Grizzly and Black Bear Feeding Ecology In Glacier National Park, Montana

Progress Report

by

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INTRODUCTION

This project was initiated in 1982 to explore the effects of variations in food supply on grizzly bear activity in Glacier National Park, Montana. The objectives of the study were to:

1. describe food habits of grizzly bears in Glacier National Park,
2. monitor production of important bear foods,
3. examine existing bear management records for possible relationships between bear activity patterns and fluctuations in food availability, and
4. develop a model to predict berry production.

In 1982-83, efforts were focused on the establishment of study sites and the development of methods to measure annual huckleberry (Vaccinium spp.) production. In 1984-85, huckleberry production monitoring continued and mountain ash (Sorbus scopulina and S. sitchensis), serviceberry (Amelanchier alnifolia) and hawthorn (Crataegus douglasii) berry production studies were initiated.

Many people contributed to this study and deserve recognition. Foremost are R. Potter and S. Kiser who provided valuable input to sampling design and data interpretation as well as many long hours in the field. I would like to thank C. Bourgonje, R. Kikkeri, T. Marschak, U. Mattson, G. Scherman and L. Tryon for volunteering their time to provide much needed lab and field assistance. R. Klaver graciously provided his climatic index software and advice for which I am grateful. Thanks also to S. Barsness for help in data base management and L. Rogers for suggesting the "bear foraging simulation" method of berry production monitoring. My information on bear food habits would be much less complete without extensive help in the somewhat less glamorous area of scat collection. Thank you for your efforts and interest to the following contributors: T. Abell, Bob Adams, Brian Adams, K. Ahlenslager, R. Altop, R. Bahr, S. Baldwin, O. Blair, C. Bourgonje, K. Bruno, B. Butterfield, D. Casteel, E. Caton, J. Chauvette, K. Chin, B. Cidorus, B. Cobell, R. Coffman, G. Cummings, M. Danisiewicz, A. DeBolt, J. DeSanto, S. Eischeid, K. Frauson, P. Fujiwara, P. Furbush, D. Gibson, R. Griffith, D. Halloran, P. Hayward, A. Hoffs, M. Hummer, C. Janusz, K. Jenkins, J. Johnson, K. Keating, B. Kenner, C. Key, L. Key, D. Killerud, S. Kiser, B. Klaver, K. Knapp, S. Korthius, T. LaFrance, M. Lazo, R. Litchfield, M. Longden, R. Ljung, L. Marr, R. Mattson, U. Mattson, D. Maturen, B.R. McClelland, P. McClelland, B. McConnel, R. Miller, R. Milsap, E. Morey, B. Nelson, M. Ober, D. Panebaker, R. Potter, J. Potter, J. Rajkowski, C. Savage, G. Scherman, B. Schuster, R. Schwalk, K. Scott, C. Scribner, C. Shea, D. Shea, G. Smith, D. Steele, P. Steinkopf, J. Stensrud, R. Talbott, C. Talsma, L. Traeger, L. Tryon, P. Vernasky, G. Vodehnal, N. Wedum, D. Westwood, B. Williams, I. Williams, M. Wilson, C. Wolf, R. Yates, and the students of Ursula Mattson's Wildlands Research Institute class.

STUDY AREA

The study encompassed locations in and around Glacier National Park including sites in Waterton Lakes National Park and the Flathead National Forest. The area is characterized by rugged, glaciated topography with elevational extremes ranging from 3200 to 10,500 feet. The climate west of the continental divide in Glacier National Park is influenced by Pacific Maritime weather systems where winters are typically cold and snowy and summers are cool and moderately moist. The east half of the park is generally drier and cooler than the west during much of the year.

METHODS

Bear Food Habits

Foods important to grizzly bears in Glacier National Park were determined through fecal analysis. Due to the problems associated with distinguishing grizzly from black bear scat (Hamer, Herrero, and Rogers, 1981), all bear scats found were collected and analyzed. The analysis results, therefore, represent a combination of grizzly and black bear food habits.

The scats were dried immediately after collection and rehydrated for examination. After being rinsed and screened, all food items were identified to species when possible. The percentage of the total scat volume comprised by each component was estimated with some subjective adjustment for items of high or low digestibility.

Huckleberry Production

Huckleberry production was studied at 58 sites throughout Glacier National Park and in surrounding portions of Waterton Lakes National Park and Flathead National Forest (Fig. 1). The sites were selected to sample the broad geographic range of the study area and a variety of elevations and aspects (Table 1).

Sampling transects were established in each study site. Transect starting points were referenced to either a recognizable landmark or a tree marked with an aluminum tag. The transects were delineated by an azimuth from the starting point and typically lay perpendicular to the slope of the site.

Site boundaries were determined by the vegetative community. Within each site, understory and canopy species representation and cover were fairly homogeneous. To achieve this, sites varied in size and configuration from small openings in timber canopy to large areas within extensive shrubfields. Transects and plots were spaced to sample the extent of each site.

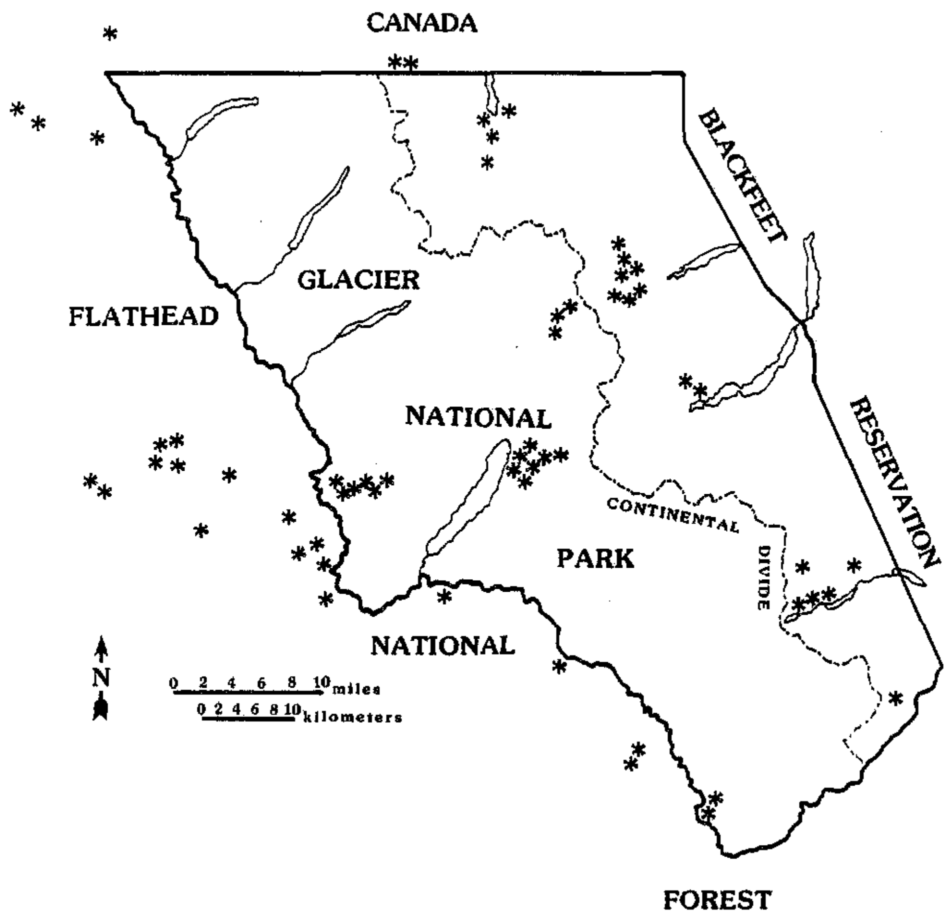


Fig.1. Location of huckleberry monitoring sites.

Table 1. Aspect and elevation of huckleberry monitoring sites.

Elevation (ft)	N (315-44°)	E (45-134°)	S (135-224°)	W (225-314°)	Flat	Total
3500-4499	2	2	5	3	5[1]	17
4500-5499	1	8	6	4	0	19
5500-6499	3	2	11	4	0	20
6500-7499	0	0	0	2	0	2
Total	6	12	22	13	5	58

1 Elevation of 1 site = 3250 ft

The study sites were described by a variety of characteristics. The following parameters were recorded for each: elevation, aspect, slope and habitat type. The vegetation community was described by a complete species list and associated cover classes.

A fast and effective technique was required for measuring the relative differences in annual huckleberry production throughout the study area. Five methods were developed and tested. In Mèthod A, 20 0.5-m^2 plots were equally spaced along a 60-m transect and all huckleberries in each plot were collected and counted.

The second method for sampling berry production (Method B) involved counting all berries in 50 0.04-m^2 plots. The plots were placed a predetermined number of paces apart along established transects. The spacing was adjusted to allow all 50 plots to fall within the site boundaries. Exceptions were made when the sample frame did not contain any part of a huckleberry plant. When this occurred, the distance to the closest huckleberry plant was measured and the frame placed at the first whole foot interval which allowed the frame to contain some part of a huckleberry plant.

Method C was developed as a faster huckleberry production monitoring technique than Methods A and B. In it, 2 people picked as many berries as possible in 15 minutes within the site boundaries. This was done when most berries were ripe at each location. The total number of berries picked were tallied later in the lab.

In Method D, huckleberry production was estimated by inspecting each site. Berry abundance was rated on a five point scale ranging from none/rare to very abundant. For consistency between sites and years, the number of different people performing the ratings were limited. Three people made all estimates 1983-85.

Method E used the number of berries on 20 permanently marked bushes or portions of bushes at each site to estimate production. Bushes were marked in the spring of 1984 when flowers and/or green berries were present. Bushes were selected that had some flowers or berries, excluding plants which would never produce berries within the time frame of this study. The number of stems marked/bush was limited to ensure accurate counts. Counts were made when berry ripeness peaked.

The five methods developed for measuring huckleberry production were tested and evaluated by their ability to detect the magnitude of annual differences in berry production and the amount of time required to carry out each procedure. The time element was important because of the large number of samples required to understand variation in huckleberry production throughout the area encompassed by the study.

A climatic index was constructed with software developed by R. Klaver which used the deviation of mean monthly temperature and total monthly precipitation from historical means following Picton's (1978) methods. The index used data from the West Glacier weather station.

Average ripe berry size was determined at each site. Berry size was measured by volumetric displacement and expressed as ml/berry. Samples to determine berry volume were obtained from approximately one cup of ripe berries picked at sites monitored by Method B. If a site did not contain one cup of berries, all ripe berries present at the site were collected. Care was taken to collect all ripe berries present on bushes where picking was initiated to avoid biasing the size of berries sampled.

Annual variation in phenology was monitored by examining the degree of berry crop ripeness when production was measured each year. At each site monitored by Method A, B, and E, all berries counted were tallied as green, ripe or pedicel. A pedicel without a berry but stained purple on the end was assumed to indicate that a ripe berry had been present but had already fallen off the bush or been eaten. The ripe and pedicel classes were combined to estimate the proportion of berries which had already ripened at the time of sampling.

