 14% of the volume (Beeman and Pelton 1980). Gypsy moth infestations in Virginia resulted in complete acorn crop failures, yet bear reproduction and survival in those areas did not decrease immediately after the infestation and subsequent failure of the mast crop (Kasbohm et al. 1996).

Soft mast is likely responsible for bear growth and muscular maintenance, and may influence reproductive effort. Black bears annually cycle through four metabolic stages (Nelson et al. 1983) that correspond to seasonal shifts in available nutrients, physical condition, and blood biochemistry (Hellegren et al. 1989). Black bears assimilate proteins used for growth during the summer and early fall; assimilation of fats and carbohydrates used for fat storage occurs during late fall at the expense of lean body growth (Eagle and Pelton 1983, Brody and Pelton 1988). The availability of soft mast likely affects the percentage of total body weight that is due to lean body mass. Lean body mass carried into the breeding season may be more critical for sexual maturity and successful pregnancy than the previous winter's fat stores (Noyce and Garshelis 1994).

Soft mast also supplies the energetic needs of bears during several critical periods. Females in GSMNP lactate as late as September (Eiler et al. 1989). Therefore, successful lactation for up to 4 months (June through September) is likely dependent on soft mast crops. The caloric content of summer berries also fulfills the metabolic needs of bears during the mating season and during exploratory movements by young animals (Garshelis and Pelton 1980, Quigley 1982).

The amount of shrub soft mast available in an area influences the seasonal and annual home range sizes of bears and their activity patterns (Garshelis 1978, Garshelis and Pelton 1980, Quigley 1982). Cherry and grape crops are important components of bear diets in fall. Black cherry (*Prunus serotina*) ripens during September and may be preferred over acorns (Quigley 1982). Bears with abundant black cherry in their home range displayed delayed movement to areas of abundant oak mast (Garshelis and Pelton

1981). Abundant grape crops reduced the impacts of a severe oak mast failure on bear reproductive effort (Eiler et al. 1989).

Relationships of reproduction and survival to nutritional condition of bears is confounded by several factors. Problems include incomplete measures of the annual food crops and subjective crop ratings (poor, fair, good, excellent) (Stringham 1990, Garshelis 1994, Noyce and Garshelis 1994). In this study, I propose to overcome these confounding factors by measuring caloric production by the majority of foods used by bears in GSMNP, thus allowing greater understanding of which foods, habitat types, seasons, and mast types are important for bears. In addition, I hope to provide insight into how important food availability is in determining habitat use, and if sexual segregation based on nutritional quality of areas occurs.

The objectives of this study were to:

(1) estimate caloric production per hectare by vegetation type, mast type, and season,

(2) estimate total calories produced by black bear foods annually, seasonally, by mast type, by vegetation type, and by each bear food species,

(3) determine relationships of habitat use with caloric production, and

(4) determine if caloric availability promotes sexual segregation.

II. STUDY AREA

Location

GSMNP is located along the border of Tennessee and North Carolina (35°29' - 35°47' N, 83°05' - 83°55' W) (Figure 1). The Park encompasses 2,075 km^2 in portions of Blount, Cocke, and Sevier counties in Tennessee and Haywood and Swain counties in North Carolina. This study was limited to the northwestern quadrant of GSMNP (613.2 km^2). This study area has been the focus for studies on many different aspects of black bear ecology during the past 29 years.

Physiography, Topography, Geology, and Soils

Great Smoky Mountains are part of the Unaka Mountain Range of the Blue Ridge Province of the Southern Appalachian Highlands (Fenneman 1938). The Unakas, a group of mountain ranges that diverge southwestward from the Blue Ridge in southwestern Virginia, form the western front of the Southern Appalachian Mountains. The area consists of many steep ridges extending out from the main ridge, separated by narrow valleys that were created by fast moving streams (King and Stupka 1950). Elevation within the study area ranges from 270 m to 2,025 m. Slopes are steep with 45% > 15°, 21% > 20°, and 10% ≤ 5° (van Manen 1994).

Bedrock of the Great Smoky Mountains is primarily Precambrian sedimentary rock of the Ocoee series and has been greatly affected by folding, faulting, metamorphism, and

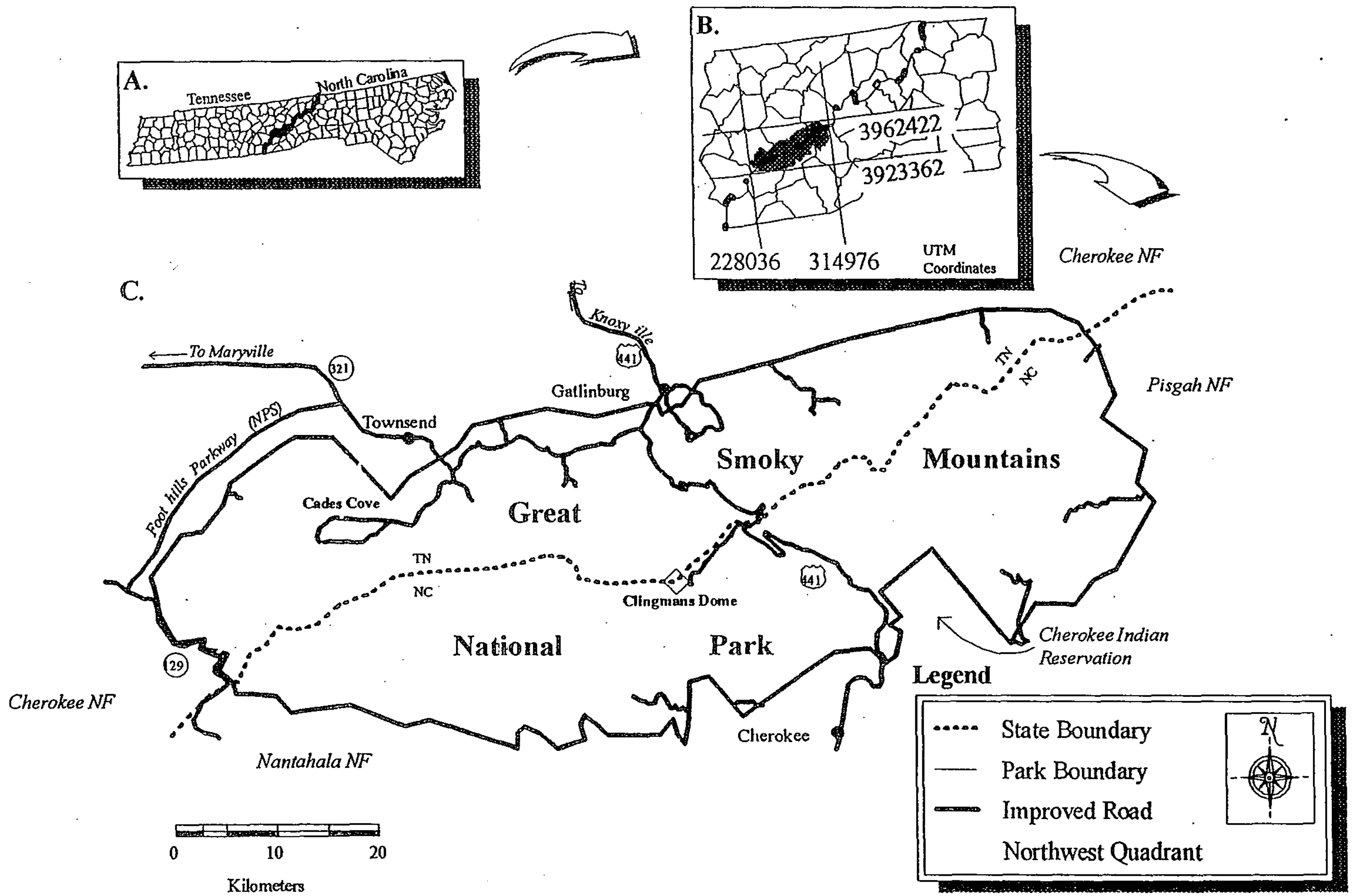

Figure 1. Location of study area

weathering (King at al. 1968). The Ocoee series is dominated by sandstone contained in a thrust sheet over Ordovician limestones and shales. Parent materials contain feldspar, shale, slate, phyllites, schists, and quartz (King at al. 1968). Colluvial and residual soils cover most of GSMNP (Golden 1974). Predominant soils are of the Ramsey association. Soils are thin and poorly developed with medium to high acidity, low water storage capacity, low to moderate fertility, and susceptibility to erosion (Soil Survey 1945, 1953). Coves and other protected sites commonly contain deep soils whereas soils on steep slopes and exposed sites generally are thin (Kyukendall 1978).

Climate

Climate of the area has been classified as a warm-temperate rain forest (Thornthwaite 1948). With each 300 m gain in elevation, temperatures in the Smokies decrease an average 1.2° C (Shanks 1954) while annual precipitation increases by 22.5 cm (Smallshaw 1953). At lower elevations, monthly mean temperatures range from 4.4° C to 22.0° C; the range at higher elevations is from -1.8° C to 13.5° C. Lowest temperatures are usually recorded in February and highest temperatures in July (Stephens 1969). July is the wettest month whereas September or October is driest. Annual precipitation ranges from 140 cm at lower elevations to 230 cm at higher elevations (Stephens 1969).

Large variation in elevation, aspect, rainfall amount, temperature, and snowcover; along with the latitudinal position and northeast-southwest orientation of the Smoky Mountains, has resulted in a large variety of microclimatic conditions within the Park.

Flora

Vegetation of GSMNP is a complex mixture of deciduous and coniferous forests, a reflection of the great variety of microclimatic conditions (Whittaker 1956). Within GSMNP, more than 1,300 flowering plants (including 131 native trees) and more than 2,400 non-flowering plants (including approximately 50 ferns and fern allies, 230 lichens, 330 mosses and liverworts, and 1,800 fungi) have been identified (King and Stupka 1950). This species richness influenced the Park's designation as an International Biosphere Reserve. Vegetation types have been classified by Cain (1935), Shanks (1954), Whittaker (1956), Golden (1974), Pyle (1988), and MacKenzie (1993). I used the classification by MacKenzie (1993) (Table 1). In the northwestern quadrant of GSMNP, the percentages of areas occupied by each vegetation type (MacKenzie 1993) are different than those within the entire Park (Table 2).

Fauna

More than 200 bird species, 130 reptiles, 39 amphibians, 70 fish species, and a large variety of invertebrates are found within GSMNP (King and Stupka 1950). Fifty-nine mammalian species are found within the park and an additional 6 mammals have been extirpated (Linzey and Linzey 1971). The river otter (*Lutra canadensis*) has been repatriated, and attempts to repatriate the red wolf (*Canis rufus*) are underway.

Table 1. Dominant tree species, area and percentage of Great Smoky Mountains National Park for each vegetation type as classified by MacKenzie (1993).

Vegetation Type	**Dominant Tree Species**[a]	**Hectares**	**% of GSMNP**
Cove Hardwood	Eastern hemlock (*Tsuga canadensis*) Sweet birch (*Betula lenta*) Red maple (*Acer rubrum*) Carolina silverbell (*Halesia carolina*) Tulip-poplar (*Liriodendron tulipifera*) Northern red oak (*Quercus rubra*) Basswood (*Tilia heterophylla*) Yellow birch (*Betula lutea*)	69,369	33 %
Mixed Mesic Hardwood	Tulip-poplar Red maple Eastern hemlock Chestnut oak (*Quercus prinus*)	33,096	16 %
Pine	Table-mountain pine (*Pinus pungens*) Pitch pine (*Pinus rigida*) Virginia pine (*Pinus virginiana*) Scarlet oak (*Quercus coccinea*)	23,167	11 %
Mesic Oak	Northern red oak Red maple Chestnut oak	21,327	10 %
Xeric Oak	Chestnut oak Red maple Tulip-poplar Sourwood (*Oxydendrum arboreum*) Scarlet oak	20,793	10 %
Northern Hardwood	Yellow birch American beech (*Fagus grandifolia*) Sweet birch Eastern hemlock Red maple Northern red oak Red spruce (*Picea rubens*)	19,329	9 %

Table 1 (Cont.).

Vegetation Type	**Dominant Tree Species**[a]	**Hectares**	**% of GSMNP**
Tulip-Poplar	Tulip-poplar Red maple Carolina silverbell	5,514	3 %
Pine-Oak	Scarlet oak Table-mountain pine Blackgum (*Nyssa sylvatica*) Red maple Chestnut oak	5,067	2 %
Spruce-Fir	Yellow birch Red spruce Red maple	5,002	2 %
Water		1,833	0.9 %
Treeless		1,417	0.7 %
Heath Bald		1,202	0.5 %
Grape Thicket		324	0.2 %
Grassy Bald		55	0.03 %

[a] Species within each vegetation type are ordered according to dominance. Dominance based on a mean of species basal area > 2.0 m^2/ha, from MacKenzie (1993).

Table 2. Comparison of hectares and percentages of areas occupied by each vegetation type in the northwestern quadrant (study area) and the remaining quadrants of Great Smoky Mountains National Park.

Vegetation Type	**NW Hectares**	**% NW Quadrant GSMNP (Study Area)**	**NE SE SW Hectares**	**% NE SE SW Quadrants GSMNP**	**% Difference**
Xeric Oak	13,235	22 %	7,558	5 %	+ 17 %
Pine	13,476	22 %	9,692	7 %	+ 15 %
Cove Hardwood	14,710	24 %	54,660	37 %	- 13 %
Mesic Oak	1,770	3 %	19,557	13 %	- 10 %
Northern Hardwood	3,363	6 %	16,159	11 %	- 6 %
Mixed Mesic Hardwood	8,017	13 %	25,079	17 %	- 4 %
Tulip-Poplar	3,045	5 %	2,470	2 %	+ 3 %
Spruce-Fir	693	1 %	4,116	3 %	- 2 %
Pine-Oak	1,542	3 %	3,525	2 %	+ 1 %
Water	17	0.03 %	1,817	1.24 %	- 1.21 %
Treeless	864	1.41 %	553	0.38 %	+ 1.03 %
Grape Thicket	163	0.27 %	161	0.11 %	+ 0.16 %
Heath Bald	397	0.65 %	806	0.55 %	+ 0.10 %
Grassy Bald	28	0.04 %	28	0.02 %	+ 0.02 %
Total	61,320 ha [a]		146,180 ha		

[a] The northwestern quadrant includes 29.6 % of Great Smoky Mountains National Park

History of Land Use

Pyle (1988) found no site specific accounts of Native American land use practices within the study area. European settlement influenced the GSMNP landscape in several ways. Common activities and forest disturbances included farming, open wood-range pasturing of livestock, fires to maintain pastures, and both small-scale and large-scale logging (Pyle 1988). Settlement in the coves and valleys was common. The fence law was enacted in 1913 and until that time, open range pasturing was legal. Fire was often used to maintain pastures (Pyle 1988). Early logging practices were generally characterized by selective logging (high grading) for farm use and for small-scale sale of lumber. This type of logging occurred from around 1880 to 1900 in the lower, accessible areas (Pyle 1988). After the turn of the century, mechanized logging by large commercial timber companies became the dominant activity in the area. Steam engines, railroads, cable logging, and clearcutting were features of large-scale logging in previously inaccessible areas. National Park status and the elimination of timbering began in 1934; by that time, around 63% of the Park area had been logged, settled, or disturbed by humans (Pyle 1988).

Although chestnut blight entered the area in 1926 and was well established throughout most of the Park during the 1930's, analysis of 1930's data indicated that American chestnut (*Castanea dentata*) was still the dominant species in the landscape (MacKenzie 1993). American chestnut was virtually eliminated by the chestnut blight during the 1930's (Pyle 1988). American chestnut was noted for its dependable production of large, nutritious, fruit crops every year. Many wildlife species, including

black bears, undoubtedly used American chestnuts as a food source. The carrying capacity of GSMNP for black bears was likely reduced significantly by chestnut blight (Pelton 1989).

Current Management

GSMNP was authorized by Congress in 1926 and dedicated in 1940 after all major land purchases had been made. GSMNP is under the jurisdiction of the US Department of the Interior, National Park Service. Part of GSMNP's role within the federal land framework of the southern Appalachians is to provide a basis for understanding population dynamics in relatively undisturbed habitats. Because GSMNP's diversity of microclimatic situations represent site potentials for much of the federally owned land in the southern Appalachians and management of the Park requires a relative absence of human alteration, GSMNP affords a unique opportunity to study habitat needs of wildlife populations in a "control" setting. The impacts of management actions undertaken on multiple-use lands can be compared with baseline data from GSMNP.

III. METHODS

Caloric Production

Based on previous food habits studies conducted in the southern Appalachians (Beeman and Pelton 1980, Eagle and Pelton 1983, Brody and Pelton 1988, Seibert and Pelton 1994), and studies that identified common plants of GSMNP (Whittaker 1956, Stupka 1960, Golden 1974), I identified 19 plant species for consideration in this study (Table 3).

Sampling Scheme

I used stratified random sampling to locate 275 sample points in the northwest quadrant of GSMNP. Calories produced per hectare by foods of black bears were sampled at each point. The study area was stratified 3 ways: by vegetation type, elevational range of the vegetation type, and aspect. For the first stratification layer, topographic maps were overlaid with a geographical information system (GIS) coverage of vegetation (MacKenzie 1993). This GIS layer had a pixel resolution of 90 x 90 m, and each pixel within the Park was classified as 1 of 14 vegetation types. I sampled in 9 of 14 vegetation types (Table 4); the 5 unsampled types comprised 2.4% of the northwest quadrant of GSMNP, with < 1% having the potential for bear food production. The second stratification layer was elevation. The range of elevations for vegetation types of GSMNP was described by Eagar (1984). I used that range and divided it in half, resulting in low and high categories (Table 4). For the third stratification layer, I divided aspect

Table 3. Plant species identified for sampling as important black bear foods in Great Smoky Mountains National Park and type of sampling measure.

Crown Volume (m^3)	**Percent Cover (m^2)**
Hickories (*Carya spp.*)	Squawroot (*Conopholis americana*)
Blackgum (*Nyssa sylvatica*)	Huckleberries (*Gaylussacia spp.*)
Black cherry (*Prunus serotina*)	Allegheny blackberry (*Rubus allegheniensis*)
Fire cherry (*Prunus pensylvanica*)	Thornless blackberry (*Rubus canadensis*)
White oak (*Quercus alba*)	Greenbriers (*Smilax spp.*)
Scarlet oak (*Quercus coccinea*)	N. highbush blueberry (*Vaccinium corymbosum*)
Chestnut oak (*Quercus prinus*)	S. mountain cranberry (*Vaccinium erythrocarpum*)
Northern red oak (*Quercus rubra*)	Hairy blueberry (*Vaccinium hirsutum*)
	Upland low blueberry (*Vaccinium pallidum*)
	Deerberry (*Vaccinium stamineum*)
	Grapes (*Vitis spp.*)

Table 4. Vegetation types (MacKenzie 1993) sampled for crown volume (m^3) and percent cover (m^2) of selected black bear foods in Great Smoky Mountains National Park.

Sampled	Elevational Breaks for Sampling Low Range; High Range (meters)	Not Sampled
Spruce-Fir	1,520-1,770; 1,771-2,000	Grassy Bald
Northern Hardwood	1,220-1,400; 1,401-1,585	Grape Thicket
Mesic Oak	1,220-1,340; 1,341-1,460	Heath Bald
Cove Hardwood	790-1,160; 1,161-1,460	Treeless
Mixed Mesic Hardwood	610-850; 851-1,035	Water
Pine-Oak	365-640; 641-915	
Xeric Oak	365-640; 641-915	
Pine	365-640; 641-915	
Tulip Poplar	365-610; 611-850	

into 2 categories: N 45° W to S 44° E (Northeastern) and S 45° E to N 44° W (Southwestern). This sampling scheme resulted in each 90 x 90 meters of the study area being classified as one of 36 categories. Thirty to 33 sample plots within each vegetation type (*n* = 9) were distributed as equally as possible at the elevation and aspect combinations where that vegetation type was found. Upon reaching a sampling point, the field crew determined if the vegetation type had been correctly classified. If the vegetation had been incorrectly classified by MacKenzie (1993), that plot was discarded and a new plot located. In addition to results of stratification, I selected sampling points based on accessibility by trail; all points were > 90 m from trails.

Distribution and Abundance of Food Species

At each sampling point, I used a square plot of 0.04 hectare (400 m^2) to measure crown volume (m^3) of tree species and percent cover (m^2) of shrub and vine species. Only those species determined to be important for bear food production were recorded. I subsequently converted m^3 of tree crown volume and m^2 of shrub coverage into caloric production per hectare for each sample point using information describing the average number of calories produced per m^3 or m^2 by each food species, and the timing of that production as described below. I also recorded a measure of landform index (McNab 1993) and terrain shape index (McNab 1989) at each sample point.

Phenology and Fruit Production

I established 4 phenological transects ranging in length from 13.8 to 17.4 km considering placement within a variety of watersheds, elevational ranges, and accessibility. These transects along with their elevational ranges were: Forge Creek-Parson's Branch-Gregory Bald Trails (549-914 m), Lead Cove-Bote Mountain-Schoolhouse Gap-Turkeypen Ridge Trails (518-945 m), Jake's Creek-Miry Ridge Trails (671-1372 m), and Appalachian-Sugarland Mountain Trails (1524-1829 m). For each species of bear food, 5 - 45 individual trees or patches of shrub were marked along these transects. I walked each transect and recorded the phenological condition of each individual tree or shrub patch once per week during the flowering period and once every 2 weeks for the remainder of 1995 (39 weeks, 20 March - 11 December). Phenological condition was recorded as flowering, ripe, neither flowering nor ripe, or no observation. An individual was recorded as "ripe" as long as fruits were mature, edible, and present. When data for an individual tree or shrub patch were the same condition in weeks A and C, then week B was also entered as that condition; if weeks A and C differed, then an entry of "no observation" was recorded for week B. When the majority of fruits of an individual tree or shrub patch were observed to be "ripe", a sample was taken to estimate the number of fruits produced by that individual tree or shrub patch during 1995.

To estimate fruit production for individual trees, I counted the number of fruits seen within a measured volume of tree crown. I took 2 samples at random locations from within each tree crown. I measured the volume of tree crown sampled by using a 15 - 45 power spotting scope mounted on a tripod and making several measurements including the

width of the tree crown. When sampling trees, magnification was always set at 1 of 2 powers. A scale for area of view at these 2 magnification powers and at any distance was determined with prior measurements (Table 5). When viewing a tree crown through the scope, a conic volume is within view; some of this volume is within the tree crown and some is not (Figure 2). I calculated the volume of tree crown viewed within the scope by subtracting the volume of cone outside the tree crown from the volume of the entire cone. The volumes of these 2 cones were calculated as described below. The distance from the spotting scope to the mid-width point of the tree crown where the sample was made (M) was determined by measuring the distance from the scope to the base of the tree (D) along with the angle from the scope to the base of the tree (θ Bot) and the angle from the scope to the sample (θ Top) (Figure 2). The following formula calculates the distance from scope to mid-width point of the tree crown where the sample was made:

$M = (\cos \theta\ Bot * D) / \cos \theta\ Top$. Next, the radius of the base of each cone (entire cone (EC) and cone outside the tree crown (OC)) was determined. For EC, I added 1/2 the tree crown width to the mid-width distance (M), and determined the radius of view at that distance with scope constants from table 5; for OC, I subtracted 1/2 the crown width (Figure 2). Finally, with measures of the radius of each cone and the height of each cone, I was able to determine the volume of each cone ($V = 1/3\ height * \pi * radius^2$). The volume of tree crown sampled for fruits was the volume of EC - volume of OC.

To estimate fruit production by shrubs, I sampled the number of fruits found within a 0.5 m^2 area of shrub coverage. I sampled by randomly tossing a square 0.5 m^2 PVC sampling grid into the patch of shrubbery and counting all fruits that were within the grid.

Table 5. Calculation of spotting scope area of view (m^2) at any known distance as used to sample tree crowns for fruit production in Great Smoky Mountains National Park.

A	B	C	D	E	F
Distance (m)	Scope Power Setting	Measured Diameter of view (m)	Resulting Radius (m)	X?	Field of View Area (m^2)
18.29	A	0.6096	0.3048	0.016666	0.2919
27.43	A	0.9144	0.4572	0.016666	0.6567
36.58	A	1.2192	0.6096	0.016666	1.1675
18.29	Z	0.3302	0.1651	0.009027	0.0856
27.43	Z	0.4953	0.2477	0.009027	0.1927
36.58	Z	0.6604	0.3302	0.009027	0.3425

At distance **A** and scope power setting **B**, the measured view within the scope was a circular area of diameter **C**. The equivalent radius is **D**. Dividing Radius **D** by distance **A** resulted in a constant (**E**) for each scope setting power. With this constant, I was able to determine the radius, and thus the area of view within the scope, at any known distance.

Radius of View = Distance * Constant (**E**)

Area Field of View = π * Radius of View^2

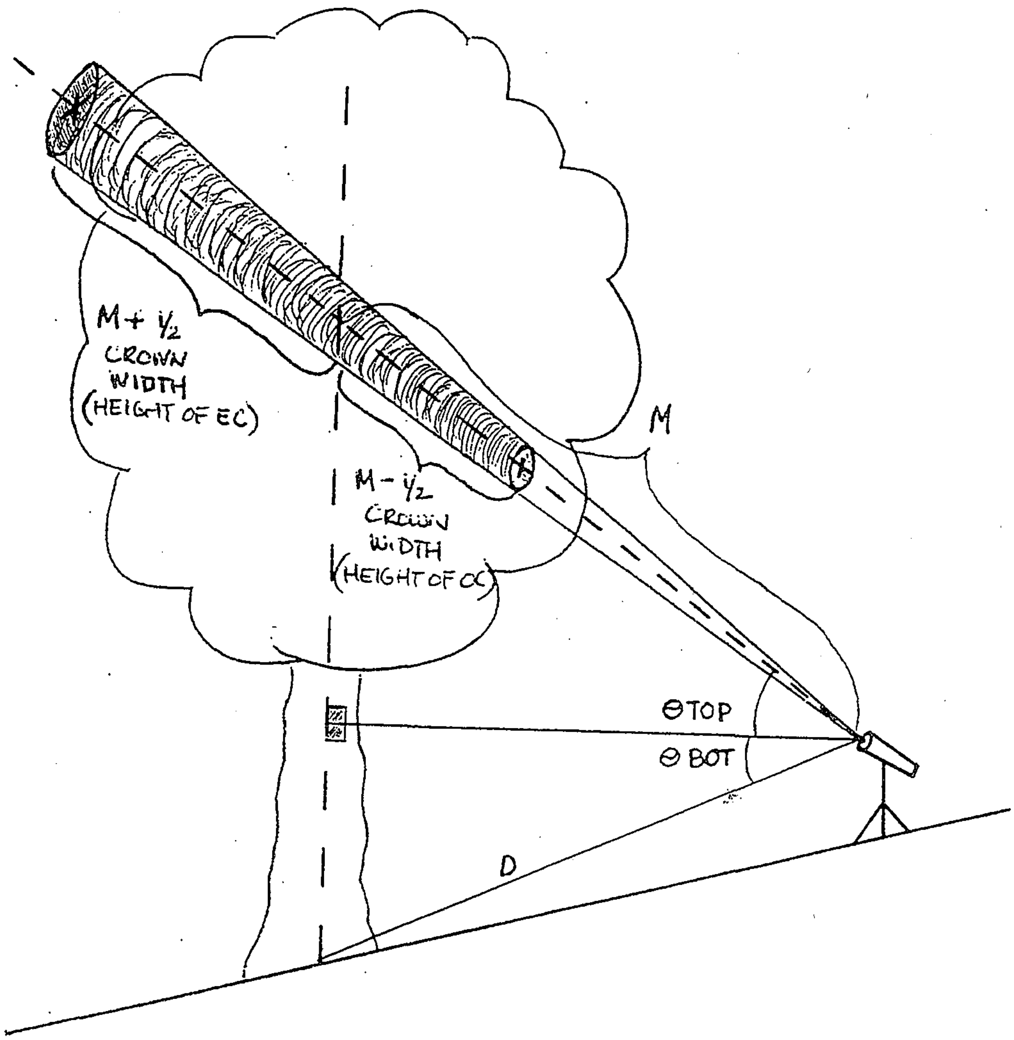

Figure 2. Measurement of sampled area of tree crown volume to estimate fruit production per m^3 of tree crown volume.

Fruits were counted from the top of the plant crown to the ground. Two 0.5 m^2 samples were taken at each patch. Additional samples were collected during vegetation sampling when patches of ripe fruits were encountered.

Gross Energetic Analysis

Fruits from each selected species were collected when ripe. For fruits with large, indigestible seeds (black cherry and blackgum) or hulls (hickories), I removed the seed or hull and analyzed only the fleshy part of the fruit. Species with minute seeds were left intact (huckleberries, blueberries, blackberries, grapes). One composite sample of each species was oven dried at 60 C until no weight change was detected. The weight of the entire sample was divided by the number of fruits in the sample to obtain the mean dry weight of an individual fruit of each species. Samples were then prepared for standard bomb calorimetry and tested for a caloric value per gram dry weight. Seeds have properties that do not allow high levels of precision; even fine ground material will contain particles of different sizes, resulting in variation during oxidation (Johnson and Robel 1968). A coefficient of variation of $\leq$ 2.5% over 4 bomb calorimetry tests was accepted by Johnson and Robel (1968). Golley (1961) accepted < 3% variation over 3 tests. I required a variation of < 3% over at least 2 tests. Bomb calorimetry results in accurate estimates of total energy content for each food species. The amount of energy available for bear use will be different, depending on the chemical composition of the food and its digestibility by black bears. Analyses determined gross energy rather than digestible energy. However, I used gross energy as an acceptable representation because of the

elimination of indigestible seeds and hulls prior to fruit weight and nutritional analyses for most food species. Trials to determine the digestibility of each food species by bears would require captive facilities and great expense.

Data Analysis

Caloric Production

I calculated mean caloric production per unit area by each food species based on: (1) the mean number of fruits produced per unit area, (2) mean dry weight of 1 fruit, and (3) the gross energetic content per g dry weight. Data from vegetation sampling (mean m^3 tree crown and mean m^2 of shrub coverage), caloric production values (mean number of calories produced per unit area for each species), and phenological observations were merged and analyzed with SAS/STAT users Guide Version 6 software (SAS Institute, Inc. Cary, NC, 1989) to determine the location, amount, and timing of caloric production by bear foods in the northwest quadrant of GSMNP during 1995.

For an individual species, the estimate of caloric production per unit area is total production during 1995. To represent the distribution of calories temporally, I pooled all phenological observations for a species. I assigned each week a portion of the total caloric production based on the percentage of the total number of "ripe" observations recorded for the species during that given week. For example, if a species had a total of 50 observations of "ripe", and 5 of those occurred in week 1, then week 1 received 10% of the total caloric production for that species. Dates used to separate seasonal periods

were based on previous black bear studies in GSMNP: spring (1 April - 15 June), summer (16 June - 15 September), fall (16 September - 15 December) (Beeman and Pelton 1980, Eagle and Pelton 1983, Garshelis 1978, Quigley 1982, Villarrubia 1982, Carr 1983, Garris 1983, van Manen 1994).

I used analyses of variance to compare caloric production per hectare among vegetation types, between mast types, and among seasons. Although sample points were located using a stratified sampling scheme, experimental design for analyses differed. Differences in mean production per hectare by vegetation type were analyzed using a completely randomized design where 275 plots were sampled for caloric production per hectare. Prior stratification resulted in approximately equal samples within all vegetation types even though percent of occupation of the study area differs among vegetation types. I tested the null hypothesis that mean caloric production per hectare did not differ among vegetation types ($\alpha = 0.05$). Differences in mean production per hectare between mast types and among seasons were analyzed using a completely random design with repeated measures where each of 275 plots were sampled for Cal/ha by soft mast and by hard mast, and during spring, summer, and fall seasons. This repeated measures design effectively blocked out the variation due to vegetation type. I tested the null hypotheses that mean caloric production per hectare did not differ between mast types ($\alpha = 0.05$) and among seasons ($\alpha = 0.05$). I used the mixed model procedure (SAS/STAT Software: Changes and enhancements through release 6.11, Cary, NC, 1996) to determine the least square means, levels of significance, and mean separations for the above analyses of variance.

I also made estimates of total caloric production on the study area for the entire year, and for each food species, vegetation type, season, and mast type. These estimates were made using the least square mean areas of coverage by each food species within each vegetation type in conjunction with the total hectares of occupation by each vegetation type. The analyses of variance tested for differences in caloric production per hectare, but I also used t-tests to check for differences in total caloric production by mast type and season on the study area as a whole.

Because 1995 included a mast failure by one group of oaks and a bumper crop by another species, I was able to simulate different scenarios of mast production by increasing or reducing the levels of production (Cal/m^3) by oak species to the optimal or minimal levels recorded in 1995. I estimated total annual, seasonal, and mast type production for 3 scenarios. To simulate a year of optimal mast production, the level of production by all oak species was set at 30.3 Cal/m^3, and hickory production was increased to half (15 Cal/m^3) of the optimal oak production. A year of hard mast failure was simulated by setting production by all oaks at the average of the levels recorded for the two lowest producers during 1995 (average = 1.6 Cal/m^3). Finally, a year of hard mast failure in conjunction with excellent soft mast production used the same hard mast failure and doubled productivity by soft mast species (with the exception of squawroot and thornless blackberry because they were believed to be producing optimally in 1995).

Relationships of Caloric Production with Bear Habitat Use

I used linear regression to determine the relationship between caloric production during 1995 and values of relative probability of habitat use (RPHU) as determined for bears in GSMNP by van Manen (1994). I used IDRISI GIS (IDRISI version 4.1, Clark Laboratories, Worcester, Mass.) to determine RPHU values at the locations of my plots (n = 240) for several models of bear habitat use. The spruce-fir plots were excluded from these analyses because the RPHU models did not include spruce-fir habitat (van Manen 1994). I regressed values of male annual, female annual, female spring, female summer, and female fall RPHU on each of 3 types of caloric measures: all calories, soft mast calories only, and hard mast calories only. Seasonal RPHU's were regressed with only those calories produced during that season on each plot. For determination of sexual habitat segregation, I compared the strength of regressions between male and female bears.

IV. RESULTS

Distribution and Abundance of Food Species

Bear foods occurred in differing numbers of vegetation types and at differing levels of abundance (Table 6). Hard mast trees occurred in 8 of 9 vegetation types and accounted for 96% of the tree crown volume, whereas soft mast trees occurred in only 5 of 9 vegetation types and accounted for 4% of the tree crown volume. Oaks occurred in 8 of 9 vegetation types and accounted for 86% of the tree crown volume. White oaks were found in fewer vegetation types than red oaks, yet white oaks accounted for more of the crown volume than did red oaks. Black cherry occurred in only 3 vegetation types. blueberries, greenbriers, and huckleberries each occurred in at least 7 of the 9 vegetation types whereas blackberries, grapes, and squawroot occurred in relatively few vegetation types. Huckleberries accounted for 58.1% of the measured area of shrub coverage, and were the most abundant shrub in 7 of the 9 vegetation types. The area of coverage by blueberries was < 1/7th of the coverage by huckleberries

The species composition and least square mean areas of coverage or volumes of crown per hectare differed greatly between vegetation types (Tables 7 and 8). To confirm accuracy of vegetation sampling, each vegetation type was compared to the estimates of basal area sampled by MacKenzie (1993). Measures were similar in the ranking of species within a vegetation type; most species that I did not find in a vegetation type occurred at low levels of basal area during sampling by MacKenzie (1993) (Appendix A). Seven of 9

Table 6. Total unit areas of coverage measured on all vegetation plots and percentage of measured coverage for bear food producing plants in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Species or Group	Number of Vegetation Types Present in	Total m^3 of Coverage	% of Measured Volume
Chestnut oak	7	60,704	37.4
N. red oak	8	53,874	33.2
Hickories	6	16,312	10.0
White oak	6	15,316	9.4
Scarlet oak	4	9,815	6.0
Black cherry	3	4,406	2.7
Blackgum	2	1,534	0.9
Fire cherry	2	496	0.3
Oaks	8	139,709	86.0
White oaks	7	76,020	46.8
Red oaks	8	63,689	39.2
Hard mast trees	8	162,786	96.0
Soft mast trees	5	6,436	4.0
		Total m^2 of Coverage	% of Measured Area
Huckleberries	7	11,102	58.1
Thornless blackberry	3	2,626	13.7
Greenbriers	8	2,445	12.9
Blueberries (all Vaccinium spp.)	8	1,719	9.1
Upland low blueberry	5	964	5.1
Grapes	4	648	3.4
Allegheny blackberry	2	558	2.9
Hairy blueberry	1	279	1.5
Deerberry	4	233	1.2
N. highbush blueberry	4	175	0.9
Squawroot	4	101	0.5
S. mountain cranberry	1	68	0.4

Table 7. Shrub coverage (m^2/ha) for bear food producing shrubs within 9 vegetation types in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Overstory Vegetation	Shrub Species	Least Square Mean (m^2/ha)	SD
Spruce-fir	Thornless blackberry	1,880	± 2,531
	S. mountain cranberry	68	± 270
	N. highbush blueberry	54	± 296
Northern Hardwood	Thornless blackberry	743	± 1,914
	Allegheny blackberry	358	± 1,187
	N. highbush blueberry	100	± 326
	Greenbriers	4	± 23
Cove Hardwood	Huckleberries	1,028	± 2,466
	Greenbriers	332	± 805
	Grapes	168	± 551
	Squawroot	88	± 259
	N. highbush blueberry	17	± 63
	Upland low blueberry	10	± 55
	Deerberry	4	± 23
Mesic Oak	Huckleberries	1,383	± 2,634
	Allegheny blackberry	200	± 779
	Greenbriers	312	± 523
	Thornless blackberry	3	± 18
	Upland low blueberry	1	± 5
Mixed Mesic Hardwood	Huckleberries	2,385	± 3,351
	Greenbriers	461	± 1,144
	Grapes	197	± 754
	Deerberry	4	± 23
	Squawroot	6	± 24
Tulip-Poplar	Huckleberries	339	± 904
	Greenbriers	323	± 613
	Grapes	275	± 1,194
	Squawroot	4	± 23
Xeric Oak	Huckleberries	1,587	± 2,337
	Upland low blueberry	566	± 1,372
	Greenbriers	385	± 450
	Deerberry	96	± 247
	N. highbush blueberry	4	± 22
Pine-Oak	Huckleberries	2,946	± 3,500
	Hairy blueberry	279	± 1,064
	Greenbriers	235	± 347
	Upland low blueberry	225	± 855
	Deerberry	129	± 418
Pine	Huckleberries	1,434	± 2,244
	Greenbriers	403	± 1,075
	Upland low blueberry	162	± 464
	Grapes	8	± 44
	Squawroot	3	± 15

Table 8. Tree crown volume (m^3/ha) for bear food producing trees in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Overstory Vegetation	Tree Species	Least Square Mean (m^3/ha)	SD
Spruce-fir	Fire cherry	449	± 1,958
Northern Hardwood	American beech	6,066	± 2,634
	Black cherry	1,704	± 631
	N. red oak	1,417	± 7,759
	Fire cherry	47	± 255
Cove Hardwood	N. red oak	14,325	±30,669
	Chestnut oak	5,563	± 5,881
	Hickories	2,048	± 7,916
	White oak	1,598	± 4,387
	Scarlet oak	1,085	± 3,675
Mesic Oak	N. red oak	9,903	±12,087
	Chestnut oak	3,536	±15,143
	Black cherry	2,173	±11,904
	White oak	2,118	± 8,429
	American beech	699	± 2,352
Mixed Mesic Hardwood	N. red oak	11,753	±17,390
	Hickories	7,984	±27,480
	Chestnut oak	7,534	±12,911
	White oak	6,523	±26,509
Tulip-Poplar	Chestnut oak	5,850	±18,713
	N. red oak	3,519	± 8,118
	Hickories	219	± 1,200
Xeric Oak	Chestnut oak	19,645	±17,402
	N. red oak	4,295	± 8,856
	Scarlet oak	3,207	± 5,940
	White oak	1,646	± 5,450
	Hickories	1,620	± 2,420
	Blackgum	809	± 2,943
Pine-Oak	Chestnut oak	14,210	±11,371
	N. red oak	3,773	± 6,329
	Scarlet oak	2,468	± 2,383
	Hickories	1,107	± 5,084
	White oak	1,066	± 2,364
Pine	N. red oak	4,889	±10,982
	Chestnut oak	4,366	±13,817
	Hickories	3,334	± 7,715
	Scarlet oak	3,055	±10,378
	White oak	2,365	± 3,565
	Blackgum	725	± 1,806
	Black cherry	529	± 2,992

vegetation types had 4-5 shrub species present; cove hardwood had the greatest diversity of shrub species and spruce-fir had the lowest number of shrub species (Figure 3). The number of tree species present in the 9 vegetation types varied more than the number of shrubs, and only 5 of 9 vegetation types had 4-5 tree species present. The greatest diversity of tree species occurred in pine and xeric oak whereas the least diversity was found in tulip-poplar and spruce-fir. Vegetation types also differed in total volumes of oak crown and cubic meters of volume due to white oaks and red oaks (Figure 4).

