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An Evaluation of Radioactive Feces-Tagging as a Technique for Determining Population Densities of the Black Bear (*Ursus americanus*) in the Great Smoky Mountains National Park

Larry Calvin Marcum
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Larry Calvin Marcum entitled "An Evaluation of Radioactive Feces-Tagging as a Technique for Determining Population Densities of the Black Bear (*Ursus americanus*) in the 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:

R. L. Murphree, Dan J. Nelson, James L. Byford

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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Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

AN EVALUATION OF RADIOACTIVE FECES-TAGGING AS A TECHNIQUE FOR DETERMINING POPULATION DENSITIES OF THE BLACK BEAR (*URSUS AMERICANUS*) IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

A Thesis

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Degree

The University of Tennessee

Larry Calvin Marcum

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Laboratory. Significant financial support was provided by McIntire-Stennis funds and the Great Smoky Mountains Natural History Association.

ABSTRACT

This study was conducted on the Tennessee side of the Great Smoky Mountains National Park west of highway U.S. 441. The major objectives were to evaluate selected radioisotopes as possible scat (feces) tags and to determine estimates of the black bear population using data collected by the technique of marking scats with a radioactive tag and to evaluate the reliability of the population estimates.

In June of 1972 two confined bears were injected with four selected radioisotopes; ^{65}Zn and ^{54}Mn proved suitable as tags but ^{109}Cd and ^{144}Ce were unsatisfactory.

From June through September of 1972, 30 bears were ear tagged of which 28 were injected with radioisotopes; 189 scats were collected from the study area, 35 of which were radioactively tagged. Using the Schnabel formula, the population was estimated to be 102 animals. For the same period 259 observations of black bears were made with 130 of these animals being tagged; a population estimate using these data was 42 animals.

From June through September of 1973, 35 bears were ear tagged of which 32 were injected with radioactive materials; 240 scats were collected with 41 being radioactively tagged. Bear observations for 1973 totaled 117 with 48 of the animals being ear tagged. Population estimates using the two sets of data were 132 and 54 animals, respectively.

The density of black bears for the area censused was estimated to be 1 bear per 1.06 square miles (680 acres). Two smaller areas within

the study area had estimated densities of 1 bear per 0.42 square miles (275) (40 bears on 17 square miles) and 1 bear per 0.54 square miles (342) (28 bears on 15 square miles).

The estimates based on data from radioactively tagged scats were believed to be more accurate than those from mark-observation data due to a removal of biases caused by unequal vulnerability of individual bears, loss of tags, and failure to recognize tags. The estimate of 1973 using radioactively tagged scats was believed to be the most accurate due to a more random distribution of marked animals within the study area. Other possible applications of the technique include population mixing, dispersal, and mortality.

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CHAPTER I

INTRODUCTION

The goals of population estimation should be two-fold: to obtain the best possible estimates commensurate with the objective of the study and the time, resources, and personnel available and to evaluate the accuracy of the estimate (Overton 1969). The techniques for estimating the density of large carnivore populations are often as diverse as the populations and habitats themselves. For example, Sandfort and Tully (1971) sent questionnaires to Conservation Officers in Colorado in an effort to determine the number of mountain lions (Felis concolor) in that state. Mech (1970) used aerial censusing techniques for determining the wolf (Canis lupus) density on Isle Royal, and Lord (1961) used an age-ratio-reduction method and the Lincoln Index to estimate gray fox (Urocyon cinereoargenteus) populations in Florida.

In reference to bear species, Klein (1959) censused brown bears (Ursus arctos) along salmon streams in Alaska by using a track differentiation technique. Several researchers have used variations of the direct count method for obtaining numbers of grizzly bears (Ursus arctos) (Hornocker 1962, Troyer and Hensel 1964). Mark-recapture methods have often been used to determine population numbers in conjunction with direct observations (Hornocker 1962).

Researchers have attempted to census black bears (Ursus americanus) using a variety of methods. Spencer (1955) attempted to make a statewide census of the black bear in Maine using tracks and other bear

signs observed on cruise lines. Barnes and Bray (1967) made direct counts of black bears along roadsides and backcountry areas in Yellowstone National Park. By obtaining annual harvest data on black bears several state agencies have arrived at statewide population estimates by assuming that the total harvest is a known percentage of the population. Carpenter (1973) assumed that the annual kill in Virginia was 20 percent of the population. Spencer (1955) arrived at an annual harvest percentage based on the total harvest and the percent of young animals in the harvest. Erickson and Petrides (1964) used the ratio of marked to unmarked bears in the harvest of Michigan black bears to determine estimates using the Lincoln Index.