To provide information on factors influencing berry development each year, I measured flower abundance on marked huckleberry bushes at the six sites established for Method E production studies. In May and June, I counted the number of flowers and/or small green berries present. Counts were made again two to three months later when most berries were ripe.

Variation in the nutritional value of huckleberries was indexed by the amount of sugar present. Sugar content analysis was conducted on the berries taken for size determination. At some sites several samples were obtained during August and September of the same year and provided information on seasonal variation in huckleberry sugar content.

Sugar content was determined in two ways for each sample. A refractometer reading gave an approximate measure of sugar content by indicating the total amount of soluble solids in huckleberry juice. A more specific measure of the amount of available energy in berries was obtained by total nonstructural carbohydrate (TNC) analysis.

Refractometer readings were obtained with a temperature compensated, hand-held refractometer (American Optics Model 10431). Ten to 30 berries (depending on berry size) were crushed using a garlic press and the juice thoroughly mixed. A refractometer reading in degrees Brix was taken using several drops of the mixed fluid. Whenever the number of berries in the sample allowed, this process was repeated up to 5 times and the reading used for the whole sample was a mean value of these replications.

In 1984, a measure of huckleberry sugar content was also obtained using a technique based on the digestion of TNC by an enzyme system followed by colorimetry using Teles' reagent (daSilveira, Teles and Stull, 1978). In 1985, The Teles' reagent test was not available and TNC levels were determined with the Phenol-Sulfuric Acid Colorimetric method (Whistler and Wolfrom, 1962). The berry samples were frozen from the time of collection until they were analyzed. Readings were given in mg of carbohydrate/ml of glucose equivalent.

Other Berry Production

Production of other berries commonly eaten by bears in Glacier National Park was studied at various locations throughout the study area. Mountain ash berry production was monitored in 1984-85 at 16 sites (Fig. 2). Beginning in 1985 serviceberry production was studied at 38 sites (Fig. 3), and hawthorn production at 19 sites (Fig. 4). All sites were described by location, elevation, aspect, slope and habitat type. At each site, 10 bushes or portions of bushes were marked with aluminum tags. For mountain ash, the number of berry clumps were counted on each marked plant and five clumps were randomly collected. If there were fewer than five clumps, all clumps present were taken. For each clump collected, counts were made of the number of berries and berry size was measured by volumetric displacement. In 1985, weight (gm) was obtained for berry samples. For serviceberry and hawthorn, all berries were counted and listed as green, ripe, shrivelled or pedicel. Sampling at each site was conducted when most berries were ripe.

Bear Activity

Bear activity was indexed by the annual number of Park bear/human-injury confrontations, campground and trail closures due to bears, property damage incidents, and bear relocations and mortalities within the Park.

Data Analysis

Linear regression was used to analyze the relationship between huckleberry production figures obtained by Methods A and B and to predict 1982 production in Method B terms. Logarithmic transformation was used for comparisons of huckleberry production estimated by Method B with Methods D, C, and E. For Methods A, B, C, and D, Wilcoxon Rank Sum was used to test for differences in annual berry production where $n_1=20$ and $n_2=40$. For larger samples, I used the Normal Approximation to the Mann-Whitney Test. Annual differences in berry production in Method E were tested with the Wilcoxon Signed Rank. Annual berry production for all sites combined was compared with the Kolmogarov-Smirnoff test. Power transformation was used for regressing berry size on huckleberry production. A paired t was used to examine annual

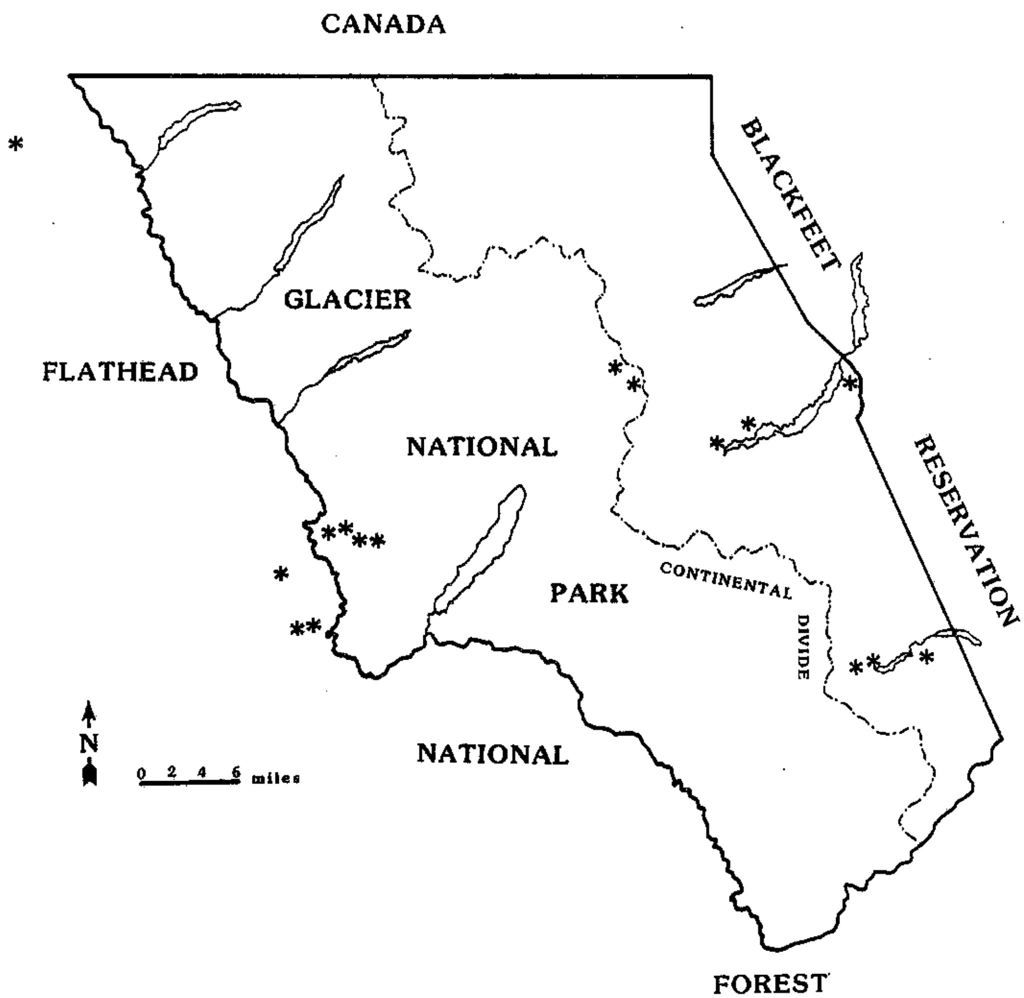


Fig.2. Location of mountain ash monitoring sites.

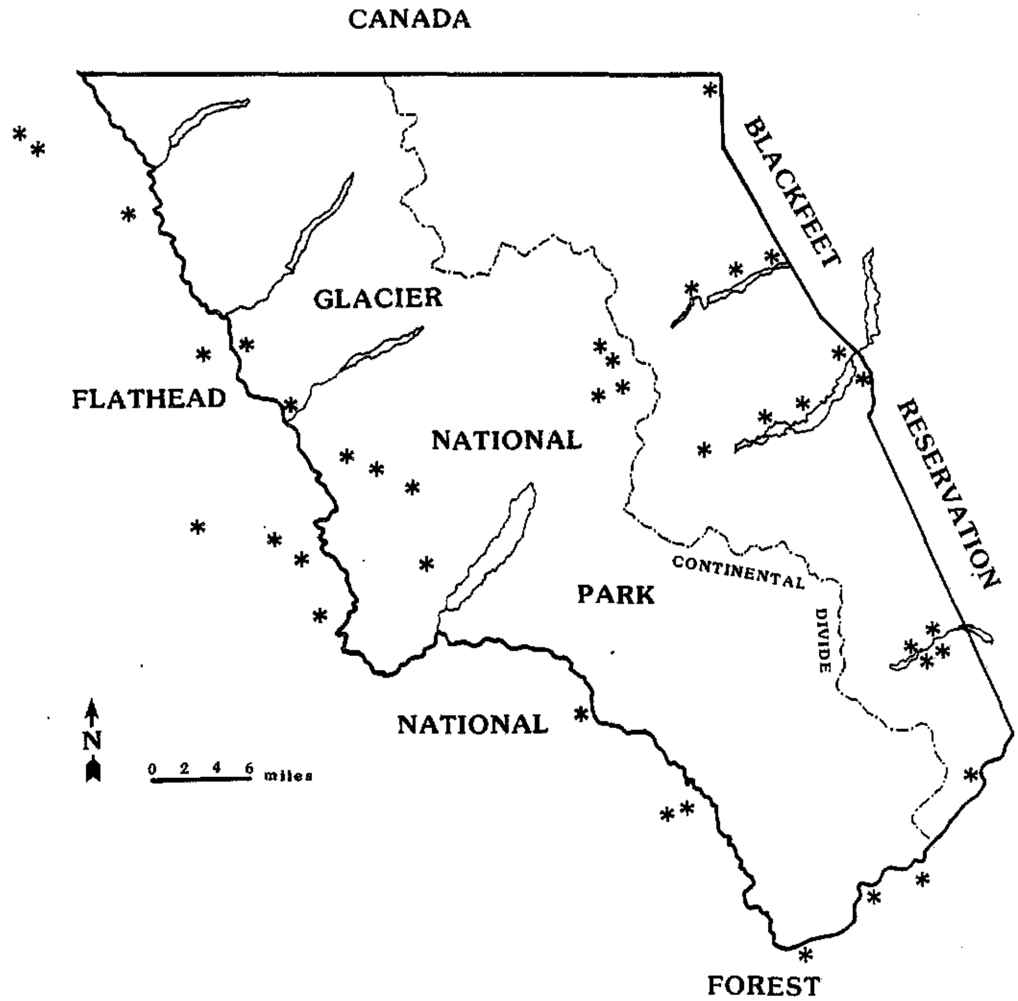


Fig.3. Location of serviceberry monitoring sites.