Phenology

Peak flowering by trees occurred during the last 2 weeks of April (Appendix B); peak flowering by red oaks and white oaks occurred the last week of April, whereas black cherry peaked one week earlier. Greater than 25% of the black cherry trees flowered for a period of 6 weeks; this occurred for 4 weeks by northern red oak, and less for the remaining oak species. Shrubs tended to flower for longer periods than trees (most shrubs > 5 weeks with > 25% flowering). (Note: When shrubs were both flowering and ripe, data were recorded as ripe because the emphasis of this study was fruit availability. Although many shrubs had a few flowers present even when the majority of fruits were ripe, this information was not included in the flowering periods. Thus, flowering periods for shrubs were generally longer than reported.)

Shrub fruits were ripe earlier (summer and early fall) than tree fruits (fall) (Appendix B, Figures B1 - B20). Squawroot was in peak production (period of > 50% of

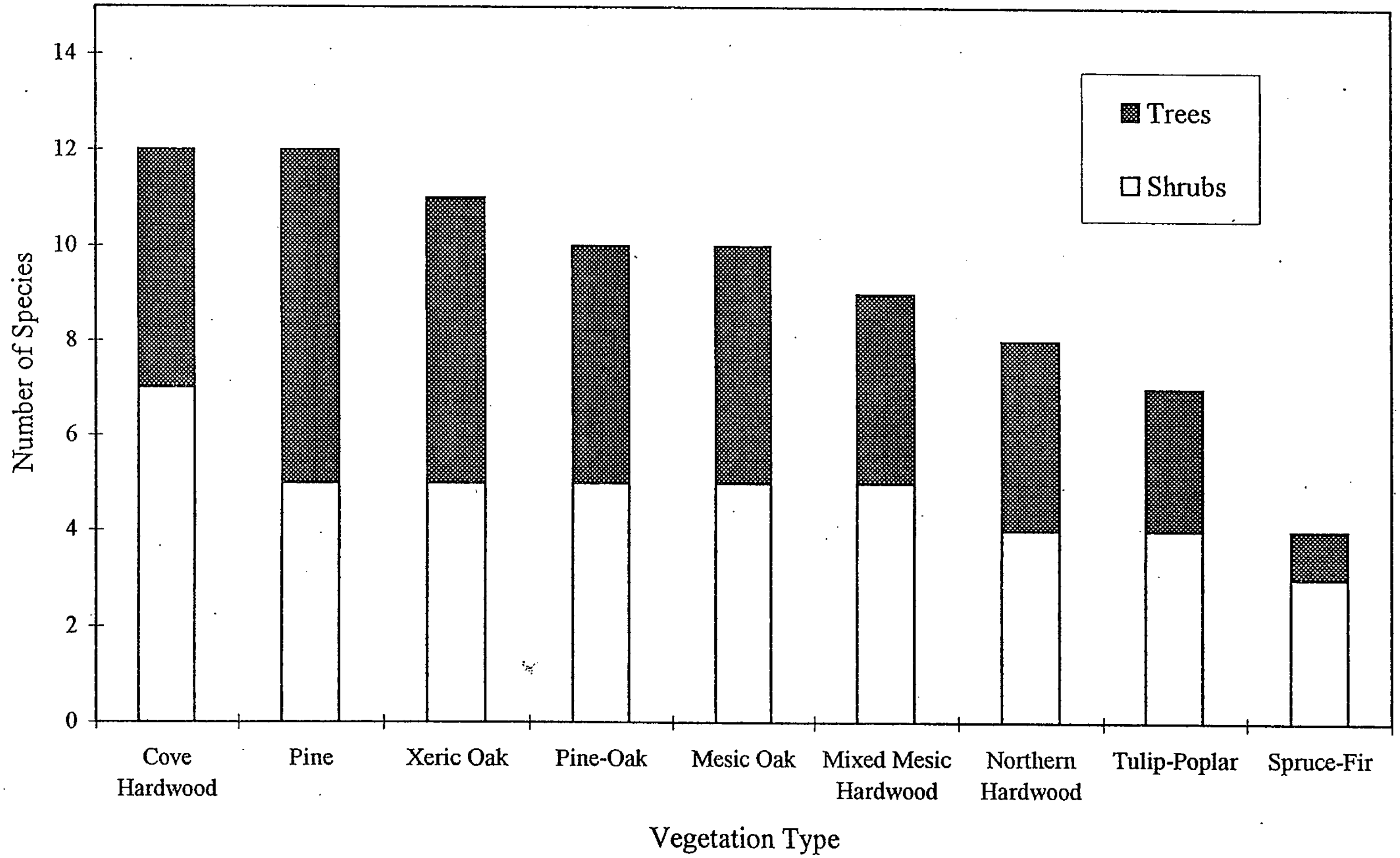

Figure 3. Diversity of bear foods found within 9 vegetation types of Great Smoky Mountains National Park, 1995

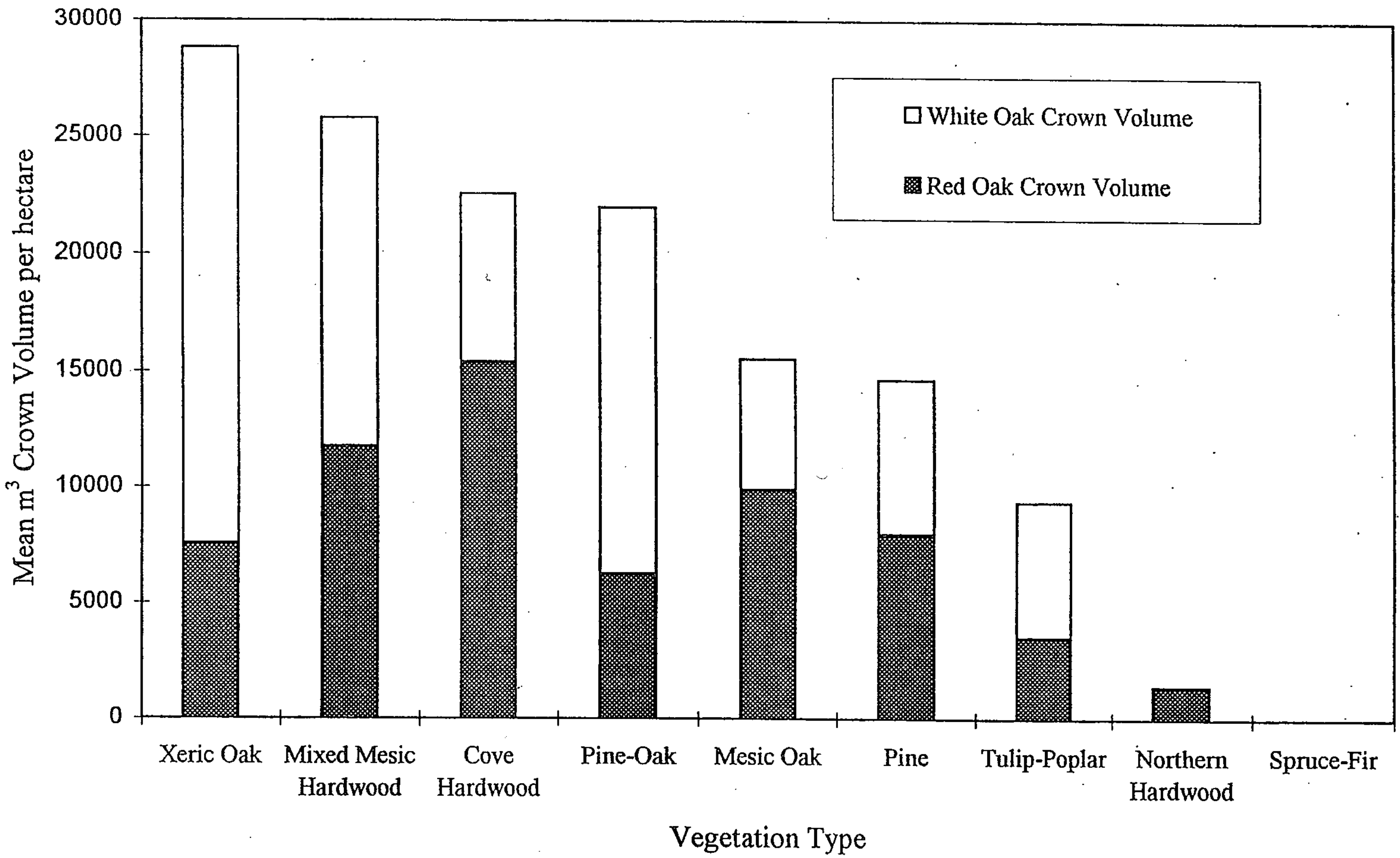

Figure 4. Mean red and white oak crown volume (m^3) per hectare of vegetation types in the northwest quadrant of Great Smoky Mountains National Park, 1995

individuals with ripe fruits) for 6 weeks (May 22 - July 2). Peak production by blueberries was earlier than huckleberries (July vs. July and August respectively) with the exception of southern mountain cranberry (*V. erythrocarpum*), which peaked during September. Black cherry was in peak production from late August through early October. Oaks were ripe from late August through late December, at which time sampling was halted. The highest periods of production were the last week of September for red oaks and early October for white oaks. Peak oak production was during early October.

Fruit Crop Productivity

The number of tree fruits produced per m^3 of crown volume ranged from 80.2 (black cherry) to 0.14 (chestnut oak) (Table 9). Fruit production by red oaks was 8 times greater than that by white oaks. Shrub fruits produced per m^2 ranged from 109.5 (huckleberries) to 21.5 (greenbriers) (Table 9). The standard deviations from fruit sampling were high although sample sizes were often large.

Mean dry weight of single fruits was calculated for each species (Table 10). Most fruits weighed less than 0.1 gram. Squawroot (9.23 g) was 3 times heavier than the largest acorn and 355 times heavier than a huckleberry (for squawroot, the entire plant, stem and capsules, was considered to be 1 fruit). Sizes of acorns were typical with the exception of white oak which was less than 1/2 "normal" size (personal observations). White oak acorns were equivalent in weight to the typical scarlet oak acorn. Acorns were 4 - 115 times heavier than soft mast fruits.

Table 9. Fruits per area or volume of coverage for black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Food Species	Mast Type[a]	Fruits/m^2	Fruits/m^3	SD	*n*
Black cherry	S	.	80.17	± 115.0	90
Fire cherry	S	.	21.64	± 46.6	48
N. red oak	H	.	2.97	± 5.1	84
Blackgum	S	.	2.76	± 16.9	78
Scarlet oak	H	.	2.69	± 5.5	86
White oak	H	.	0.59	± 1.3	80
Hickories	H	.	0.20	± 1.5	78
Chestnut oak	H	.	0.14	± 0.4	92
Huckleberries	S	109.54	.	± 105.8	78
Upland low blueberry	S	106.96	.	± 155.7	50
S. mountain cranberry	S	74.71	.	± 119.6	102
N. highbush blueberry	S	70.00	.	± 38.7	4
Thornless blackberry	S	67.96	.	± 72.1	90
Grapes	S	66.36	.	± 62.1	14
Squawroot	S	57.33	.	± 38.5	6
Allegheny blackberry	S	32.77	.	± 65.6	26
Hairy blueberry	S	28.50	.	± 31.5	8
Deerberry	S	25.50	.	± 40.3	8
Greenbriers	S	21.50	.	± 80.7	50

[a] H - Hard Mast
S - Soft Mast

Table 10. Mean dry weight of 1 fruit for black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Food Species	**Mast Type**[a]	**Sample Type**	**Mean Dry Weight of 1 Fruit (grams)**	**n**
Squawroot	S	whole stalk	9.231	8
Chestnut oak	H	whole fruit	2.992	57
N. red oak	H	whole fruit	2.220	35
White oak	H	whole fruit	0.668	33
Scarlet oak	H	whole fruit	0.667	30
American beech	H	outer husk removed	0.174	80
Thornless blackberry	S	whole fruit	0.166	160
Hickories	H	meat only	0.151	50
Greenbriers	S	whole fruit	0.095	178
Grapes	S	whole fruit	0.093	245
Blackgum	S	seed removed	0.082	142
Alleghey blackberry	S	whole fruit	0.062	11
N. highbush blueberry	S	whole fruit	0.057	218
Hairy blueberry	S	whole fruit	0.052	5
Fire cherry	S	whole fruit	0.042	66
Black cherry	S	seed removed	0.041	100
Deerberry	S	whole fruit	0.039	389
S. mountain cranberry	S	whole fruit	0.038	57
Upland low blueberry	S	whole fruit	0.029	662
Huckleberries	S	whole fruit	0.026	83

[a] H - Hard Mast
S - Soft Mast

Gross Energetic Analysis

Calories per gram of dry fruit weight ranged from 5.27 Cal/g (thornless blackberry) to 3.44 Cal/g (hairy blueberry) (Table 11). The 8 highest values were soft mast species; hard mast species ranked relatively low with all falling in the bottom 2/3 of the group. However, there was not a significant difference in the Cal/gram dry weight of soft mast species and hard mast species ($Z = -0.618$, $P = 0.536$, $n = 20$).

Caloric Production per Square Meter and Cubic Meter

Mean calories per single fruit ranged from 43.0 Cal (squawroot) to 0.1 Cal (huckleberries) with the high values generally for hard mast species (Table 12). Individual fruits of most species (15 of 20) had less than 1 calorie per fruit. All oak species had > 2.5 calories per individual fruit.

Caloric production by tree species ranged from 30.3 Cal/m^3 (northern red oak) to 0.1 Cal/m^3 (hickories) (Table 13). A soft mast species (black cherry) ranked second among tree species while both species of the white oak group were in the bottom 1/2 of the tree species. Black cherry produced 7.5 - 8 times more calories per unit area of tree crown than did white oaks. Caloric production by shrub species (excluding squawroot) ranged from 59.5 Cal/m^2 (thornless blackberry) to 4.1 Cal/m^2 (deerberry). Production by squawroot was almost 50 times greater than the next highest shrub producer and 80 times greater than the highest tree producer. Thornless blackberry and grapes produced a high number of calories per m^2 relative to the other shrub species.

Table 11. Calories per gram (dry weight basis) of black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Food Species	Mast Type[a]	Sample Type	Cal/g	SD
Thornless blackberry	S	whole fruit	5.271	±0.01
Blackgum	S	seed removed	4.982	±0.01
Fire cherry	S	whole fruit	4.941	±0.09
Grapes	S	whole fruit	4.901	±0.01
Squawroot	S	whole fruit	4.662	±0.03
Allegheny blackberry	S	whole fruit	4.657	±0.04
Huckleberries	S	whole fruit	4.647	±0.07
American beech	H	outer husk removed	4.609	±0.04
N. red oak	H	whole fruit	4.541	±0.00
Hickories	H	meat only	4.534	±0.01
Greenbriers	S	whole fruit	4.444	±0.04
Scarlet oak	H	whole fruit	4.259	±0.07
Upland low blueberry	S	whole fruit	4.241	±0.00
Chestnut oak	H	whole fruit	4.188	±0.07
N. highbush blueberry	S	whole fruit	4.177	±0.03
S. mountain cranberry	S	whole fruit	4.170	±0.07
Deerberry	S	whole fruit	4.167	±0.06
White oak	H	whole fruit	4.054	±0.07
Black cherry	S	seed removed	3.953	±0.01
Hairy blueberry	S	whole fruit	3.435	

[a] H - Hard Mast
S - Soft Mast

See appendix D for a list of reported Cal/g for these species in the literature.

Table 12. Mean calories per fruit (dry weight basis) of black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Food Species	Mast Type[a]	Mean Cal / 1 fruit
Squawroot	S	43.03
Chestnut oak	H	12.53
N. red oak	H	10.20
Scarlet oak	H	2.84
White oak	H	2.71
Thornless blackberry	S	0.87
American beech	H	0.80
Hickories	H	0.68
Grapes	S	0.46
Greenbriers	S	0.42
Blackgum	S	0.41
Allegheny blackberry	S	0.29
N. highbush blueberry	S	0.24
Fire cherry	S	0.21
Hairy blueberry	S	0.18
Black cherry	S	0.16
Deerberry	S	0.16
S. mountain cranberry	S	0.16
Upland low blueberry	S	0.12
Huckleberries	S	0.12

[a] H - Hard Mast
S - Soft Mast

Table 13. Calories produced per area and volume of coverage by black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Food Species	Mast Type[a]	Cal/m^2	Cal/m^3
N. red oak	H	.	30.3268
Black cherry	S	.	12.9924
Scarlet oak	H	.	7.6331
Fire cherry	S	.	4.4908
Chestnut oak	H	.	1.7303
White oak	H	.	1.5886
Blackgum	S	.	1.1273
Hickories	H	.	0.1381
Squawroot	S	2,467.3341	.
Thornless blackberry	S	59.4602	.
Grapes	S	30.2455	.
N. highbush blueberry	S	16.6642	.
Huckleberries	S	13.2332	.
Upland low blueberry	S	13.1534	.
S. mountain cranberry	S	11.8365	.
Allegheny blackberry	S	9.4606	.
Greenbriers	S	9.0769	.
Hairy blueberry	S	5.0907	.
Deerberry	S	4.1436	.

[a] H - Hard Mast
S - Soft Mast

Assuming the mean height of the shrub layer was 1 meter (2 meters for blackberries), shrub and tree total production can be compared on a cubic meter basis. Under this assumption, mean production by soft mast species was 12.0 Cal/m^3 (excluding squawroot) and by hard mast species was 8.3 Cal/m^3; hard mast species occupy only the 2nd, 11th, 16th, 17th, and 19th ranks of caloric production per cubic meter out of 19 species (Table 14). However, data were not normally distributed and I did not find a significant difference between the Cal/m^3 production by soft mast and hard mast species ($P < 0.1260$) using a log transformation. Soft mast accounted for 13.4% of the measured plant volume per hectare whereas hard mast accounted for 86.6% (Table 15).

Caloric Productivity

The study area produced 21.5 billion Cal (SE = 3.0 billion Cal) during 1995. Mean calories produced annually per hectare was 351,209 Cal/ha (SE = 49,834).

Caloric production (per hectare) differed among seasons ($F = 284.92$, df = 2, $P = 0.0001$). Calories (least square mean) produced per hectare were greatest during fall (x = 167,600 Cal/ha, SD = 455,525, n = 275) and lowest during spring (x = 22,300 Cal/ha, SD = 164,950 Cal/ha, n = 275). Summer production was intermediate (x = 89,850 Cal/ha, SD = 168,200 Cal/ha, n = 275). Summer and fall production (per hectare) did not differ, whereas spring production (per hectare) differed from both summer and fall (Table 16). Estimates of production over the entire study area indicated that the fall season produced 59.3% of the calories, summer produced 28.2%, and spring produced 12.5% (Table 17).

Table 14. Estimated calories produced per m^3 of coverage by black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Food Species	**Mast Type**[a]	**Estimated Cal/m^3**
N. red oak	H	30.3268
Grapes	S	30.2455
Thornless blackberry	S	29.7301
N. highbush blueberry	S	16.6642
Huckleberries	S	13.2332
Upland low blueberry	S	13.1534
Black cherry	S	12.9924
S. mountain cranberry	S	11.8365
Greenbriers	S	9.0769
Scarlet oak	H	7.6331
Hairy blueberry	S	5.0907
Allegheny blackberry	S	4.7303
Fire cherry	S	4.4908
Deerberry	S	4.1436
Chestnut oak	H	1.7303
White oak	H	1.5886
Blackgum	S	1.1273
Hickories	H	0.1381
Squawroot [b]	S	2,467.3341

[a] H - Hard Mast
S - Soft Mast

[b] Squawroot was not included in the comparison

Table 15. Percent of measured volumes of coverage for soft and hard mast bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Species	**m^2 Coverage**	**m^3 Coverage**	**% of Total m^3**
Huckleberries	11,102	11,102	6.2
Black cherry	.	4,406	2.4
Greenbriers	2,445	2,445	1.4
Blackgum	.	1,534	0.9
Thornless blackberry	2,626	1,313	0.7
Upland low blueberry	964	964	0.5
Grapes	648	648	0.4
Fire cherry	.	496	0.3
Allegheny blackberry	558	279	0.2
Hairy blueberry	279	279	0.2
Deerberry	233	233	0.1
N. highbush blueberry	175	175	0.1
Squawroot	101	101	0.1
S. mountain cranberry	68	68	0.0
Total Soft Mast		**24,043**	**13.4**
Chestnut oak	.	60,704	33.7
N. red oak	.	53,874	29.9
Hickories	.	16,312	9.1
White oak	.	15,316	8.5
Scarlet oak	.	9,815	5.5
Total Hard Mast		**156,021**	**86.6**
Total All		**180,064**	**100**

Table 16. Seasonal least square mean caloric production per hectare by bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Season[a]	LS Mean Cal/ha	SD	n	MS Groups[b]
Spring	22,300	164,950	275	A
Summer	89,850	168,200	275	B
Fall	167,600	455,525	275	B

[a] Spring (1 April - 15 June)
Summer (16 June - 15 September)
Fall (16 September - 15 December)

[b] Groups that are not statistically different share a common letter

Table 17. Total seasonal calories produced by bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Season[a]	Calories	% of Area Production	SE[b c]
Spring	2,682,006,255	12.5 %	± 1,343,241,754
Summer	6,078,994,704	28.2 %	± 1,343,241,754
Fall	12,775,132,113	59.3 %	± 1,343,241,754
Total	21,536,133,072	100 %	

[a] Spring (1 April - 15 June)
Summer (16 June - 15 September)
Fall (16 September - 15 December)

[b] Least square means result in pooled standard deviations and thus equal standard errors

[c] df = 798

Total caloric production during summer and fall was not different ($t = 0.14$, df = 798, $Pr > |t| = 0.8896$). However, 63% of the calories produced during summer were hard mast and less than 5% of the fall calories were produced by soft mast (Table 18). Total production during spring was less than summer ($t = -9.21$, df = 798, $Pr > |t| = 0.0001$) and less than fall ($t = -9.07$, df = 798, $Pr > |t| = 0.0001$). Examination of the total calories produced per week in the northwest quadrant of GSMNP revealed a period of relatively low caloric production during mid-summer (3 July - 14 August; dates designated as summer during previous studies resulted in the inclusion of many hard mast calories during the summer period; mid-summer is referred to here as the period before hard mast was first produced and after squawroot waned) (Figure 5).

Caloric production per hectare also differed between mast types ($F = 32.16$, df = 1, $P = 0.0001$). Calories (least square mean) produced per hectare were greater for hard mast (x = 204,475 Cal/ha, SD = 592,775 Cal/ha, n = 275) than for soft mast (x = 75,275 Cal/ha, SD = 74,550 Cal/ha, n = 275). Although production (per hectare) by mast types differed (Table 19), the variance about the means was less for soft mast, indicating a less patchy distribution. Estimates of total caloric production in the study area found that hard mast produced 74.5% of the calories, and soft mast produced 25.5% (Table 20). Total production by soft and hard mast differed ($t = -2.79$, df = 532, $Pr > |t| = 0.0054$).

Caloric production per hectare also differed among vegetation types ($F = 3.36$, df = 8, $P = 0.0011$). The mean number of calories produced annually (per hectare) by vegetation type separated the 9 types into 2 groups. Cove hardwood was the most

Table 18. Total calories produced by season and mast type by bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Season[a]	Mast Type[b]	Calories	% of Total	SE[c]
Spring	Soft	2,682,006,255	12.5%	± 947,155,511
Spring	Hard	0	0.0%	± 946,797,877
Summer	Soft	2,271,507,155	10.5%	± 947,155,511
Summer	Hard	3,807,487,549	17.7%	± 946,797,877
Fall	Soft	532,212,939	2.5%	± 947,155,511
Fall	Hard	12,242,919,173	56.8%	± 946,797,877
Total		21,536,133,072	100%	

[a] Spring (1 April - 15 June)
Summer (16 June - 15 September)
Fall (16 September - 15 December)

[b] Hard mast: Hickories, chestnut oak, n. red oak, scarlet oak, white oak

Soft mast: Squawroot, huckleberries, Allegheny blackberry, thornless blackberry, greenbriers, n. highbush blueberry, s. mountain cranberry, hairy blueberry, upland low blueberry, deerberry, blackgum, fire cherry, black cherry, grapes.

[c] Least square means result in pooled standard deviations and thus equal standard errors, however the absence of hard mast calories during spring results in an unbalanced design

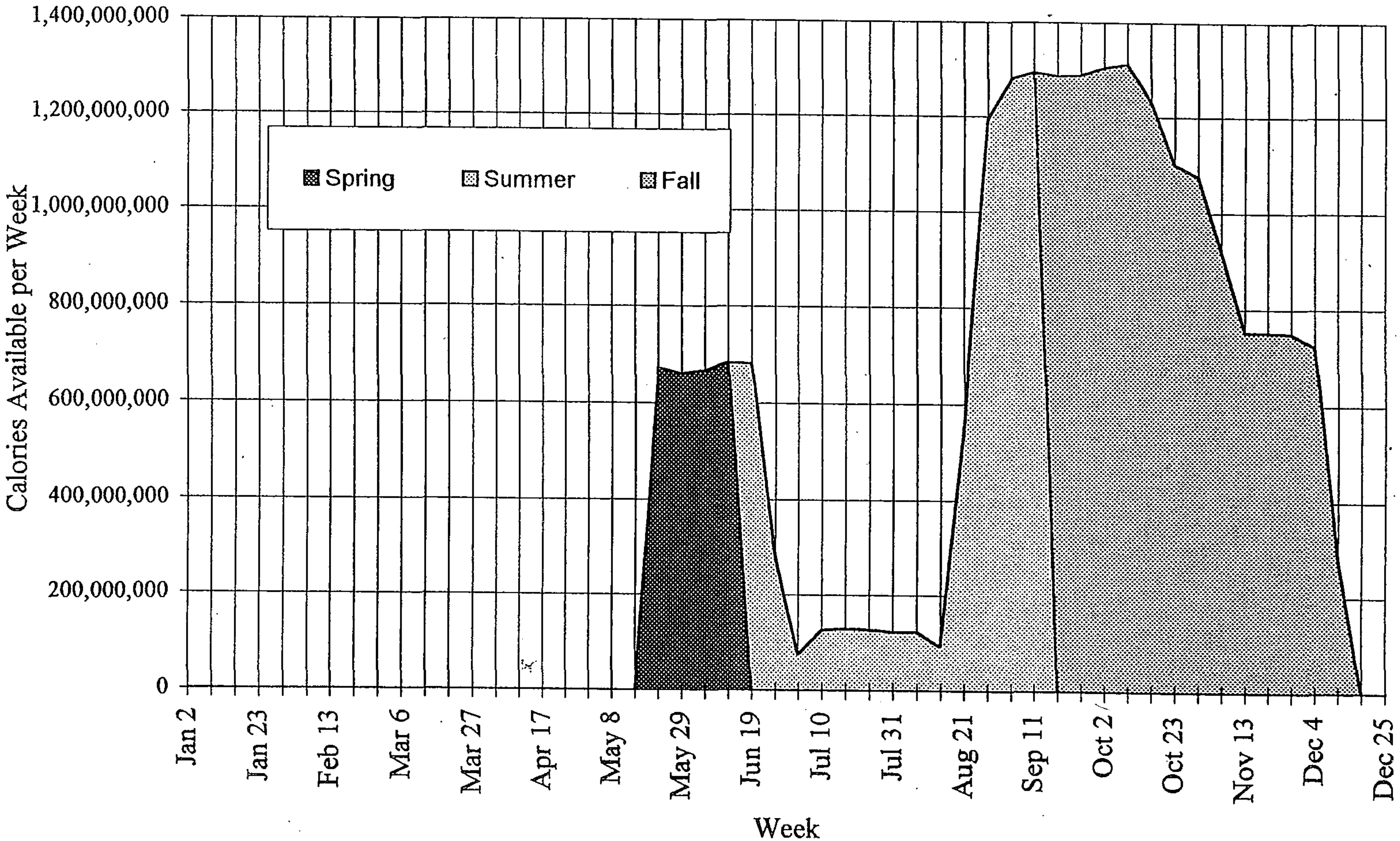

Figure 5. Total calories available per week by black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Table 19. Mast type least square mean caloric production per hectare by bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Mast Type[a]	LS Mean Cal/ha	SD	n	MS Groups[b]
Hard Mast	204,475	592,775	275	A
Soft Mast	75,275	74,550	275	B

[a] Hard mast: Hickories, chestnut oak, n. red oak, scarlet oak, white oak

Soft mast: Squawroot, huckleberries, Allegheny blackberry, thornless blackberry, greenbriers, n. highbush blueberry, s. mountain cranberry, hairy blueberry, upland low blueberry, deerberry, blackgum, fire cherry, black cherry, grapes.

[b] Groups that are not statistically different share a common letter

Table 20. Total mast type calories produced by bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995

Mast Type[a]	Calories	% of Area Production	SE
Hard Mast	16,050,406,722	74.5 %	± 2,044,014,423
Soft Mast	5,485,726,350	25.5 %	± 2,044,786,507
Total	21,536,133,072	100 %	

[a] Hard mast: Hickories, chestnut oak, n. red oak, scarlet oak, white oak

Soft mast: Squawroot, huckleberries, Allegheny blackberry, thornless blackberry, greenbriers, n. highbush blueberry, s. mountain cranberry, hairy blueberry, upland low blueberry, deerberry, blackgum, fire cherry, black cherry, grapes.

productive vegetation type and was significantly different from all vegetation types except mixed mesic hardwood and mesic oak (Table 21). Although cove hardwood occupied only 24% of the study area, it produced 47% of the calories. The ratio of percentage of caloric production : percentage of area occupied was > 1 for Cove hardwood and Mixed mesic hardwood only (Table 22). Caloric production by vegetation type and season revealed that fall vegetation types had the greatest production followed by summer and spring vegetation types; only 5 of 27 combinations of vegetation type and season differed from this trend (Table 23). Caloric production by cove hardwood during spring and summer was greater than 6 of the 9 fall combinations. Mean fall productions by tulip-poplar, northern hardwood, and spruce-fir were below several summer productions. Hard mast production within each vegetation type generally ranked higher than soft mast production; of 18 combinations, only the high soft mast production within cove hardwood and the low hard mast production within northern hardwood and spruce-fir do not fit this trend (Table 24). Large variation in the number of calories on each vegetation plot created large standard deviations.

Northern red oak produced 65.7% of annual bear food calories; squawroot ranked second, producing 15.8%; these 2 species accounted for 81.5% of the caloric production during 1995 (Table 25). The remaining oak species (chestnut oak, scarlet oak, and white oak) accounted for a combined 8.8%. Although white oaks accounted for 46.8% of tree crown volume, they produced only 6.7% of the calories available from trees. Red oaks accounted for 39.2% of the measured tree crown volume and produced 91.7% of tree calories. White oak (*Quercus alba*) produced < 1% of available calories and hickories

Table 21. Least square mean calories produced annually per hectare by bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Vegetation Type	**LS Mean Annual Production Cal/ha**	**SD**	**n**	**MS Group**[a]
Cove Hardwood	693,188	1,407,493	30	A
Mixed Mesic Hardwood	437,028	841,940	30	AB
Mesic Oak	361,267	822,566	30	AB
Xeric Oak	224,866	465,833	33	B
Pine	222,803	383,989	32	B
Oak-Pine	205,733	258,215	30	B
Tulip-Poplar	142,899	312,701	30	B
Spruce-Fir	115,514	149,797	30	B
Northern Hardwood	114,549	291,643	30	B

[a] Groups that are not statistically different share a common letter.

Table 22. Ratio of percentage of caloric production by vegetation type to percentage of area occupied by vegetation type in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Vegetation Type	**% of Area**	**% of Caloric Production**	**% Caloric Production / % of Area**
Cove Hardwood	24 %	47.4 %	1.97
Mixed Mesic Hardwood	13 %	16.3 %	1.25
Mesic Oak	3 %	3.0 %	.99
Pine	22 %	13.9 %	.63
Xeric Oak	22 %	13.8 %	.63
Oak-Pine	3 %	1.5 %	.49
Tulip-Poplar	5 %	2.0 %	.40
Spruce-Fir	1 %	0.4 %	.37
Northern Hardwood	6 %	1.8 %	.29

Table 23. Season and vegetation type least square mean calories produced per hectare by bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Vegetation Type	Season[a]	LS Mean Production Cal/ha	SD	MS Group[b]
Cove Hardwood	Fall	356,250	851,625	E
Mixed Mesic Hardwood	Fall	301,550	611,475	C E
Mesic Oak	Fall	260,025	631,925	BC E
Cove Hardwood	Summer	173,875	334,875	ABC
Cove Hardwood	Spring	163,075	478,465	ABCD
Pine	Fall	148,825	297,025	AB D H
Xeric Oak	Fall	148,575	355,125	AB D I
Oak-Pine	Fall	123,900	182,150	AB D G
Mixed Mesic Hardwood	Summer	122,100	197,650	AB D F
Mesic Oak	Summer	99,700	192,950	A D F
Spruce-Fir	Summer	99,025	128,750	A D F
Tulip-Poplar	Fall	98,825	207,125	A D F
Oak-Pine	Summer	77,925	81,825	A D F
Xeric Oak	Summer	72,800	112,900	A D F
Pine	Summer	66,850	91,475	A D F
Northern Hardwood	Summer	60,375	115,350	A D F
Northern Hardwood	Fall	54,100	207,825	A D F
Tulip-Poplar	Summer	36,000	75,950	A D F
Spruce-Fir	Fall	16,500	21,100	D F
Mixed Mesic Hardwood	Spring	13,400	44,450	FGHI
Tulip-Poplar	Spring	8,075	42,300	FGHI
Pine	Spring	7,125	28,375	FG I
Oak-Pine	Spring	3,900	4,425	F H
Xeric Oak	Spring	3,500	4,425	FG
Mesic Oak	Spring	1,550	2,850	FG
Northern Hardwood	Spring	50	175	FG
Spruce-Fir	Spring	0	0	FG

[a] Spring (1 April - 15 June)
Summer (16 June - 15 September)
Fall (16 September - 15 December)

[b] Groups that are not statistically different share a common letter.

Table 24. Mast type and vegetation type least square mean calories produced per hectare by bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Vegetation Type	Mast Type[a]	LS Mean Production Cal/ha	SD	MS Group[b]
Cove Hardwood	Hard	455,150	1,110,550	A
Mixed Mesic Hardwood	Hard	380,925	799,550	AB
Mesic Oak	Hard	309,800	820,650	AB D
Cove Hardwood	Soft	238,025	634,025	BC
Xeric Oak	Hard	191,550	462,175	BC E
Pine	Hard	183,375	390,875	BC E
Oak-Pine	Hard	159,700	238,000	BC E
Tulip-Poplar	Hard	116,875	270,825	CDE
Spruce-Fir	Soft	115,525	149,800	CDE
Northern Hardwood	Soft	71,575	138,400	C E
Mixed Mesic Hardwood	Soft	56,100	67,225	C E
Mesic Oak	Soft	51,475	154,500	C E
Oak-Pine	Soft	46,025	47,450	C E
Northern Hardwood	Hard	42,975	235,325	C E
Pine	Soft	39,450	56,000	C E
Xeric Oak	Soft	33,325	33,100	C E
Tulip-Poplar	Soft	26,025	68,450	C E
Spruce-Fir	Hard	0	0	E

[a] Hard mast: Hickories, chestnut oak, n. red oak, scarlet oak, white oak

Soft mast: Squawroot, huckleberries, Allegheny blackberry, thornless blackberry, greenbriers, n. highbush blueberry, s. mountain cranberry, hairy blueberry, upland low blueberry, deerberry, blackgum, fire cherry, black cherry, grapes.

[b] Groups that are not statistically different share a common letter.

Table 25. Estimates of total calories produced, percentage of study area production, and caloric production per hectare for black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Species	Mast Type	Total Calories	% of Area Production	SE	Cal/ha	SD
N. red oak	H	14,147,184,151	65.70%	± 648,797,209	230,711	10,581
Squawroot	S	3,413,293,121	15.80%	± 551,769,040	55,664	8,998
Huckleberries	S	1,093,165,414	5.10%	± 643,004,494	17,827	10,486
Chestnut oak	H	877,345,427	4.10%	± 643,004,494	14,308	10,486
Scarlet oak	H	789,142,618	3.70%	± 602,264,335	12,869	9,822
Thornless blackberry	S	226,337,206	1.10%	± 99,365,195	3,691	1,620
Black cherry	S	217,041,793	1.00%	± 349,561,350	3,539	5,701
White oak	H	214,239,731	1.00%	± 638,217,240	3,494	10,408
Greenbriers	S	190,784,595	0.89%	± 648,797,209	3,111	10,581
Blueberries (all Vaccinium spp.)	S	154,101,237	0.72%		2,513	
Grapes	S	151,090,557	0.70%	± 551,769,040	2,464	8,998
Upland low blueberry	S	133,703,304	0.62%	± 603,982,343	2,180	9,850
Blackgum	S	23,085,653	0.11%	± 466,902,036	376	7,614
Hickories	H	22,494,795	0.10%	± 641,391,018	367	10,460
Allegheny blackberry	S	14,723,375	0.07%	± 97,751,627	240	1,594
N. highbush blueberry	S	11,151,068	0.05%	± 506,272,716	182	8,256
Deerberry	S	6,494,296	0.03%	± 540,935,436	106	8,822
Hairy blueberry	S	2,191,760	0.01%	± 39,668,758	36	647
Fire cherry	S	2,103,400	0.01%	± 88,323,839	34	1,440
S. mountain cranberry	S	560,809	0.00%	± 17,834,274	9	291
Total		21,536,133,072	100%		351,209	
Oaks					261,381	41,296
Berries (Rubus spp., Vaccinium spp., and Gaylussacia spp.)					24,271	41,566

produced only 0.1%. White oaks produced only 5.1% of all calories, which was equivalent to production by huckleberries (5.1%). Excluding squawroot, huckleberries produced 59.7% of the shrub calories. All 5 blueberry species combined to produce < 1% of all calories whereas blackberry species produced 1.2% of all calories. Soft mast species ranked as 2 of the top 3 producers and 4 of the top 7. Caloric production per hectare was 261,381 Cal/ha by oaks, and 24,271 Cal/ha by berries (blackberries., blueberries, and huckleberries) (Table 25).

Simulations of different mast production scenarios resulted in a wide range of estimates for annual, seasonal, and mast type production (Table 26). Estimates of annual production ranged from 7.5 billion Cal during a year of complete hard mast failure to 42.3 billion Cal during a year of optimal hard mast production. Effects of increases in production by soft mast were less noticeable. However in a year of complete hard mast failure, soft mast accounted for 72.4% of all caloric production. Additionally, fall was the season of least production during a year of complete hard mast failure.

Caloric Production and Habitat Use

Annual relative probability of habitat use (RPHU) by male bears was not correlated to caloric production during 1995 for any group of calories. However, the slope of the hard mast model differed from zero and was positive ($P < 0.0027$) (Table 27). Annual RPHU of female bears was not correlated to caloric production during 1995 for

Table 26. Total caloric production in the northwest quadrant of Great Smoky Mountains National Park from simulations of years of optimal hard mast production, total hard mast failure, and total hard mast failure with excellent soft mast production.

Caloric Production	1995	Hard Mast Optimal	Hard Mast Failure	Hard Mast Failure and Excellent Soft Mast Production
Annual	21.5[a]	42.3	7.5	9.1
Spring	2.7	2.7	2.7	2.8
Summer	6.1	13.1	2.8	3.9
Fall	12.8	26.5	2.0	2.4
Hard Mast	16.1	36.8	2.1	2.1
Soft Mast	5.5	5.5	5.5	7.0

[a] Billions of Calories

Table 27. Summary statistics for regressions of Relative Probability of Habitat Use (RPHU) of black bears and caloric production in the northwest quadrant of Great Smoky Mountains National Park, 1995[a].

RPHU	Calories	R^2	y-intercept	Slope	Prob > F
Male Annual	All	0.0099	46	0.50	0.1249
	Soft Mast	0.0002	49	0.08	0.8123
	Hard Mast	0.0372	46	0.80	0.0027
Female Annual	All	0.0001	30	0.07	0.8541
	Soft Mast	0.0034	29	0.37	0.3688
	Hard Mast	0.0007	30	0.13	0.6807
Female Spring	All	0.0000	30	- 0.04	0.9541
	Soft Mast	0.0000	30	- 0.04	0.9541
	Hard Mast	0.0000	30	0.00	.
Female Summer	All	0.0000	31	- 0.02	0.9624
	Soft Mast	0.0068	29	0.53	0.2036
	Hard Mast	0.0006	32	- 0.13	0.7112
Female Fall	All	0.0158	30	0.64	0.0518
	Soft Mast	0.0180	30	0.93	0.0376
	Hard Mast	0.0286	30	0.73	0.0087

[a] (*n* = 240 for all regressions)

any group of calories. None of the slopes differed from zero. The soft mast model had the largest slope of the 3 female annual models and was nearly significant (Table 27).

Spring RPHU of females was not correlated to caloric production during the spring of 1995 for any group of calories. There were no hard mast calories available during spring. (Surveys did not measure foods remaining from the fall of 1994.) Slopes were not different from zero (Table 27). Summer RPHU of females was not correlated to caloric production during the summer of 1995 for any group of calories. None of the slopes were significantly different from zero (Table 27). The soft mast model had the greatest r^2 value of the female summer models. Fall RPHU of females was not correlated to caloric production during the fall of 1995 for any group of calories. However, slopes of regression lines for all 3 models were positive, and all slopes were significantly different from zero. The hard mast model had the greatest r^2 value of the female fall models, and the soft mast model had the largest slope (Table 27).

V. DISCUSSION

Caloric Production

Species

Oaks Oaks are an important food source for bears because of their nutritional content, digestibility, amount of energetic production, and timing of that production (Pelton 1989). Acorns are often plentiful during the period when bears are storing energy for hibernation; acorns are high in fat and carbohydrate content, which facilitates energy storage. Good oak crops have significant effects on the annual natality and overwinter survival of bears in the southern Appalachians (Eiler et al. 1989); this is a result of the ability of oaks to produce such a large (75% of all available calories during this study) and easily digestible energy source just prior to den entrance. The carrying capacity of an area for bears is likely affected by the abundance of oaks. Also, spring acorn availability could be an important food source and should be considered as part of future studies.

Average fruit production (fruits/m^3) by red oaks was eight times greater than production by white oaks. In addition, red oaks accounted for less tree crown volume yet produced more calories than white oaks. These data indicate a mast failure for white oaks during 1995. Many of the samples of the white oak group were zero. When both random samples of fruit production for a tree resulted in zeros, I scanned the tree with binoculars to determine if this was an underestimate of fruit production. It was usually difficult to

find even one acorn in the crown of both white oak and chestnut oak. Inherent productive ability of the red and white oak groups is not represented well by my data. Had measurement occurred during 1996, white oaks would have dominated caloric production by oaks (personal observation). The NPS's hard mast surveys for the Tennessee side of GSMNP resulted in values of 1.35 for white oaks and 4.05 for red oaks during 1995; values for 1996 were 4.07 for white oaks and 1.99 for red oaks (index values < 2.01 were classified as poor, 2.01 - 3.00 were fair, and > 3.00 were good.)

Several studies have measured mast production by oak species in the southern Appalachian mountains and variability among studies is high (Table 28). Beck (1977) provides the most extensive data, with measurements of mast production during 12 consecutive years; this same study yielded the greatest estimates of Cal/ha of any study in the southern Appalachians. However, Beck (1977) measured acorn crops in areas "very favorable to acorn production", so over-estimation of forest-wide production likely occurred. Additionally, the relationship of fresh weight and dry weight of the reported lbs./acre was unclear and estimates may again be too high. Although Downs (1944) reported far less production per hectare in the same general area, maturation of the oak forest may have resulted in increased production during Beck's study. French (1985) sampled forests with high basal areas of oaks on the Tellico WMA, but adjusted estimates of mast production by considering the oak basal area for the entire area. Strickland (1972) sampled oaks by 1-inch-diameter classes and predicted yields per acre by using diameter class information for the entire forest. The estimate of production by oaks made during my study was less than the average of 21 years of estimates of yields of oak mast in the

Table 28. Comparison of studies of caloric production per hectare by oak species in the southern Appalachian mountains[a].

Study	Year	Area	Species	Estimated Cal/ha
Downs (1944)	1936-42	Bent Creek, NC	**Total**	**62,462**
			white oak	8,179
			scarlet oak	12,095
			chestnut oak	31,859
			n. red oak	10,329
Beck (1977)	1962-73	Bent Creek, NC	**Total**	**900,444**
			white oak	462,202
			scarlet oak	149,287
			chestnut oak	103,274
			n. red oak	185,681
Strickland (1972)	1971	Tellico Wildlife Management Area, TN	**Total**	**507,434**
			white oak	20,655
			n. red oak	486,779
French (1985)	1983	Tellico Wildlife Management Area, TN	**Oaks**	**110,760**
All Studies			**Average**	**395,275**
			Low	**62,462**
			High	**900,444**
This Study	1995	Northwest Quadrant of Great Smoky Mountains National Park	**Total**	**261,381**
			white oak	3,494
			scarlet oak	12,869
			chestnut oak	14,308
			n. red oak	230,711

[a] Estimates of Cal/ha based on data from studies (usually lbs. of acorns produced per acre) and the following conversion factors: 1.) 70.4 % of the weight of an acorn is dry weight (Grodzinski and Sawicka-Kapusta 1970). 2.) Caloric values per gram of dry weight for each species as determined during this study, or the mean for all oak species from this study (Table 10).

southern Appalachians (Table 28). However, the influence of data from Beck (1977) overestimates caloric production; the average without these data was 226,885 Cal/ha; slightly less than that measured in GSMNP, 1995. Production within GSMNP 1995 could have doubled over that measured had chestnut and white oak also produced a bumper crop (Table 26).

Oak mast production is highly variable from year to year (Beck 1977, Christisen 1955, Feret et al. 1982, Downs and McQuilkin 1944, Sork et al. 1993). Production of annual crops is affected by factors such as flower abundance during spring (Feret et al. 1982, Gysel 1958), flower survival (Sork et al. 1993), temperature, humidity, and wind conditions during pollination (Sork et al. 1993, Sharp and Sprague 1967), late spring frost (Goodrum et al. 1971), and drought and high temperatures during the growing season (Sweet 1973). Additionally, because oak mast is destroyed upon ingestion by seed predators, predation has exerted selective pressures that have pushed environmentally induced crop fluctuations into more pronounced cycles of mast production. Cyclic production occasionally satiates seed predators, thus increasing seed survival (Silvertown 1980). However, schedules of cyclic production often are modified by environmental factors mentioned above. White oak seems to be primed to produce abundant crops every 3 years, whereas northern red oak is set to produce abundant crops every 4 years, and black oak every 2 years (Sork et al. 1993).

Although black bears do have tannin-binding salivary proteins, digestibility of dry matter and protein is reduced by increased tannin content (Robbins et al. 1991). Acorns of the white and red oak groups differ in concentration of tannins; white oaks contain less

tannin than red oaks (Ofcarcik and Burns 1971). Therefore, bears are able to utilize acorns of the white oak group with greater efficiency than those of the red oak group.

Results from this study indicate that oaks may be the single most influential genera affecting bear ecology in the southern Appalachians. Forest management that includes an adequate area of sites occupied by mature oak stands is important for successful management of black bears in the southern Appalachians (Eiler at al. 1989, Pelton 1989, van Manen 1994). If forest managers plan for a diversity of oak species at a variety of elevations and in different watersheds, then total failures of acorn crops will be minimized; high years of cyclic production would be represented often, and the negative impacts of spring weather at certain elevations or within certain watersheds may not influence other locations. In addition, a balance of red and white oak would minimize crop failures due to environmental conditions because of the differential periods of fruit maturity (1 growing season for white oaks and 2 for red oaks). However, a diversity of food resources in addition to oaks are likely needed; providing the different food types in proper proportions will likely result in a healthier bear population and a greater carrying capacity of an area for bears.

Squawroot Measures of gross energetic content of squawroot were similar to values reported in the literature (Powell and Seaman 1990, Seibert and Pelton 1994). Squawroot was the 2nd greatest producer of calories annually. Squawroot was the most productive "shrub" species when considering the calories within a square meter of 100% coverage (2,467 Cal/m^2 vs. 59 Cal/m^2 for the next greatest). However, areas of

100% coverage by squawroot rarely occur (57 stalks/m^2 = area of 100% coverage in this study) whereas all other species occur frequently at a level of 100% coverage.

My estimate of caloric production per hectare by squawroot (55,664 Cal/ha) is greater than the 2,800 Cal/ha reported by Powell and Seaman (1990) in Pisgah National Forest, North Carolina. (Because of the patchy nature of plant abundance as indicated by the high standard deviations in Tables 7 and 8, mean values may provide the best comparison between studies.) Powell and Seaman (1990) measured caloric production from only the capsules of squawroot, whereas I included the whole plant. The capsules of squawroot make up 55% of the plant (Powell and Seaman 1990), and are not different in gross energetic content than the plant stem (Powell and Seaman 1990, Seibert and Pelton 1994). Thus, a production of 5,090 Cal/ha as measured by Powell and Seaman (1990) (2,800 is 55% of 5,090) requires 118 whole plants of squawroot per hectare. In my study, cove hardwood averaged 5,016 plants/ha of coverage by squawroot; the remaining eight vegetation types averaged 91 plants/ha of coverage. Production of squawroot was similar for my study and Powell and Seaman (1990) in all types except cove hardwood. Cove hardwood occupied more of my study area than any other vegetation type, and the high production therein resulted in greater overall production.

The high caloric production, timing of that production, nutritional content, and ease of acquisition make squawroot an important food for bears in the southern Appalachians. Squawroot is a major source of carbohydrates for bears in spring (Beeman and Pelton 1980, Eagle and Pelton 1983, Seibert and Pelton 1994). After 4-5 months of no energy intake, bears (especially females with young) are in need of sufficient nutrition;

this may be particularly important after years of fall mast failure. Because squawroot is abundant where it does occur (cove hardwood), it is a food which may be acquired with relatively little effort. Once a bear has moved to a cove hardwood site, energy is abundant, close, and easily consumed. Three of the top 4 vegetation types used by female bears in spring (van Manen 1994) were also 3 of the 4 types where I recorded the presence of squawroot.

Management to insure production by squawroot is important for maintaining the quality of bear habitat in the southern Appalachians. Yet, techniques for management of this species have not been developed. Squawroot is a parasitic plant that grows on the roots of oak trees, therefore management for an abundance of oak stands may increase the presence of squawroot.. However, information about preferred soil types, site conditions, silvicultural harvest and site preparation techniques, and the effects of prescribed fire regimes may prove useful for improving the abundance of this important bear food in the southern Appalachians.

Huckleberries and Blueberries Huckleberries are an important food because of the diversity of locations in which they are found, their abundance, their total caloric production (3rd rank of all species), and the time period during which fruits are available. Blueberries produced less calories than huckleberries, but blueberries may be selected over huckleberries. Whereas huckleberries accounted for 58% of the measured shrub coverage, blueberries accounted for only 9%. However, blueberries occurred in 11% of the annual scats whereas huckleberries occurred in 10%, and each constituted 6% of the annual volume index (5th and 6th ranking foods overall) (Beeman and Pelton 1980). Both genera

were used equally although huckleberries were more abundant and productive. Even if blueberry crops were poor during 1995, the percentages of measured shrub coverage by each genus indicated that huckleberry would have produced more calories. However, abundance of the two genera may have changed significantly during the period between this study and that by Beeman and Pelton.

Annual caloric production by berries (huckleberries, blackberries, and blueberries) over a 3-year-period was 1,600 Cal/ha (range = 210 - 2,690 Cal/ha) in Pisgah National Forest, North Carolina (Powell and Seaman 1990). My estimate of caloric production by berries for the northwest quadrant of GSMNP was greater (24,271 Cal/ha). Mean Cal/dry g was similar for Pisgah (4.4 Cal/dry g) and my study (4.3 Cal/dry g), yet production by berries was higher on my study (5.3 kg/ha ± 10.0 kg/ha) than in Pisgah (3-year average of 2.6 kg/ha, range of 0.32 kg/ha - 4.19 kg/ha). The greater production in my study area may be due in large part to the greater percentage of the area covered by plants that produce berries (16.9% for my study area vs. 4.9% for Pisgah). In addition, Powell and Seaman (1990) sampled berries weekly over a period > 2 months; by sampling fruit production once, early in the period of ripeness, my study may have been less affected by consumption of fruits by animals. However, I may have missed production by late maturing fruits.

Management to improve the abundance of these genera will improve the quality of bear habitat. Many blueberry and huckleberry species re-sprout after disturbance via underground reproductive organs such as rhizomes and root crowns (Zager et al. 1983). Reports from outside of the southern Appalachian mountains indicate that these plants

resprout vigorously after fire and that fruit production shows marked increase (Johnson and Landers 1978). Zager et al. (1983) found that density of shrub coverage was affected by burning regimes and methods of logging slash disposal. Where logging slash had been piled by bulldozer and then burned, rootstocks of these shrubs had been damaged by the bulldozer and the heat intensity of burning slash piles; soil compaction also occurred. When slash was burned where it lay, the vigor of these shrubs increased with the increase in sunlight, the intact rootstock, and no soil compaction. Techniques for improvement of the blueberry and huckleberry resources may include prescribed fire in national parks and burning slash where it lay in national forests.

Black Cherry Black cherry is used extensively by bears during early fall (Beeman and Pelton 1980), and produced well during 1995. Total production by black cherry was lower than expected considering the apparent abundance of fruits observed during field work. Black cherry often occurs in stands and vegetation sampling may have missed inclusion of a cherry stand. Black cherry occurred on only 5 of 275 vegetation plots, each plot with 1 tree. Although sampling by MacKenzie (1993) determined that black cherry was 16% of the basal area of bear food tree species in cove hardwood, I recorded no black cherry in the cove hardwood type.

Because of the extensive use of black cherry by bears and the relatively high productive potential (2nd of 8 tree species Cal/m^3), management for significant stands of this species is recommended.

Blackberries Excluding squawroot, blackberries ranked 2nd in production of shrub calories. Thornless blackberry was abundant in the spruce-fir

vegetation (20 of 30 plots), and productivity likely was at a high level because of the complete removal of the once predominant fir canopy by the balsam woolly adelgid. Blackberries accounted for 8% of the annual volume index of black bear scats in GSMNP (Beeman and Pelton 1980), and produced 1.2% of the total calories during this study. The fruits of thornless blackberry are large, occur in a high density, and have the greatest Cal/g value of all species. Allegheny blackberry was found in medium abundance in 2 vegetation types, but production was relatively low. A lack of disturbance is likely responsible for the low abundance of Allegheny blackberry. However, this species may occur in small gaps where large trees have fallen and may have been missed during sampling because of the small patchy nature.

The time of availability of blackberries along with their high caloric value and use by bears deem them important for management consideration. Blackberries seem to be most abundant in full sunlight. Therefore, a certain amount of forest disturbance accompanied by an adequate seed source would likely improve the quality of bear habitat. Naturally occurring seed sources may be adequate, yet the expense involved in broadcasting seed of blackberries along logging roads, after prescribed burns, in logged areas, or maintained openings may prove worthwhile.

Greenbriers Greenbriers occurred in all but 1 vegetation type and was the 3rd ranking shrub for caloric production (excluding squawroot). However, the production per unit area of coverage was low (9th of 11 shrubs). Also, seeds of greenbriers were not removed prior to weight of an individual fruit and gross energetic analysis; these seeds were relatively large and overestimation of production by greenbriers

occurred. Although greenbriers produced a relatively large amount of calories, these calories were not concentrated. Therefore, if bears focused on searching for greenbrier fruits, energy would be acquired at a relatively high cost. The regularity of occurrence of greenbriers along with the higher energetic cost of acquisition and the low use by bears indicates that this food may be eaten opportunistically and that it does not warrant special management effort.

Grapes Grapes have been described as an important fall resource for bears particularly during years of hard mast failures (Carlock et al. 1983, Eiler et al. 1989). Grapes accounted for 3% of the annual volume index of bear scat in GSMNP (Beeman and Pelton 1980). Grapes produced 8.3% of the shrub/vine calories during 1995 while accounting for only 3.4% of the measured coverage. The high ratio of percent production : percent area indicates that grapes were some of the more productive foods per unit of coverage. Often, grapes are found in patches where they have strangled trees and dominate the local flora. I did not include sampling of the grape thicket vegetation type because it occupied only 0.27% of the study area (163 ha). These grape thickets likely provide a good source of fall food. If grape thickets had been sampled, the overall contribution of grapes would have increased. Techniques to increase the abundance of grapes are largely unknown. Management of forest sites where grapes occur in order to maintain or improve abundance and production would increase the quality of bear habitat.

Hickories Hickories were low producers during 1995. While encompassing 10.0% of the measured tree crown volume, hickories produced only 0.1% of the measured calories. However, hickories were the most difficult to sample accurately for fruit

production. The dense leaves may have obscured fruits within the scope field of view to a greater degree than in other species. Hickories are common in the southern Appalachian forests, and produce a high energy and fat content food during the same critical fat storage period as oaks. However, hickory nutrition is enclosed within a hard shell and the energetic cost of utilizing this resource likely is greater than the cost of utilizing oak acorns. Hickories accounted for 3% of the annual volume of bear scats whereas oaks accounted for 9% (Beeman and Pelton 1980). Hickories may be a source of nutrition during periods of oak mast failure, although, flowering periods are similar to that of the oak species and crops may be affected similarly.

Mast Type

Gross energetic contents (Cal/g) of soft and hard masts were not significantly different, suggesting that size and number of fruits produced per unit area are the determining factors for caloric production rather than mast type. Other comparisons also revealed similarities in caloric production of soft and hard masts. After assuming the height of shrubs to be 1 meter (2 meters for blackberries), mean production by soft mast species (Cal/m^3, excluding squawroot) was slightly greater but not different than hard mast species. Soft mast accounted for 13.4% of the measured plant volume per hectare whereas hard mast accounted for 86.6%. Yet, soft mast produced 25.5% of the calories available on the entire study area and hard mast produced 74.5%. The above suggests that a cubic meter of soft mast coverage produced more than a cubic meter of hard mast coverage during 1995. This comparison is based on data from 1995 only; caloric

production per cubic meter during years of good white oak or hickory crops might result in significant differences. Although production per cubic meter during 1995 by soft and hard masts did not differ, other characteristics of the mast types may result in differences in usability by bears.

In the southern Appalachian mountains, soft and hard masts fuel different physiological needs of bears (Brody and Pelton 1988, Nelson et al. 1983, Hellgren et al. 1989), and each type is important. Soft mast supplies the proteins needed for growth and rebuilding of muscle mass; hard mast supplies fats and carbohydrates responsible for energy storage for use during hibernation. A bear must store enough energy during fall so that it does not fall below a state of nutrient equilibrium beyond recovery. During years following good hard mast crops, weight loss during hibernation is due to use of fat stores; after years of poor hard mast crops, protein catabolization of muscle mass will occur (Crampton and Harris 1969). A good crop of soft mast in summer to supply needed proteins for growth and rebuilding of muscle mass is important for bears, particularly sub-adults. Sub-adult bears must store enough fat for the denning period, and they must also acquire enough protein for skeletal and muscular growth during periods other than the intense fat storage period of fall. Although summer crops of soft mast are relatively low in the amount of available protein (Eagle and Pelton 1983), an increased intake of soft mast can compensate for low amounts of available of protein therein (Crampton and Harris 1969).

The amount of variation in annual crops of soft and hard masts may differ. Soft and hard mast fruits have differential methods of seed dispersal and propagation

(Silvertown 1980, Sork et al. 1993, Levey et al. in press). Acorns and hickory nuts are destroyed by consumption, and hard mast producers have gained selective advantage by producing large crops infrequently, thus occasionally satiating seed predators. Soft mast species, on the other hand, have seeds that are scarified and dispersed when fleshy fruits are eaten; therefore, consumption enhances reproductive potential. Thus from an evolutionary perspective, hard mast producers have selective advantage by investing in production of occasional large crops whereas soft mast producers would have an advantage in relatively stable and high production. Therefore, soft mast may provide a relatively stable source of energy for bears whereas hard mast fluctuates.

Although I found no significant differences in gross energetic production or production per m^3 between soft and hard mast, differences in usefulness to bears are a result of the timing of production in conjunction with the nutritional content and specific bear needs, the size of annual fluctuations in total production, energy expenditure to acquire the food (consumption effort and travel between patches), and digestibility. Both mast types serve necessary functions for bears and are important components of bear habitat. Forest management that provides adequate sources of each will be most beneficial to bears. Future research that focuses on the types and timing of specific nutritional needs of bears, especially lactating females, and what is supplied by various foods may provide greater insight into the factors that influence bear population dynamics and how management actions might improve bear habitats.

Season

Black bears are large carnivores whose diet now consists of mostly vegetative matter, hence, they have a relatively low basal rate of metabolism; this results in low fecundity, long generation time, and altricial young (McNab 1989). The above indicates that energetic availability limits individual success and the growth of bear populations. Therefore, constraints on carrying capacity may be centered around the period of lowest energetic availability. I found a period of relatively low caloric production during summer. Spring and summer bear conditions can influence the ability of a female to lactate (cub survival), the likelihood of females reaching sexual maturity during the following breeding season, the fertility of mature females, and juvenile survival (Noyce and Garshelis 1994). Thus, food availability in spring and summer are important. Bears have adapted to the period of low caloric availability during winter with fall hyperphagia and winter hibernation, effectively increasing the energetic availability during winter via fat storage and inactivity. The question remains of how bears have adapted to the period of low caloric availability during summer.

Several points are illustrated by comparison of available calories and estimated caloric needs of a bear population throughout the year (Figure 6, see also Appendix D). Mid-summer (1 July - 14 August) is the period of lowest availability, and calories consumed approaches what is available (66% of available food is consumed). In addition, more vertebrate species consume fleshy fruits than hard mast (Martin et al. 1951), and inter-specific competition may be most intense during summer. Relatively few scats were found during mid-summer (15 June - 1 August) over a 6-year-period in GSMNP

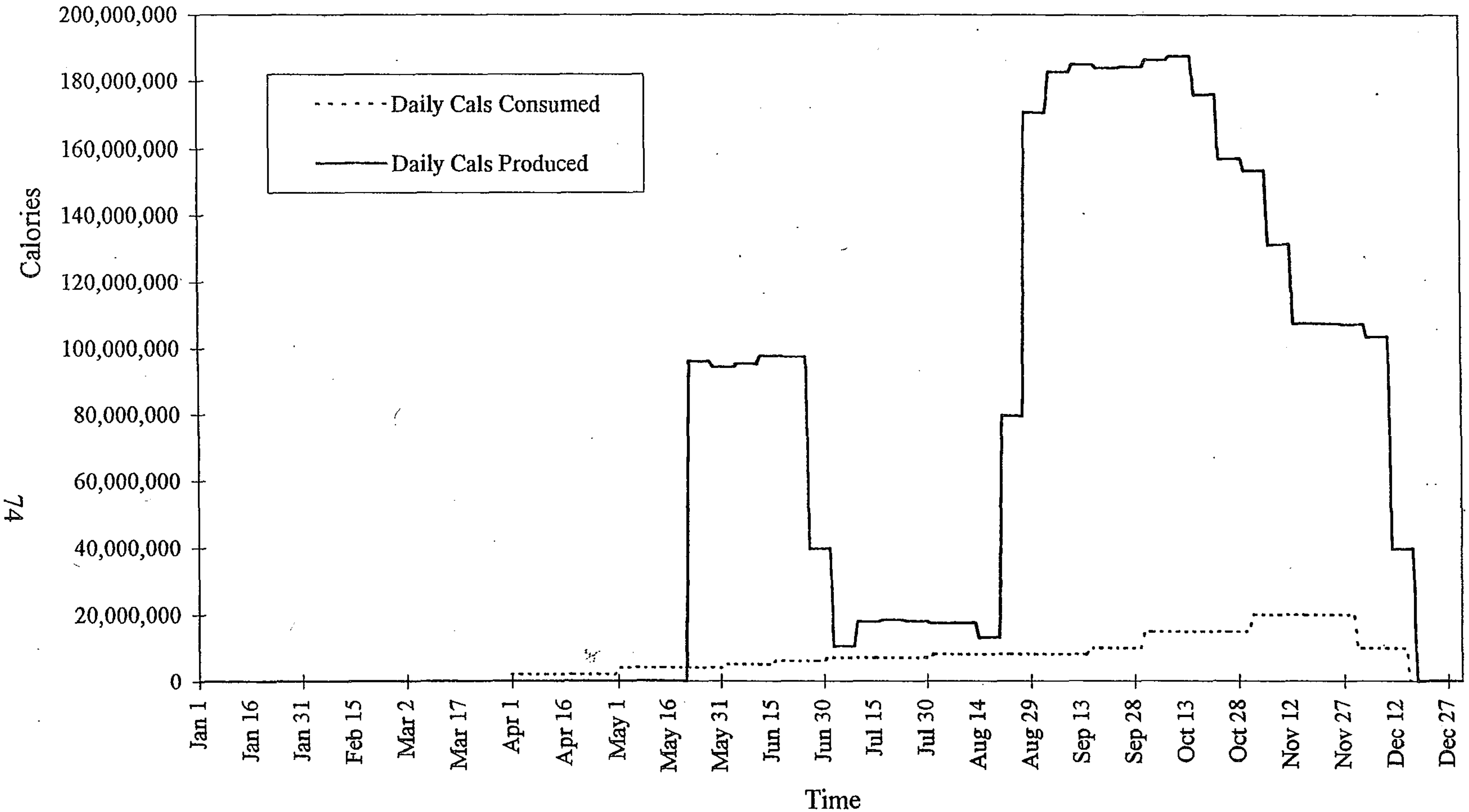

Figure 6. Daily calories produced by bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995; and estimated daily calories consumed by a population of 1,000 bears (1.6/km^2) (Consumption based on Nelson et al. 1983)

(Matthews 1977). In years when fall mast crops are average to good, such as 1995, caloric availability far exceeds what the bear population can consume. Because fall caloric availability is great during an average year of hard mast production and bears are physiologically capable of efficient storage of energy during the fall, the availability of calories during winter may actually be higher than during mid-summer (these winter calories are in the form of fat, yet they are available during winter). Thus, availability of food in fall may limit the population only during years of mast failure (Figure 7). A certain threshold level of low mast availability may affect the survival and reproduction of bears negatively; above that threshold, the amount of available fall food is sufficient for survival and reproduction of all bears that the summer foods of the study area will support. Thus, a fall mast failure may be a largely density-independent regulator.

If the density of bears increases so that during an average year of hard mast production the level of consumption during fall approaches 66% of availability, then mid-summer becomes a negative foraging period (Figure 8). However, bears gain weight during July and August in GSMNP (Wathen 1983). In addition, the density of bears required to approach 66% consumption during fall (5.8/km^2) is much greater than estimates based on mark-recapture studies (1.36/km^2) (Coley 1995).

Assuming that production of calories is representative of actual availability, I suggest that mid-summer caloric availability is currently a limiting factor, acting as a density-dependent regulator of bears in the northwest quadrant of GSMNP. Mid-summer is the period when the energetic need of the population is closest to what is available, inter-specific competition likely is greatest, and availability may be more stable than during

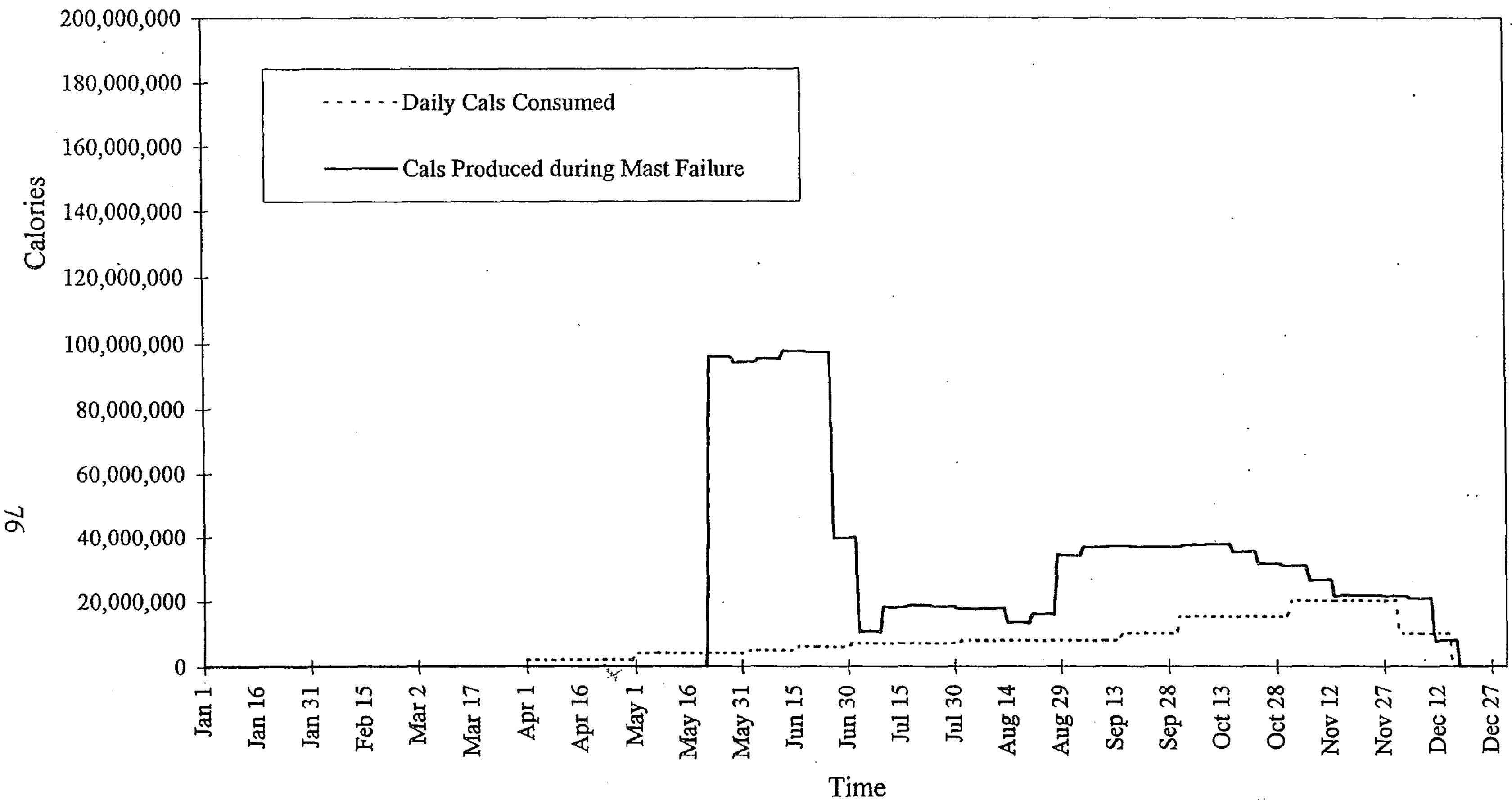

Figure 7. During a year of mast failure, daily calories produced by bear foods in the nw quad of GSMNP; and estimated daily calories consumed by a population of 1,000 bears (1.6/km^2)
(Consumption based on Nelson et al. 1983)

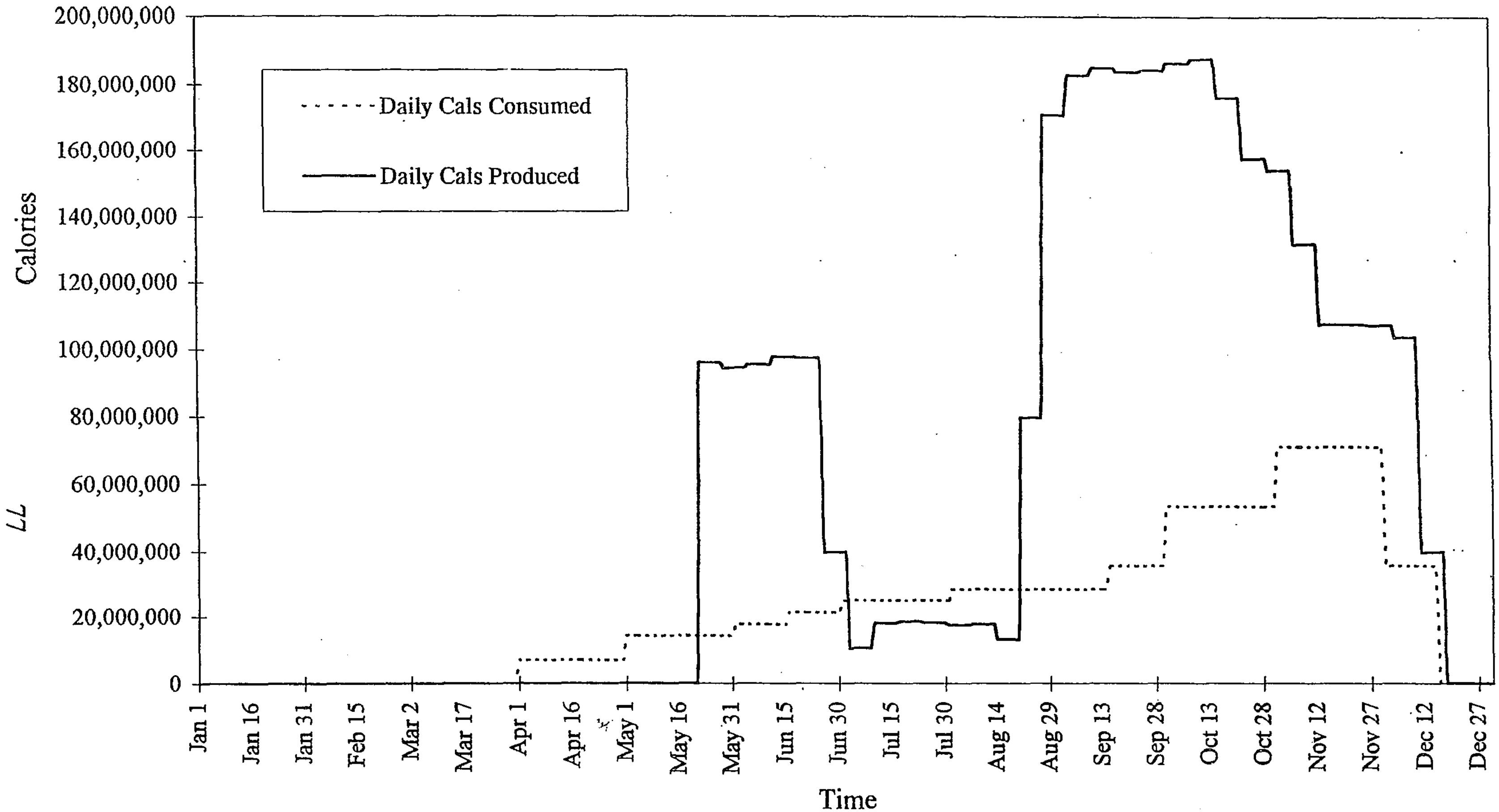

Figure 8. Daily calories produced by bear foods in the nw quad of GSMNP, 1995; and estimated daily calories consumed (66% consumption during fall period of closest availability and consumption) (5.8 bears/km^2) (Consumption based on Nelson et al. 1983).

fall. Moreover, several important biological functions are taking place during summer, indicating that the population is at a point where energetic need is great, and closest to availability. Therefore, whereas availability of fall mast may correlate with overwinter survival and annual natality (Eiler et al. 1989), the influence of fall mast crops on recruitment and the current ability of the bear population to reach maximum carrying capacity may be secondary to that of mid-summer food availability. However, this study area has a large percentage of area occupied by oak vegetation types; if there was a low percentage of area occupied by oak types, carrying capacity would not be limited by mid-summer food availability. I suggest that a certain ratio of mid-summer calories to fall calories would result in a maximum density of bears. Future research should be directed to determine if over-winter survival and annual natality are related to fall food abundance, whereas recruitment and current limits on carrying capacity are related to mid-summer food availability.