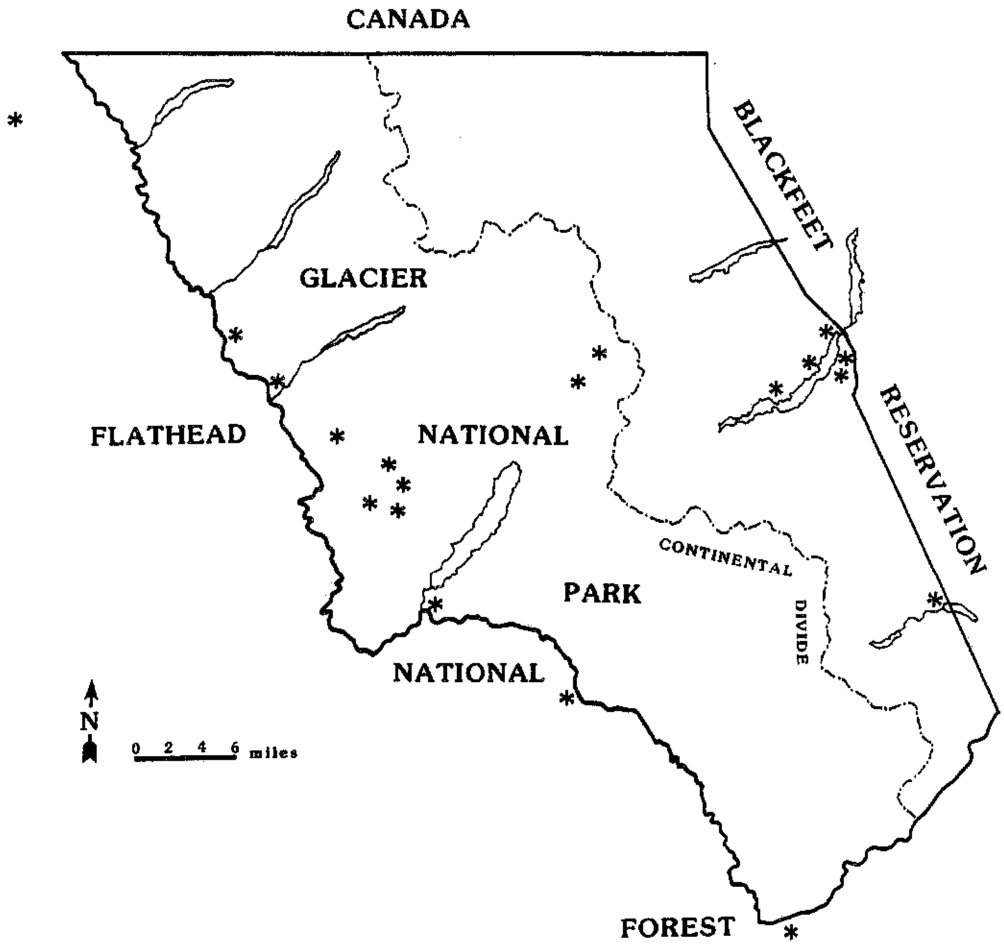


Fig.4. Location of hawthorn monitoring sites.

differences in berry size, mean sugar content and flower survival. Refractometer readings (°Brix) and TNC levels were compared with linear regression as was the relationship between sugar content and elevation and mean berry size.

Annual differences in the number of mountain ash berries/clump, total number of berries and berry clumps, and berry size were tested with a paired t. The dependence of sample weight on the number of mountain ash berries and clumps sampled was tested with linear regression. For all tests, significance was assumed where $a \leq 0.05$.

RESULTS AND DISCUSSION

Food Habits

Throughout the study area, 1176 bear fecal samples were collected from mid-April to mid-November 1982-85. Samples collected in Glacier National Park from 1967-71 (N=338) (Martinka,unpubl. rep., Glacier N. P.) were combined for composite food habits analyses producing monthly sample sizes of more than 200 from May through September (Table 2). The small number of samples for April, October and November reflected lower levels of collector effort as well as lower levels of bear sign found in the field during those months.

Bear diets were predominantly vegetarian with approximately 60% of the year-long diet volume composed of plant leaves, stems and roots, 30% berries and fruit and 7% mammals and insects (Fig. 5, Appendix A).

Several items dominated the major food groups (Table 3). The most important herbs were cow parsnip (*Heracleum lanatum*), horsetail (*Equisetum* spp.) and angelica (*Angelica* spp.). Huckleberries dominated the fruits eaten. They were followed in importance by hawthorn, serviceberry and mountain ash berries. Mammals, primarily elk (*Cervus canadensis*) and deer (*Odocoileus* spp.) formed the bulk of the animal matter and sweetvetch (*Hedysarum* spp.) was the dominant root/bulb eaten. Most graminoids were not identified to species and were typically listed as an unspecified combination of grass/sedge.

Annual food habits were separated into four seasons according to bimonthly food consumption (Fig. 6) and availability: spring (April 15 - May 31), summer (June 1 - July 31), late summer (August 1 - September 30), and fall (October 1 - November 14) (Table 3). In spring, bears grazed heavily on graminoids and herbaceous material supplemented with carrion. Grasses waned in importance in early summer as they became less succulent and bears relied extensively on herbaceous matter. Berries dominated the late summer season but bears continued to feed on small amounts of grasses and herbs. Most huckleberries ripened from August through mid-September and were often present on bushes until mid-October. Hawthorn and mountain ash berries typically ripened in August and September and were available later in the year than other berries. Ripe serviceberries were available from approximately early July through early September. During fall, berries and grasses were the largest contributors to diet volume followed by animal material, roots/bulbs and herbs.

Table 2. Monthly totals of bear feces collected in Glacier National Park, 1967-71 and 1982-85.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total[1]
1967	0	0	0	0	1	8	1	0	10
1968	1	23	13	11	23	14	3	0	88
1969	4	28	3	6	2	21	7	0	71
1970	2	20	10	12	12	20	4	0	80
1971	3	18	15	14	12	26	1	0	89
1982	0	0	3	21	14	11	0	0	49
1983	4	40	34	26	23	51	33	0	211
1984	1	11	59	51	75	134	19	1	351
1985	15	82	100	98	73	126	39	2	535
Total	30	222	237	239	235	411	107	3	1484

1 Only includes feces <1 month old when collected; samples which could only be identified as deposited in the current year were included in composite food habits analyses for entire year.

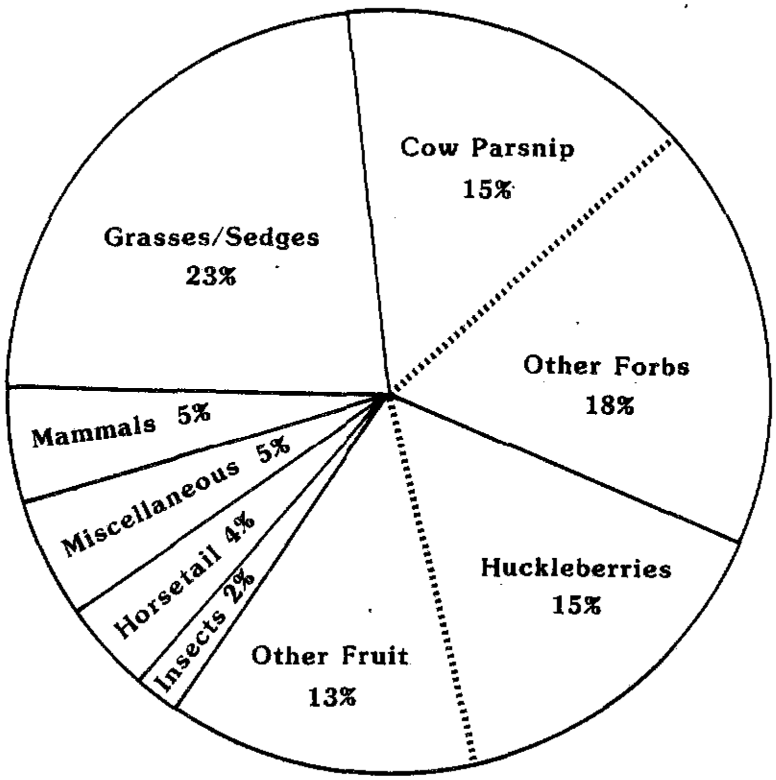


Fig.5. Proportionate contribution of major food classes to the total diet volume of bears in Glacier N.P. as determined by fecal analysis, 1967-71 and 1982-85 (N=1514).

Table 3. Seasonal food habits of bears in Glacier National Park, Montana, from analysis of 1484 fecal samples collected 1967-71 and 1982-85.

	Spring 4/15-5/31 N=252		Summer 6/1-7/31 N=476		Late Summer 8/1-9/30 N=646		Fall 10/1-11/14 N=110	
Food Item	%Freq	%Vol	%Freq	%Vol	%Freq	%Vol	%Freq	%Vol
GRASS, SEDGE, RUSH	74	45	38	19	34	17	40	27
HERBACEOUS MATERIAL								
Angelica spp.	2	1	4	3	4	2	0	0
Equisetum spp	19	8	15	7	3	1	5	1
Heracleum lanatum	13	9	41	34	8	6	6	4
Misc. umbels	16	7	12	10	5	3	3	1
Misc. forbs	15	9	12	7	8	4	16	7
Misc. other	10	0	6	1	3	1	1	0
Total		34		62		17		13
FRUITS								
Amalanchier alnifolia	0	0	3	2	13	7	4	2
Crataegus douglasii	0	0	0	0	13	10	7	6
Sorbus spp.	0	0	0	0	8	5	3	2
Vaccinium spp	0	0	7	4	42	29	15	12
Misc. fruits	1	1	1	1	10	4	9	6
Total		1		7		55		28
ANIMAL								
Fish	0	0	0	0	0	0	5	2
Insect	16	0	18	2	9	1	5	1
Mammal	29	12	9	2	9	3	20	11
Total		12		4		4		14
ROOTS, BULBS								
Erythronium grandiflorum	0	0	4	3	0	0	0	0
Hedysarum spp.	6	5	0	0	5	4	17	13
Misc. root	0	0	1	0	1	0	0	0
Total		5		3		4		13