Vegetation Type

Several factors influence the relative importance of a vegetation type for production of bear foods. Important factors include the amount of production, timing of production (Appendix B, Figures B1 - B9), diversity of species, and likelihood of consistent production from year to year. Caloric production during this study was influenced by the white oak mast failure. By comparing the amount of red oak and white oak crown volume within each vegetation type, it is possible to determine which

vegetation types would likely produce high in a year of excellent red oak yield or a year of excellent white oak yield.

For discussion of management techniques to improve the quality of vegetation types as a food resource for bears, I suggest improving a type by taking advantage of that type's comparative advantages for improving the food resources rather than suggesting manipulation to increase abundance of foods that occur in inherently low numbers within that type. It should be noted that suggestions for improvement of bear habitat are not an advocation of active forestry practices within GSMNP (with the exception of prescribed fire), but are suggestions as applicable to similar vegetation types of the southern Appalachians where forest management does occur. In addition, the needs of other wildlife species should be considered before forest manipulation to maximize habitat quality for bears is undertaken; however, bears are opportunistic omnivores, and their food habits likely represent the food habits of many species.

Cove Hardwood Cove hardwood was more diverse than all vegetation types except pine, both had 12 bear food species present ($\bar{x} = 9.2$, $n = 9$). Cove hardwood was also the largest producer of calories per hectare during 1995, this was largely due to the presence of squawroot and northern red oak. Cove hardwood had the greatest coverage per hectare of both squawroot and northern red oak. The time of availability for these 2 species, particularly the spring squawroot, increases the importance of cove hardwood. Cove hardwood also occupied more of the northwest quadrant (24%) and the entire Park (33%) than any other vegetation type. This large coverage and the fact that 1995 was heavily influenced by production of red oak acorns combined to make cove hardwood the

largest producer of calories for the entire study area during 1995 (47.4%). However, cove hardwood had more red oak crown volume than white oak, and would be less important in a year of white oak abundance and red oak failure.

Although no black cherry was recorded in cove hardwood during my study, black cherry stands do occur in this type (Shanks 1954). MacKenzie (1993) reported the greatest basal area of black cherry in cove hardwood. Bears make frequent use of black cherry stands during early fall (Quigley 1982, Garshelis and Pelton 1981). Black cherry scored the greatest volume index value of all species used by black bears in GSMNP (Beeman and Pelton 1980). When black cherry was available during this study, bears used this resource almost exclusively (pers. observ.).

Management of cove hardwood areas in the southern Appalachians to favor squawroot, black cherry stands, and northern red oak should improve the quality of food resources for bears. Although huckleberries do not occur here in great abundance relative to other vegetation types, the amount of annual contribution by the genus and the timing of that production warrants management improvements wherever it occurs. Maintenance of a large component of cove hardwood within the forest also may be important because of the diversity of food species present within the type and the need for varied food resources to offset mast failures.

Mixed Mesic Hardwood Mixed mesic hardwood was fairly diverse (9 species) and contained large amounts of huckleberries and squawroot relative to other vegetation types. Mixed mesic hardwood occupied 13% of the northwest quadrant and 17% of the remainder of GSMNP; only cove hardwood occupied a greater area of GSMNP. Mixed

mesic hardwood was one of 3 vegetation types used frequently by both male and female bears on an annual basis (van Manen 1994). Mixed mesic hardwood contained large oak crown volumes (2nd rank) and had an even ratio of red oak to white oak (0.8:1). The greatest amount of crown volume due to hickories also occurred in this vegetation type. Although production by hickories was extremely low during the study, this genus may produce a significant amount in certain years. Hickories accounted for 3% of the annual volume index of black bear scats in GSMNP (Beeman and Pelton 1980). Mixed mesic hardwood should be a relatively consistent and high producer of fall hard mast from year to year.

Management of mixed mesic hardwood should focus on maintenance of a high volume of oak and hickory crown along with a balanced ratio of red and white oaks. Also important are efforts to maximize the inherent ability of the type to produce huckleberries and squawroot. Because of the large site potential for the type and large volumes and areas of important foods within the type, concentration of management effort within this type may improve the quality of bear habitat more effectively than in other types.

Mesic Oak Mesic oak was the 3rd greatest annual caloric producer per hectare. Mesic oak favored red oak crown by a ratio of almost 2:1 over white oak, and would be less important in a year of white oak abundance and red oak failure. Total oak crown volume ranked low at 5th of the 9 types. Diversity of bear foods (10 species) was good within mesic oak although amounts of coverage for most species were low relative to other vegetation types. Mesic oak contained more black cherry crown volume per hectare

than any other vegetation type. MacKenzie (1993) also reported relatively high basal areas of black cherry in the mesic oak type.

Mesic oak occupied only 3% of the study area. The low amount of site potential for this type within the northwest quadrant indicates that management efforts within other types may be more effective. However, this vegetation type occupied 13% of the remainder of GSMNP (3rd rank), and management improvements therein may yield significant improvements to bear habitat. Management of mesic oak that focuses on improvement of black cherry stands and abundance of huckleberries will lead to an improvement in food resources for bears; management to improve the oak component of bear habitat will be more effective in other vegetation types.

Xeric oak Xeric oak was diverse (11 species), and was one of 3 vegetation types used frequently by both male and female bears on an annual basis (van Manen 1994). Both huckleberries and blueberries occurred in relatively great abundance in this type. Xeric oak ranked 4th in caloric production per hectare. This vegetation type contained the most oak crown volume, and the majority was due to white oaks. Xeric oak was dominated by chestnut oak crown volume; this species had a large fruit and on occasion produces heavily. In a year of heavy white oak production this vegetation type would likely produce more calories per hectare than any other type. In addition, xeric oak occupies 22% of the northwest quadrant (2nd rank) and would likely produce more total calories than any other vegetation type. This vegetation type occupies only 5% of the remainder of GSMNP.

Much of the sites of the southern Appalachians are occupied by xeric oak types, and management improvement therein would be significant. One focus of xeric oak management is the maintenance of a strong white oak component. The red oak component is present in the cove hardwood, mesic oak and mixed mesic hardwood types. Another focus of xeric oak management should be to capitalize on the ability of the type to support large areas of huckleberries and blueberries. Because xeric oak does not produce squawroot and is located on dry sites, fire may be a useful tool for improving the important shrub component.

Pine Caloric production per hectare by pine was midrange. Although the red and white oak groups were represented evenly, the pine type contained relatively little oak crown. However, pine ranked 4th in area of coverage by huckleberries and by blueberries Pine was tied with cove hardwood as the most diverse type (12 species), yet the areas of coverage by this diversity of species were low within pine. Because pine occupied 22% of the northwest quadrant study area, it was the 3rd greatest producer of total calories on an annual basis (13.9%). However, the ratio of percent production : percent area was < 1 and would likely remain < 1 during a year of good white oak crops. Pine occupied only 7% of the remainder of GSMNP and would be much less of a factor in total production. However, the diversity of foods available within this type may make pine of greater significance in the remainder of GSMNP during years of oak mast failure.

The pine type also occupies much of the sites of the southern Appalachians, and management improvement therein would likely be significant. It should be noted that the pine types measured in this study did not result from any site preparation treatments,

planting, or thinnings. In addition, the species of pine in the stands were native to the southern Appalachian mountains. Stands of pine where the site was prepared and/or loblolly pine was planted may result in different species compositions and abundances, and may affect the quality of bear habitat differently. Management of pine stands that insures a diversity of foods along with an abundance of huckleberries and blueberries would likely result in an improved quality of habitat for bears. However, the lack of oak within the type indicated that care should be taken to avoid an overabundance of the pine type.

Pine-oak Pine-oak ranked 6th of 9 vegetation types in caloric production per hectare on an annual basis. Pine-oak contained a relatively large amount of oak crown volume, however most of that volume was due to white oaks. Therefore, during a year of white oak crop abundance this type would be of greater significance. Pine-oak occupied only 3% of the study area and produced 1.5% of the calories. The ratio of percent production : percent area was less than that for pine, but this would not likely be the case during a year of good white oak production. Pine-oak was relatively diverse (10 species). Most important for this vegetation type were the areas of coverage by chestnut oak, huckleberries, and blueberries. The coverage per hectare by huckleberries was greatest in the pine-oak type, whereas blueberries coverage and chestnut oak crown volume were both 2nd greatest in pine-oak. Although chestnut oak produced poorly during 1995 (4.1%, 4th ranking species), the amount of crown volume (37% of the measured tree crown volume, the greatest amount for any tree species) and the large fruit size were indicative of the potential of this species. Management of pine-oak types that focuses on increasing the abundance and productivity of huckleberries and blueberries while

maintaining a large component of chestnut oak will lead to improvement of food resources for bears.

Tulip-poplar Tulip-poplar was 1 of 3 vegetation types used frequently by both male and female bears on an annual basis (van Manen 1994). However, it does not appear that bears used this type because of food availability. Tulip-poplar ranked 7th of 9 vegetation types in production of calories per hectare during 1995. Although there was more white oak than red oak in tulip-poplar, the total amount of oak crown volume was low (7th rank) and a year of good white oak production would not elevate the overall rank of this type. Shrub diversity and total area of shrub coverage also were low in tulip-poplar. The area of coverage by huckleberries in the other 6 vegetation types where it was found equals 1,793 m^2/ha; tulip-poplar contained only 339 m^2/ha. No blueberries were recorded in the tulip-poplar vegetation plots. I speculate that tulip-poplar stands occurred in low elevation cove hardwood sites where intense soil disturbance has occurred (i.e. farming), and that this was likely responsible for the lack of shrub coverage (Zager et al. 1983). Tulip-poplar occupied only 3% of GSMNP and may be more important for bears as denning habitat than for food production. Squawroot occurred in this type, and the combination of available den sites, use of areas close to the den site after emergence, and squawroot presence may result in the frequent use of the tulip-poplar type. Tulip-poplar had the greatest area of coverage per hectare by grapes and could provide this important resource in years of oak mast failure. Management of tulip-poplar should promote squawroot and grapes along with den site availability.

Northern hardwood Northern hardwood was the lowest producer of calories per hectare during the study. Diversity of species was also relatively low (8 species); only tulip-poplar and spruce-fir scored lower. Northern hardwood was relatively devoid of oak crown volume and is not likely to be a significant producer of oak calories under any type of oak mast crop scenario. While occupying 6% of the study area, northern hardwood produced only 1.8% of the calories, resulting in the lowest ratio of percent production : percent area for any vegetation type. However, most of the caloric production came from thornless blackberry and black cherry. These 2 species produced high energy foods which were distributed in a manner that likely requires relatively little energy expenditure for acquisition. The timing of availability of these 2 species (early fall) and their usefulness during years of oak failure also increased their importance, and that of northern hardwood. In addition, beech was not sampled for fruit production during the study; northern hardwood contained more beech crown than any other vegetation type; inclusion of this species in fruit production sampling would have resulted in greater relative productivity by northern hardwood. Management efforts within the northern hardwood type should focus on improving stands of black cherry, opening the overstory to promote abundance of thornless blackberry, and maintaining beech stands.

Spruce-fir Spruce-fir was the 2nd lowest producer of calories per hectare and the least diverse of the 9 vegetation types. No oak species were recorded in this vegetation type. Spruce-fir occupied only 1% of the study area and produced 0.4% of the calories during 1995. However, the ratio of percent production : percent area was similar to that of tulip-poplar and greater than northern hardwood. The primary source of food

within the spruce-fir vegetation type was thornless blackberry. The fruits of this species were large, occurred in a high density, and had the greatest Cal/g value. In addition, thornless blackberry was available just prior to hard mast. The plant abundance and fruit production by thornless blackberry likely was affected by the removal of the Fir component of the overstory by the balsam woolly adelgid. Use of this food source likely was high by bears whose home range contains spruce-fir habitats. These areas also provide an important alternative food source during years of oak mast failure. In a year of complete oak mast failure, spruce-fir would contain the greatest number of calories/hectare during any two month period. Management to favor abundance of thornless blackberry and fire cherry would make the greatest advances for quality of bear habitat in the spruce-fir type.

Caloric Production and Habitat Use

Black bear habitat use in GSMNP is largely a response to variation in distribution, abundance, and nutritive value of foods (van Manen 1994). However, relationships between bear habitat use and caloric production during 1995 were weak. There may be several reasons for the weak relationships. Caloric production during 1995 may not have represented an average year (habitat use models were constructed with telemetry locations over a period of 7 years). Also, factors other than caloric production may be important in determining bear habitat use. For example, road density and traffic volume affect bear centers of activity and movements (Brody and Pelton 1989, Beringer et al. 1990). Van Manen (1994) found that bears were 2.6 times more likely to use areas > 5,750 m from

human activity sites than areas < 5,750 m from human activity sites, and that relative bear use of areas > 2,500 m from improved roads was 3 times more likely than areas < 2,500 m from improved roads. Other explanations of the weak relationships include telemetry data collection, food abundance, and poor habitat use models. Telemetry locations of bears for habitat use studies were made at various times of the day, which likely represented not only the location of a bear as it feeds but also as it rests and travels. Other possibilities are that there may be such an abundance of food that food availability does not influence habitat selection, or habitat use models may be inaccurate. In addition, the high variation in caloric production from plot to plot within a vegetation type and the lack of ability of habitat use models to discern areas of a vegetation type that contain high or low caloric value may have obscured the significance of any relationships. In addition, the large home range of bears along with the complexity of habitat use may also obscure relationships. Therefore, the strength of relationships may be low, yet discernible trends may actually be important. Multiple years of data or simultaneous studies of habitat use and caloric production are needed to address this question more accurately.

Although relationships of bear habitat use and caloric production during 1995 were weak, there were several interesting numbers that suggested sexual segregation based on mast type or that differential use of mast types occurs. When male annual RPHU was regressed on all calories, soft mast calories, and hard mast calories, the largest R^2 value and the largest slope (which is significantly different from zero) all occurred with the hard mast only calories. Considering female annual regressions, the largest R^2, slope, and level of significance all occurred with the soft mast only calories.

Differences in habitat use by sex and age groups of black bears occurs, suggesting sexual habitat segregation of black bears (Jonkel and Cowan 1971, Garshelis and Pelton 1981, Rogers 1987, Clark 1991, Wielgus and Bunnel 1994, van Manen 1994). Most studies suggested a hierarchy of adult males followed by adult females and then sub-adults. Reproduction by female grizzly bears (*Ursus arctos*) in western Canada declined when they avoided nutritionally rich habitats that were occupied by immigrant males (Wielgus 1993). If female black bears are forced to use habitats of poorer nutritional quality, reproductive effort may decline similarly. If sexual habitat segregation of black bears does occur, the dynamics of bear populations could be affected in several ways. Indications are that males exclude females from prime feeding habitats, and that older or larger bears dominate areas of use. There are several possible interpretations of the selective advantages that would result, including self-regulation at high densities, competitive exclusion, and differential nutritional needs.

If females are excluded from prime feeding habitats by dominant males, and reproductive effort is largely controlled by female nutritional condition, it may not be of selective advantage for inter-specific competition. Yet, this could be of selective advantage as a self-regulating mechanism which occurs only at high bear densities. A lower reproductive effort would result in less intra-specific competition and bears that are better able to compete inter-specifically.

A second possibility of selective advantage due to habitat segregation involves competitive exclusion. If males forage in areas where they do not breed, then competitive exclusion of females and sub-adults would be of selective advantage. Females remain in

summer home ranges longer than males (Carr 1983), and males travel greater distances between summer and fall home ranges (Garris 1983). Males move to productive acorn areas earlier, and occupy more productive areas than females (Garshelis 1978, Quigley 1982, Carr 1983). Male bears may make extensive movements from their summer breeding range and prevent females with whom they have not mated from acquiring sufficient nutrition, and thus reduce genetic input of other males and competition for their own dispersing offspring. Garshelis and Pelton (1981) documented heavier males using areas of higher oak concentration than lighter males during fall in GSMNP. Whether these males are related or not was unknown. This behavior would be effective only if a dominant male occupies a breeding range that has abundant food resources. These abundant resources may make it impossible for other males to immigrate after the breeding season and force females and sub-adults into poor habitats. Mark trees are common in black bear habitat (Burst and Pelton 1983). There is likely some system of social communication occurring at these mark trees, yet it is poorly understood. Intra-specific antagonism occurs and may be more common than documented.

A 3rd possibility is that the sexes have evolved to take advantage of different food sources. There is evidence of differential use of habitats by male and female bears in the southern Appalachians, and these observations point toward females utilizing soft masts and males using prime oak areas. Female bears were the only sex or age group to show a significant preference for shrub (huckleberries and blueberries) areas in GSMNP (Quigley 1982). Black cherry is often found in cove hardwood forests of GSMNP (Shanks 1954), and females with cubs were the only group to use the cove hardwood forest type

significantly more than expected during a year of poor hard mast production (Carr 1983). Thus far, interpretations have been that males are excluding females from prime feeding habitats. But, they could simply be utilizing different resources. Important nutritional needs because of gestation and lactation may be better met through the nutritional content of soft mast species.

It is important to know how much of a factor food availability is in determining habitat use, and if sexual segregation based on nutritional quality of areas is occurring so that managers can provide the secondary habitats necessary for use by female and sub-adult bears. Misunderstanding the regulatory influences of specific foods or sexually segregated habitats in a largely density-independent regulated species could lead to ineffective management strategies. Although food is only one component of habitat, its availability may be influenced by policies regarding natural disturbances in national parks and by silvicultural practices on multiple-use lands. Future research to determine the absence/presence and functions of sexual segregation would aid in understanding fundamental bear ecology and allow management improvements.

Survey Method

Reproductive Research

The number of fruits produced per unit area combined with the mean dry weight of a fruit are measures that would provide an accurate and useful index of bear nutrition from year to year. In addition, by measuring these two variables and using previously

determined measures of Cal/g for each species and areas of coverage across the landscape, a calculation of caloric production per hectare or total caloric production during a year is possible. This information could be used in addition to telemetry data to analyze differences in home range quality, reproduction, and social implications.

Long-term Datasets and Ecosystem Management

Noyce and Coy (1990) expressed the need to define relationships between bear reproduction, habitat composition, silvicultural practices, and food abundance. Future research on the impacts of silvicultural treatments and prescribed burning regimes on regeneration of bear food species is needed. The USDA Forest Service controls >15,000 km^2 of land in the southern Appalachian mountains and has recently adopted an ecosystem management approach based on sustainable development and conservation (Yoke 1994). This management approach will require knowledge of site potentials for vegetational growth; progression of habitat changes through the life of forest stands; specific habitat needs of wildlife species; and affects of the shifting spatial arrangements of different types of habitat patches on population dynamics of wildlife species. Data from the present study can be used as a basis for designing experiments to research the effects of forest management practices on bear habitat. Results will allow land managers to accurately assess the value of shifting spatial arrangements of habitat patches of various disturbance histories on the dynamics of bear populations.

VI. SUMMARY

1. Mean annual caloric production of black bear foods in the northwest quadrant of GSMNP was 351,209 Cal/ha. Total production for the study area was 21.5 billion Cal. Simulations of total production ranged from 7.5 billion Cal during total hard mast failure to 42.3 billion Cal during a year of optimal hard mast production.

2. Northern red oak produced 66% of the calories of bear foods. Other important producers included squawroot (16%), and huckleberries (5%). Most of the 19 selected species produced < 1% of the calories of bear foods. A white oak mast failure occurred in the study area during 1995 resulting in poor representation of the potential production by white oaks. Oaks are likely the single most influential genera affecting bear ecology in the southern Appalachians. However, adequate sources of squawroot and berries, along with a diversity of food sources, are also likely to influence population dynamics.

3. Hard mast produced 75% of the calories during 1995; soft mast produced 25%. Gross energetic contents of soft and hard mast species did not differ. Differences in caloric production by species occurred as a result of the size of fruits, the number of fruits produced per unit area, and the abundance of each species rather than mast type. Simulations of mast scenarios resulted in hard mast producing

87% of calories during an optimal hard mast year, and soft mast producing 72% of calories during a year of hard mast failure.

4. The fall season produced 59% of the calories; summer produced 28% and spring produced 13%. Much of the summer production was due to hard mast (18 of the 28%) and occurred late; thus the lowest period of weekly production occurred during summer. Availability of plants and habitats that produce spring and summer foods likely has significant impacts on bear recruitment and carrying capacity.

5. Differences in annual and seasonal production of selected foods per hectare occurred between vegetation types and were indicative of the need for management that considers the food producing potential of each vegetation type including seasonal and species specific effects. Suggestions for management of vegetation types are summarized in Table 29.

6. There was not a strong relationship between any measured caloric production during 1995 and any bear habitat use model. Factors such as road density and proximity to human activity may affect habitat use more than food production. Also, multiple years of data or simultaneous studies of habitat use and caloric production are needed to address this question more accurately.

Table 29. Summary of management recommendations to improve the quality of food resources for bears in the southern Appalachian mountains.

	Spring	Summer	Fall	General
Cove Hardwood	Promote **Squawroot**		Promote **Northern Red Oak** Promote **Black Cherry**	Red Oak Component Diversity to Offset Mast Failure Den Sites
Mesic Oak		Promote **Huckleberry** abundance and use **fire** to increase productivity	Insure significant basal areas of mature **Black Cherry**	Soft Mast Summer & Early Fall
Mixed Mesic Hardwood	Promote **Squawroot**	Promote **Huckleberry** abundance and use **fire** to increase productivity	Insure significant basal areas of mature **Oak & Hickory**, with a balance of red and white oaks	High Oak Volumes Balance of Red and White Oaks Year Round Production
Xeric Oak		Promote **Huckleberry** and **Blueberry** abundance and use **fire** to increase productivity	Insure significant basal areas of mature **White Oaks**, esp. Chestnut Oak	White Oak Component Summer Foods
Pine		Promote **Huckleberry** and **Blueberry** abundance and use **fire** to increase productivity		Diversity to Offset Mast Failure Summer Foods
Pine-Oak		Promote **Huckleberry** and **Blueberry** abundance and use **fire** to increase productivity	Promote **White Oak**	White Oak Component Summer Foods
Tulip-Poplar	Promote **Squawroot**		Create light gaps to increase **Grape** abundance	Den Sites
Northern Hardwood	(Serviceberry)	Open the overstory to increase abundance of **Blackberry**	Insure significant basal areas of mature **Black Cherry** and **Beech**	Late Summer & Early Fall Production
Spruce-Fir	(Serviceberry)	Open the overstory to increase abundance of	Provide areas of early succession to promote	Late Summer & Early Fall Production

7. Although there were no strong relationships between caloric production and bear habitat use, results suggest sexual habitat segregation and the importance of soft mast for female bears. These trends are likely more important than data prove because of the high variation in caloric production from plot to plot within a vegetation type and the lack of ability of habitat use models to discern areas of a vegetation type that contain high or low caloric value.

8. The number of fruits produced per unit area combined with the mean dry weight of a fruit are measures that should provide an accurate and useful index of nutrition available to bears from year to year.

9. Data from this study can be used as a basis for designing experiments to research the effects of forest management practices on bear habitat. Results will allow land managers to assess the impacts of forest management plans on bear populations.

LITERATURE CITED

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Beck, D. E. 1977. Twelve year acorn yield in southern Appalachian oaks. United States Department of Agriculture Forest Service Research Note SE-244.

Beecham, J. J. 1980. Some population characteristics of two black bear populations in Idaho. Int. Conf. Bear Res. and Manage. 4:201-204.

Beeman, L. E., and M. R. Pelton. 1980. Seasonal foods and feeding ecology of black bears in the Smoky Mountains. Int. Conf. Bear Res. and Manage. 4:141-147.

Beringer, J. J., S. G. Seibert, and M. R. Pelton. 1990. Incidence of road crossing by black bears on Pisgah National Forest, North Carolina. Int. Conf. Bear Res. and Manage. 8:85-92.

Brody, A. J., and M. R. Pelton. 1988. Seasonal changes in digestion in black bears. Canad. J. Zool. 66:1482-1484.

_____ and _____. 1989. Effects of roads on black bear movements in western North Carolina. Wildl. Soc. Bull. 17:5-10.

Burst, T. L., and M. R. Pelton 1983. Black bear mark trees in the Smoky Mountains. Int. Conf. Bear Res. and Manage. 5:45-53.

Cain, S. A. 1935. Ecological studies of the vegetation of the Great Smoky Mountains. II. The quadrat method applied to sampling spruce and fir forest. Amer. Mid. Nat. 16:566-584.

Carlock, D. M., R. H. Conley, J. M. Collins, P. E. Hale, K. G. Johnson, A. J. Johnson, and M. R. Pelton. 1983. The tri-state black bear study. Tech. Rep. 83-9. Univ. Tenn., Knoxville. 286pp.

Carr, P. C. 1983. Habitat utilization and seasonal movements of black bears in Great Smoky Mountains National Park. M.S. Thesis, Univ. Tenn., Knoxville. 95pp.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons. N.Y. 234pp.

Christisen, D. M. 1955. Yield of seed by oaks in the Missouri ozarks. J. For. 53:439-441.

Clark, J. D. 1991. Ecology of two black bear populations in the interior highlands of Arkansas. Ph.D. Diss., Univ. Ark. Fayetteville. 228pp.

Clevenger, A. P. 1986. Habitat and space utilization of black bears in Cherokee National Forest, Tennessee. M.S. Thesis, Univ. Tenn., Knoxville. 125pp.

Coley, A. B. 1995. Population dynamics of black bears in Great Smoky Mountains National Park. M.S. Thesis, Univ. Tenn., Knoxville. 180pp.

Crampton, E. W. and L. E. Harris. 1969. Applied animal nutrition. W. H. Freeman and Co., San Francisco, CA. 753pp.

Downs, A. A., and W. E. McQuilkin. 1944. Seed production of southern Appalachian oaks. J. For. 42:913-920.

Downs, A. A. 1944. Estimating acorn crops for wildlife in the southern Appalachians. J. Wildl. Manage. 8:339-340.

Eagar, C. 1984. Description of community types. Report available from Uplands Field Research Lab, Great Smoky Mountains National Park, Gatlinburg, TN.

Eagle, T. C. and M. R. Pelton. 1983. Seasonal nutrition of black bears in the Great Smoky Mountains National Park. Int. Conf. Bear Res. and Manage. 5:94-101.

Eiler, J. H., W. G. Wathen, and M. R. Pelton. 1989. Reproduction in black bears in the southern Appalachian mountains. J. Wildl. Manage. 52:353-360.

Elowe, K. D., and W. E. Dodge. 1989. Factors affecting black bear reproductive success and cub survival. J. Wildl. Manage. 53(4):962-968.

Fenneman, N. M. 1938. Physiography of the eastern United States. McGraw-Hill Book Co., New York and London. 714pp.

Feret, P. P., R. E. Creh, S. A. Merkle, and R. G. Oderwald. 1982. Flower abundance, premature acorn abscission, and acorn production in Quercus alba L. Bot. Gaz. 143(2):216-218.

French, J. R. 1985. Oak mast availability and use by large mammals in eastern Tennessee. Tennessee Wildlife Resources Agency Technical Report No. 85-5.

Garris, R. S. 1983. Movement ecology of black bears in Cherokee National Forest, Tennessee. M.S. Thesis, Univ. Tenn., Knoxville. 98pp.

Garshelis, D. L. 1978. Movement ecology and activity behavior of black bears in the Great Smoky Mountains National Park. M.S. Thesis, Univ. Tenn., Knoxville. 117pp.

_____. 1994. Density-dependent population regulation of black bears. Pages 3-14 in M. Taylor, ed. Density-dependent population regulation in black, brown, and polar bears. Int. Conf. Bear Res. and Manage. Monogr. Series No. 3. 43pp.

_____, and M. R. Pelton. 1980. Activity of black bears in Great Smoky Mountains National Park. J. Mammal. 61:8-19.

_____, and _____. 1981. Movements of black bears in the Great Smoky Mountains National Park. J. Wildl. Manage. 45:912-925.

Goodrum, P. D., V. H. Reid and C. E. Boyd. 1971. Acorn yields, characteristics, and management criteria of oaks for wildlife. J. Wildl. Manage. 35:520-532.

Golden, M. S. 1974. Forest vegetation and site relationships in the central portion of the of Great Smoky Mountains National Park. Ph.D. Dissertation, Univ. Tenn., Knoxville. 275 pp.

Golley, F. B. 1961. Energy values of ecological materials. Ecology 42:581-584.

Grodzinski, W., and K. Sawicka-Kapusta. 1970. Energy values of tree seeds eaten by small mammals. Oikos 21:52-58.

Gysel, L. W. 1958. Prediction of acorn crops. Forest Sci. 4:239-245.

Hellgren, E. C., M. R. Vaughn, and R. L. Kirkpatrick. 1989. Seasonal patterns in physiology and nutrition of black bears in Great Dismal Swamp, Virginia - North Carolina. Can. J. Zool. 67: 1837-1850.

Johnson, A. S., and J. L. Landers. 1978. Fruit production in slash pine plantations in Georgia. J. Wildl. Manage. 42:606-613.

Johnson, S. R., and R. J. Robel. 1968. Caloric values of seeds from four range sites in northeastern Kansas. Ecology 49(5):956-961.

Jonkel, C. J., and I. M. Cowen. 1971. The black bear in the spruce-fir forest. Wildl. Monogr. 27. 57 pp.

Kasbohm, J. W., M. R. Vaughn, and J. G. Kraus. 1996. Effects of gypsy moth infestation on black bear reproduction and survival. J. Wildl. Manage. 60:408-416.

King, P. B., and A. Stupka. 1950. The Great Smoky Mountains -- their geology and natural history. Sci. Month. 71:31-43.

_____., R. B. Neuman, and J. B. Hadley. 1968. Geology of the Great Smoky Mountains National Park, Tennessee and North Carolina. USDI, Geological Survey Professional Paper 587. 23pp.

Kuykendall, N. W. III. 1978. Composition and structure of replacement forest stands following southern pine beetle infestations as related to selected site variables in the Great Smoky Mountains. M.S. Thesis, Univ. Tenn., Knoxville. 122pp.

LeCount, A. L. 1982. Characteristics of a central Arizona black bear population. J. Wildl. Manage. 46:861-868.

_____. 1987. Causes of black bear cub mortality. Int. Conf. Bear Res. and Manage. 7:75-82.

Levey, D. J., C. H. Greenberg, and R. L. Mumme. in press. Spatial and temporal abundance of hard mast and fleshy fruit in five habitats at the Savannah River site, South Carolina.

Linzey, A. V., and D. N. Linzey. 1971. Mammals of the Great Smoky Mountains National Park. Univ. Tenn. Press., Knoxville. 114pp.

MacKenzie, M. D. 1993. The vegetation of Great Smoky Mountains National Park: past, present, and future. Ph.D. Dissertation, Univ. Tenn., Knoxville. 154pp.

Martin, A. C., H. S. Zim, and A. L. Nelson. 1951. American wildlife and plants: a guide to wildlife food habits. Dover Publications, Inc., New York.

McLaughlin, C. R., Matula, G. J. Jr., and R. J. O'Conner. 1994. Syncronous reproduction by Maine black bears. Int. Conf. Bear Res. and Manage. 9:471-479.

McLean, P. K. 1991. The demographic and morphological characteristics of black bears in the Smoky Mountains. M.S. Thesis, Univ. Tenn., Knoxville. 156pp.

McNab, B. K. 1989. Basal rate of metabolism, body size, and food habits in the Order Carnivora. Pages 335-354 in J. L. Gittleman ed. Carnivore behavior, ecology, and evolution. Cornell University Press, Ithaca, NY. 620pp.

McNab, W. H. 1989. Terrain shape index: quantifying effect of minor landforms on tree hieght. Forest Science. 35:91-104.

_____. 1993. A topographical index to quantify the effect of mesoscale landform on site productivity. Canadian Journal of Forest Resources. 23:1100-1107.

Miller, S. D. 1994. Black bear production and cub survival in south-central Alaska. Int. Conf. Bear Res. and Manage. 9:263-273.

National Park Service. 1980. Resource management plan for the Great Smoky Mountain National Park. Gatlinburg, TN. 70pp.

Nelson, R. A., G. E. Folk, E. W. Pfeiffer, J. J. Craighead, C. J. Jonkle, and D. L. Steiger. 1983. Behavior, biochemistry, and hibernation in black, grizzly, and polar bears. Int. Conf. Bear Res. and Manage. 5:284-290.

Nicholas, N. S., and P. S. White. 1984. Great Smoky Mountains National Park hard mast survey: An evaluation of the current survey, analysis of past data and discussion of alternatives for future use. U. S. Dept. of the Interior, National Park Service, Research/Resource Mgmt. Report SER-68. 66pp.

Noyce, K. V., and P. L. Coy. 1990. Abundance and productivity of bear food species in different forest types of northcentral Minnesota. Int. Conf. Bear Res. and Manage. 8:169-181.

_____, and D. L. Garshelis. 1994. Body size and blood characteristics as indicators of condition and reproductive performance in black bears. Int. Conf. Bear Res. and Manage. 9:481-496.

Ofcarick, R. P. and E. E. Burns. 1971. Chemical and physical properties of selected acorns. J. Food Sci. 36:576-578.

Pelton, M. R. 1982. Black bear. Pages 504-514 *in* J. A. Chapman and G. A. Feldhamer, eds. Wild Mammals of North America. The Johns Hopkins Univ. Press, Baltimore, MD.

_____. 1989. The impacts of oak mast on black bears in the southern Appalachians. *In* C. E. McGee, ed. Proceedings of the workshop: southern Appalachian mast management. The University of Tennessee, Knoxville. 85pp.

Powell, R. A., and D. E. Seaman. 1990. Production of important black bear foods in the southern Appalachians. Int. Conf. Bear Res. and Manage. 8:183-187.

Pozzanghera, S. A. 1990. The reproductive biology, winter dormancy and denning physiology of black bears in Great Smoky Mountains National Park. M.S. Thesis, Univ. Tenn., Knoxville. 126pp.

Pyle, C. 1988. Prediction of forest type and productivity index on disturbed sites in Great Smoky Mountains National Park. M.S. Thesis, Univ. Tenn., Knoxville. 202pp.

Quigley, H. B. 1982. Activity patterns, movement ecology, and habitat utilization of black bears in the Great Smoky Mountains National Park. M.S. Thesis, Univ. Tenn., Knoxville. 140pp.

Robbins, C. T., A. E. Hagerman, P. J. Austin, C. McArthur, and T. A. Hanley. 1991. Variation in mammalian physiological responses to a condensed tannin and its ecological implications. J. Mammal. 72:480-486.

Rogers, L. L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. Trans. North Am. Wildl. and Nat. Resour. Conf. 41:431-438.

_____. 1987. Effects of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. Wildl. Monogr. 97. 72 pp.

SAS Institute, Inc. 1989. SAS/STAT User's Guide, Version 6, 4th edition, Volumes 1 and 2. SAS Institute Inc., Cary, NC.

Schoen, J. W. 1990. Bear habitat management: a review and future perspective. Int. Conf. Bear Res. and Manage. 8:143-154.

Seibert, S. G., and M. R. Pelton. 1994. Nutrient content of Squawroot, *Conopholis americana*, and its importance to southern Appalachian black bears, *Ursus americanus* (Carnivora: Ursidae). Brimleyana 21:151-156.

Shanks, R. E. 1954. Climates of the Great Smoky Mountains. Ecology 34:354-361.

Sharp, W. M. and V. G. Sprague. 1967. Flowering and fruiting in the white oaks: pistillate flowering, acorn development, weather, and yields. Ecology 48:243-251.

Silvertown, J. H. 1980. The evolutionary ecology of mast seeding in trees. Biological Journal of the Linnean Society. 14:235-250.

Smallshaw, J. 1953. Some precipitation altitude studies of the Tennessee Valley Authority. Trans. Amer. Geophys. Union 34:583-588.

Soil Survey. 1945. Sevier County. US Dept. of Agric., Univ. Tenn. Agric. Exp. Sta. and Tenn. Valley Authority. 203pp.