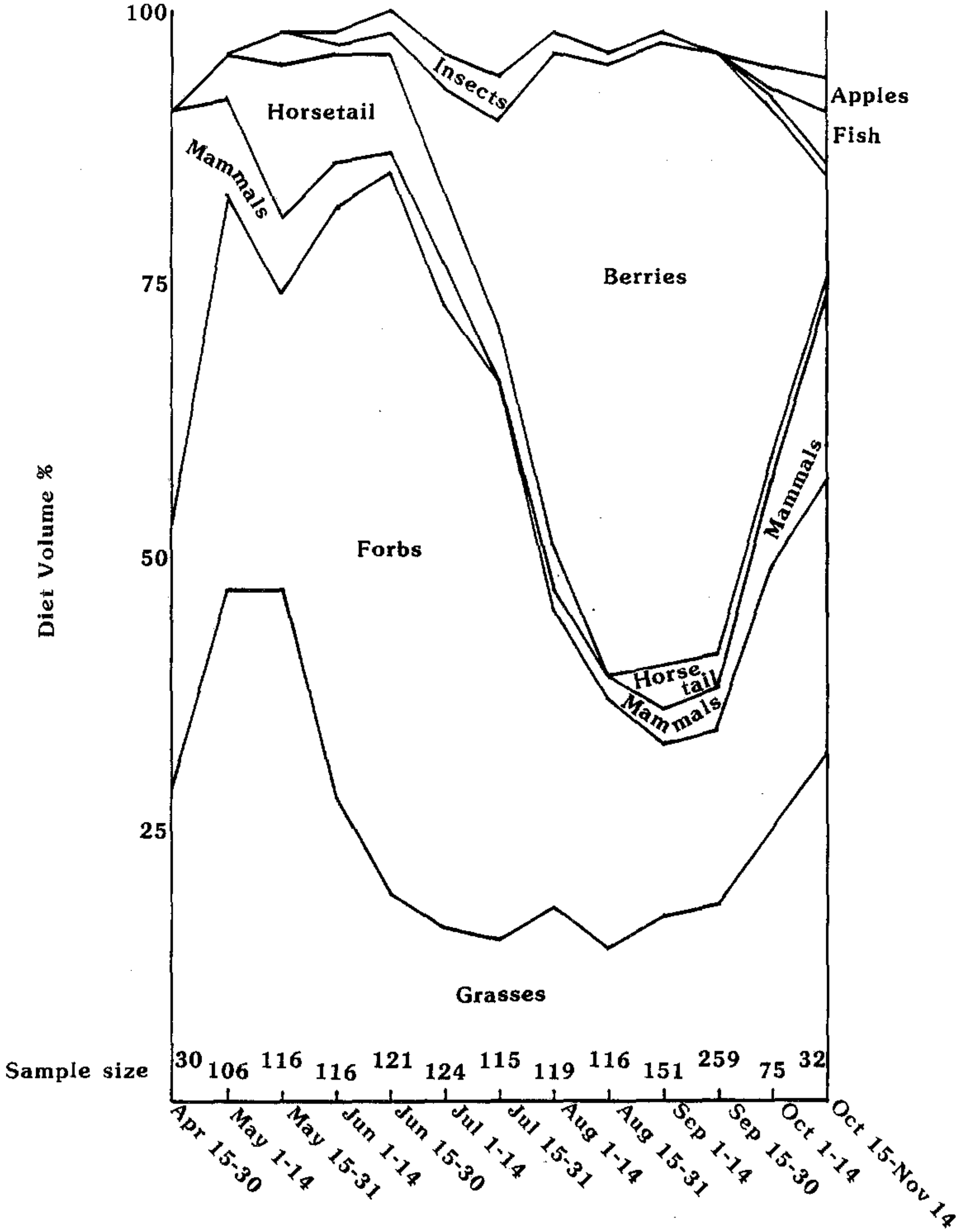


Fig.6. Bimonthly proportionate contribution of major food groups to Glacier N.P. bear diet volume from fecal analysis 1967-71 and 1982-85 (N=1484).

Food habits determined through fecal analysis were subject to several sources of bias. The analysis technique attempted some correction, but the volume of easily digested food items may have been underestimated and coarse, fibrous vegetation and other hard-to-digest items, overestimated. If an item was highly digested, its presence may not have been detected at all.

Another potential bias lay in the locations selected for feces collection. Almost all samples were collected along trails with a small proportion collected off-trail and on roads. It is likely that this collection pattern resulted in an underestimation of the importance of carrion/meat in the diet (McLellan, pers. comm.). When bears feed on a carcass, they generally remain in the immediate vicinity until they have finished feeding. Feces containing this food item are likely to be deposited in this small area. The limitations on bear movements while feeding on carrion result in a low probability that feces from this feeding activity will appear on the trail system.

Because fecal samples were collected in 1982-83 primarily during berry production monitoring activities, sampling distribution was not random throughout the Park or consistent either during the year or between years. While the analysis results probably accurately represent general food habits, they were not adequate to detect differences in food habits between years except in a few cases. Between year comparisons were legitimate in those areas where field work was concentrated and Parkwide in 1984-85 when feces collection effort and distribution were fairly uniform.

Food habits differed between 1984 and 1985 and appeared to be correlated with food availability. Huckleberry production in 1984 was 31% of the 1985 level (see Huckleberry Production) and bear consumption of fruit, especially huckleberries, in 1984 was markedly lower than in 1985 (Table 4). Unlike 1985, no huckleberries were found in feces in summer and fall in 1984. When huckleberry consumption declined, hawthorn and mountain ash berry feeding increased in late summer and fall, respectively. Feeding on graminoids also increased when the amount of fruit in the diet declined.

Table 4. Proportionate contribution of major food items to total diet volume as determined by analysis of bear feces in Glacier National Park, 1984 and 1985.

	Spring 4/15-5/31		Summer 6/1-7/31		Late Summer 8/1-9/30		Fall 10/1-11/14	
	1984 N=12	1985 N=97	1984 N=110	1985 N=198	1984 N=209	1985 N=199	1984 N=20	1985 N=41
Grass, Sedge, Rush	42	43	25	13	17	14	34	27
Equisetum spp.	0	10	10	7	0	2	5	0
Forbs								
Angelica spp.	4	0	0	5	5	2	0	0
Erythronium grandiflorum	0	0	0	1	0	0	0	0
Hedysarum spp.	1	6	0	0	6	5	8	12
Heracleum lanatum	13	12	41	44	6	7	10	4
Misc. umbels	4	2	6	2	1	0	0	0
Misc. forbs	1	5	5	5	3	1	8	2
Taraxacum	0	5	4	2	0	0	0	0
Total	23	30	56	59	21	15	26	18
Fruit								
Amelanchier alnifolia	0	0	0	4	4	12	3	3
Arctostaphylos uva-ursi	17	0	1	0	0	1	0	2
Crataegus douglasii	0	0	0	0	15	9	0	16
Sorbus spp.	0	0	0	0	6	6	10	1
Vaccinium spp.	0	0	0	7	22	30	0	6
Misc. shrubs	0	0	0	2	4	1	0	0
Total	17	0	1	13	51	59	13	28
Animal								
Fish	0	0	0	0	0	0	7	2
Insect	1	0	1	2	1	1	2	1
Large mammal	13	12	0	2	2	5	7	14
Small mammal	0	0	1	1	1	1	2	0
Total	14	12	2	5	4	7	18	17

Berry Production

Huckleberry

Taxonomy

Six species of *Vaccinuim* occurred within the study area: *V. caespitosum* (dwarf huckleberry), *V. globulare* (blue h.), *V. membranaceum* (tall h.), *V. myrtilloides* (velvet-leaved h.), *V. myrtillus* (low h.), and *V. scoparium* (grouse whortleberry). There was considerable range overlap between species with as many as four species present at one site. It was apparent from scat analysis and evidence of feeding activities in the field that *V. globulare* and *V. membranaceum* comprised the bulk of the huckleberries eaten by bears in Glacier National Park. Low huckleberry and grouse whortleberry formed a small part of Park bear diets while the contribution of dwarf and velvet-leaved huckleberry was negligible. Huckleberry production studies therefore were limited to blue and tall huckleberry. In several sites which contained both blue and low huckleberry plants with overlapping characteristics, berries which may have been low huckleberry were included in the berry production counts. Otherwise, only blue and tall huckleberries were tallied. The tendency for blue and tall huckleberry to hybridize created difficulties in identification. For simplicity, *V. globulare* was used to identify all plants within the *V. globulare - membranaceum* complex.

Monitoring Technique Assessment

Method A (20 0.5-m^2 plots) Huckleberry production was monitored using Method A in 15 sites in 1982 and in 12 sites in 1983. Monitoring was continued in 3-4 sites in 1984 and 1985 (Table 5). Two people completed the field sampling in one to three hours with a like amount of lab time required to process the samples collected.

At most sites measured by Method A, the number of berries/plot was highly variable. Because of this, 20 replicate plots were considered the minimum needed to obtain a reliable estimate of mean berry production although this may not have been an adequate sample when berry production was high (Fig. 7). Although production was higher in 1982 than in 1983 in 11 of the 12 sites and the combined production for all sites declined 56%, the high within-site-variability meant that production was significantly higher in 1982 in only 8 of 12 sites.

Method B (50 0.04-m^2 plots) Method B was used to monitor huckleberry production at 59-62 sites from 1983-85 (Table 5). These sites included all those monitored with Method A in 1983-85. Method B was typically completed by two people in 15-30 minutes.

Plots of the running mean number of berries at each site (Fig. 8) suggest that 20-25 sample plots may have been sufficient to

Table 5. Number of sites at which huckleberry production was monitored with 5 techniques, 1982-1985.

METHOD	1982	1983	1984	1985
Method A (20 0.5-m^2 plots)	15	12	4	3
Method B (50 0.04-m^2 plots)	0	59	62	61
Method C (15 min. pick)	13	22	0	0
Method D (estimate on 1-5 scale)	0	47	57	62
Method E (marked bushes)	0	0	6	6

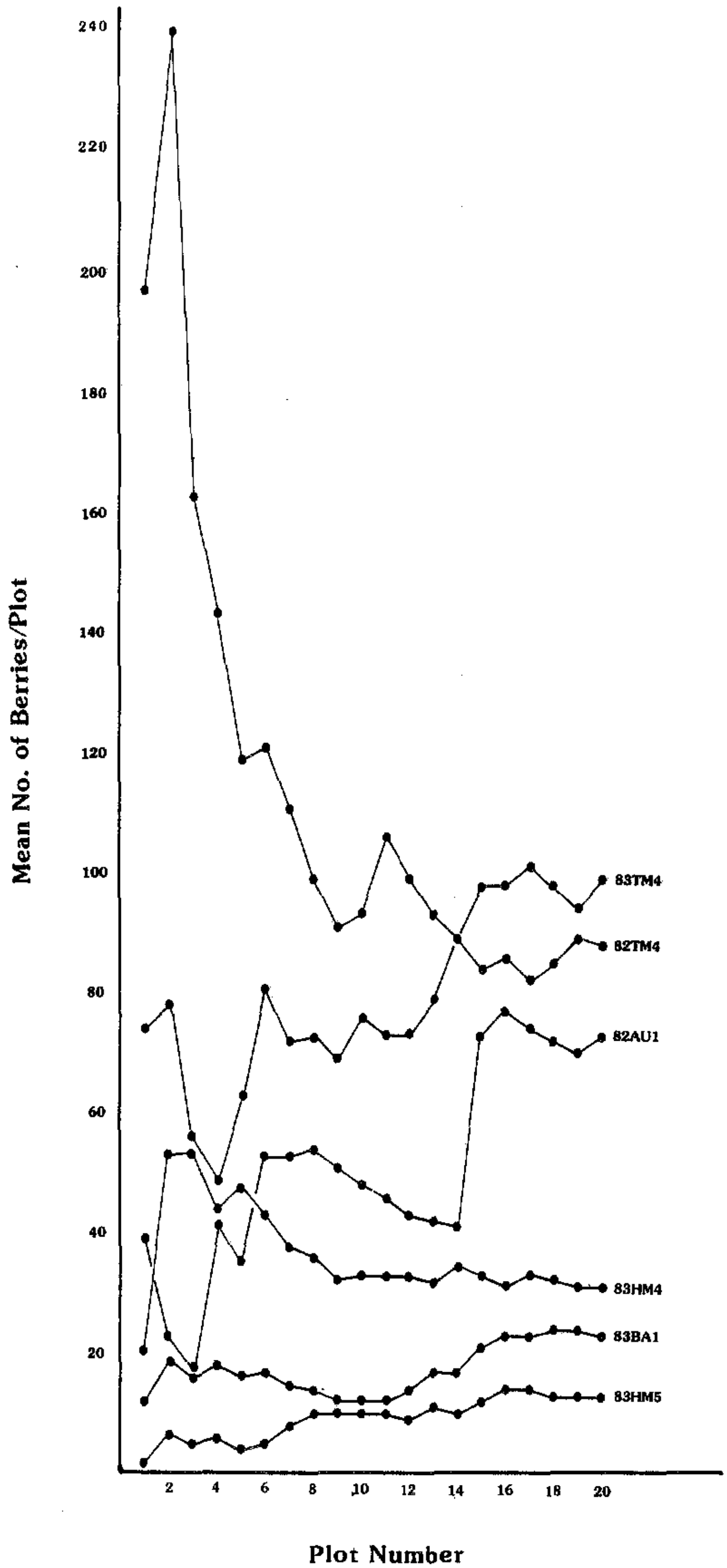


Fig.7. Cumulative mean number of berries/plot at 6 huckleberry monitoring sites in Glacier N.P. sampled by Method A.