_____. 1953. Blount County. US Dept. of Agric., Univ. Tenn. Agric. Exp. Sta. and Tenn. Valley Authority. 119pp.

Sork, V. L., J. Bramble, and O. Sexton. 1993. Ecology of mast-fruiting in three species of North American deciduous oaks. Ecology 74:528-541.

Stephens, L. A. 1969. A comparison of climatic elements at four elevations in the Great Smoky Mountains National Park. M.S. Thesis, University of Tennessee, Knoxville. 119pp.

Strickland, M. D. 1972. Production of mast by selected species of oak (Quercus sp.) and its use by wildlife on the Tellico Wildlife Management Area, Monroe County, Tennessee. M.S. Thesis, Univ. Tenn., Knoxville. 62pp.

Stringham, S. F. 1990. Black bear reproductive rate relative to body weight in hunted populations. Int. Conf. Bear Res. and Manage. 8:425-432.

Stupka, A. 1960. Great Smoky Mountains National Park natural history handbook. No. 5. U. S. Govt. Printing Office, Washington, D. C. 75pp.

Sweet, G. B. 1973. Shedding of reproductive structures in forest trees. Pages 341-382 *in* T. T. Kozlowski, editor. Shedding of plant parts. Academic Press, New York, NY, USA.

Thornthwaite, C. W. 1948. An approach toward a rational classification of climate. Geog. Rev. 38:55-94.

van Manen, F. T. 1994. Black bear habitat use in Great Smoky Mountains National Park. Ph.D. Dissertation, Univ. Tenn., Knoxville. 212 pp.

Villarubia, C. R. 1982. Movement ecology and habitat utilization of black bears in Cherokee National Forest, Tennessee. M.S. Thesis, Univ. Tenn., Knoxville. 159 pp.

Whitehead, C. J. 1969. Oak mast yields on wildlife management areas in Tennessee. Unpub. Rept. TN Game and Fish Commission, Nashville. 11pp.

Whittaker, R. H. 1956. The vegetation of Great Smoky Mountains. Ecological Monographs 26:1-80.

Wielgus, R. B., and F. L. Bunnel. 1994. Sexual segregation and female grizzly bear avoidance of males. J. Wildl. Manage. 58:405-413.

Yoke, K. A. 1994. Landscape ecosystem classification in the Cherokee National Forest. M.S. Thesis, Univ. Tenn., Knoxville. 100 pp.

Young, B. F., and R. L. Ruff. 1982. Population dynamics and movements of black bears in east central Alberta. J. Wildl. Manage. 46:845-860.

Zager, P., C. Jonkle, and J. Habeck. 1983. Logging and wildfire influence on grizzly bear habitat in northwestern Montana. Int. Conf. Bear Res. and Manage. 5:124-132.

APPENDICES

Appendix A. Comparison of mean m^3 crown volume and basal area per hectare for bear food trees in each of 9 overstory vegetation types of Great Smoky Mountains National Park.

Appendix A. Comparison of mean m^3 crown volume and basal area per hectare for bear food trees in each of 9 vegetation types of Great Smoky Mountains National Park.

Vegetation Type	Tree Species	Crown Volume m^3/ha	Basal Area m^2/ha[a]
Spruce-fir	Fire cherry	449	0.65
	American beech	.	0.17
Northern Hardwood	American beech	6,066	5.23
	Black cherry	1,704	0.53
	Northern red oak	1,417	2.28
	Fire cherry	47	1.76
	Serviceberry	.	0.42
	Chestnut oak	.	0.10
	Scarlet oak	.	0.05
Cove Hardwood	Northern red oak	14,325	3.16
	Chestnut oak	5,563	0.59
	Hickories	2,048	0.40
	White oak	1,598	0.01
	Scarlet oak	1,085	0.02
	American beech	.	1.58
	Black cherry	.	1.04
	Serviceberry	.	0.26
	Fire cherry	.	0.16
	Blackgum	.	0.08
Mesic Oak	Northern red oak	9,903	14.68
	Chestnut oak	3,536	5.99
	Black cherry	2,173	0.50
	White oak	2,118	0.63
	American beech	699	0.51
	Blackgum	.	1.87
	Scarlet oak	.	0.50
	Hickories	.	0.47
	Serviceberry	.	0.28
Mixed Mesic Hardwood	Northern red oak	11,753	1.63
	Hickories	7,984	0.85
	Chestnut oak	7,534	2.43
	White oak	6,523	0.42
	Scarlet oak	.	0.22
	Blackgum	.	0.17
	Serviceberry	.	0.17
	Black cherry	.	0.14
	American beech	.	0.07

Appendix A. (Cont.).

Vegetation Type	Tree Species	Crown Volume m^3/ha	Basal Area m^2/ha [a]
Tulip-Poplar	Chestnut oak	5,850	.
	Northern red oak	3,519	.
	Hickories	219	0.16
	Black cherry	.	0.08
Xeric Oak	Chestnut oak	19,645	5.80
	Northern red oak	4,295	1.62
	Scarlet oak	3,207	2.05
	White oak	1,646	1.84
	Hickories	1,620	1.12
	Blackgum	809	0.22
	American beech	.	0.09
	Serviceberry	.	0.06
Pine-Oak	Chestnut oak	14,210	2.61
	Northern red oak	3,773	0.63
	Scarlet oak	2,468	5.55
	Hickories	1,107	.
	White oak	1,066	1.34
	Blackgum	.	2.90
Pine	Northern red oak	4,889	0.23
	Chestnut oak	4,366	1.28
	Hickories	3,334	0.33
	Scarlet oak	3,055	2.30
	White oak	2,365	0.09
	Blackgum	725	0.91
	Black cherry	529	.

[a] Basal areas as determined by MacKenzie (1993). Number of vegetation plots sampled by MacKenzie were as follows:

Spruce-Fir - 14
Northern Hardwood - 2
Cove Hardwood - 29
Mesic Oak - 40
Mixed Mesic Hardwood - 68
Tulip-Poplar - 40
Xeric Oak - 15
Oak-Pine - 5
Pine - 10.

Appendix B. Figures of weekly percent flowering and fruiting and number of weekly observations for each bear food species

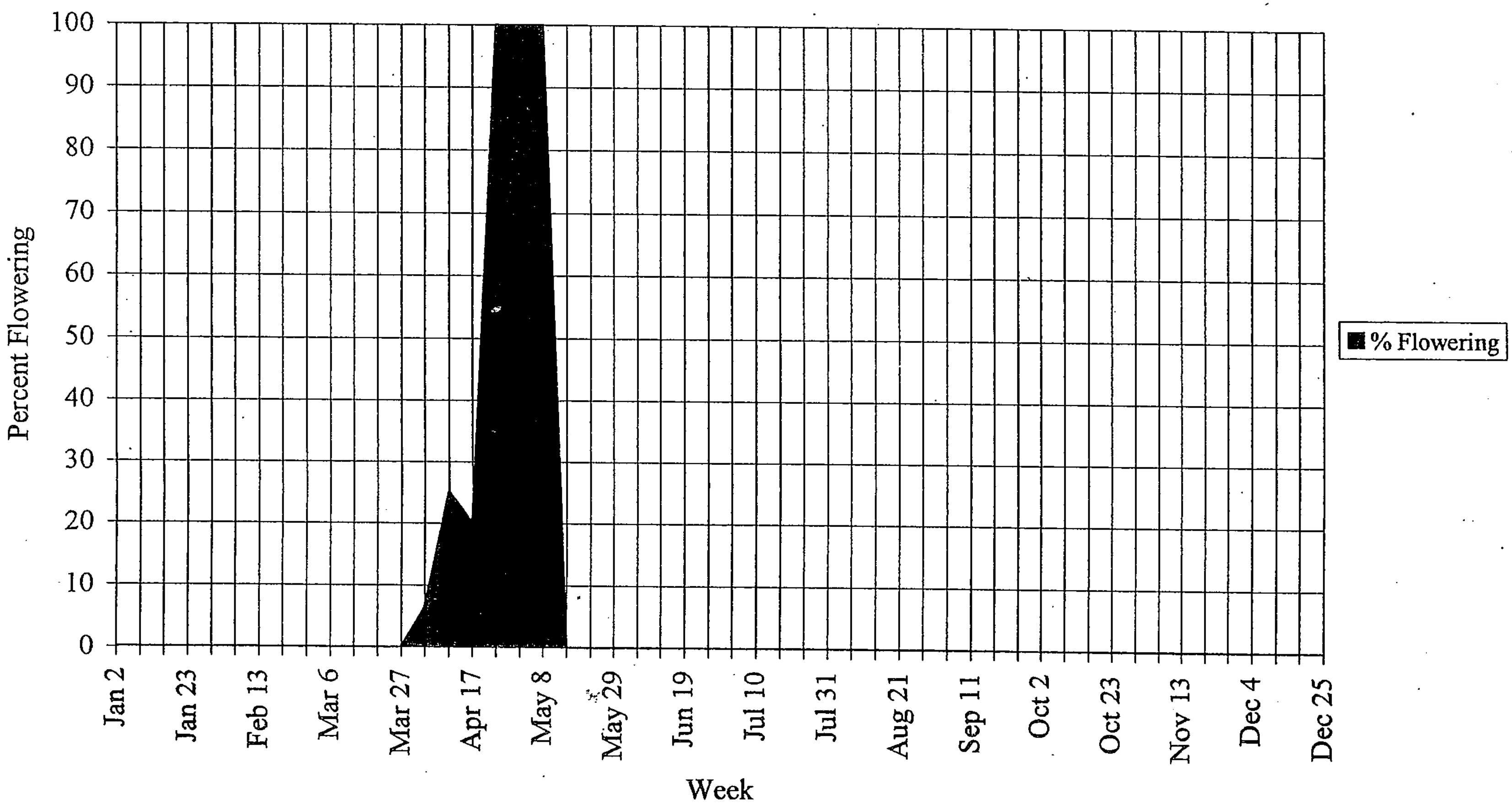

Figure B1. Weekly percentage of Serviceberry *(Amelanchier spp.)* flowering in the northwest quadrant of Great Smoky Mountains National Park, 1995

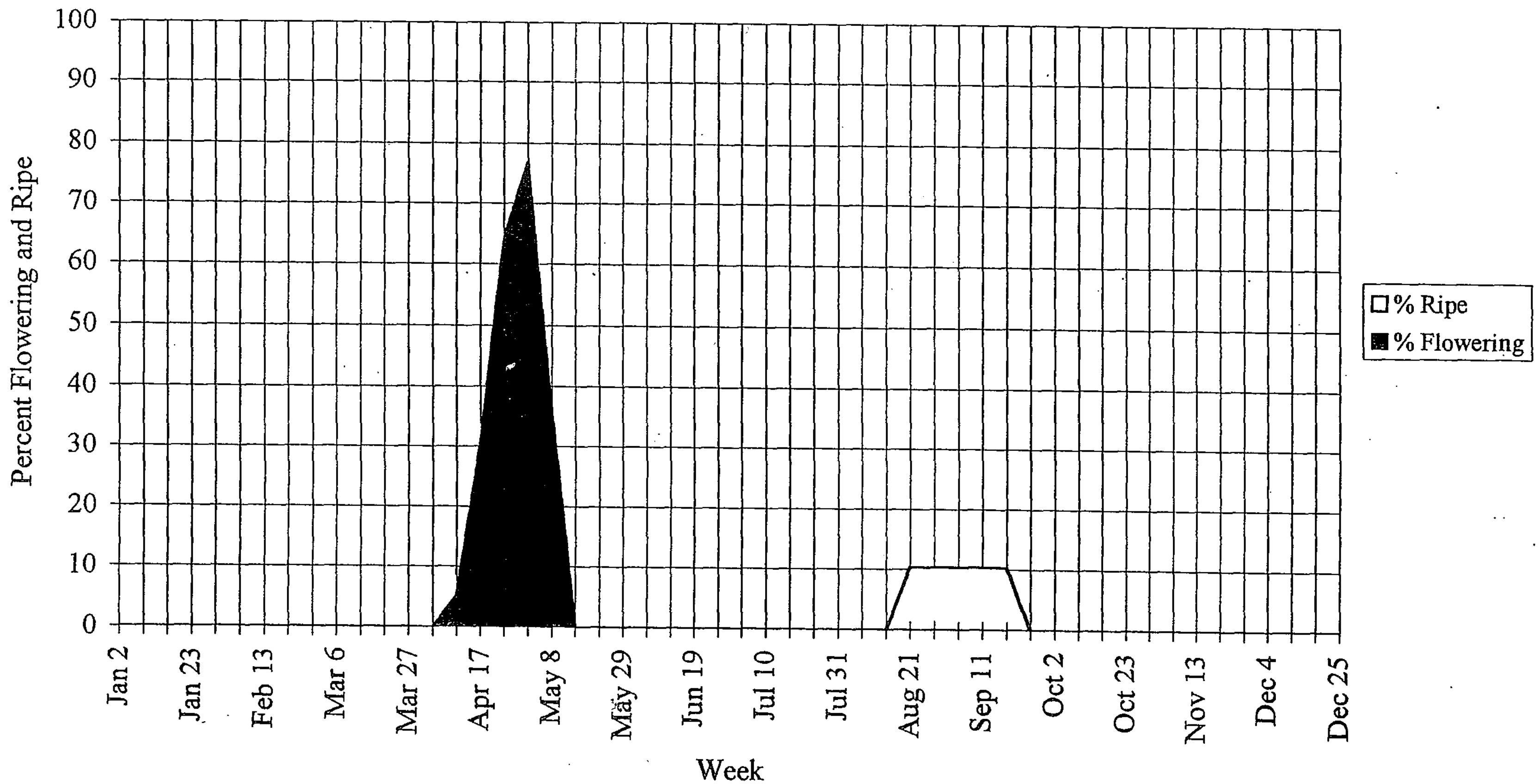

Figure B2. Weekly percentage of Hickories *(Carya spp.)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

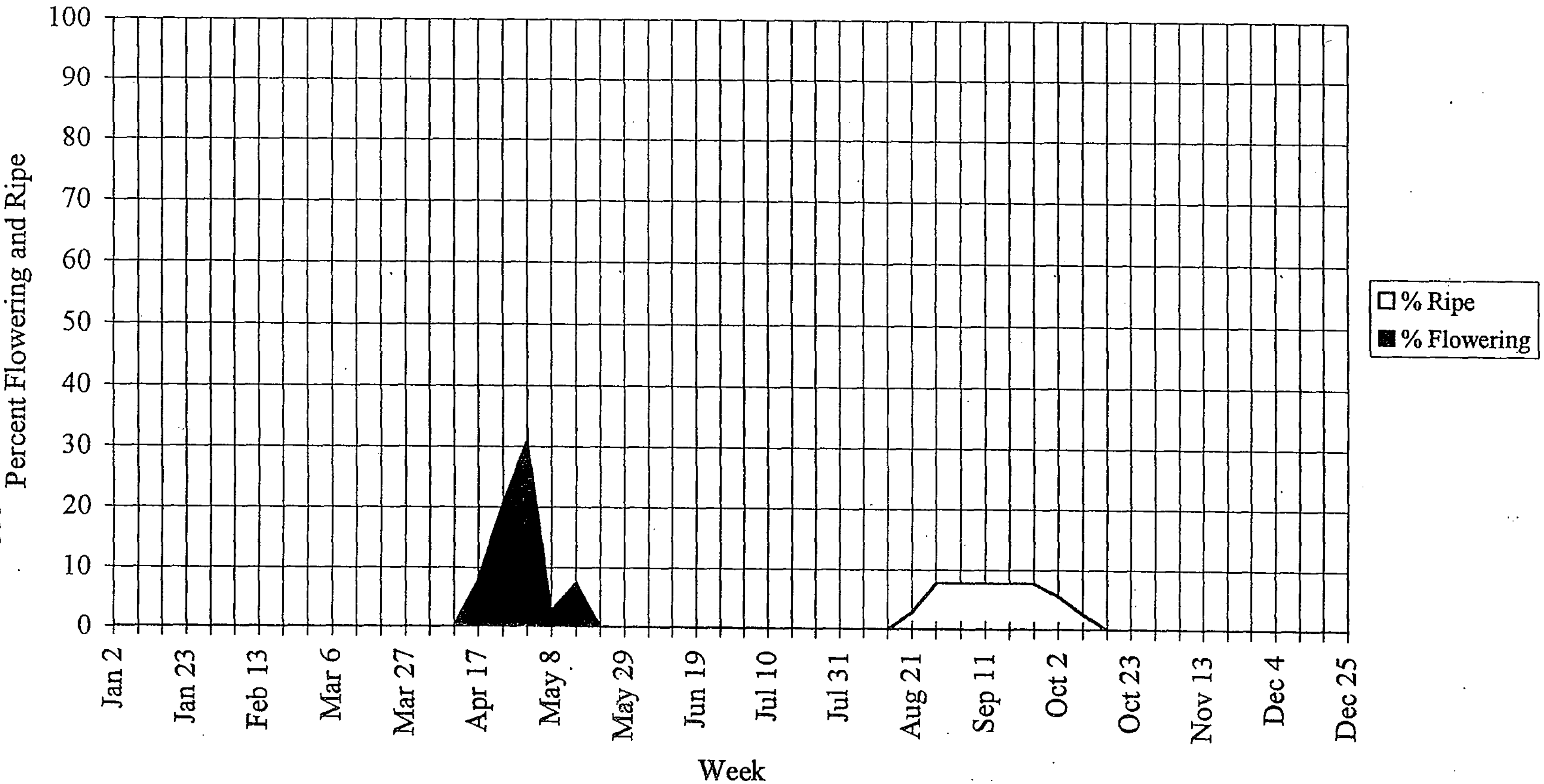

Figure B3. Weekly percentage of Blackgum *(Nyssa sylvatica)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

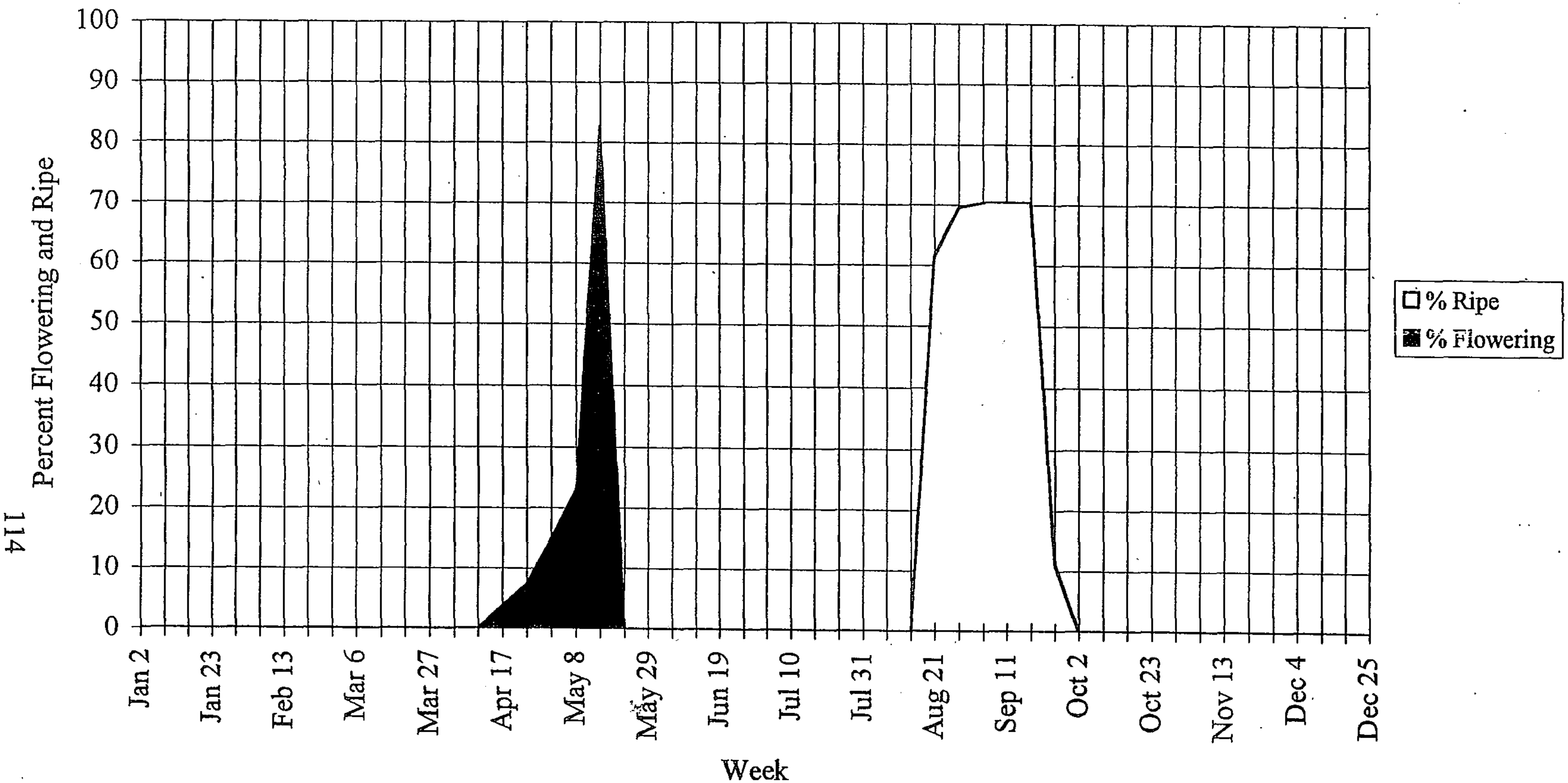

Figure B4. Weekly percentage of Fire cherry *(Prunus pensylvanica)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

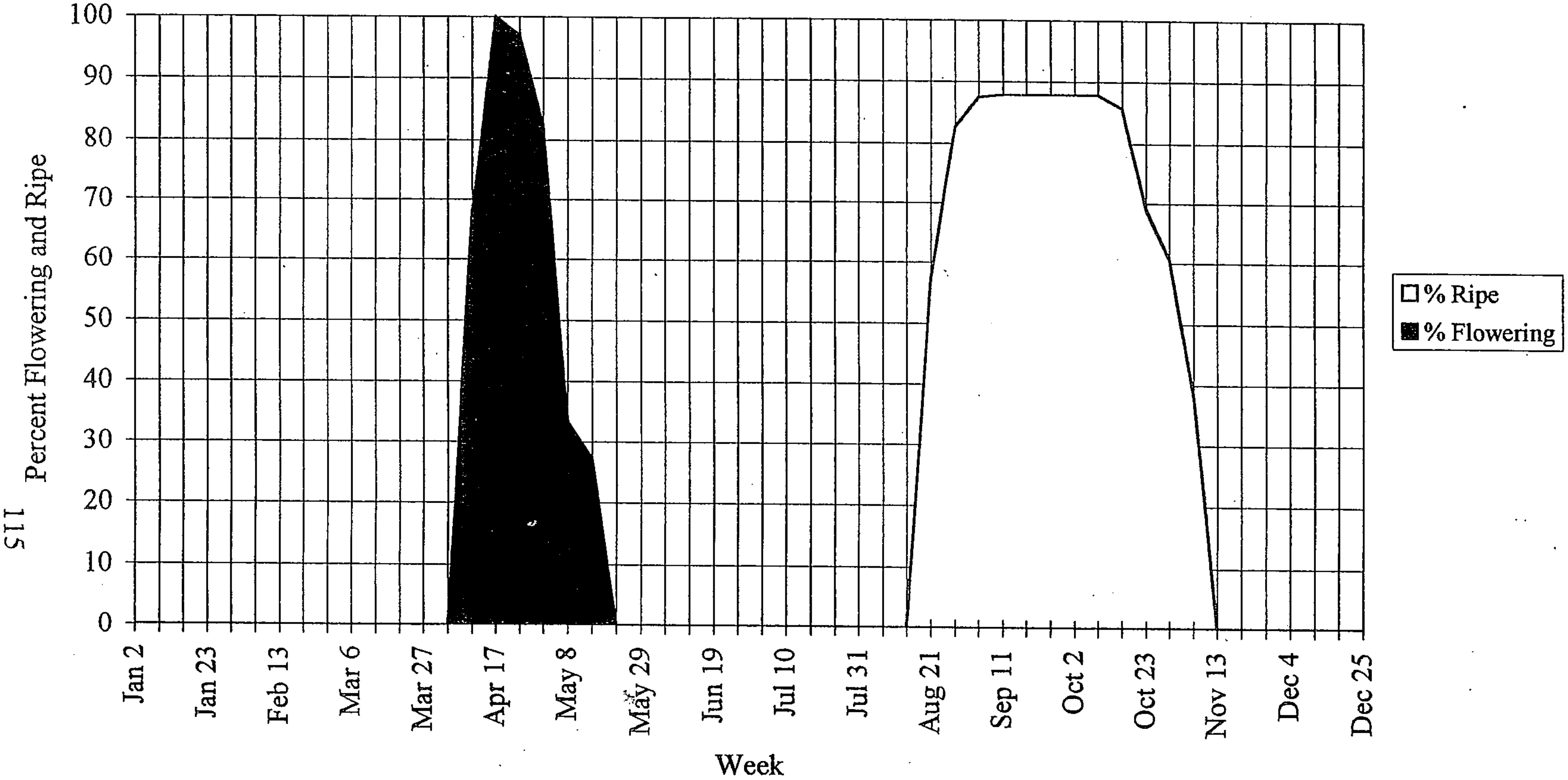

Figure B5. Weekly percentage of Black cherry *(Prunus serotina)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

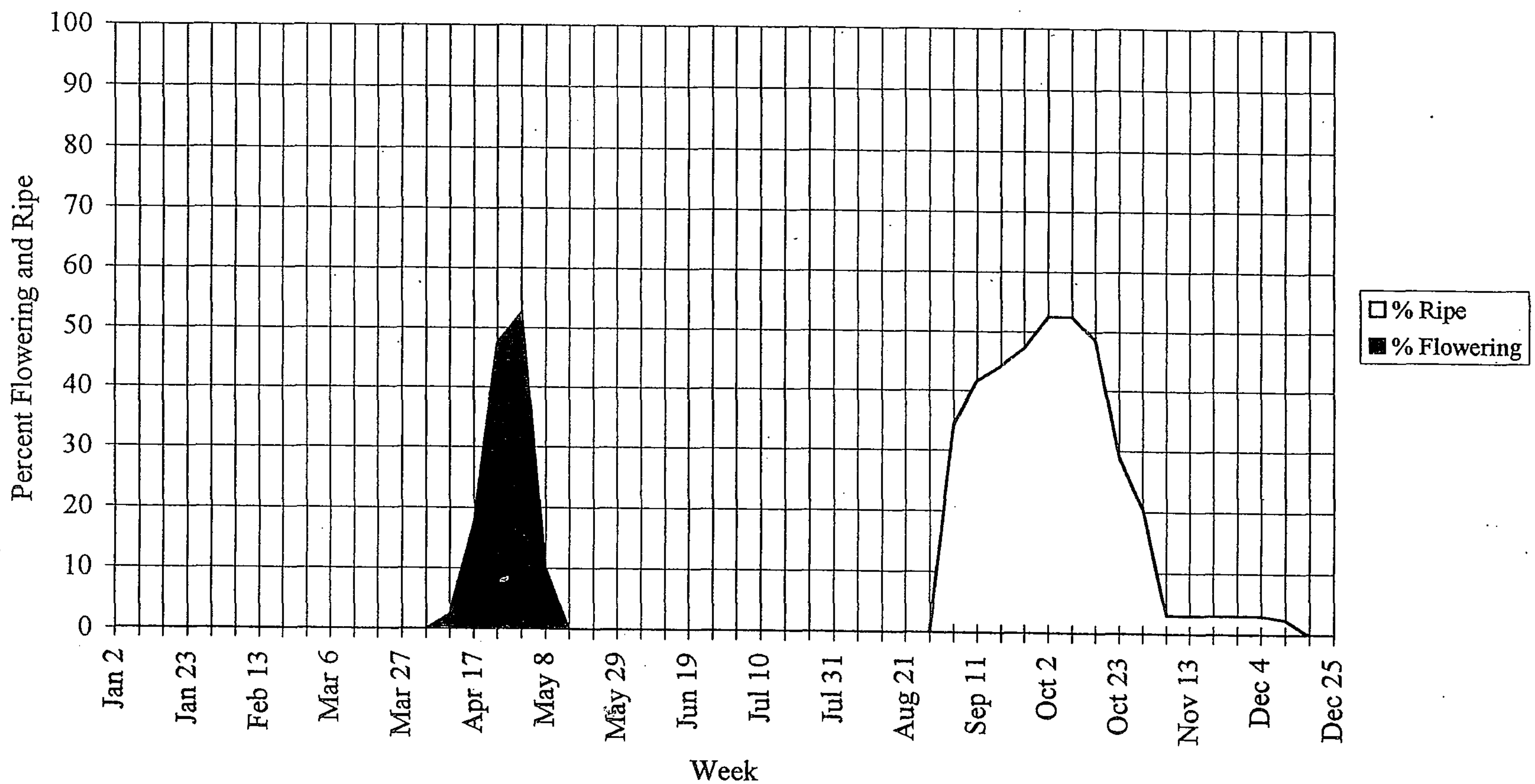

Figure B6. Weekly percentage of White oak *(Quercus alba)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

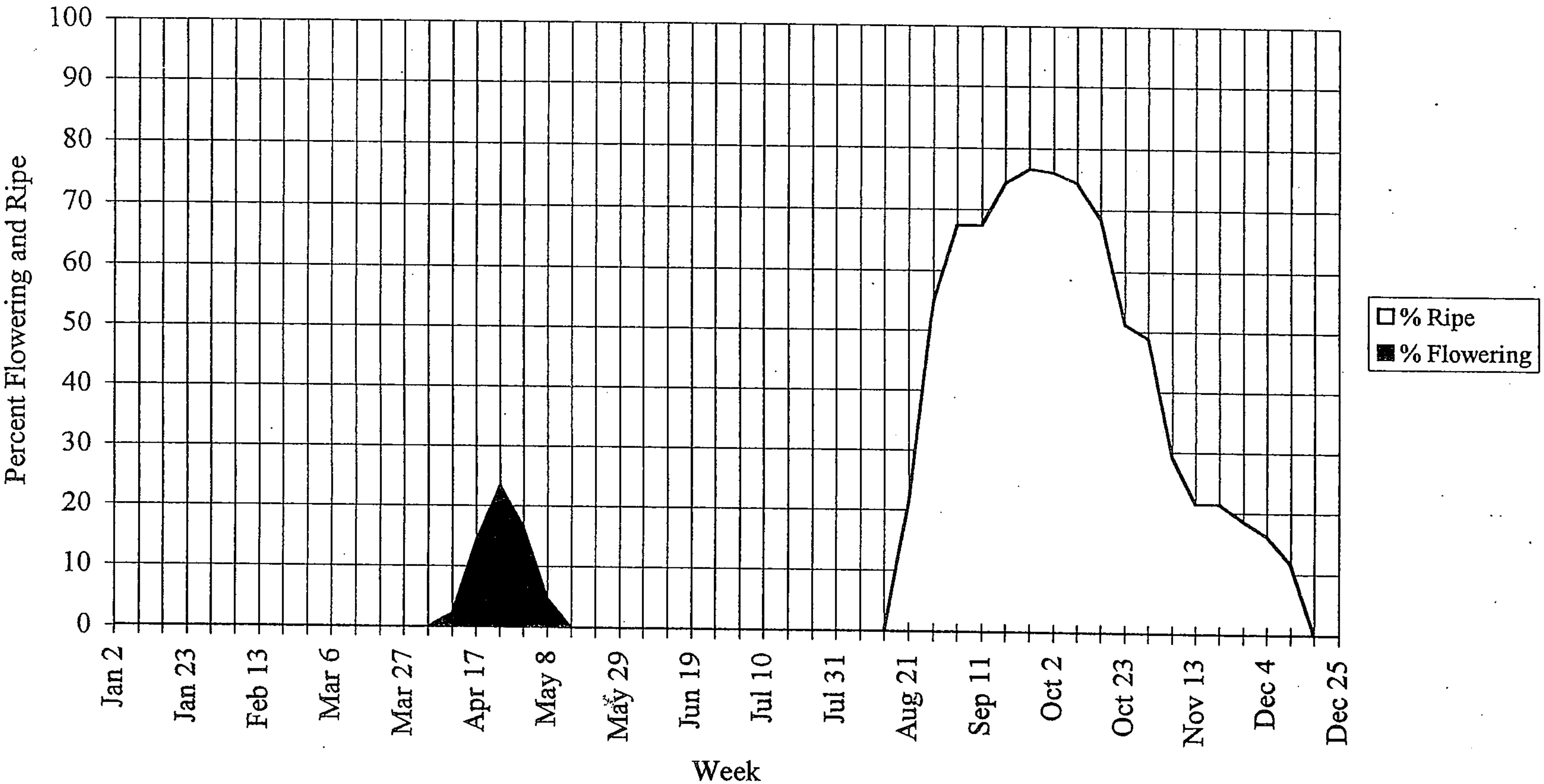

Figure B7. Weekly percentage of Scarlet oak *(Quercus coccinea)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

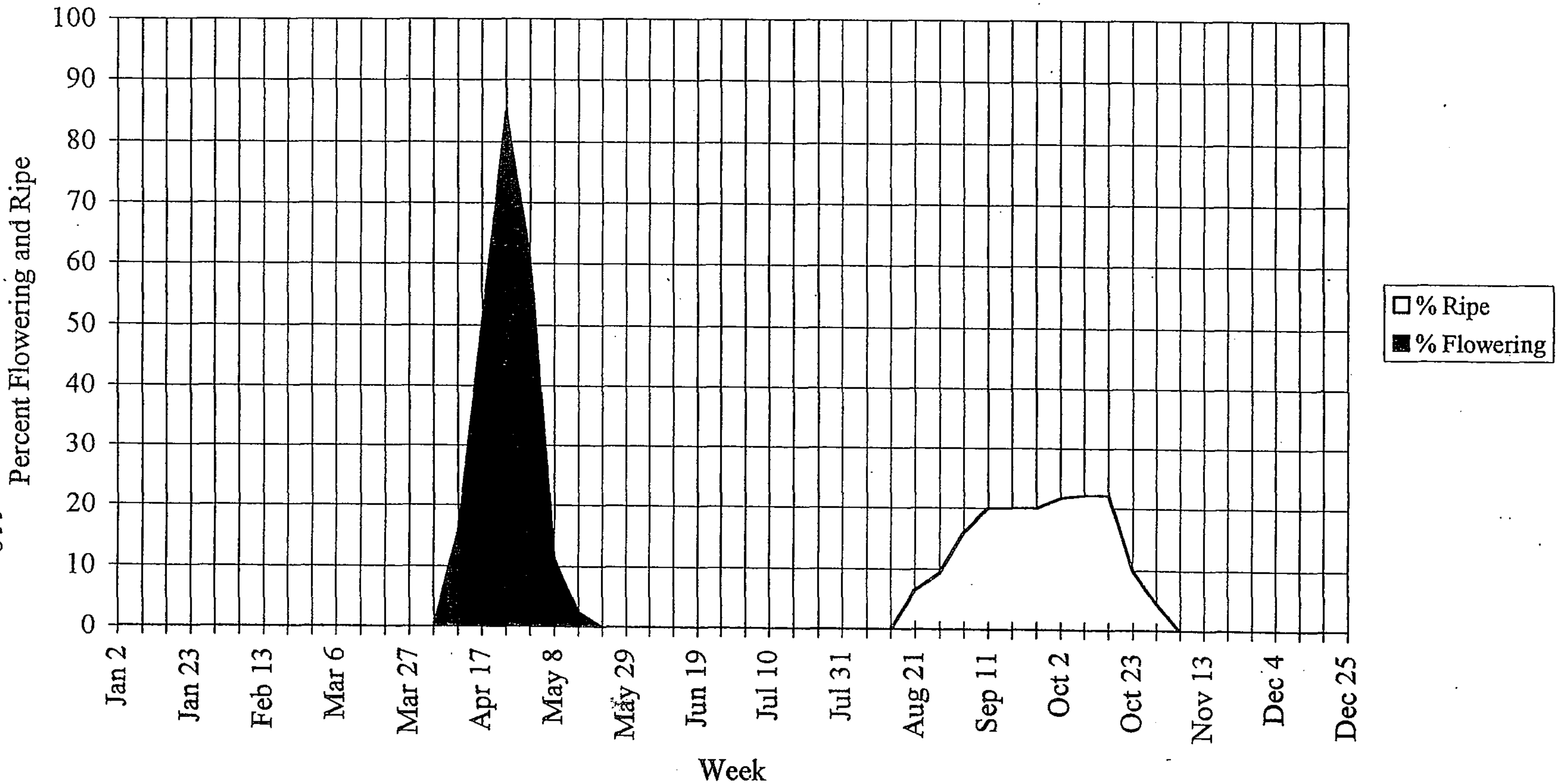

Figure B8. Weekly percentage of Chestnut oak *(Quercus prinus)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

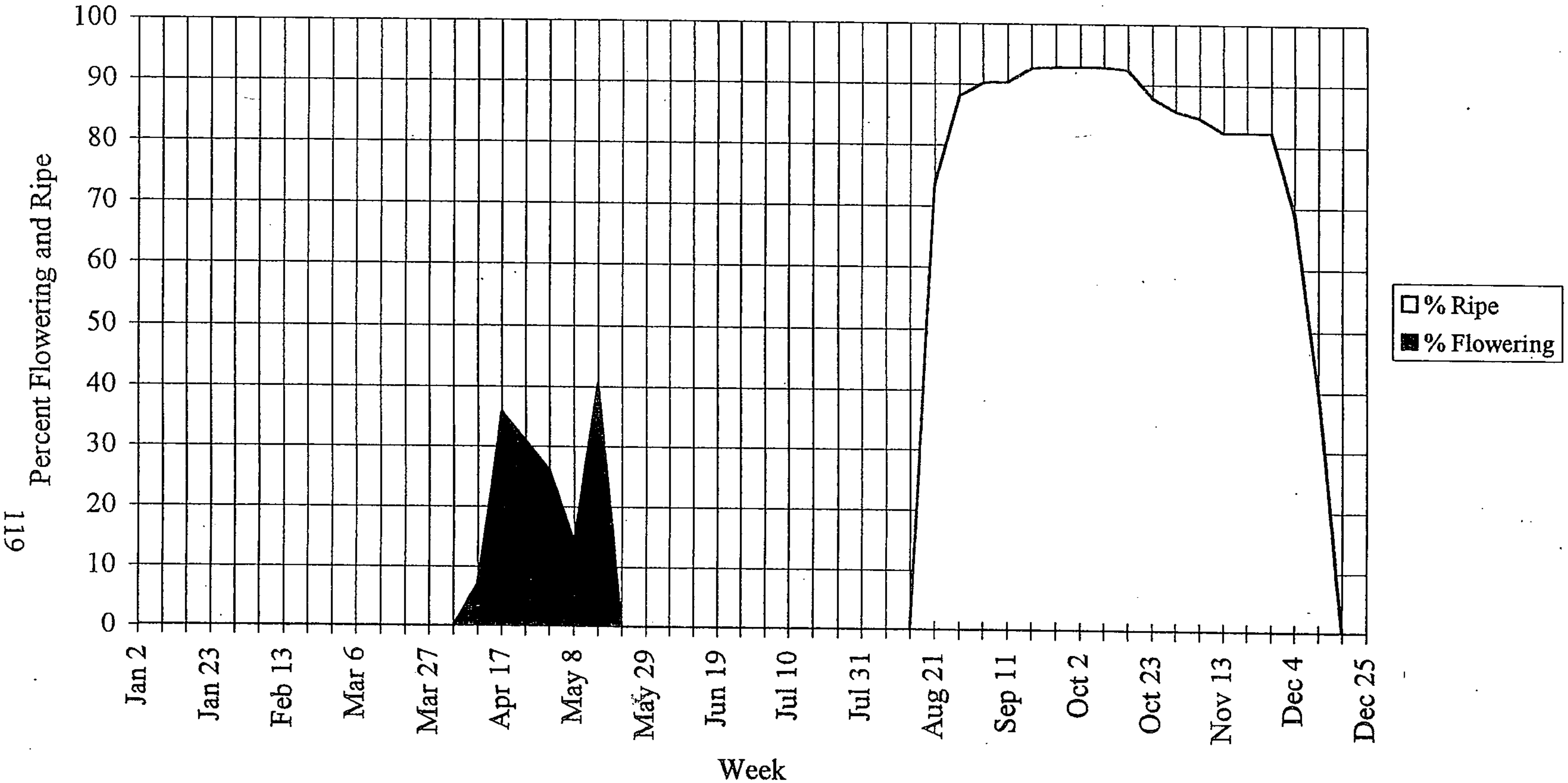

Figure B9. Weekly percentage of Northern red oak *(Quercus rubra)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

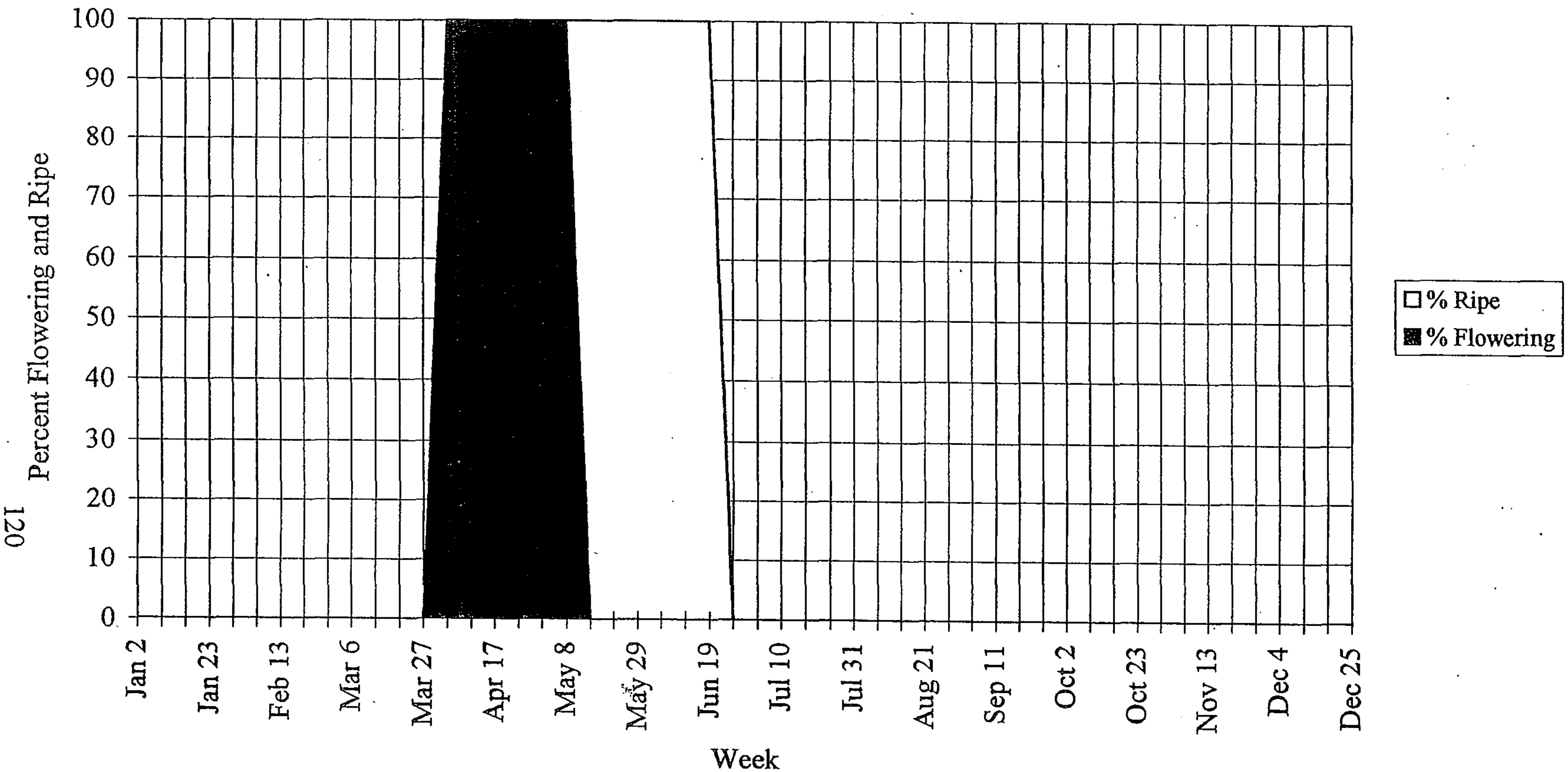

Figure B10. Weekly percentage of Squawroot *(Conopholis americana)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

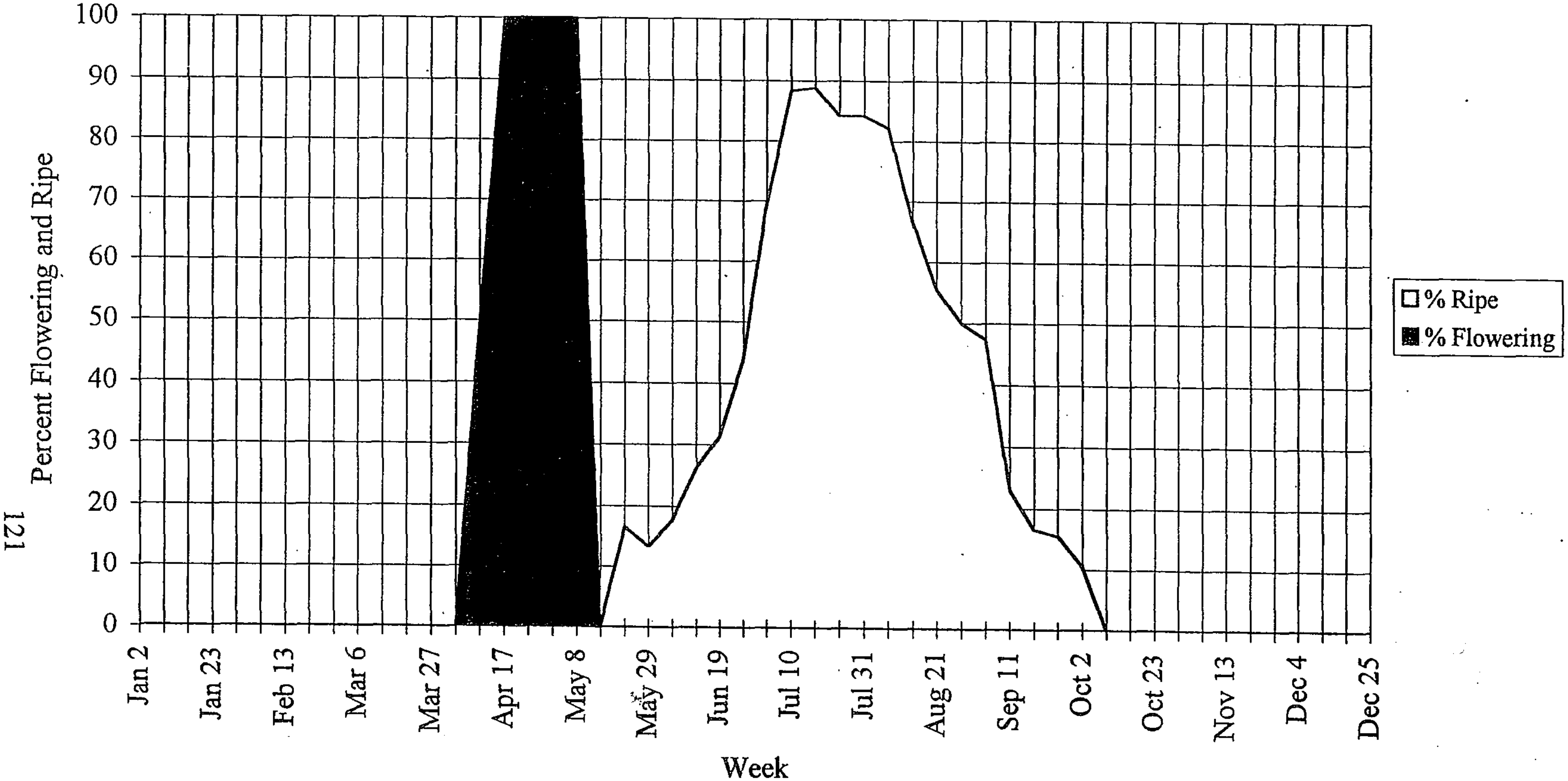

Figure B11. Weekly percenatge of Huckleberries *(Gaylussacia spp.)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

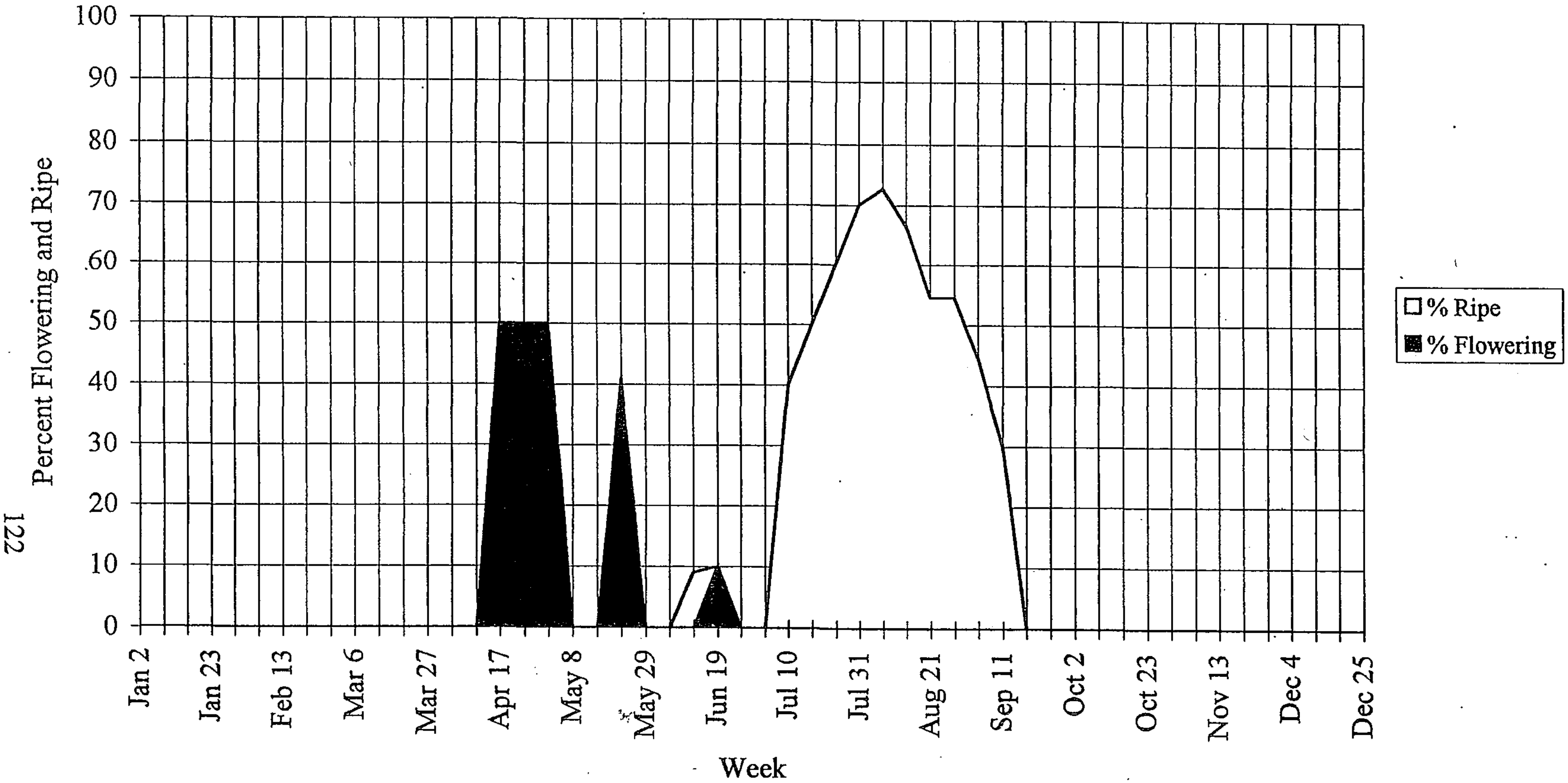

Figure B12. Weekly percentage of Allegheny blackberry *(Rubus allegheneinsis)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

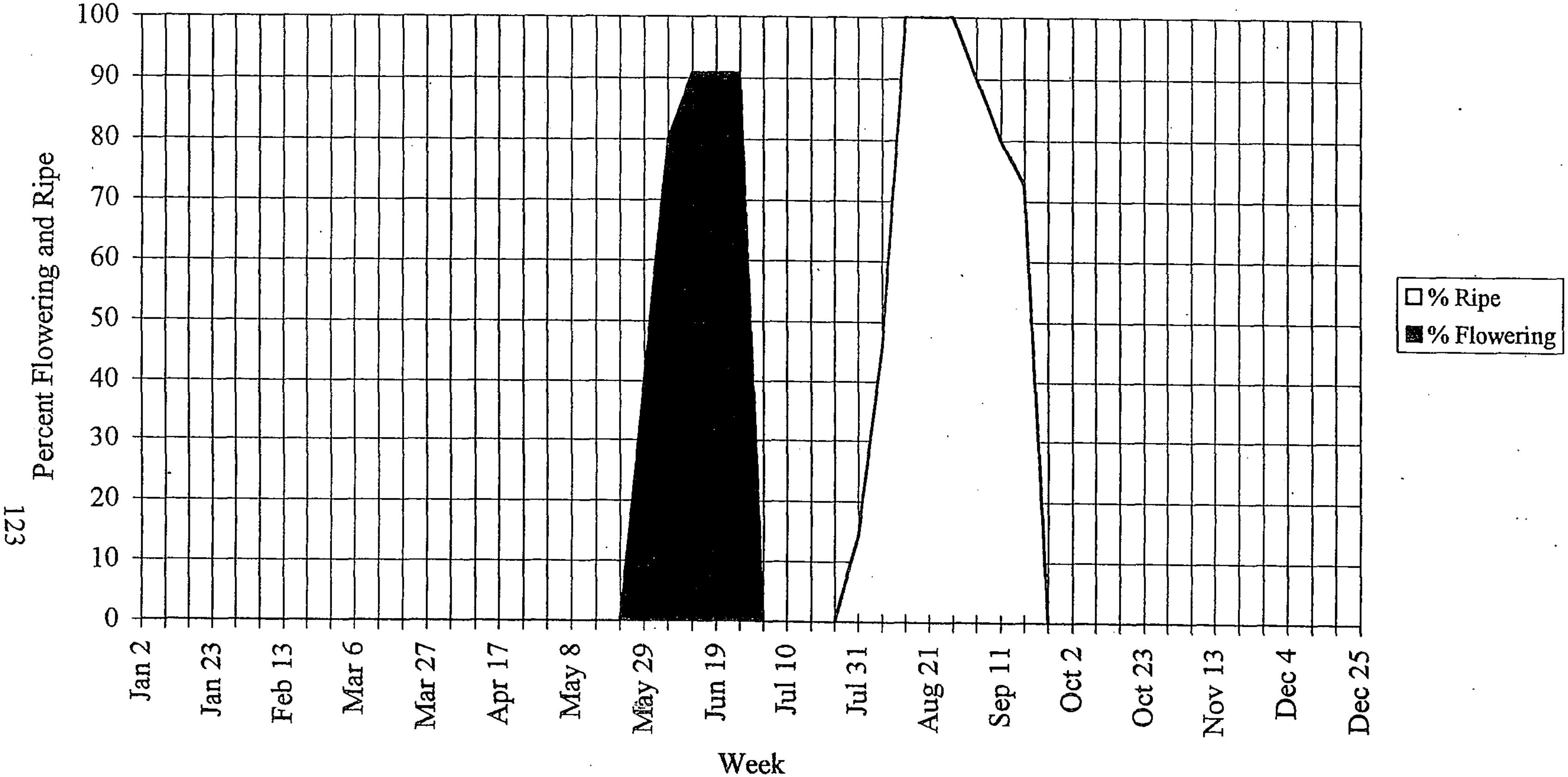

Figure B13. Weekly percentage of Thornless blackberry *(Rubus canadensis)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

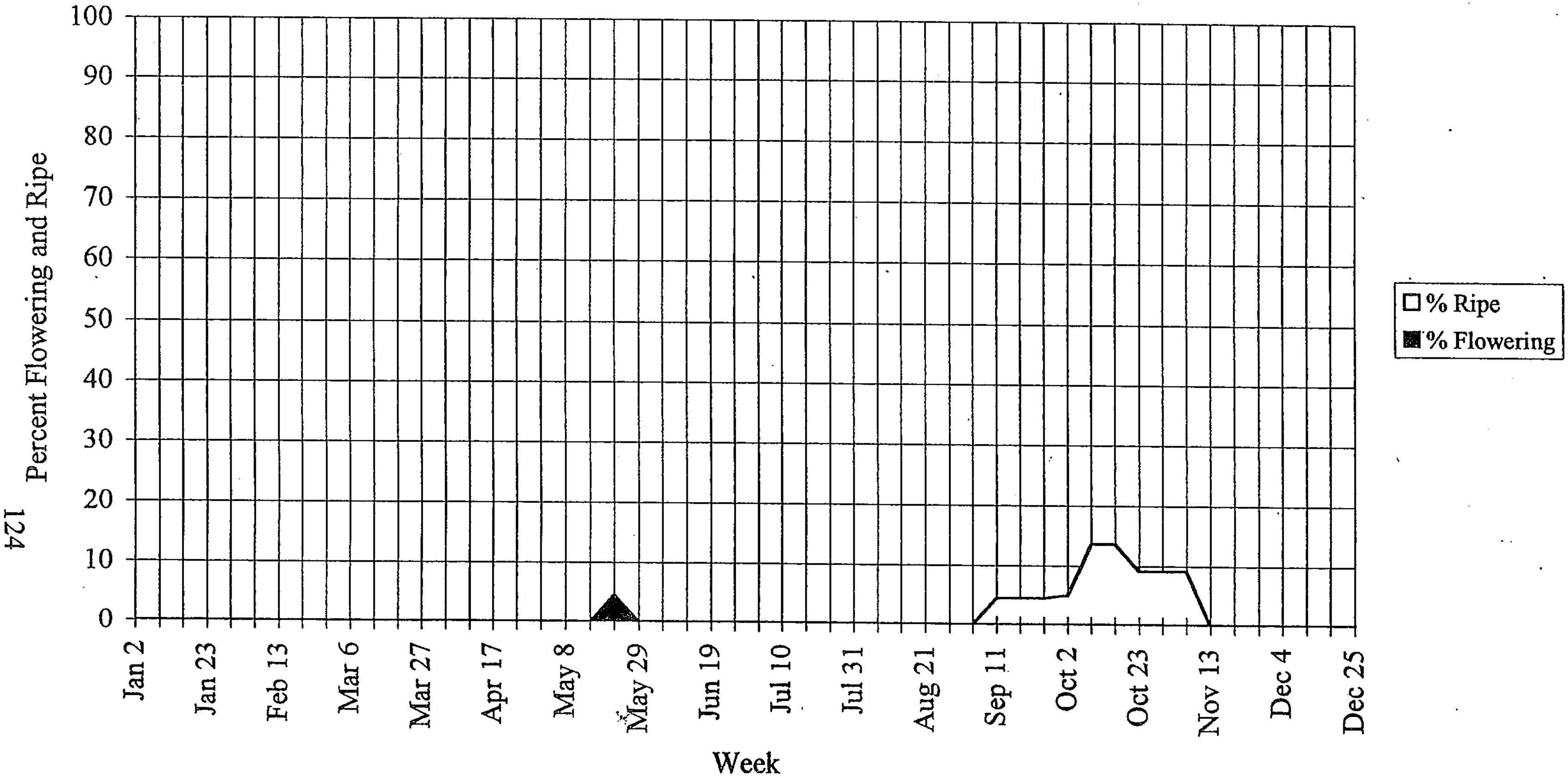

Figure B14. Weekly percentage of Greenbriers *(Smilax spp.)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

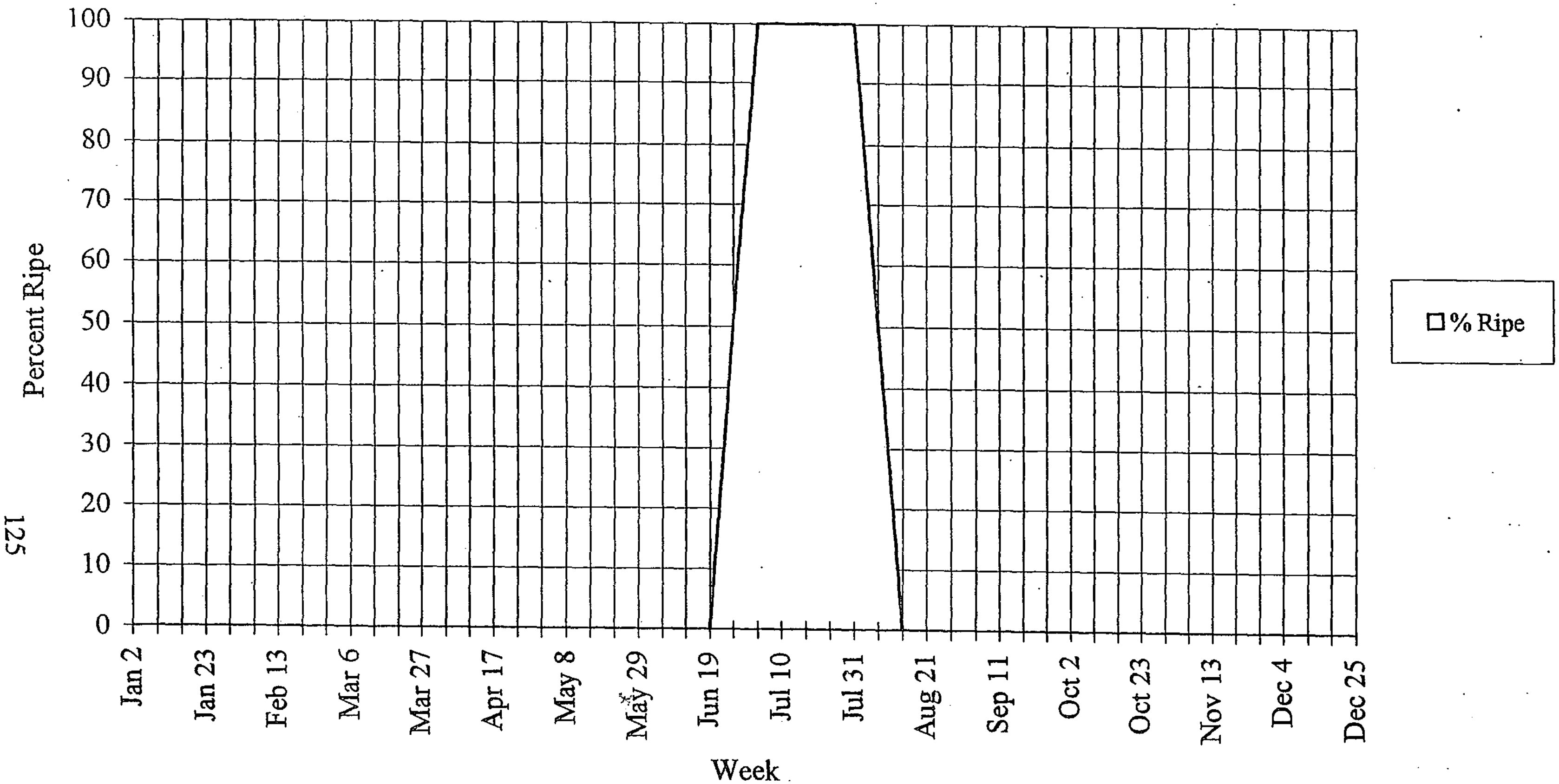

Figure B15. Weekly percentage of N. highbush blueberry *(Vaccinium corybosum)* with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

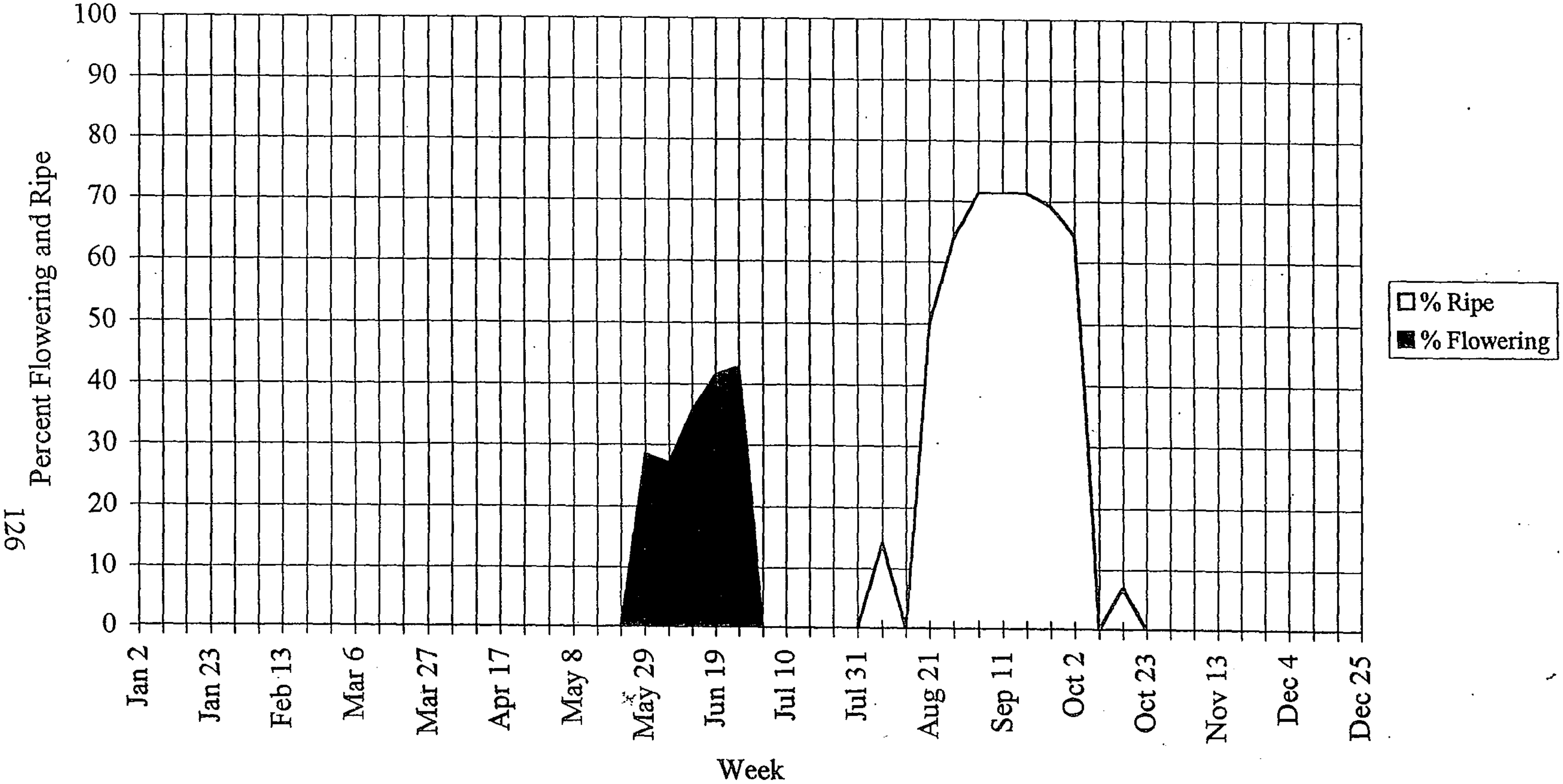

Figure B16. Weekly percentage of S. mountain cranberry *(Vaccinium erythrocarpum)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

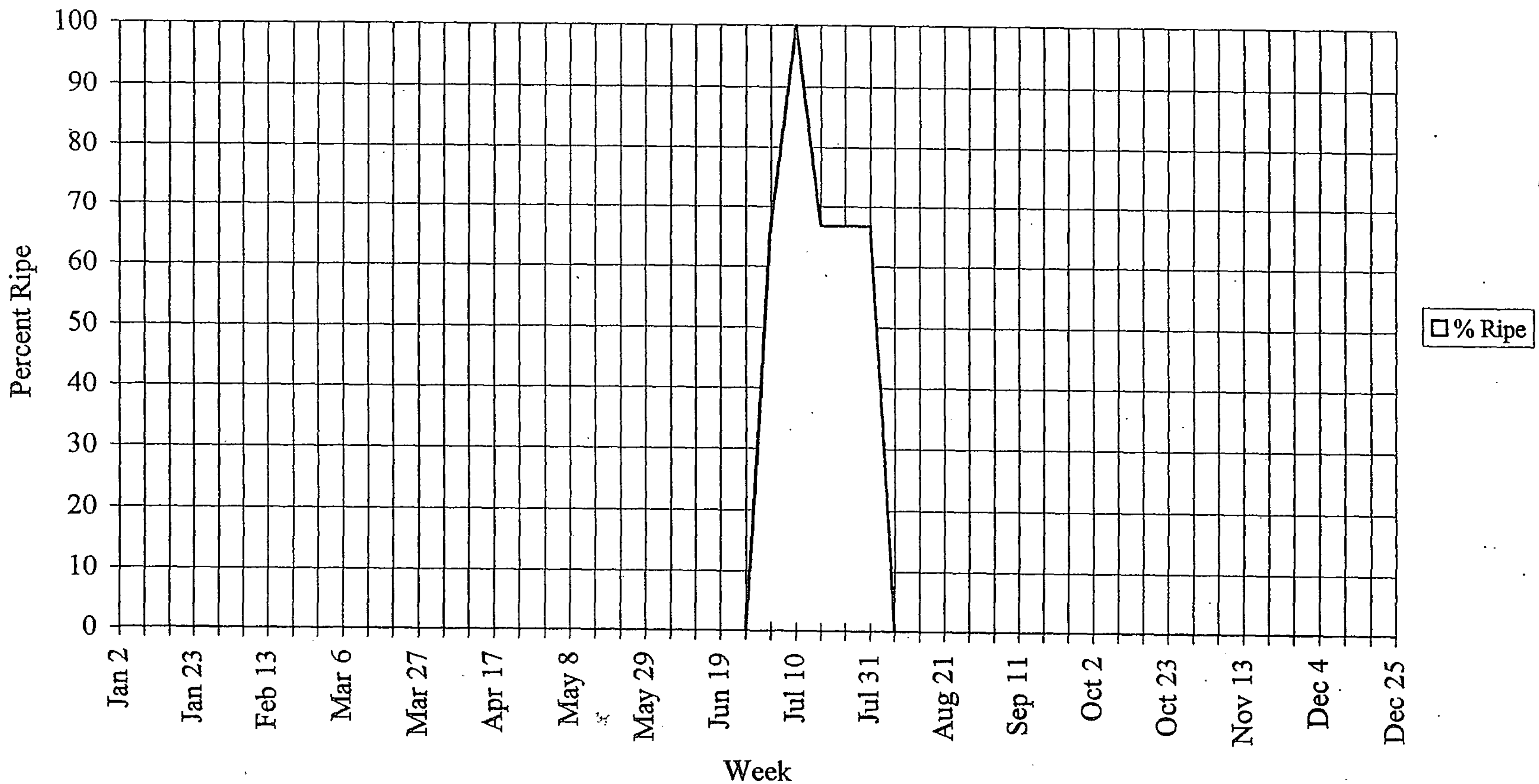

Figure B17. Weekly percentage of Hairy blueberry *(Vaccinium hirsutum)* with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

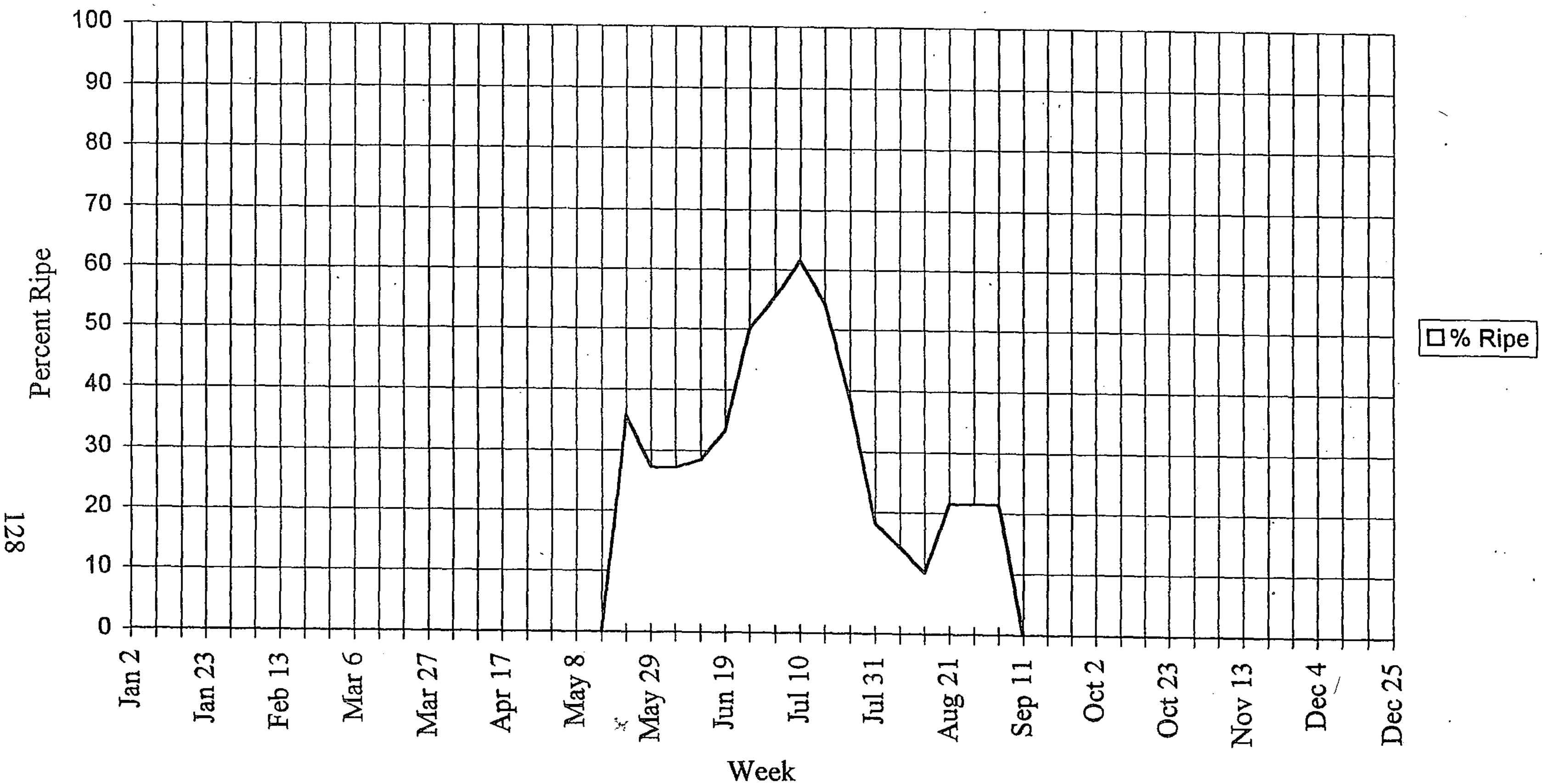

Figure B18. Weekly percentage of Upland low blueberry *(Vaccinium pallidium)* with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995