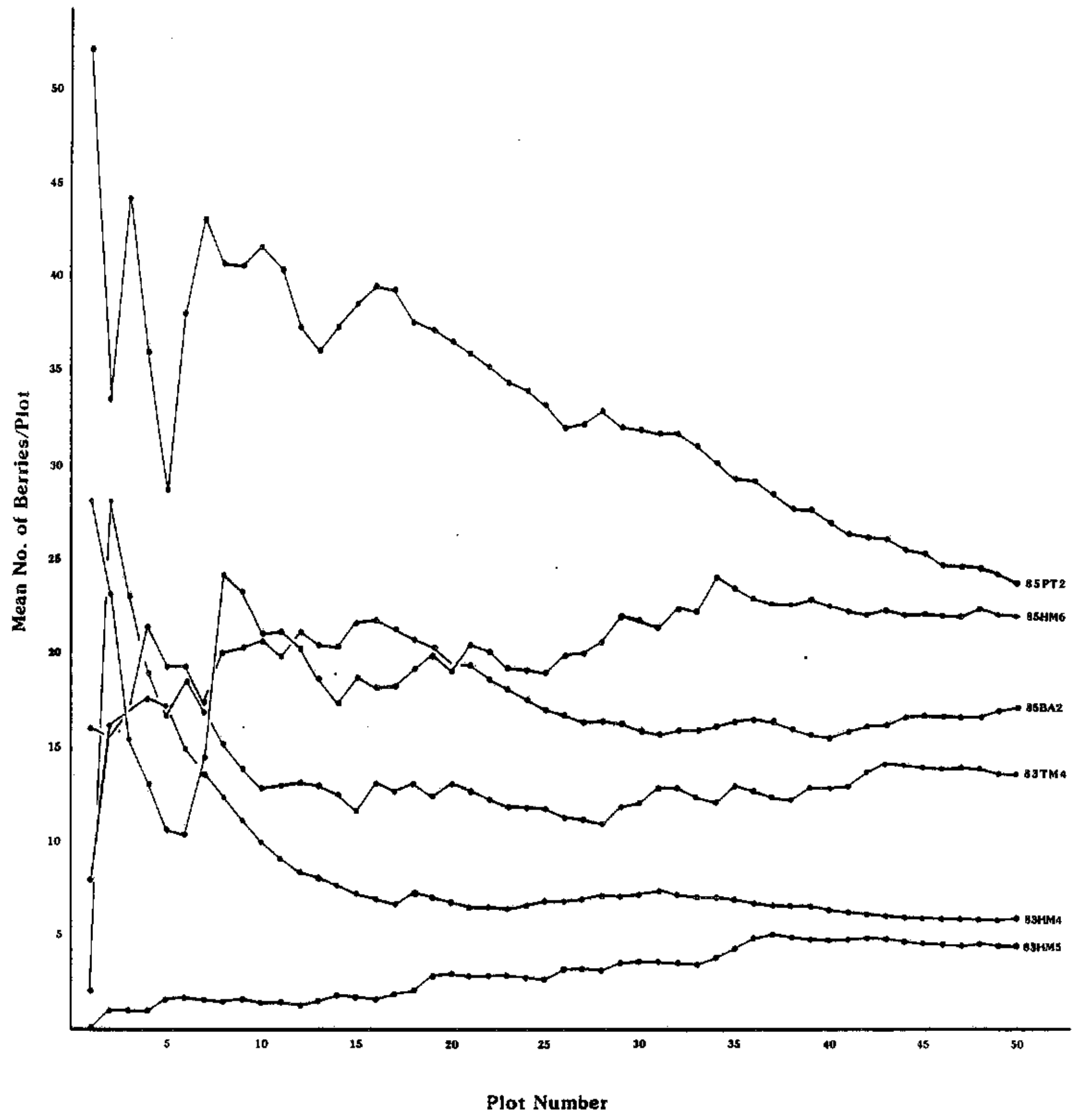


Fig.8. Cumulative mean number of berries/plot at 6 huckleberry monitoring sites in Glacier N.P. sampled by Method B.

obtain an accurate representation of mean berry production. In fact, the sample variability was greater using 50 plots than 20 at 7 of 12 sites examined (Table 6). However, this method was not employed in 1982 when berry production was very high. With higher production, berry distribution may be more variable. If so, a larger sample would be needed to reliably estimate mean berry production at each site. A large sample (50 plots) was advantageous in that it permitted the use of more powerful statistical tests for data analysis than could be used on smaller samples.

Methods A and B appeared to be equally sensitive in detecting variation in production between years at individual sites despite the higher variability associated with Method B estimates. At 5 sites monitored in consecutive years, huckleberry production was significantly different between years at all sites as measured by both monitoring methods. Yet at 16 of 19 sites monitored the coefficient of variation for mean huckleberry production was higher for Method B than Method A (Table 7). The difference in variability between the 2 methods resulted primarily from sample plot size (0.5-m^2 vs. 0.04-m^2). Because huckleberry plant distribution and berry production were clumped, larger plots contained more variation within the sample unit which reduced variation between plots. Method B however was preferred to Method A because it appeared sensitive enough to detect annual variation in production and because sampling was completed in less than 1/4 the amount of time required to sample by Method A. Method B was also preferred to Methods C, D, E.

<u>Method C (15-min pick)</u> Huckleberry production was estimated with Method C at 35 sites. By design, sampling was completed in the field in 15 minutes, and the berries were counted in the lab in 15-30 minutes.

Method C production estimates corresponded poorly with Method B estimates r^2=0.49). There appeared to be an upper limit to the number of berries which could be picked in 15 minutes. Increases in berry abundance (as measured by Method B) beyond moderate levels, failed to yield more berries by Method C (Fig. 9).

<u>Method D (estimate on 1-5 scale)</u> Berry production was rated on a 1-5 scale at 166 sites 1983-85. Method D estimates were loosely related to Method B estimates (r^2=0.59). There was a high degree of overlap in the number of berries/plot (as measured by Method B) between levels in the 5-point scale (Fig. 10). In addition, a wide range of berry abundance was associated with each level and that range increased as the scale increased.

<u>Method E (marked bushes)</u> Method E was used to measure huckleberry production at 6 sites. Two people usually completed sampling in 30-60 min/site.

Production estimates by Method E were not strongly related to Method B estimates (r^2=0.51) (Fig. 11). Mean production figures

Table 6. Comparison of variability associated with estimates of mean huckleberry production/site obtained with Method B using 50 and 20 sample plots/sites.

	50 Plots			20 Plots		
Site	mean	SD	V%[1]	mean	SD	V%
AU1	0.6	1.2	200	0.6	1.3	218
BA1	4.2	4.1	98	6.4	4.7	73
DF1	1.8	2.6	144	1.4	1.6	114
HM1	0.3	0.6	200	0.4	0.7	175
HM2	1.2	1.9	158	1.6	2.5	156
HM3	3.1	4.6	148	3.7	5.2	141
HM4	5.8	6.0	103	6.6	7.7	117
HM5	4.4	6.0	136	2.9	4.1	141
MB1	2.9	3.2	110	1.7	2.0	118
TM1	1.7	2.1	124	1.9	1.7	90
TM2	6.8	8.0	118	7.1	6.8	96
TM4	13.5	13.7	102	13.0	13.5	104

[1] Coefficient of variation

Table 7. Coefficient of variation for mean huckleberry production/site estimated by Methods A and B.

Site No.	V% Method A	V% Method B
1AU83	108.3	191.5
1BA83	92.0	98.7
1DF83	87.8	143.5
1HM83	156.0	226.3
2HM83	132.0	159.9
3HM83	118.0	146.6
4HM83	79.7	102.2
5HM83	95.2	137.7
1MB83	93.9	109.3
1TM83	230.7	118.2
2TM83	114.7	117.6
4TM83	64.8	101.4
1BA84	76.2	134.3
4HM84	213.9	165.2
6HM84	108.9	98.2
2SN84	97.0	148.1
4HM85	101.4	158.6
6HM85	55.2	93.6

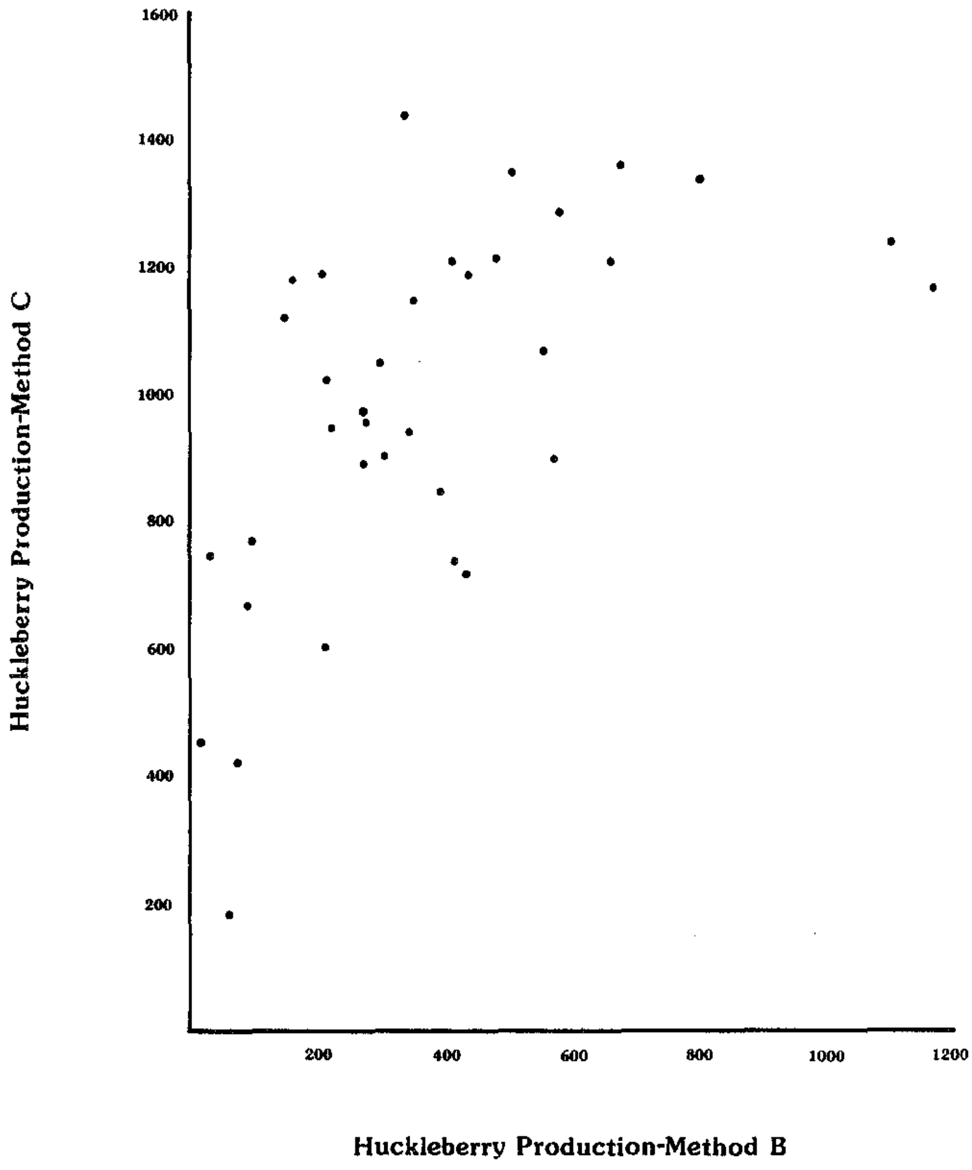


Fig.9. Comparison of huckleberry abundance measured by Methods B and C.