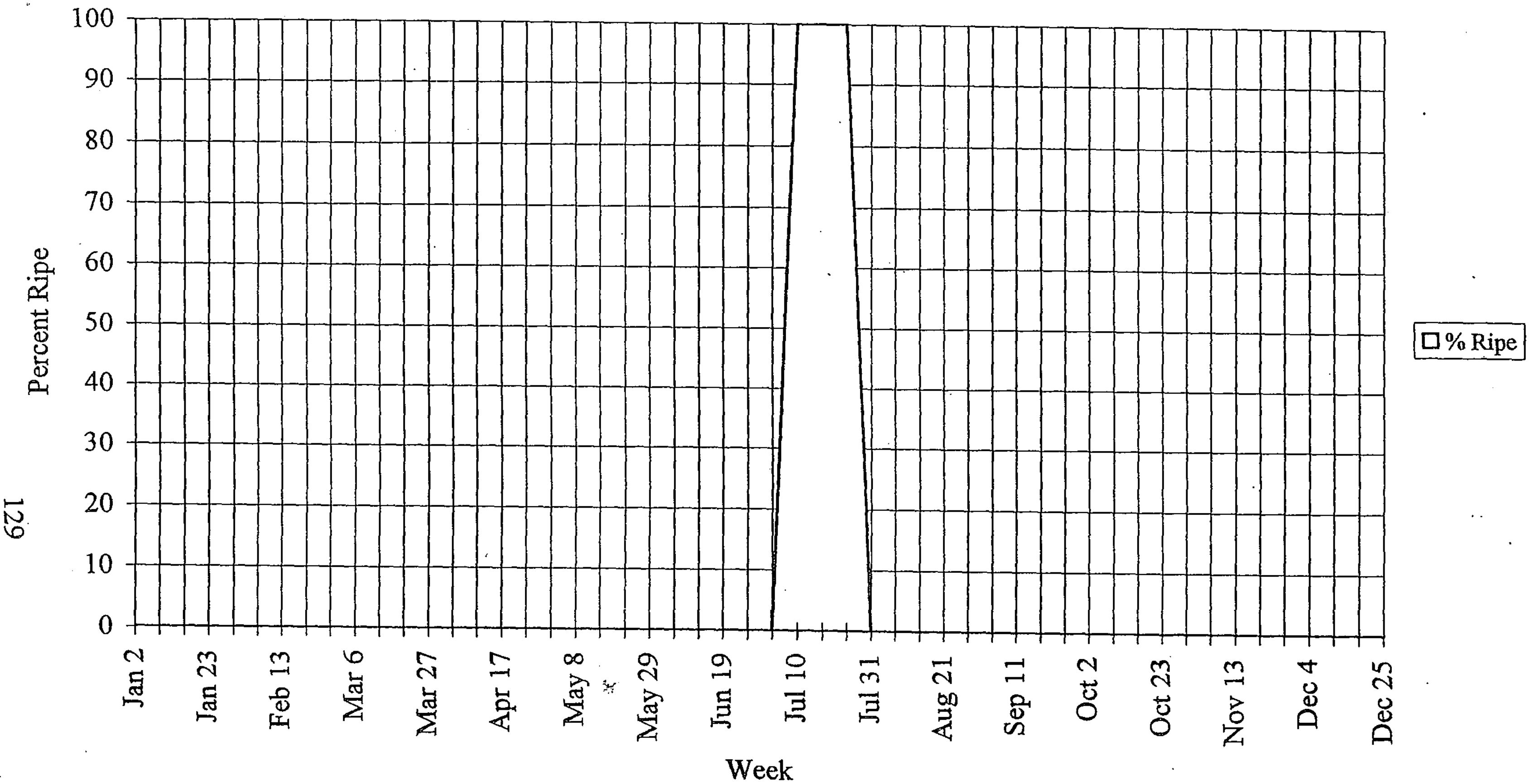

Figure B19. Weekly percentage of Deerberry *(Vaccinium stamineum)* with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

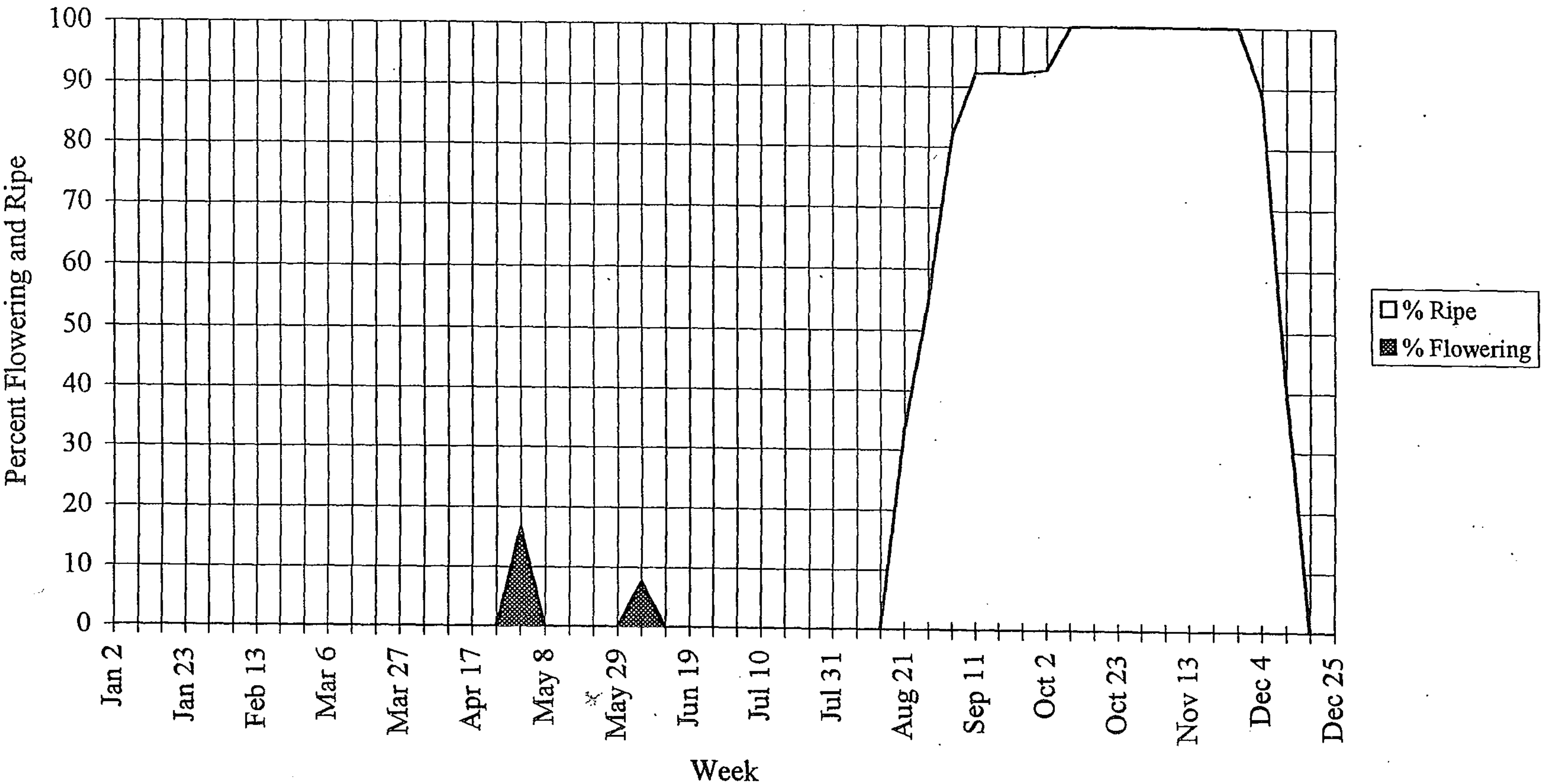

Figure B20. Weekly percentage of Grapes *(Vitis spp.)* flowering and with ripe fruits in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Appendix B. "Raw data for Phenological observations: Week, Number of observations, % Flowering, % Ripe."

Serviceberry (*Amelanchier spp.*)				Grapes (*Vitis spp.*)			
Week	n =	% flwr	% ripe	Week	n =	% flwr	% ripe
Mar 20	15	0	0	Mar 20	10	0	0
Mar 27	15	0	0	Mar 27	10	0	0
Apr 03	16	6	0	Apr 03	10	0	0
Apr 10	16	25	0	Apr 10	6	0	0
Apr 17	15	20	0	Apr 17	6	0	0
Apr 24	15	100	0	Apr 24	6	0	0
May 01	15	100	0	May 01	6	17	0
May 08	15	100	0	May 08	6	0	0
May 15	15	0	0	May 15	6	0	0
May 22	0	.	.	May 22	13	0	0
May 29	0	.	.	May 29	13	0	0
Jun 05	0	.	.	Jun 05	13	8	0
Jun 12	0	.	.	Jun 12	12	0	0
Jun 19	0	.	.	Jun 19	14	0	0
Jun 26	0	.	.	Jun 26	14	0	0
Jul 03	0	.	.	Jul 03	14	0	0
Jul 10	0	.	.	Jul 10	14	0	0
Jul 17	0	.	.	Jul 17	14	0	0
Jul 24	0	.	.	Jul 24	14	0	0
Jul 31	0	.	.	Jul 31	13	0	0
Aug 07	0	.	.	Aug 07	13	0	0
Aug 14	0	.	.	Aug 14	10	0	0
Aug 21	0	.	.	Aug 21	12	0	33
Aug 28	0	.	.	Aug 28	11	0	55
Sep 04	0	.	.	Sep 04	11	0	82
Sep 11	0	.	.	Sep 11	13	0	92
Sep 18	0	.	.	Sep 18	13	0	92
Sep 25	0	.	.	Sep 25	13	0	92
Oct 02	0	.	.	Oct 02	14	0	93
Oct 09	0	.	.	Oct 09	13	0	100
Oct 16	0	.	.	Oct 16	14	0	100
Oct 23	0	.	.	Oct 23	14	0	100
Oct 30	0	.	.	Oct 30	14	0	100
Nov 06	0	.	.	Nov 06	9	0	100
Nov 13	0	.	.	Nov 13	8	0	100
Nov 20	0	.	.	Nov 20	8	0	100
Nov 27	0	.	.	Nov 27	8	0	100
Dec 04	0	.	.	Dec 04	9	0	89
Dec 11	0	.	.	Dec 11	10	0	40

Hickories (*Carya spp.*)				Squawroot (*Conopholis americana*)			
Week	n =	% flwr	% ripe	Week	n =	% flwr	% ripe
Mar 20	39	0	0	Mar 20	1	0	0
Mar 27	39	0	0	Mar 27	1	0	0
Apr 03	39	0	0	Apr 03	1	100	0
Apr 10	39	5	0	Apr 10	1	100	0
Apr 17	39	31	0	Apr 17	1	100	0
Apr 24	39	64	0	Apr 24	1	100	0
May 01	39	77	0	May 01	1	100	0
May 08	39	36	0	May 08	1	100	0
May 15	20	0	0	May 15	0	.	.
May 22	20	0	0	May 22	3	0	100
May 29	39	0	0	May 29	3	0	100
Jun 05	39	0	0	Jun 05	3	0	100
Jun 12	39	0	0	Jun 12	3	0	100
Jun 19	39	0	0	Jun 19	3	0	100
Jun 26	39	0	0	Jun 26	1	0	100
Jul 03	39	0	0	Jul 03	2	0	0
Jul 10	39	0	0	Jul 10	3	0	0
Jul 17	39	0	0	Jul 17	3	0	0
Jul 24	39	0	0	Jul 24	3	0	0
Jul 31	35	0	0	Jul 31	3	0	0
Aug 07	35	0	0	Aug 07	3	0	0
Aug 14	35	0	0	Aug 14	3	0	0
Aug 21	39	0	10	Aug 21	3	0	0
Aug 28	39	0	10	Aug 28	3	0	0
Sep 04	39	0	10	Sep 04	3	0	0
Sep 11	39	0	10	Sep 11	3	0	0
Sep 18	39	0	10	Sep 18	3	0	0
Sep 25	35	0	0	Sep 25	3	0	0
Oct 02	39	0	0	Oct 02	3	0	0
Oct 09	39	0	0	Oct 09	3	0	0
Oct 16	39	0	0	Oct 16	3	0	0
Oct 23	39	0	0	Oct 23	3	0	0
Oct 30	39	0	0	Oct 30	3	0	0
Nov 06	39	0	0	Nov 06	3	0	0
Nov 13	39	0	0	Nov 13	3	0	0
Nov 20	39	0	0	Nov 20	3	0	0
Nov 27	39	0	0	Nov 27	3	0	0
Dec 04	39	0	0	Dec 04	3	0	0
Dec 11	39	0	0	Dec 11	3	0	0

Huckleberries (*Gaylussacia spp.*)

Week	n =	% flwr	% ripe
20-Mar	15	0	0
27-Mar	15	0	0
3-Apr	15	0	0
10-Apr	2	50	0
17-Apr	2	100	0
24-Apr	2	100	0
1-May	2	100	0
8-May	2	100	0
15-May	0	.	.
22-May	18	0	17
29-May	15	0	13
5-Jun	17	0	18
12-Jun	19	0	26
19-Jun	16	0	31
26-Jun	16	0	44
3-Jul	13	0	69
10-Jul	17	0	88
17-Jul	18	0	89
24-Jul	19	0	84
31-Jul	19	0	84
7-Aug	17	0	82
14-Aug	15	0	67
21-Aug	18	0	56
28-Aug	18	0	50
4-Sep	19	0	47
11-Sep	13	0	23
18-Sep	12	0	17
25-Sep	13	0	15
2-Oct	19	0	11
9-Oct	17	0	0
16-Oct	19	0	0
23-Oct	19	0	0
30-Oct	19	0	0
6-Nov	19	0	0
13-Nov	19	0	0
20-Nov	19	0	0
27-Nov	19	0	0
4-Dec	19	0	0
11-Dec	19	0	0

S. mountain cranberry (*Vaccinium erythrocarpum*)

Week	n =	% flwr	% ripe
20-Mar	14	0	0
27-Mar	14	0	0
3-Apr	14	0	0
10-Apr	14	0	0
17-Apr	14	0	0
24-Apr	14	0	0
1-May	0	.	.
8-May	0	.	.
15-May	0	.	.
22-May	0	.	.
29-May	14	29	0
5-Jun	11	27	0
12-Jun	14	36	0
19-Jun	12	42	0
26-Jun	14	43	0
3-Jul	8	0	0
10-Jul	14	0	0
17-Jul	14	0	0
24-Jul	14	0	0
31-Jul	12	0	0
7-Aug	14	0	14
14-Aug	5	0	0
21-Aug	14	0	50
28-Aug	11	0	64
4-Sep	14	0	71
11-Sep	14	0	71
18-Sep	14	0	71
25-Sep	13	0	69
2-Oct	14	0	64
9-Oct	5	0	0
16-Oct	14	0	7
23-Oct	13	0	0
30-Oct	13	0	0
6-Nov	13	0	0
13-Nov	13	0	0
20-Nov	13	0	0
27-Nov	13	0	0
4-Dec	13	0	0
11-Dec	13	0	0

Blackgum (*Nyssa sylvatica*)

Week	n =	% flwr	% ripe
20-Mar	39	0	0
27-Mar	39	0	0
3-Apr	39	0	0
10-Apr	39	0	0
17-Apr	39	8	0
24-Apr	39	21	0
1-May	39	31	0
8-May	38	3	0
15-May	27	7	0
22-May	23	0	0
29-May	35	0	0
5-Jun	35	0	0
12-Jun	35	0	0
19-Jun	35	0	0
26-Jun	35	0	0
3-Jul	39	0	0
10-Jul	39	0	0
17-Jul	39	0	0
24-Jul	39	0	0
31-Jul	38	0	0
7-Aug	38	0	0
14-Aug	36	0	0
21-Aug	37	0	3
28-Aug	39	0	8
4-Sep	39	0	8
11-Sep	39	0	8
18-Sep	39	0	8
25-Sep	39	0	8
2-Oct	38	0	5
9-Oct	38	0	3
16-Oct	38	0	0
23-Oct	39	0	0
30-Oct	39	0	0
6-Nov	39	0	0
13-Nov	39	0	0
20-Nov	39	0	0
27-Nov	39	0	0
4-Dec	39	0	0
11-Dec	39	0	0

Greenbriers (*Smilax spp.*)

Week	n =	% flwr	% ripe
20-Mar	6	0	0
27-Mar	6	0	0
3-Apr	6	0	0
10-Apr	2	0	0
17-Apr	2	0	0
24-Apr	2	0	0
1-May	2	0	0
8-May	2	0	0
15-May	2	0	0
22-May	22	5	0
29-May	21	0	0
5-Jun	22	0	0
12-Jun	22	0	0
19-Jun	22	0	0
26-Jun	22	0	0
3-Jul	22	0	0
10-Jul	22	0	0
17-Jul	22	0	0
24-Jul	22	0	0
31-Jul	22	0	0
7-Aug	22	0	0
14-Aug	22	0	0
21-Aug	22	0	0
28-Aug	22	0	0
4-Sep	21	0	0
11-Sep	22	0	5
18-Sep	22	0	5
25-Sep	22	0	5
2-Oct	20	0	5
9-Oct	22	0	14
16-Oct	22	0	14
23-Oct	22	0	9
30-Oct	22	0	9
6-Nov	22	0	9
13-Nov	20	0	0
20-Nov	20	0	0
27-Nov	20	0	0
4-Dec	22	0	0
11-Dec	22	0	0

Fire cherry (*Prunus pennsylvanica*)				Black cherry (*Prunus serotina*)			
Week	n =	% flwr	% ripe	Week	n =	% flwr	% ripe
20-Mar	27	0	0	20-Mar	34	0	0
27-Mar	27	0	0	27-Mar	34	0	0
3-Apr	27	0	0	3-Apr	34	0	0
10-Apr	27	0	0	10-Apr	34	68	0
17-Apr	27	4	0	17-Apr	34	100	0
24-Apr	27	7	0	24-Apr	34	97	0
1-May	27	15	0	1-May	34	82	0
8-May	26	23	0	8-May	33	33	0
15-May	23	83	0	15-May	33	27	0
22-May	0	.	.	22-May	24	0	0
29-May	0	.	.	29-May	25	0	0
5-Jun	0	.	.	5-Jun	25	0	0
12-Jun	0	.	.	12-Jun	25	0	0
19-Jun	0	.	.	19-Jun	25	0	0
26-Jun	0	.	.	26-Jun	25	0	0
3-Jul	1	0	0	3-Jul	34	0	0
10-Jul	27	0	0	10-Jul	34	0	0
17-Jul	27	0	0	17-Jul	34	0	0
24-Jul	27	0	0	24-Jul	34	0	0
31-Jul	11	0	0	31-Jul	21	0	0
7-Aug	11	0	0	7-Aug	21	0	0
14-Aug	9	0	0	14-Aug	10	0	0
21-Aug	26	0	62	21-Aug	21	0	57
28-Aug	23	0	70	28-Aug	29	0	83
4-Sep	27	0	70	4-Sep	32	0	88
11-Sep	27	0	70	11-Sep	33	0	88
18-Sep	27	0	70	18-Sep	33	0	88
25-Sep	9	0	11	25-Sep	33	0	88
2-Oct	26	0	0	2-Oct	33	0	88
9-Oct	27	0	0	9-Oct	33	0	88
16-Oct	27	0	0	16-Oct	28	0	86
23-Oct	27	0	0	23-Oct	29	0	69
30-Oct	27	0	0	30-Oct	33	0	61
6-Nov	27	0	0	6-Nov	21	0	38
13-Nov	27	0	0	13-Nov	13	0	0
20-Nov	27	0	0	20-Nov	13	0	0
27-Nov	27	0	0	27-Nov	13	0	0
4-Dec	27	0	0	4-Dec	21	0	0
11-Dec	27	0	0	11-Dec	33	0	0

White oak (*Quercus alba*)

Week	n =	% flwr	% ripe
20-Mar	40	0	0
27-Mar	40	0	0
3-Apr	40	0	0
10-Apr	40	3	0
17-Apr	40	18	0
24-Apr	40	48	0
1-May	40	53	0
8-May	40	10	0
15-May	33	0	0
22-May	33	0	0
29-May	40	0	0
5-Jun	40	0	0
12-Jun	40	0	0
19-Jun	40	0	0
26-Jun	40	0	0
3-Jul	40	0	0
10-Jul	40	0	0
17-Jul	40	0	0
24-Jul	40	0	0
31-Jul	40	0	0
7-Aug	40	0	0
14-Aug	40	0	0
21-Aug	40	0	0
28-Aug	27	0	0
4-Sep	38	0	34
11-Sep	36	0	42
18-Sep	34	0	44
25-Sep	36	0	47
2-Oct	40	0	53
9-Oct	40	0	53
16-Oct	37	0	49
23-Oct	31	0	29
30-Oct	39	0	21
6-Nov	33	0	3
13-Nov	33	0	3
20-Nov	33	0	3
27-Nov	33	0	3
4-Dec	33	0	3
11-Dec	40	0	3

Chestnut oak (*Quercus prinus*)

Week	n =	% flwr	% ripe
20-Mar	46	0	0
27-Mar	46	0	0
3-Apr	46	0	0
10-Apr	46	15	0
17-Apr	46	50	0
24-Apr	46	85	0
1-May	46	61	0
8-May	44	11	0
15-May	40	3	0
22-May	39	0	0
29-May	45	0	0
5-Jun	45	0	0
12-Jun	45	0	0
19-Jun	45	0	0
26-Jun	45	0	0
3-Jul	46	0	0
10-Jul	46	0	0
17-Jul	46	0	0
24-Jul	46	0	0
31-Jul	43	0	0
7-Aug	43	0	0
14-Aug	43	0	0
21-Aug	45	0	7
28-Aug	43	0	9
4-Sep	44	0	16
11-Sep	45	0	20
18-Sep	45	0	20
25-Sep	45	0	20
2-Oct	46	0	22
9-Oct	45	0	22
16-Oct	45	0	22
23-Oct	40	0	10
30-Oct	44	0	5
6-Nov	44	0	0
13-Nov	44	0	0
20-Nov	44	0	0
27-Nov	44	0	0
4-Dec	44	0	0
11-Dec	46	0	0

Scarlet oak (*Quercus coccinea*)

Week	n =	% flwr	% ripe
20-Mar	43	0	0
27-Mar	43	0	0
3-Apr	43	0	0
10-Apr	43	2	0
17-Apr	43	14	0
24-Apr	43	23	0
1-May	43	16	0
8-May	43	5	0
15-May	31	0	0
22-May	31	0	0
29-May	43	0	0
5-Jun	43	0	0
12-Jun	43	0	0
19-Jun	43	0	0
26-Jun	43	0	0
3-Jul	43	0	0
10-Jul	43	0	0
17-Jul	43	0	0
24-Jul	43	0	0
31-Jul	36	0	0
7-Aug	36	0	0
14-Aug	36	0	0
21-Aug	33	0	21
28-Aug	31	0	55
4-Sep	43	0	67
11-Sep	43	0	67
18-Sep	39	0	74
25-Sep	43	0	77
2-Oct	42	0	76
9-Oct	43	0	74
16-Oct	35	0	69
23-Oct	41	0	51
30-Oct	43	0	49
6-Nov	31	0	29
13-Nov	28	0	21
20-Nov	28	0	21
27-Nov	27	0	19
4-Dec	31	0	16
11-Dec	43	0	12

Northern red oak (*Quercus rubra*)

Week	n =	% flwr	% ripe
20-Mar	42	0	0
27-Mar	42	0	0
3-Apr	42	0	0
10-Apr	42	7	0
17-Apr	42	36	0
24-Apr	42	31	0
1-May	42	26	0
8-May	42	14	0
15-May	37	41	0
22-May	22	0	0
29-May	27	0	0
5-Jun	27	0	0
12-Jun	27	0	0
19-Jun	27	0	0
26-Jun	27	0	0
3-Jul	42	0	0
10-Jul	42	0	0
17-Jul	42	0	0
24-Jul	42	0	0
31-Jul	28	0	0
7-Aug	28	0	0
14-Aug	12	0	0
21-Aug	19	0	74
28-Aug	42	0	88
4-Sep	41	0	90
11-Sep	42	0	90
18-Sep	41	0	93
25-Sep	42	0	93
2-Oct	42	0	93
9-Oct	42	0	93
16-Oct	40	0	93
23-Oct	41	0	88
30-Oct	42	0	86
6-Nov	39	0	85
13-Nov	34	0	82
20-Nov	34	0	82
27-Nov	34	0	82
4-Dec	39	0	69
11-Dec	25	0	40

Allegheny blackberry (*Rubus allegheneinsis*)				Thornless blackberry (*Rubus canadensis*)			
Week	n =	% flwr	% ripe	Week	n =	% flwr	% ripe
20-Mar	7	0	0	20-Mar	11	0	0
27-Mar	7	0	0	27-Mar	11	0	0
3-Apr	7	0	0	3-Apr	11	0	0
10-Apr	2	0	0	10-Apr	11	0	0
17-Apr	2	50	0	17-Apr	11	0	0
24-Apr	2	50	0	24-Apr	11	0	0
1-May	2	50	0	1-May	1	0	0
8-May	2	0	0	8-May	1	0	0
15-May	2	0	0	15-May	0	.	.
22-May	12	42	0	22-May	1	100	0
29-May	5	0	0	29-May	10	40	0
5-Jun	11	0	0	5-Jun	5	80	0
12-Jun	11	0	9	12-Jun	11	91	0
19-Jun	10	10	0	19-Jun	11	91	0
26-Jun	10	0	0	26-Jun	11	91	0
3-Jul	7	0	0	3-Jul	1	0	0
10-Jul	10	0	40	10-Jul	11	0	0
17-Jul	12	0	50	17-Jul	11	0	0
24-Jul	10	0	60	24-Jul	10	0	0
31-Jul	10	0	70	31-Jul	7	0	14
7-Aug	11	0	73	7-Aug	11	0	45
14-Aug	9	0	67	14-Aug	5	0	100
21-Aug	11	0	55	21-Aug	11	0	100
28-Aug	11	0	55	28-Aug	10	0	100
4-Sep	9	0	44	4-Sep	10	0	90
11-Sep	10	0	30	11-Sep	10	0	80
18-Sep	8	0	0	18-Sep	11	0	73
25-Sep	11	0	0	25-Sep	3	0	0
2-Oct	11	0	0	2-Oct	11	0	0
9-Oct	11	0	0	9-Oct	11	0	0
16-Oct	11	0	0	16-Oct	11	0	0
23-Oct	11	0	0	23-Oct	11	0	0
30-Oct	11	0	0	30-Oct	11	0	0
6-Nov	11	0	0	6-Nov	11	0	0
13-Nov	11	0	0	13-Nov	11	0	0
20-Nov	11	0	0	20-Nov	11	0	0
27-Nov	11	0	0	27-Nov	11	0	0
4-Dec	11	0	0	4-Dec	11	0	0
11-Dec	10	0	0	11-Dec	11	0	0

N. highbush blueberry (*Vaccinium corybosum*)

Week	n =	% flwr	% ripe
20-Mar	2	0	0
27-Mar	2	0	0
3-Apr	2	0	0
10-Apr	0	.	.
17-Apr	0	.	.
24-Apr	0	.	.
1-May	0	.	.
8-May	0	.	.
15-May	0	.	.
22-May	2	0	0
29-May	2	0	0
5-Jun	2	0	0
12-Jun	2	0	0
19-Jun	1	0	0
26-Jun	2	0	50
3-Jul	1	0	100
10-Jul	2	0	100
17-Jul	2	0	100
24-Jul	2	0	100
31-Jul	1	0	100
7-Aug	2	0	50
14-Aug	1	0	0
21-Aug	2	0	0
28-Aug	2	0	0
4-Sep	2	0	0
11-Sep	2	0	0
18-Sep	2	0	0
25-Sep	2	0	0
2-Oct	2	0	0
9-Oct	2	0	0
16-Oct	2	0	0
23-Oct	2	0	0
30-Oct	2	0	0
6-Nov	2	0	0
13-Nov	2	0	0
20-Nov	2	0	0
27-Nov	2	0	0
4-Dec	2	0	0
11-Dec	2	0	0

Upland low blueberry (*Vaccinium pallidium*)

Week	n =	% flwr	% ripe
20-Mar	12	0	0
27-Mar	12	0	0
3-Apr	12	0	0
10-Apr	0	.	.
17-Apr	0	.	.
24-Apr	0	.	.
1-May	0	.	.
8-May	0	.	.
15-May	0	.	.
22-May	14	0	36
29-May	11	0	27
5-Jun	11	0	27
12-Jun	14	0	29
19-Jun	9	0	33
26-Jun	14	0	50
3-Jul	9	0	56
10-Jul	13	0	62
17-Jul	11	0	55
24-Jul	13	0	38
31-Jul	11	0	18
7-Aug	14	0	14
14-Aug	10	0	10
21-Aug	14	0	21
28-Aug	14	0	21
4-Sep	14	0	21
11-Sep	11	0	0
18-Sep	11	0	0
25-Sep	11	0	0
2-Oct	14	0	0
9-Oct	14	0	0
16-Oct	14	0	0
23-Oct	14	0	0
30-Oct	14	0	0
6-Nov	14	0	0
13-Nov	14	0	0
20-Nov	14	0	0
27-Nov	14	0	0
4-Dec	14	0	0
11-Dec	14	0	0

Hairy blueberry (*Vaccinium hirsutum*)

Week	n =	% flwr	% ripe
20-Mar	0	.	.
27-Mar	0	.	.
3-Apr	0	.	.
10-Apr	0	.	.
17-Apr	0	.	.
24-Apr	0	.	.
1-May	0	.	.
8-May	0	.	.
15-May	0	.	.
22-May	3	0	0
29-May	3	0	0
5-Jun	3	0	0
12-Jun	3	0	0
19-Jun	3	0	0
26-Jun	1	0	0
3-Jul	3	0	67
10-Jul	1	0	100
17-Jul	3	0	67
24-Jul	3	0	67
31-Jul	3	0	67
7-Aug	1	0	0
14-Aug	3	0	0
21-Aug	3	0	0
28-Aug	3	0	0
4-Sep	3	0	0
11-Sep	3	0	0
18-Sep	3	0	0
25-Sep	3	0	0
2-Oct	3	0	0
9-Oct	3	0	0
16-Oct	3	0	0
23-Oct	3	0	0
30-Oct	3	0	0
6-Nov	3	0	0
13-Nov	3	0	0
20-Nov	3	0	0
27-Nov	3	0	0
4-Dec	3	0	0
11-Dec	3	0	0

Deerberry (*Vaccinium stamineum*)

Week	n =	% flwr	% ripe
20-Mar	0	.	.
27-Mar	0	.	.
3-Apr	0	.	.
10-Apr	0	.	.
17-Apr	0	.	.
24-Apr	0	.	.
1-May	0	.	.
8-May	0	.	.
15-May	0	.	.
22-May	2	0	0
29-May	2	0	0
5-Jun	2	0	0
12-Jun	2	0	0
19-Jun	2	0	0
26-Jun	2	0	0
3-Jul	2	0	0
10-Jul	2	0	100
17-Jul	2	0	100
24-Jul	2	0	100
31-Jul	2	0	0
7-Aug	2	0	0
14-Aug	2	0	0
21-Aug	2	0	0
28-Aug	2	0	0
4-Sep	2	0	0
11-Sep	2	0	0
18-Sep	2	0	0
25-Sep	2	0	0
2-Oct	2	0	0
9-Oct	2	0	0
16-Oct	2	0	0
23-Oct	2	0	0
30-Oct	2	0	0
6-Nov	2	0	0
13-Nov	2	0	0
20-Nov	2	0	0
27-Nov	2	0	0
4-Dec	2	0	0
11-Dec	2	0	0

Appendix C. Figures of weekly caloric production by each vegetation type

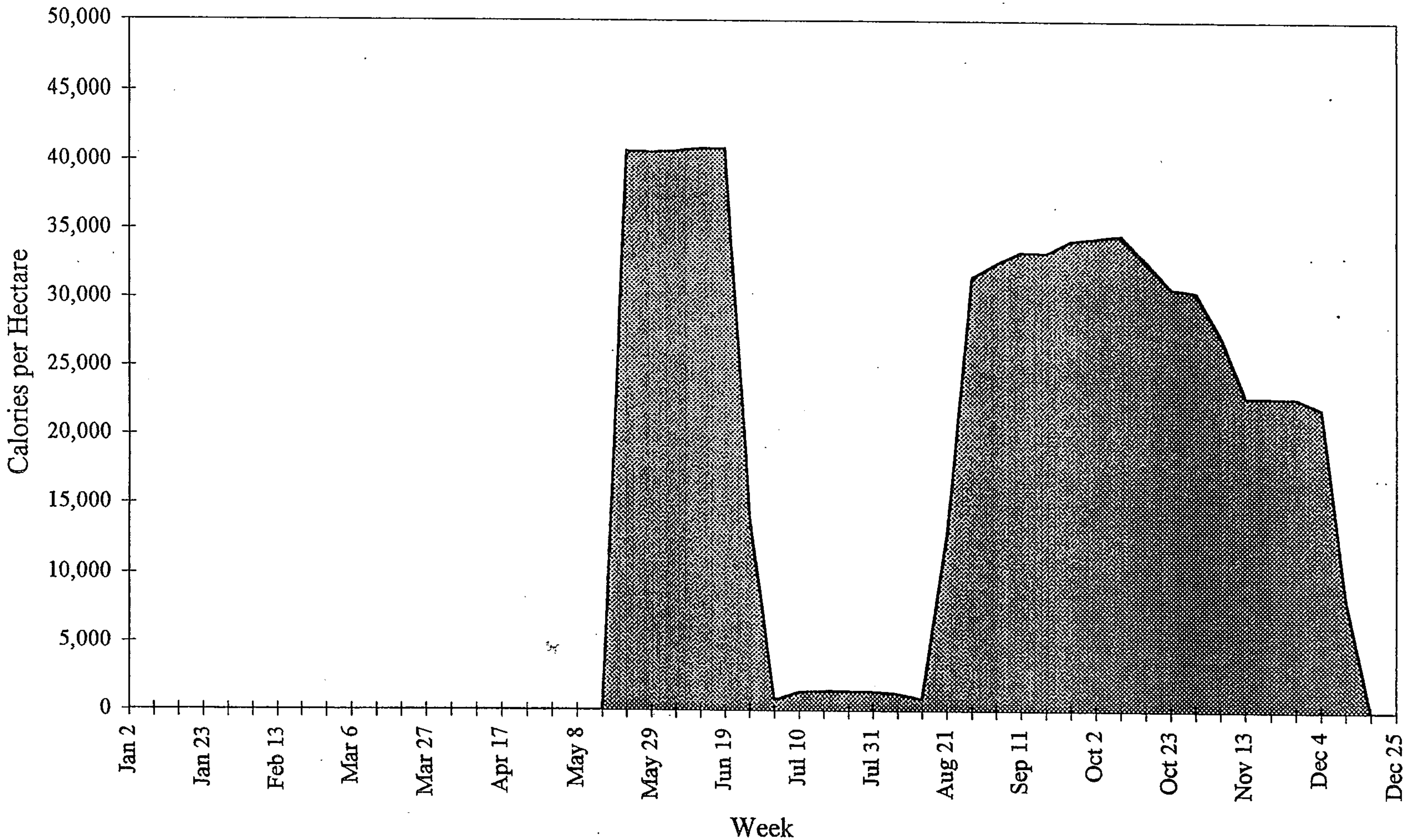

Figure C1. Cove Hardwood: Mean weekly calories produced per hectare in the northwest quadrant of Great Smoky Mountains National Park, 1995.

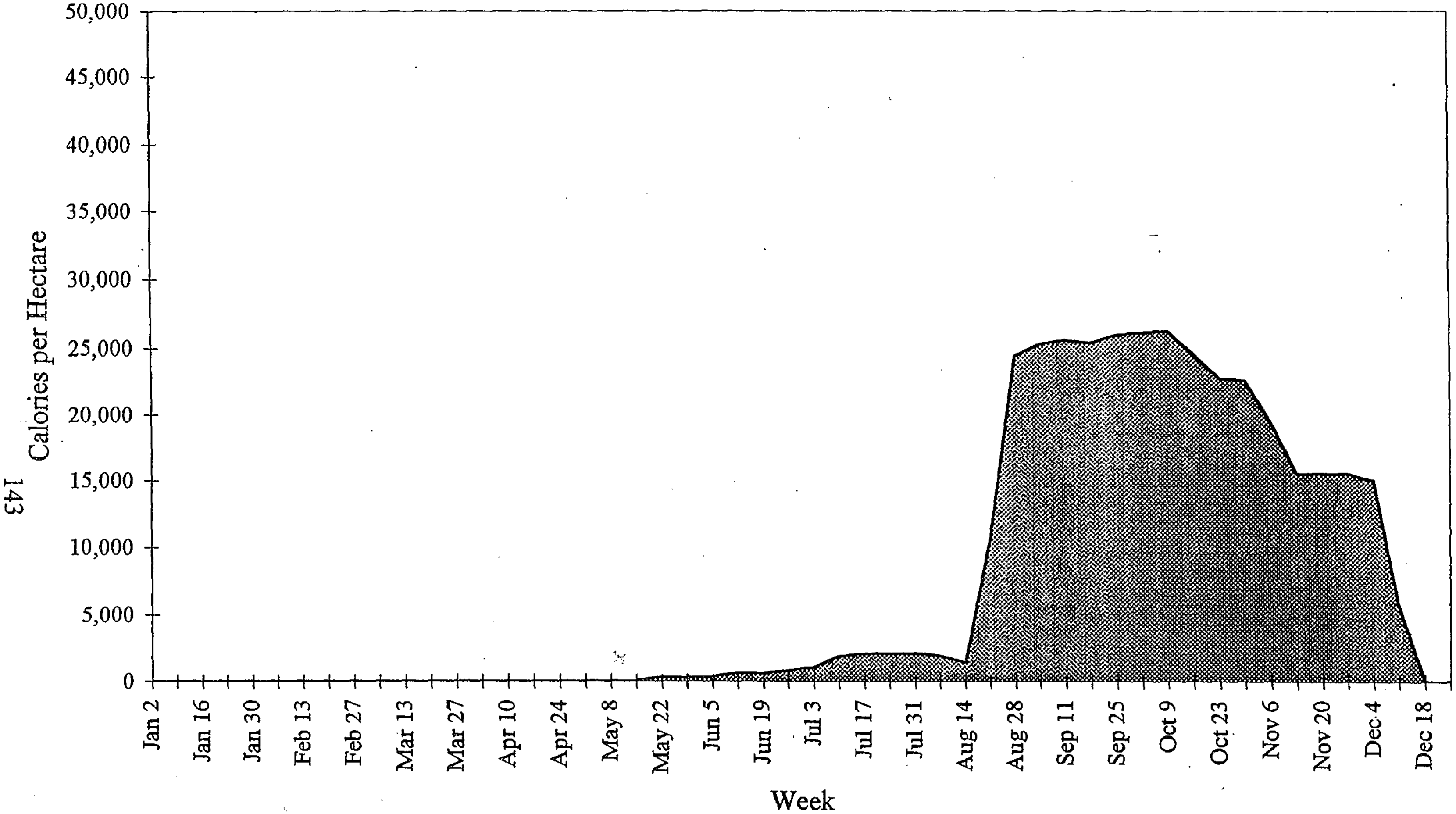

Figure C2. Mesic Oak: Mean weekly calories produced per hectare in the northwest quadrant of Great Smoky Mountains National Park, 1995.