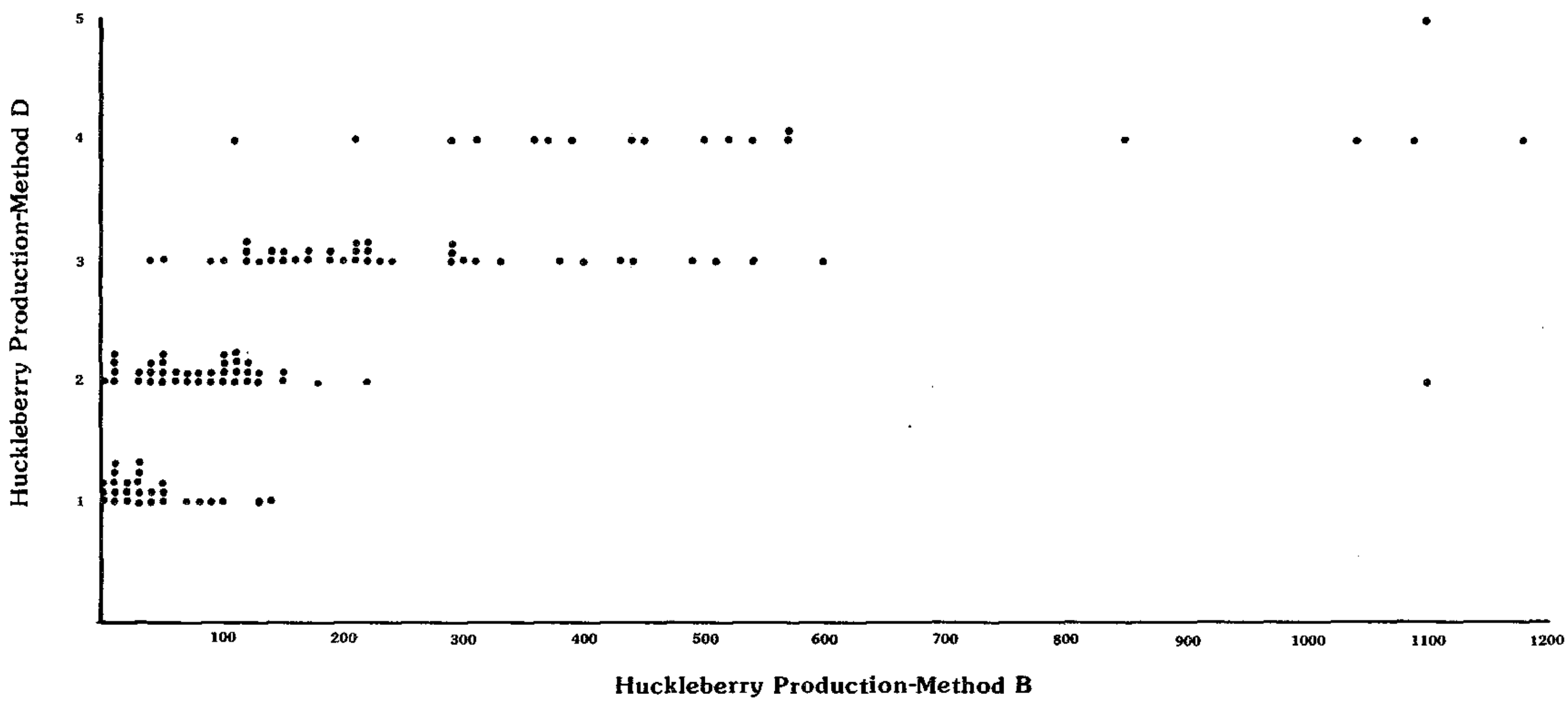


Fig.10. Comparison of huckleberry abundance measured by Methods B and D.

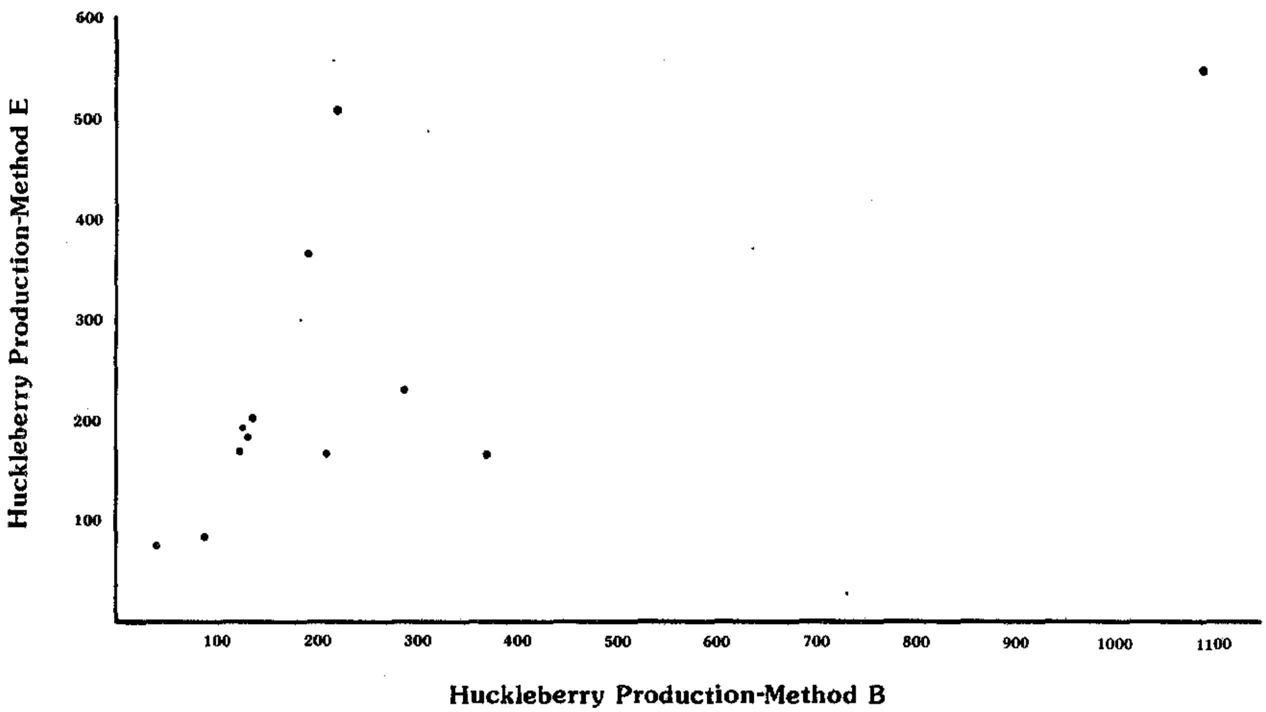


Fig.11. Comparison of huckleberry production measured by Methods B and E.

using marked bushes were less variable than those by Method B (Table 8) but at 50% of the sites, the 2 methods did not yield the same results when tested for annual differences in production (Table 9).

Method E estimates may have been biased because all marked bushes were selected in one year. Since a large proportion of randomly selected bushes may never have been capable of producing berries, all marked bushes selected had at least some huckleberries and/or flowers. This criteria may have prevented berry production on marked bushes from being representative of the site and if, in addition, production on individual bushes was cyclic, choosing plants which were productive in 1984 could cause marked-bush productivity to run counter to general area trends. This problem could be avoided by either selecting bushes over several years or by randomly selecting bushes but increasing the sample size to compensate for the unproductive portions of bushes in the sample. Unfortunately increasing the sample size would substantially increase the sampling time.

Sampling marked bushes presented other problems. Because huckleberry branches are brittle, it was common to break portions of marked bushes when counting berries. The aluminum tags used to identify the plants appeared to attract animals, especially bears, which increased mechanical damage to the marked bushes by feeding and trampling. In 2 years, of the 20 bushes marked at one site, 3 were broken off at the base and 3 died of unknown cause. Because of this attrition, 20 bushes may not be an adequate sample for long term production monitoring.

Annual Variation

Examination of annual variation in huckleberry crops required comparable production estimates for all years. Since Method B was not used in 1982, comparable 1982 estimates were derived from Method A figures by regressing Method B on A using those cases where both methods were employed 1983-85 (r^2=0.94).

Huckleberry production fluctuated dramatically throughout the study area 1982-85 (Fig. 12). Production for all sites was higher in 1982 and lower in 1984 than all other years ($p \leq 0.005$). There was no clear difference in production in 1983 and 1985 ($p=0.429$).

The patterns of site-specific variation in berry crops were remarkably consistent given the differences in site characteristics and the broad geographic area covered by the study. Berry production decreased at 12 of 13 sites between 1982 and 1983 and at 56 of 58 sites between 1983 and 1984 and increased at 52 of 58 sites between 1984 and 1985. The 2 sites which showed modest increases in production between 1983 and 1984 were both in the Many Glacier valley. On July 20, 1983, a localized hail storm damaged the leaves and developing berries of huckleberry plants in the area resulting in a very poor berry crop in 1983. Production

Table 8. Coefficient of variation (%) for mean huckleberry production estimated by Methods B and E.

	1984		1985	
Site	Method B	Method E	Method B	Method E
1DE	223	71	163	78
2DF	192	71	170	102
4HM	165	111	159	110
5HM	111	68	108	107
6HM	98	91	94	56
4TM	114	61	119	73

Table 9. Results of tests to determine if huckleberry production differed between 1984 and 1985 when measured by Methods B and C (a=0.05).

Site	Method B	Method E
1DE	85>84	85>84
2DF	no difference	84>85
4HM	85>84	no difference
5HM	no difference	no difference
6HM	85>84	85>84
4TM	85>84	no difference

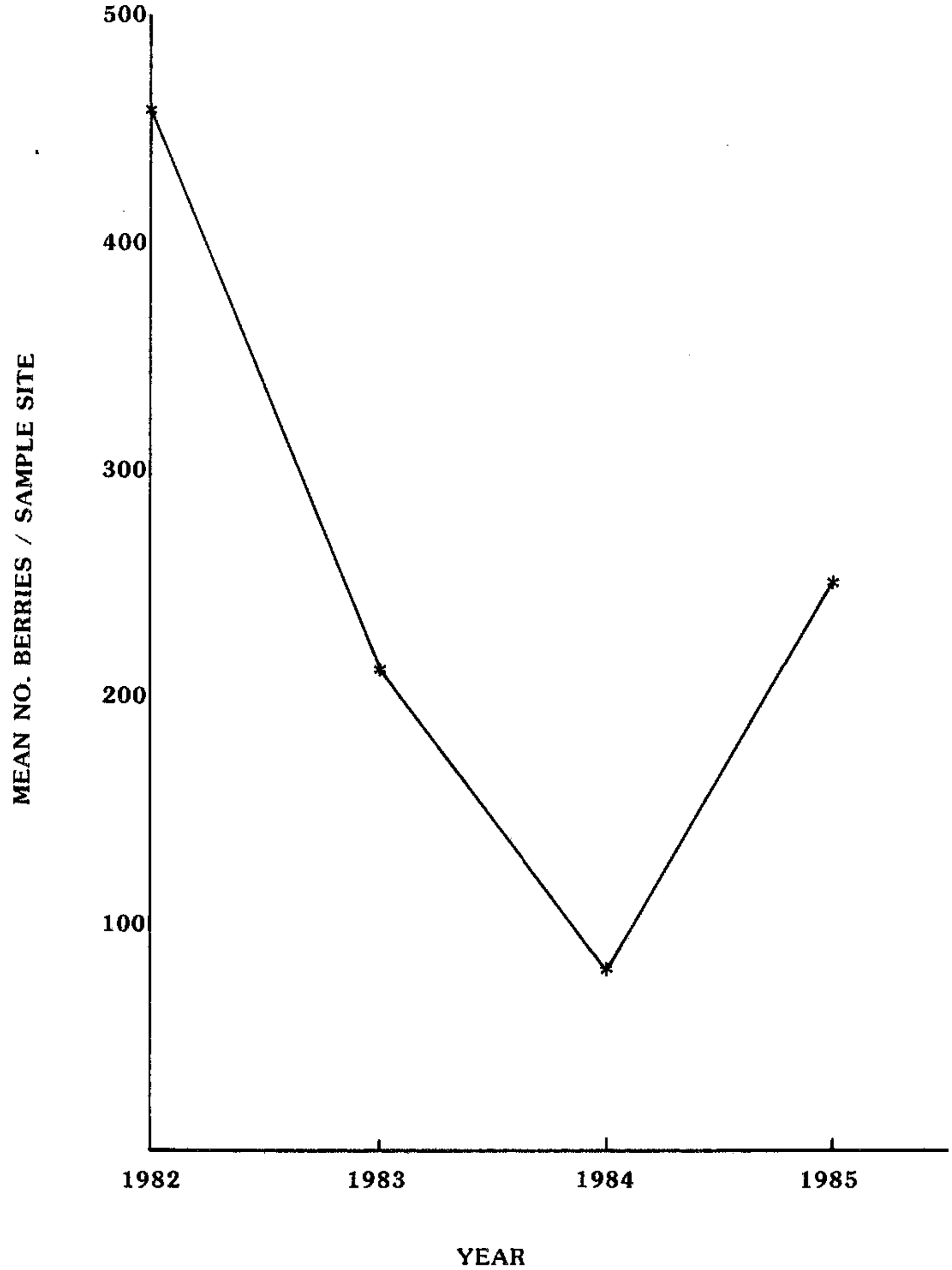


Fig.12. Mean huckleberry production in and around Glacier N.P., 1982-85.

at these 2 sites in 1984 was not high but was slightly better than the hail-damaged crop on 1983. Synchrony of relative berry production throughout the study area suggests large scale weather patterns as the primary controlling influence on huckleberry production under conditions present from 1982-85.

A climatic index was derived which predicted huckleberry production 1982-85 with a high degree of accuracy ($r^2=0.97$) (Fig. 13). The previous year's weather was especially important in determining the following year's crop. Good huckleberry production appeared to be dependent on an unusually warm, dry March; warm, wet May; cool, dry July; and cool, wet August of the previous year and a cool, dry May of the current year. Flower buds form during the summer of the year prior to berry development (Darrow 1942) and unfavorable weather may limit the number of buds produced.

Berry Size

Berry size was a poor predictor of huckleberry production. Berry size was measured at 88 sites 1984-85 and was not dependent upon site productivity ($r^2=0.01$). There was no difference in mean berry size between the poor berry year of 1984 and the moderately productive year of 1985 ($p>0.90$).

Phenology

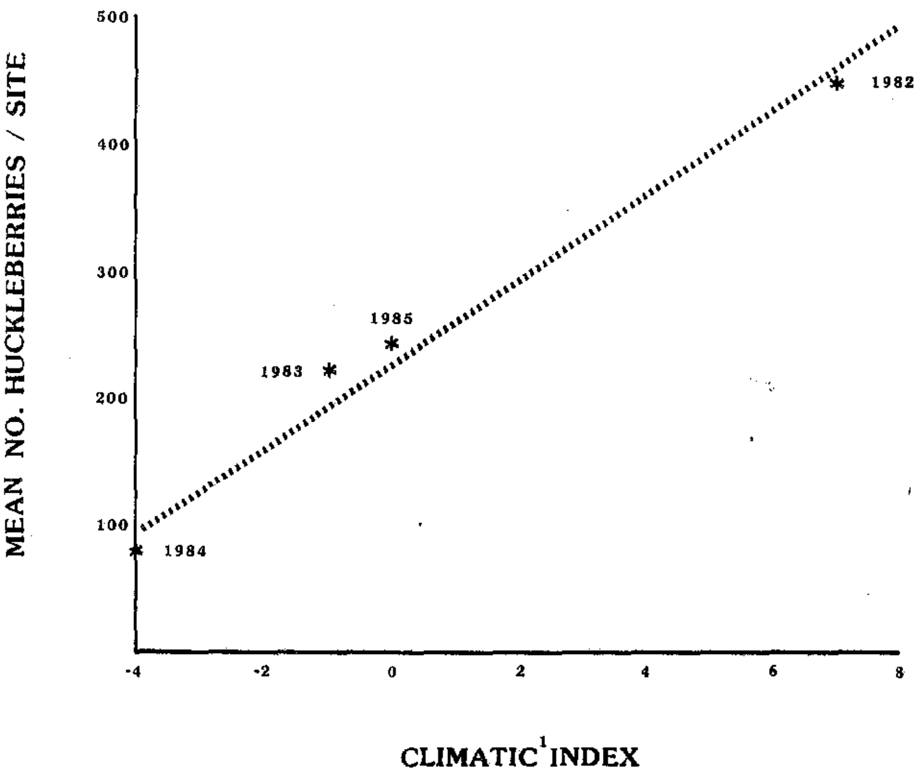
The timing of huckleberry maturation varied between years. Ripening occurred earlier than the previous year in all years of the study (Fig. 14) and those differences were independent of elevation or aspect of the site.

Flower Survival

In 4 of the 6 sites where flower survival to ripe berry stage was studied, survival was higher in 1985 than in 1984 (Table 10) but the overall difference was not significant ($0.50>p>0.20$). However, in 1984, the early counts were conducted at a later phenological stage and the plants may have undergone considerable flower or green berry loss before examination. Weather in April and May was unusually wet and cool in 1984, and dry and warm in 1985. Cool, wet spring weather may inhibit pollination or cause mechanical damage to flowers and green berries.

Sugar Content

Refractometer readings of huckleberry sugar levels corresponded loosely with the amount of TNC ($r^2=0.62$). Mean sugar levels of berries were higher in 1985 than 1984 ($p<0.001$). Sugar content of berries at sites sampled when at least 90% of the berries were ripe did not vary consistently with elevation ($r^2=0.34$) or with mean berry size/site ($r^2=0.31$). However, in the hot, dry summer of 1984 at both sites where the sugar content of large and small berries were tested separately, small berries were sweeter than large berries.



1 West Glacier weather station data used in climatic index.

Fig.13. Relationship of climatic index to huckleberry production, Glacier N.P., 1982-85.

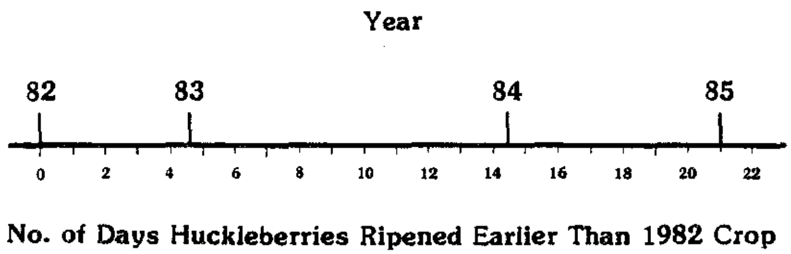


Fig.14. Annual variation in the timing of huckleberry maturation in Glacier N.P., 1982-85.

Table 10. Percent survival from flower to ripe berry stage of huckleberries at 6 sites in Glacier National Park, 1984-85.

	4HM	5HM	6HM	2DF	4TM	1DE	Mean
1984	23(9)[1]	19(1)	55(74)	30(87)	21(44)	29(84)	30
1985	37(10)	48(0)	40(0)	10(0)	31(0)	47(0)	36

[1] Percent of early count which consisted of berries in which the ovary had begun to enlarge.

At individual sites, sugar content declined after increasing during berry maturation. The elevation of sites where multiple berry samples were taken ranged from 5000-6200 ft. and 75-93% of the berries were ripe when first sampled. Sugar levels appeared to peak at the end of August and then declined at most sites (Fig. 15). This may have reflected a rise in sugar content as berries became fully ripe and then a decline as carbohydrates in the berries were used in seed formation (N. Stark, pers. comm.).

Mountain Ash

Monitoring sites for mountain ash berry production were concentrated at mid-elevations but represented all exposures (Table 11). There was no annual difference in the mean number of berries/clump 1984-85 when all sites were combined ($p>0.90$) despite many large differences (7-89%) between years at individual sites (Table 12). Total berry production ($0.05>p>0.02$) and the number of berry clumps ($0.02>p>0.01$) were higher in 1984 than 1985. Thus, the total number of clumps appeared to be an adequate measure of berry production when averaged over a number of sites. Weight was a better predictor of the number of berries ($r^2=0.81$) than the number of clumps ($r^2=0.67$). There was no marked annual difference in mean berry size 1984-85 ($0.40>p>0.20$) although again large differences (3-45%) existed between years at individual sites.

Bear Activity

Preliminary analysis of bear management action and bear activity records did not reveal patterns that appeared to be related to annual huckleberry production (Table 13). Of particular interest was the similarity in the level of bear problems in the fall and spring following high (1982) and low (1984) huckleberry crops.