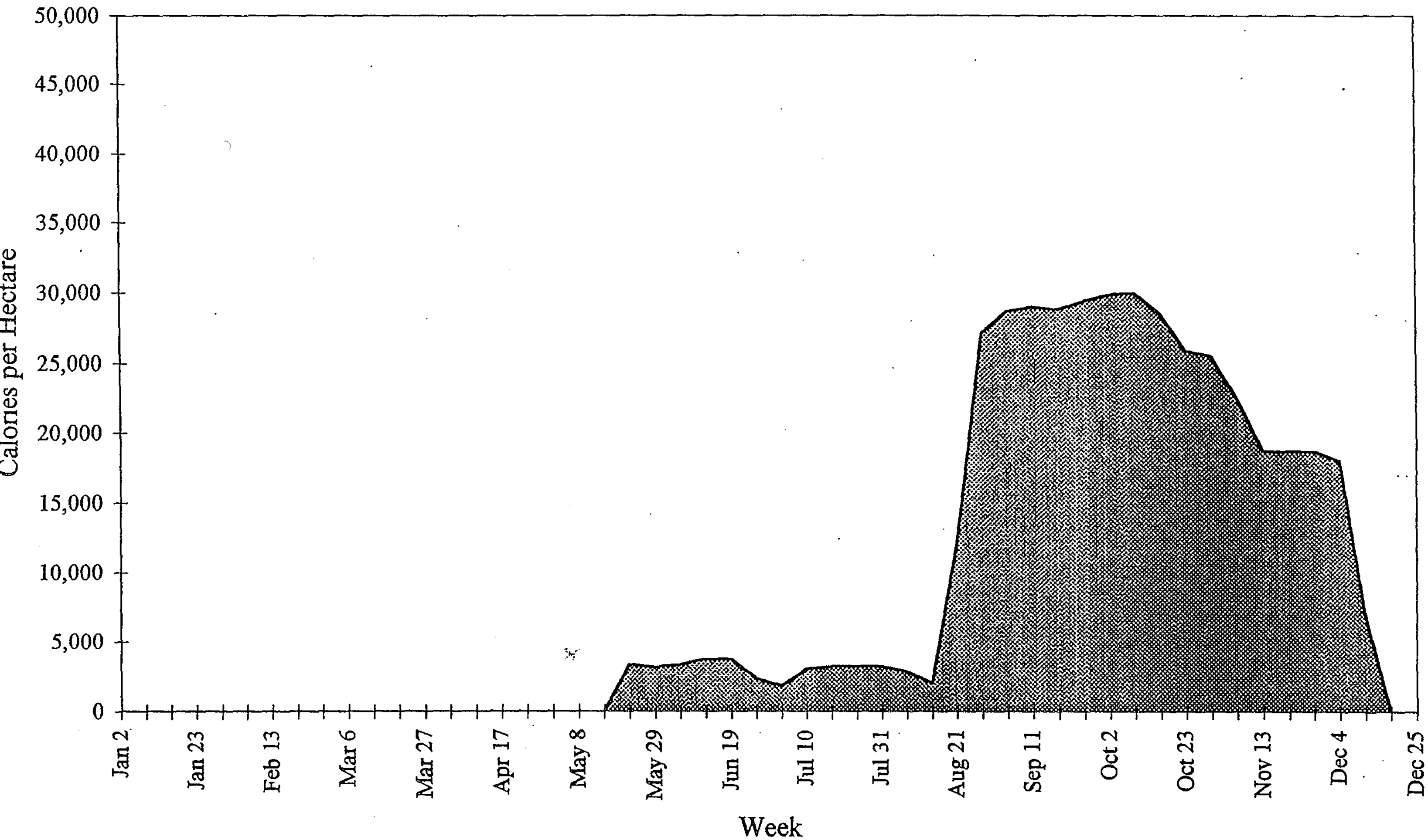

Figure C3. Mixed Mesic Hardwood: Mean weekly calories produced per hectare in the northwest quadrant of Great Smoky Mountains National Park, 1995.

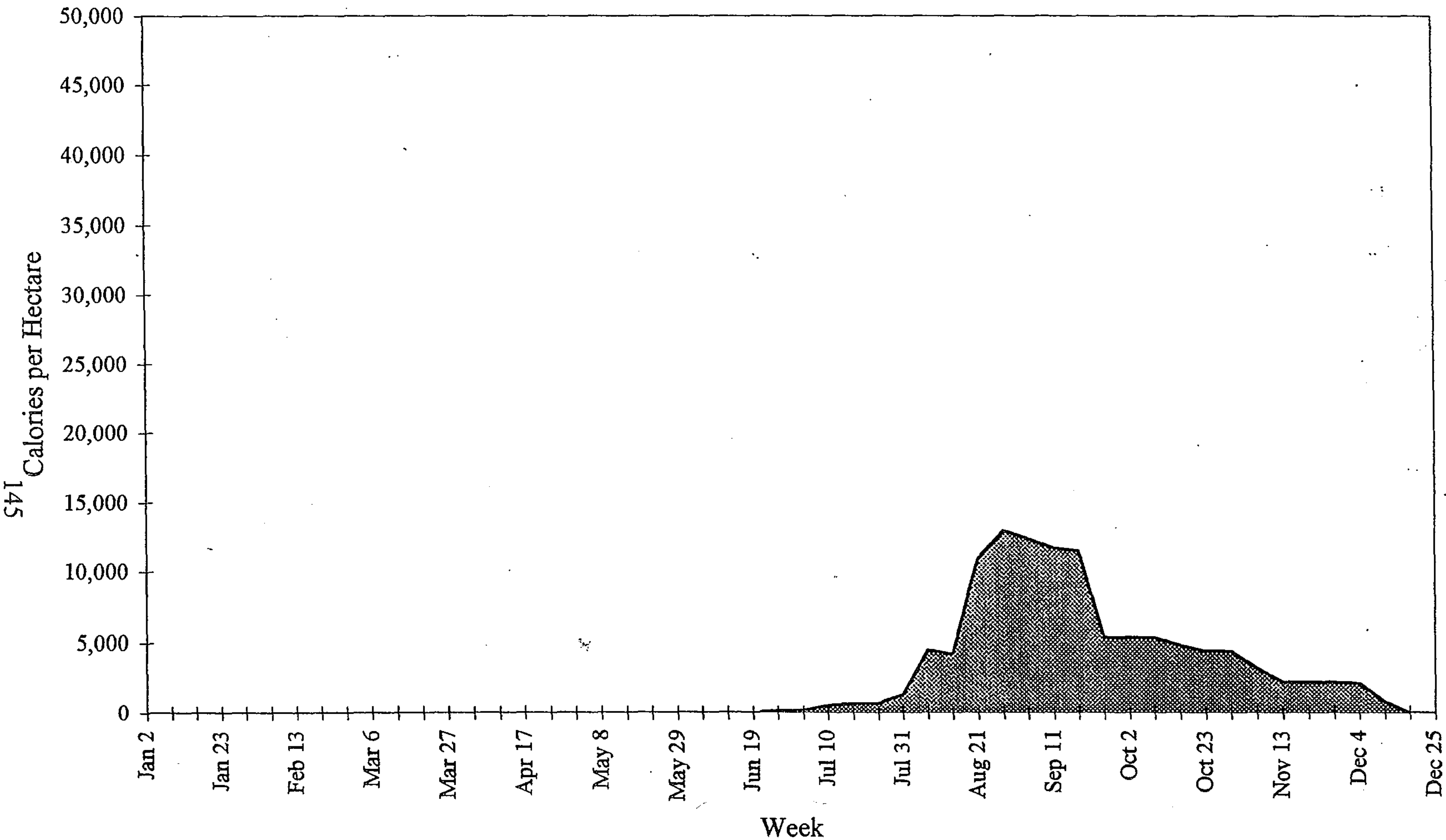

Figure C4. Northern Hardwood: Mean weekly calories produced per hectare in the northwest quadrant of Great Smoky Mountains National Park, 1995.

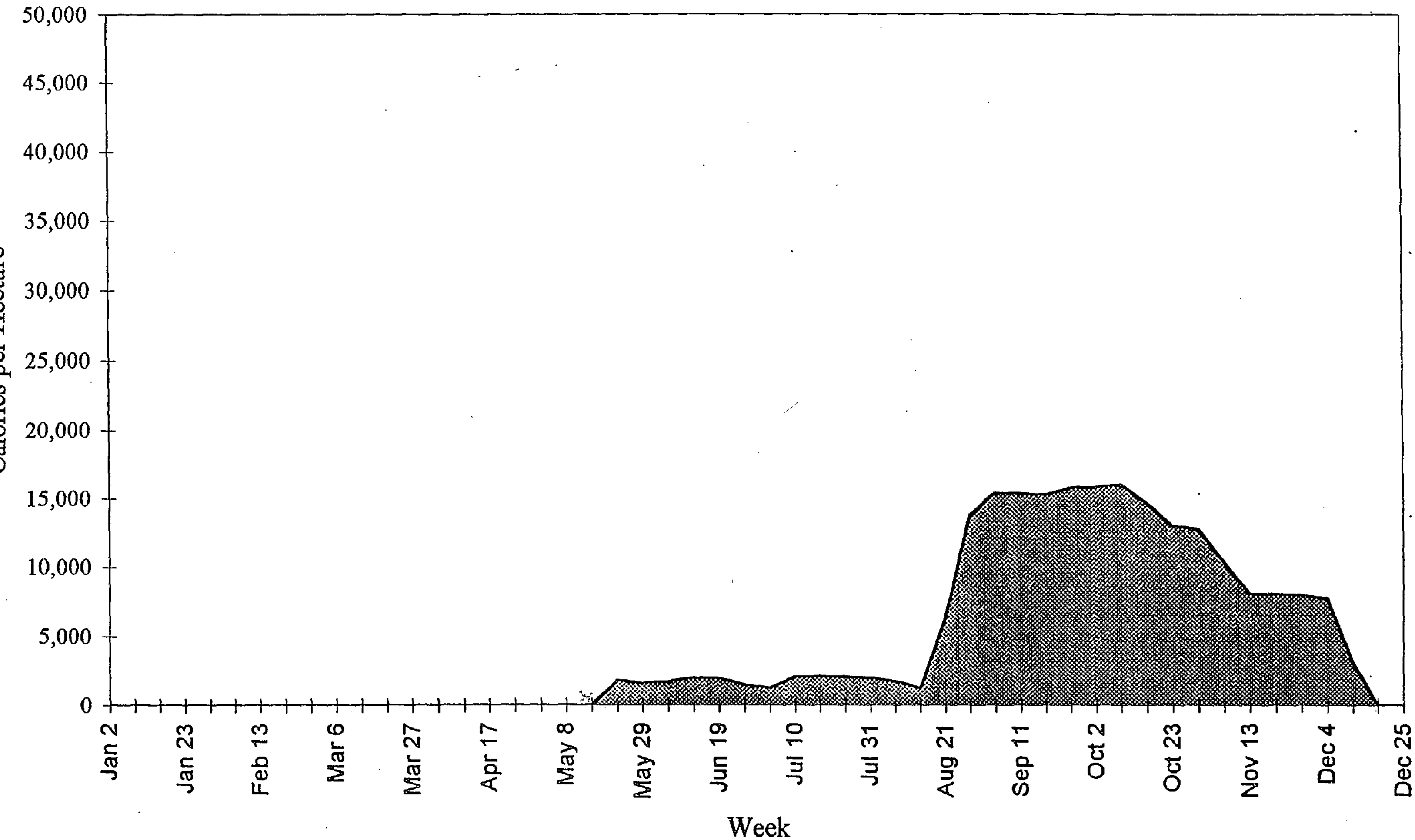

Figure C5. Pine: Mean weekly calories produced per hectare in the northwest quadrant of Great Smoky Mountains National Park, 1995.

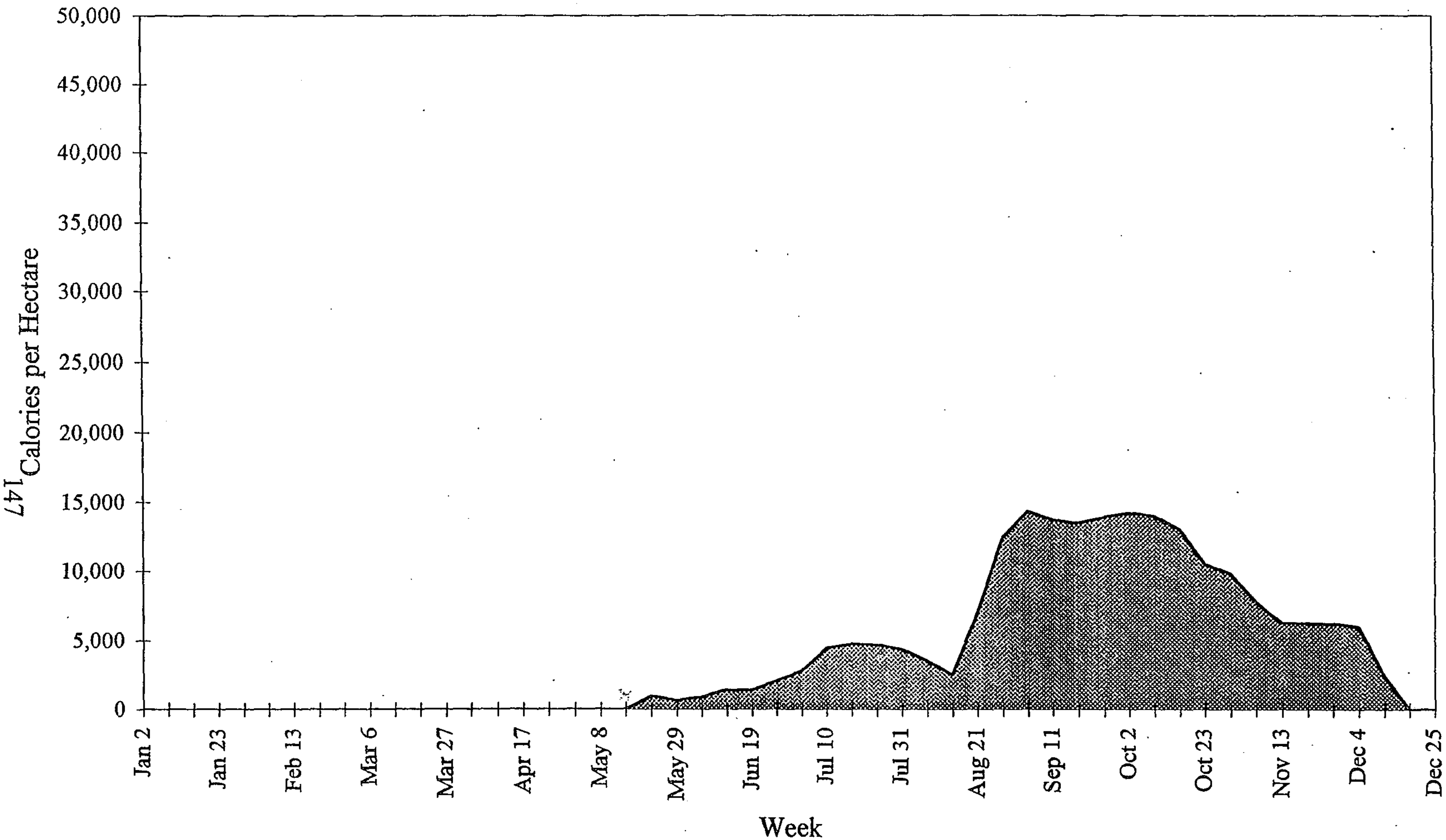

Figure C6. Pine-Oak: Mean weekly calories produced per hectare in the northwest quadrant of Great Smoky Mountains National Park, 1995.

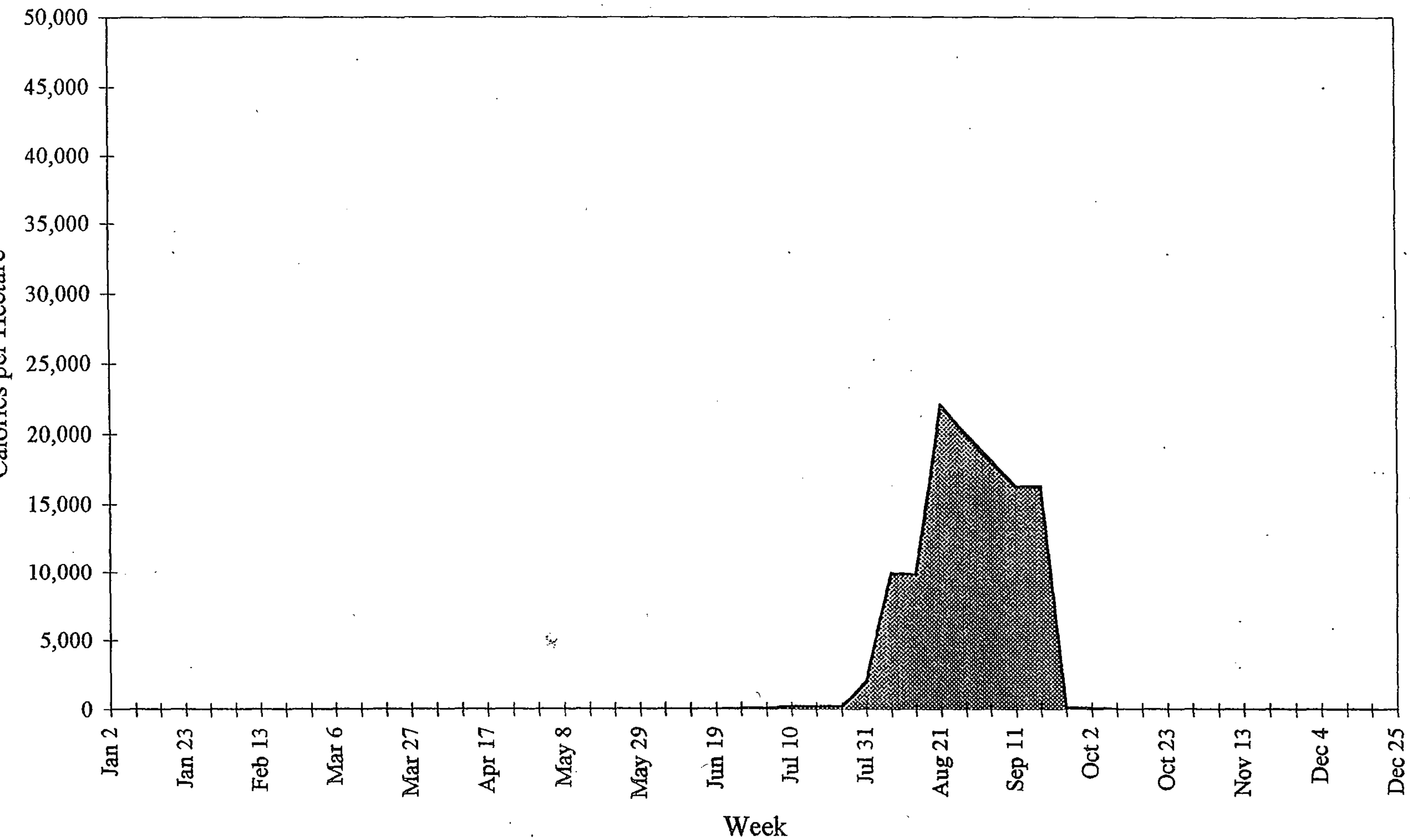

Figure C7. Spruce-Fir: Mean weekly calories produced per hectare in the northwest quadrant of Great Smoky Mountains National Park, 1995.

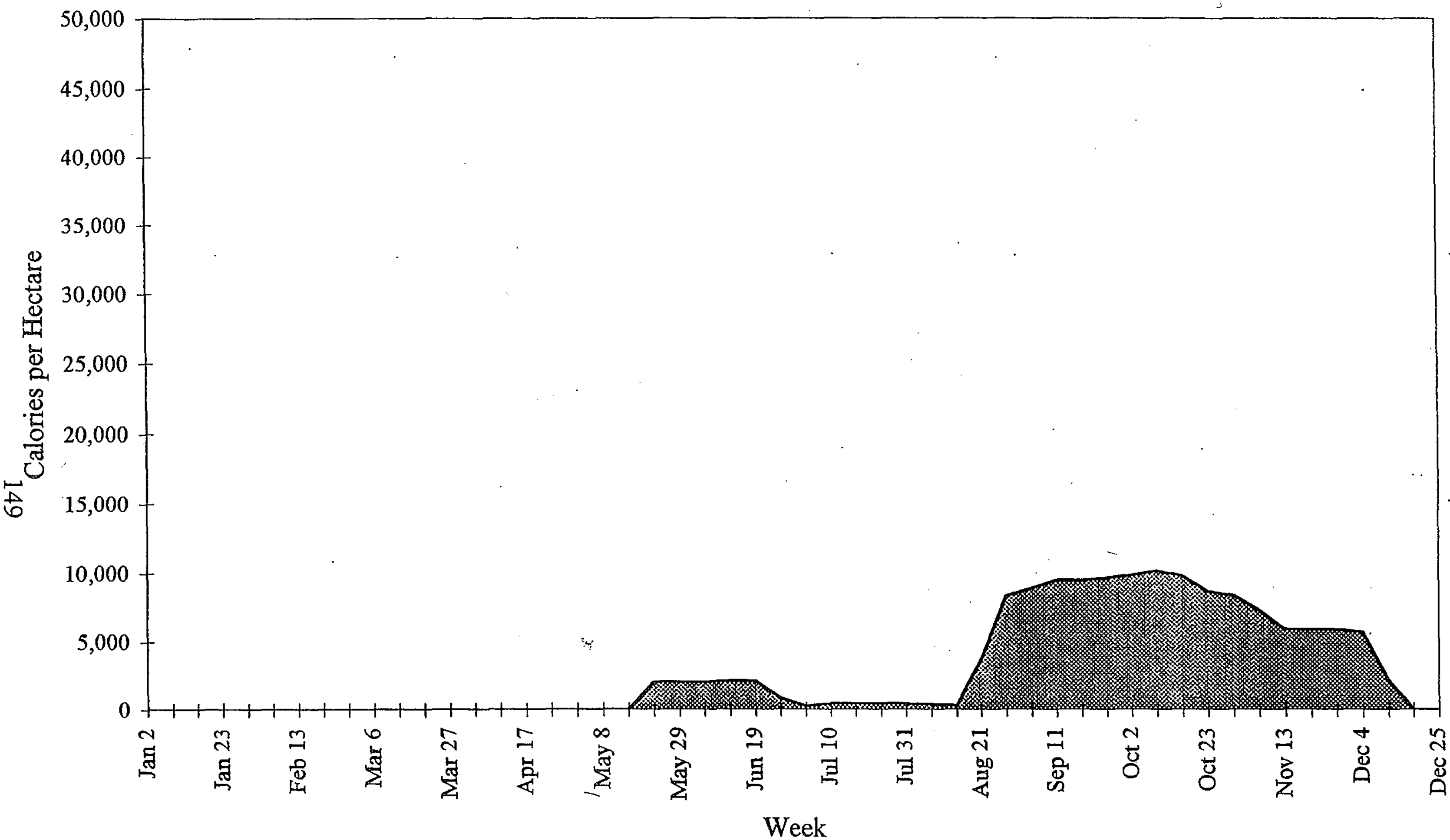

Figure C8. Tulip-Poplar: Mean weekly calories produced per hectare in the northwest quadrant of Great Smoky Mountains National Park, 1995.

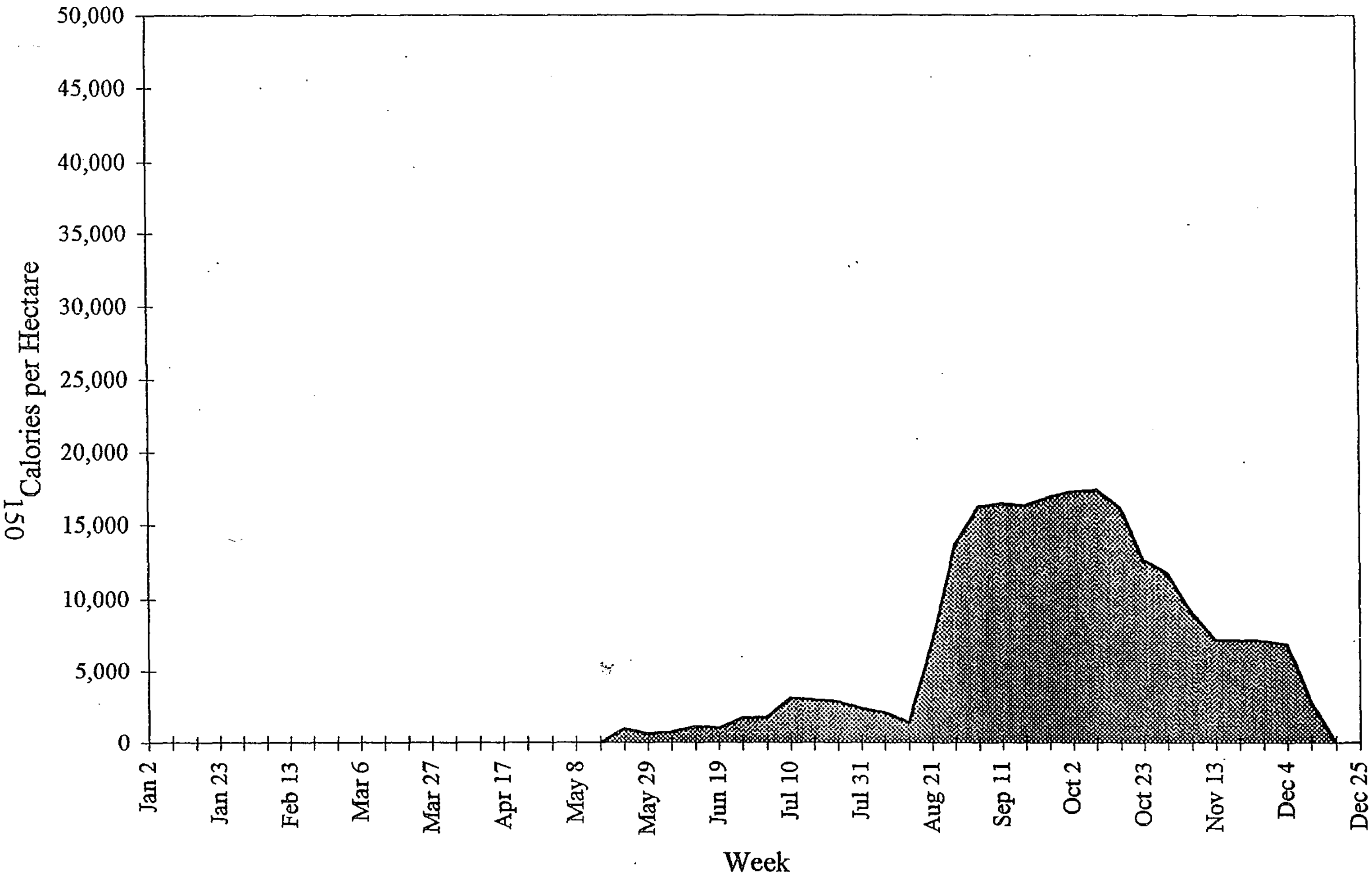

Figure C9. Xeric Oak: Mean weekly calories produced per hectare in the northwest quadrant of Great Smoky Mountains National Park, 1995.

Appendix D. Percent crude protein of black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995

Appendix D. Percent crude protein (dry weight basis) of black bear foods in the northwest quadrant of Great Smoky Mountains National Park, 1995

Food Species	Mast Type[a]	Sample Type	% CP	S.E.
Thornless blackberry	S	whole fruit	18.81	±0.16
Fire cherry	S	whole fruit	12.11	±0.09
Greenbriers	S	whole fruit	8.80	±0.00
Grapes	S	whole fruit	8.68	±0.18
Huckleberries	S	whole fruit	8.47	±0.28
Allegheny blackberry	S	whole fruit	7.88	±0.24
Black cherry	S	whole fruit	7.46	±0.10
Blackgum	S	whole fruit	6.67	±0.29
Scarlet oak	H	whole fruit	5.37	±0.18
White oak	H	whole fruit	5.32	±0.08
Northern red oak	H	whole fruit	5.22	±0.13
Squawroot	S	whole fruit	5.14	±0.21
S. mountain cranberry	S	whole fruit	4.88	±0.10
Chestnut oak	H	whole fruit	4.63	±0.08
Deerberry	S	whole fruit	4.50	±0.56
N. highbush blueberry	S	whole fruit	3.99	±0.29
Upland low blueberry	S	whole fruit	3.12	±0.01
American beech	H	.	.	.
Hickories	H	.	.	.
Hairy blueberry	S	.	.	.

[a] Hard mast: Hickories, chestnut oak, n. red oak, scarlet oak, white oak

Soft mast: Squawroot, huckleberries, Allegheny blackberry, thornless blackberry, greenbriers, n. highbush blueberry, s. mountain cranberry, hairy blueberry, upland low blueberry, deerberry, blackgum, fire cherry, black cherry, grapes.

Appendix E. Nutritional values of black bear foods reported in the literature

Appendix E. Nutritional values of black bear foods reported in the literature.

Species	Gross Energy Kcal/g dry wt.	Crude Protein %dry wt.	Crude Fat %dry wt.	Crude Fiber %dry wt.	ADF	Ash	N-Free Extract %	Reference
Quercus spp.		6.00	5.5	18.7	23.8			5
Quercus spp.	5.120							8
Quercus (white oaks)		5.90	4.3	18.7	23.8			14
Quercus spp.(with shells)	4.95	7.00						12
Quercus spp.(kernel only)	4.54	8.00						12
Quercus spp.(kernal only)		6.00			4			3
Quercus alba	4.461							4
Quercus alba		4.60	5.8	18.6	21.8	2.7	68.3	13
Quercus alba		6.25	6.32	2.47			82.32	17
Quercus alba		6.73	5.67	17.38		3.19	67.25	7
Quercus alba	3.907							2
Quercus alba (kernel)	4.170							15
Quercus alba (shell)	4.590							15
Quercus alba (cap)	4.020							15
Quercus rubra	4.919							4
Quercus rubra		4.90	14	26.4	29.3	2.4	52.3	13
Quercus rubra (meat only)	5.199							10
Quercus prinus		6.94	5.05	2.62		2.22	83.17	17
Quercus prinus		6.42	3.34	15.22		2.17	72.93	7
Quercus velutina	5.360							4
Quercus velutina	4.698							2
Quercus stellata	4.382							2
Quercus falcata	5.289							2

Appendix E. (Cont.)...

Species	Gross Energy Kcal/g dry wt.	Crude Protein %dry wt.	Crude Fat %dry wt.	Crude Fiber %dry wt.	ADF	Ash	N-Free Extract %	Reference
Carya glabra	7.965							2
Carya ovata	7.788							2
Carya ovata	7.561							4
Carya tomentosa	7.379							2
Carya tomentosa	7.386							4
Vaccinium corymbosum	4.472							9
Vaccinium corymbosum		8.95	7.2	11.74		3.27	53.79	16
Vaccinium spp.		5.70	7	14.1				5
Vaccinium spp.		4.19	3.8	9.67		1.44	80.9	17
Gaylussacia baccata	4.324							2
Cornus florida	5.361							2
Cornus florida		6.49	18.75	25.13		6.01	38.44	1
Cornus florida		6.62	11.5	31.79		5.9	35.01	16
Pokeweed	5.230							6
Smilax rotundifolia		8.52	4.335	12.89		6.63	60.74	1
Smilax glauca		10.24	7.53	18.59		3.4	60.77	7
Smilax spp.		6.60	6.3	17.1				5
Smilax spp.	4.53	7.70						12
Summer Grape		6.64	7.395	13.235		4.79	59.735	1
Vitis spp.		7.40		21.3			10.9	5
Vitis spp.	4.11	8.70						12

Appendix E. (Cont.)...

Species	Gross Energy Kcal/g dry wt.	Crude Protein %dry wt.	Crude Fat %dry wt.	Crude Fiber %dry wt.	ADF	Ash	N-Free Extract %	Reference
Conopholis americana		8.00			22			3
Conopholis americana	4.8	8.8	1.34	16.53			69.1	11
Amelanchier spp.		10.00			23			3
Rubus allegheniensis		7.93	7.2	20.45		3.74	48.8	16
Rubus spp.		10.00			30			3
Rubus spp.		9.40	7.1	22.2				5
Prunus serotina		13.94	6.97	32.66		3.7	43	7
Prunus serotina		8.30	4.7	21.2				5
Prunus serotina		6.95	3.65	20		2.15	53.88	16
Nyssa sylvatica		4.70	13.3	17.3				5
Nyssa sylvatica		4.77	15.18	8.2		4.46	56.35	16
Nyssa sylvatica	4.93	8.10						12
Fagus gandifolia	5.5	15.30						12

References in Appendix E.

1. Billingsley, B. B., and D. H. Arner. 1970. The nutritive value and digestability of some winter foods of the eastern wild turkey. J. Wildl. Manage. 34 (1):176-182.

2. Burns, T. A., and C. E. Viers. 1973. Caloric and moisture content values of selected fruits and mast. J. Wildl. Manage. 37(4):585-587.

3. Eagle, T. C. and M. R. Pelton. 1983. Seasonal nutrition of black bears in the Great Smoky Mountains National Park. Int. Conf. Bear Res. and Manage. 5:94-101.

4. Havera, S. P., and K. E. Smith. 1979. A nutritional comparison of selected fox squirrel foods. J. Wildl. Manage. 43:691-704.

5. Hellgren, E. C. 1988. Ecology and physiology of a black bear (*Ursus americanus*) population in Great Dismal Swamp and reproductive physiology in the captive female black bear. Ph.D. Dissertation, Virginia Polytechnic Institute and State University, Blacksburg, VA.

6. Kendeigh, S. C., and G. C. West. 1965. Caloric values of plant seeds eaten by birds. Ecology 46:553-555.

7. King, T. R., and H. E. McClure. 1944. Chemical composition of some American wild feedstuffs. Journal of Agricultural Research. 69(1):33-46.

8. Pekins, P. J., and W. M. Mautz. 1988. Digestability and nutritional value of autumn diets of deer. J. Wildl. Manage. 52:328-332.

9. Pritchard, G. T., and C. T. Robbins. 1990. Digestive and metabolic efficiencies of grizzly and black bears. Can. J. Zool. 68:1645-1651.

10. Robel, R. J., A. R. Bisset, and T. M. Clement Jr. 1979. Metabolizable energy of important foods of bobwhites in Kansas. J. Wildl. Manage. 43:982-986.

11. Seibert, S. G., and M. R. Pelton. 1994. Nutrient content of Squawroot, *Conopholis americana*, and its importance to southern Appalachian black bears, *Ursus americanus* (Carnivora: Ursidae). Brimleyana 21:151-156.

12. Servello, F. A., and R. L. Kirkpatrick. 1987. Regional variation in the nutritional ecology of ruffed grouse. J. Wildl. Manage. 51:749-770.

13. Short, H. L. 1976. Composition and squirrel use of acorns of black and white oak groups. J. Wildl. Manage. 40:479-483.

14. Short, H. L. and E. A. Epps Jr. 1976. Nutrient quality and digestability of seeds and fruits from southern forests. J. Wildl. Manage. 40:283-289.

15. Smith, C. C., and D. Follmer. 1972. Food preferences of squirrels. Ecology 53:82-91.

16. Spinner, G. P. and J. S. Bishop. 1950. Chemical analysis of some wildlife foods in Connecticut. J. Wildl. Manage. 14:175-179.

17. Wainio, W. W., and E. B. Forbes. 1941. The chemical composition of forest fruits and nuts from Pennsylvania. Journal of Agricultural Research 62:627-635.

Appendix F. Derivation of estimates of caloric consumption by the bear population in the northwest quadrant of Great Smoky Mountains National Park

The daily estimates of caloric consumption by bears in the study area were based on the following:

1. A black bear consumes between 5,000 and 8,000 Cal/day during normal activity; consumption increases with fall hyperphagia up to 20,000 Cal/day (Nelson et al. 1983). Increases in consumption were modeled with the following dates and rates:

Dates	Rate of Consumption per Bear
1 January - 30 March	0 Cal/day
1 April - 30 April	2,000 Cal/day
1 May - 31 May	4,000 Cal/day
1 June - 15 June	5,000 Cal/day
16 June - 30 June	6,000 Cal/day
1 July - 31 July	7,000 Cal/day
1 August - 14 September	8,000 Cal/day
15 September - 30 September	10,000 Cal/day
1 October - 31 October	15,000 Cal/day
1 November - 30 November	20,000 Cal/day
1 December - 15 December	10,000 Cal/day
15 December - 31 December	0 Cal/day

2. The hypothetical population of 1,000 bears in the northwest quadrant of GSMNP (1.6 bears/km^2).

Appendix G. Black bear litter size in the northwest quadrant of Great Smoky Mountains National Park during winter 1995 - 1996

Appendix G. Minimum litter size of black bears during the winter of 1995-96 in the northwestern quadrant of Great Smoky Mountains National Park.

Female Bear	Age	Minimum Litter Size	Type of Estimate
1248B 1248M	5.0	1	Immobilization of Female
1288B 1288M	5.0	3	Sound of Nursing Cubs
1244B 1244M	6.0	2	Sound of Nursing Cubs
1212B 1146M	7.0	3	Immobilization of Female
1227B 1227M	7.0	2	Immobilization of Female
1269B 1269M	7.0	3	Sound of Nursing Cubs
1183B 1183M	10.0	0	No cubs seen or heard
881R 881M	11.0	3	Immobilization of Female
1121B 1121M [a]	13.0	0	No cubs seen or heard
1275B 776M [a]	16.0	3	Immobilization of Female
1105B 1105M	17.0	3	Immobilization of Female
Mean Litter Size =		2.1	

[a] As part of an experimental repatriation, these adult females were translocated during the denning period (between den entrance and partuition) from the northwestern quadrant of Great Smoky Mountains National Park to selected den sites in the Big South Fork National River and Recreation Area. Litter estimates for these females were made at Big South Fork, after relocation.

VITA

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