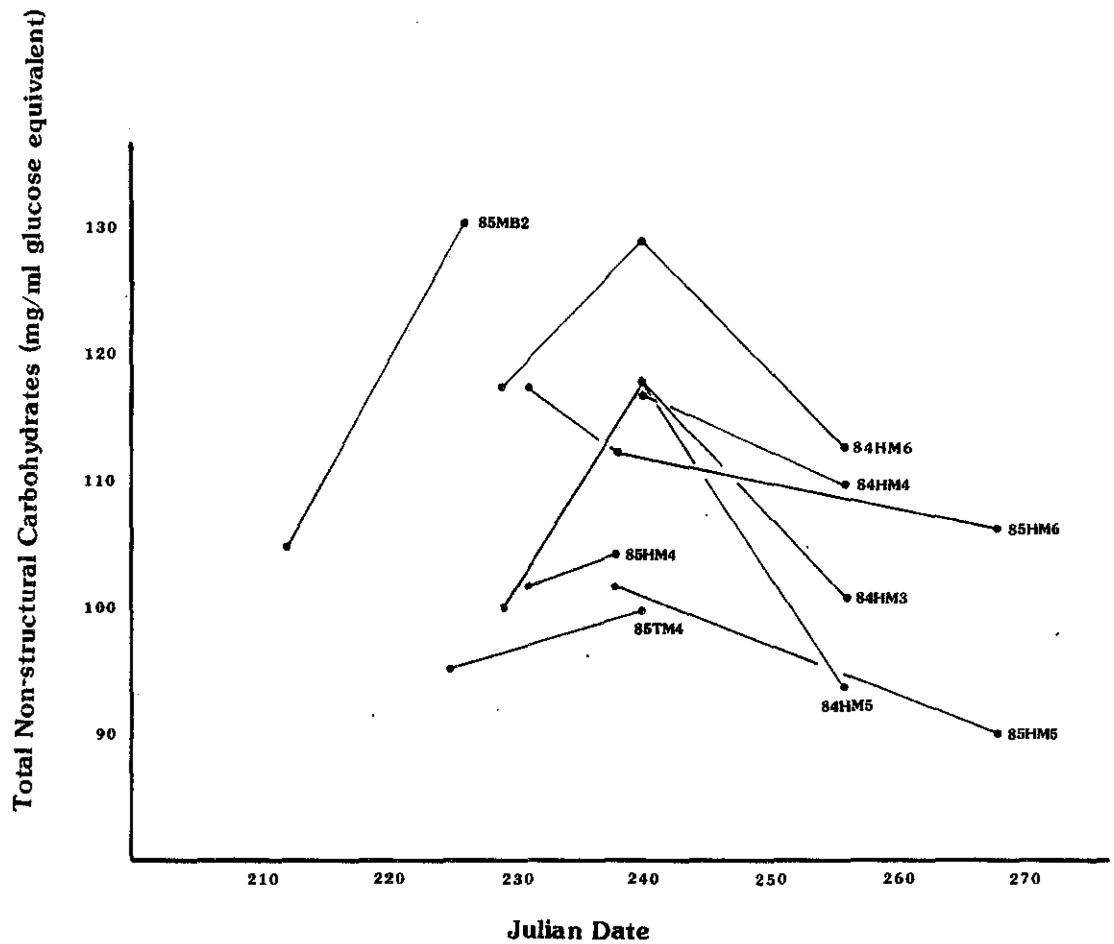


Fig.15. Seasonal fluctuations in huckleberry sugar content at 6 sites in Glacier N.P., 1984 1985.

Table 11. Aspect and elevation of mountain ash monitoring sites in and around Glacier National Park.

	N (315-44°)	E (45-134°)	S (135-224°)	W (225-314°)	Flat	Total
Elevation (ft)						
3500-4499	0	1	0	1	1	3
4500-5499	4	3	1	1	1	10
5500-6499	0	0	1	2	0	3
Total	4	4	2	4	2	16

Table 12. Mountain ash berry production at 15 sites in and around Glacier National Park, 1984-85.

	Total No. Berries		Total No. Berry Clumps		Mean No. Berries/Clump	
Site	1984	1985	1984	1985	1984	1985
1	7865	1232	116	37	67.8	33.3
2	12018	4623	166	99	72.4	46.7
3	6651	932	90	36	73.9	25.9
4	6680	1412	80	13	83.5	108.6
5	3938	105	58	2	67.9	52.5
6	3968	1134	91	16	43.6	70.9
7	2020	2718	42	30	48.1	90.6
8	4278	76	112	5	38.2	15.2
9	2926	141	70	4	41.8	35.3
10	2408	3175	52	42	46.3	75.6
11	77	4481	10	66	7.7	67.9
12	2335	1767	52	31	44.9	57.0
13	6384	3297	57	42	112.0	78.5
14	3380	2371	73	55	46.3	43.1
15	9345	12675	113	169	82.7	75.0
Total	74273	40139	1182	647	62.8	62.0

Table 13. Grizzly and black bear activity in Glacier National Park, 1982-85.

BEAR and BEAR MANAGEMENT ACTIVITY	1982			1983			1984			1985		
	Early[1]	Mid[2]	Late[3]	Early	Mid	Late	Early	Mid	Late	Early	Mid	Late
Bear Relocated or Destroyed	3	0	0	4	0	0	6	1	2	5	0	2
Bear Obtained Human Food/Garbage	1	0	0	1	0	0	5	1	0	1	0	2
Instances of Property Damage	1	0	0	0	2	0	2	0	1	3	0	0
Bear Sighted in Campground/ Picnic Area	26	8	5	21	10	3	24	7	7	22	4	6
Campground & Trail Closures	18	5	3	20	10	6	18	9	5	17	5	7
Injury to Human	1	0	0	2	0	0	2	0	1	0	0	0
Bluff Charge	4	3	0	1	2	0	3	0	1	2	1	0

1 Early = April-July
2 Mid = August
3 Late = September-November

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Appendix A. Glacier National Park bear scat content analysis 1967-71 and 1982-85 (N = 1514).

Species	%Frequency	%Volume	Parts consumed
TREES			
Abies spp.	0.07	0.00	needle, seed
Picea spp.	0.07	0.00	needle, seed
Pinus albicauli	0.07	0.02	needle
Pinus contorta	0.07	0.00	seed
Pinus monticola	0.07	0.00	seed
Pinus spp.	0.46	0.00	needle, seed
Populus tremuloides	0.13	0.00	leaf, flower, stem
Populus trichocarpa	0.07	0.00	leaf, stem
Pyrus spp. (apple)	0.26	0.25	fruit, leaf, stem
Thuja plicata	0.07	0.00	needle
Subtotal	1.39	0.27	
SHRUBS			
Amelanchier alnifolia	6.67	3.76	berry, leaf,
Arctostaphylos uva-ursi	0.99	0.55	berry, leaf,
Berberis repens	0.53	0.01	leaf, stem
Betulaceae	0.92	0.00	flower
Cornus stolonifera	1.12	0.54	berry, leaf,
Crataegus douglasii	5.95	4.79	berry, leaf, stem
Juniperus communis	0.13	0.00	needle, stem
Lonicera spp.	0.07	0.01	berry
Oplopanax horridum	0.99	0.35	berry, leaf,
Pachistima spp.	0.07	0.00	leaf, stem
Prunus virginana	0.20	0.05	fruit, leaf,
Rhamnus alnifolia	0.20	0.08	berry, leaf, stem
Ribes inerme	0.07	0.01	berry
Ribes lacustre	0.07	0.03	berry
Ribes spp.	0.53	0.23	berry, leaf, stem
Rosa spp.	0.86	0.18	fruit, leaf, stem
Salix spp.	0.26	0.21	flower, leaf, stem
Shepherdia canadensis	0.79	0.32	berry, leaf, stem
Sorbus scopulina/ sitchensis	3.44	2.07	berry, leaf, stem
Symphoricarpos spp.	0.20	0.00	berry
Vaccinium globulare	12.75	9.63	berry, leaf, stem, root
Vaccinium membranaceum	0.46	0.20	berry, leaf, stem, root
Vaccinium spp.	8.26	4.79	berry, leaf, stem
Viburnum edule	0.27	0.23	fruit, leaf, stem
Unidentified shrub	1.39	0.17	berry, leaf, stem, root
Subtotal	39.04	28.20	

Species	%Frequency	%Volume	Parts consumed
Osmorhiza spp.	0.33	0.31	leaf, stem
Pastinaca sativa	0.07	0.00	seed
Pedicularis spp	0.26	0.01	leaf, stem
Portulaceae	0.07	0.00	leaf, stem
Senecio spp.	0.07	0.03	leaf, stem
Smilacina spp.	0.07	0.00	fruit, seed
Taraxacum officinale	0.99	0.58	leaf, stem, seed, flower
Taraxacum spp.	1.59	0.61	leaf, stem, seed, flower
Tragopogon dubius	0.07	0.05	leaf, stem, seed, flower
Trifolium spp.	1.78	0.52	leaf, stem, seed
Urtica dioica	0.07	0.00	leaf, stem
Vicia americana	0.07	0.03	leaf, stem
Xerophyllum tenax	0.07	0.05	leaf, stem
Unidentified forb	9.11	3.50	leaf, stem, flower, seed, root
Subtotal	48.08	33.11	
MAMMALS			
Alces alces	0.26	0.08	meat, hair, bone
Cervidae	0.79	0.53	meat, hair, bone
Cervus canadensis	2.31	1.27	meat, hair, bone
Lagomorpha	0.07	0.03	meat, hair, teeth
Large mammal	1.32	0.15	meat, hair, bone
Marmota	0.40	0.19	meat, hair, bone, teeth, claw
Microtinae	0.13	0.01	meat, hair, bone, teeth, claw
Microtus spp.	0.46	0.16	meat, hair, bone, teeth, claw
Odocoileus spp.	3.24	1.61	meat, hair, bone, hoof
Oreamnos americanus	0.59	0.22	meat, hair, bone
Small mammal	1.52	0.09	meat, hair, bone
Spermophilus citellus	1.32	0.27	meat, hair, bone, teeth, claw
Tamiasciuous hudsonicus	0.20	0.06	meat, hair, bone, teeth, claw
Ursus americanus	0.07	0.03	meat, hair, bone
Ursus arctos	0.33	0.12	meat, hair, bone
Ursus spp.	0.13	0.00	meat, hair
Unidentified meat	0.26	0.02	meat, bone
Subtotal	13.14	4.83	

Species	%Frequency	%Volume	Parts consumed
INSECTS			
Acarina spp. (ticks)	0.13	0.00	adults
Coleoptera (beetles)	2.77	0.01	adults
Formicidae (ants)	10.11	1.13	adults, larva
Hemiptera (bugs)	0.07	0.00	adults
Isoptera (termites)	0.07	0.00	adults
Lepidoptera (moths)	0.99	0.58	adults
Unidentified insect	0.40	0.00	larva
Subtotal	13.47	1.72	
FISH			
Unidentified fish	0.33	0.17	meat, bone
BIRD			
Tetraonidae (grouse)	0.13	0.03	meat, feather, claw
Unidentified bird	0.40	0.02	meat, feather
Subtotal	0.53	0.05	
GARBAGE	0.40	0.03	
Debris (rock, dirt, forest litter)	15.65	3.69	