In working with large carnivores such as the black bear, attaining reliable data concerning population density is often hindered by such factors as: 1) generally sparse populations; 2) large home ranges and movement patterns of the animals; 3) characteristic shy and secretive nature of the animals; 4) habitat often characterized by rough, almost impenetrable terrain; 5) inaccessibility by the researcher to large areas; and 6) difficulty of capture-observation or recapture-reobservation. For these reasons censusing requires a great expenditure of time and resources.

Techniques employed in previous studies on population estimation of black bears as well as other carnivores often have limited applicability or have yielded results of questionable accuracy. Hornocker (1962) believed that direct counts of bears were reliable in areas where there were adequate open areas for observations to be made. However, in the Eastern United States where the vegetation is dense and

often continuous, the above technique is not feasible. The roadside census technique often is biased due to human traffic and activities (Hayne 1949). Removal techniques are becoming less applicable due to the fact that many species of carnivores are rare and have received protected status in many states (Faulkner 1971). Multiple recapture techniques (Eberhardt 1969, Jolly 1963) have been used extensively in estimating populations of smaller animals such as rodents and rabbits (Brady 1973), but their applicability to species such as the black bear is limited due to the factors mentioned above. Kemp (1972) used a multiple recapture method for estimating black bear populations in Canada, although the size of the study area was quite small which enabled him to engage in a very intensive trapping program.

The Lincoln Index and its modifications (Schnabel 1938, Schumacher and Eschmeyer 1944) have been used extensively to census populations of terrestrial as well as aquatic animals. Providing that certain assumptions about the population and the technique are met, the Lincoln Index provides reliable results. Hornocker (1962) and Troyer and Hensel (1964) were able to correlate estimates obtained by the Schnabel method with direct counts of grizzly bears in the Northwest. However, too often the results are not reliable because the sample is too small and the data are biased due to non-random sampling, loss of marks, and unequal vulnerability of the individuals in the population.

Miller (1957), one of the earlier researchers to use feces tagged with radioactive materials, studied vole movements and suggested the possibility of using radioactive feces tags as a means of determining population densities. Nellis, Jenkins, and Marshall (1967) conducted

preliminary research with radioisotopes which might be suitable as scat tags for carnivores. However, there is no indication in the literature that the technique has been used on any animal populations. Pelton (1972) stated that black bears seem to utilize trails in daily movements from one place to another, and tend to defecate on these trails, and suggested the potential use of radioactive scat tags as a technique to estimate their population density.

The present study is an attempt to incorporate the principles of the previous paragraph into a useful technique for estimating the density of the black bear population in the Great Smoky Mountains National Park. It would seem, with the precarious status of many carnivores at present, that future population estimates will not be able to rely on harvest or removal methods and that reliable population status figures will become increasingly critical. With the present inadequacies in the estimation techniques and future situations which will probably magnify these problems, new techniques for censusing populations of wild carnivores is imperative.

CHAPTER II

DESCRIPTION OF STUDY AREA

A. GEOGRAPHY

The Great Smoky Mountains National Park (GSMNP or Park) is located along the common boundary of Tennessee and North Carolina. The Park is composed of parts of Blount, Sevier, and Cocke Counties in Tennessee and Haywood and Swain Counties in North Carolina. The Park boundary encompasses slightly more than 500,000 acres (800 square miles) of mountainous terrain. Major highways include one transmountain road (U.S. 441) which bisects the Park from Gatlinburg, Tennessee, to Cherokee, North Carolina, with Tennessee State Route 73 running parallel to the northern boundary just inside the Park from Townsend, Tennessee, to Gatlinburg, and another road connecting Townsend with the Cades Cove area of the Park (Figure 1).

The study was restricted to the Tennessee portion of the Park located west of U.S. 441 encompassing an area of approximately 125,000 acres. Approximately 40 miles of major highways, 55 miles of unimproved and jeep roads, 250 miles of maintained foot trails, and more than 150 miles of unmaintained and abandoned trails exist in the study area. Most of the area is accessible only by foot trails, especially at higher elevations. More than half of the study area is above 3,000 feet in elevation; less than 10 miles of roads are above this elevation.

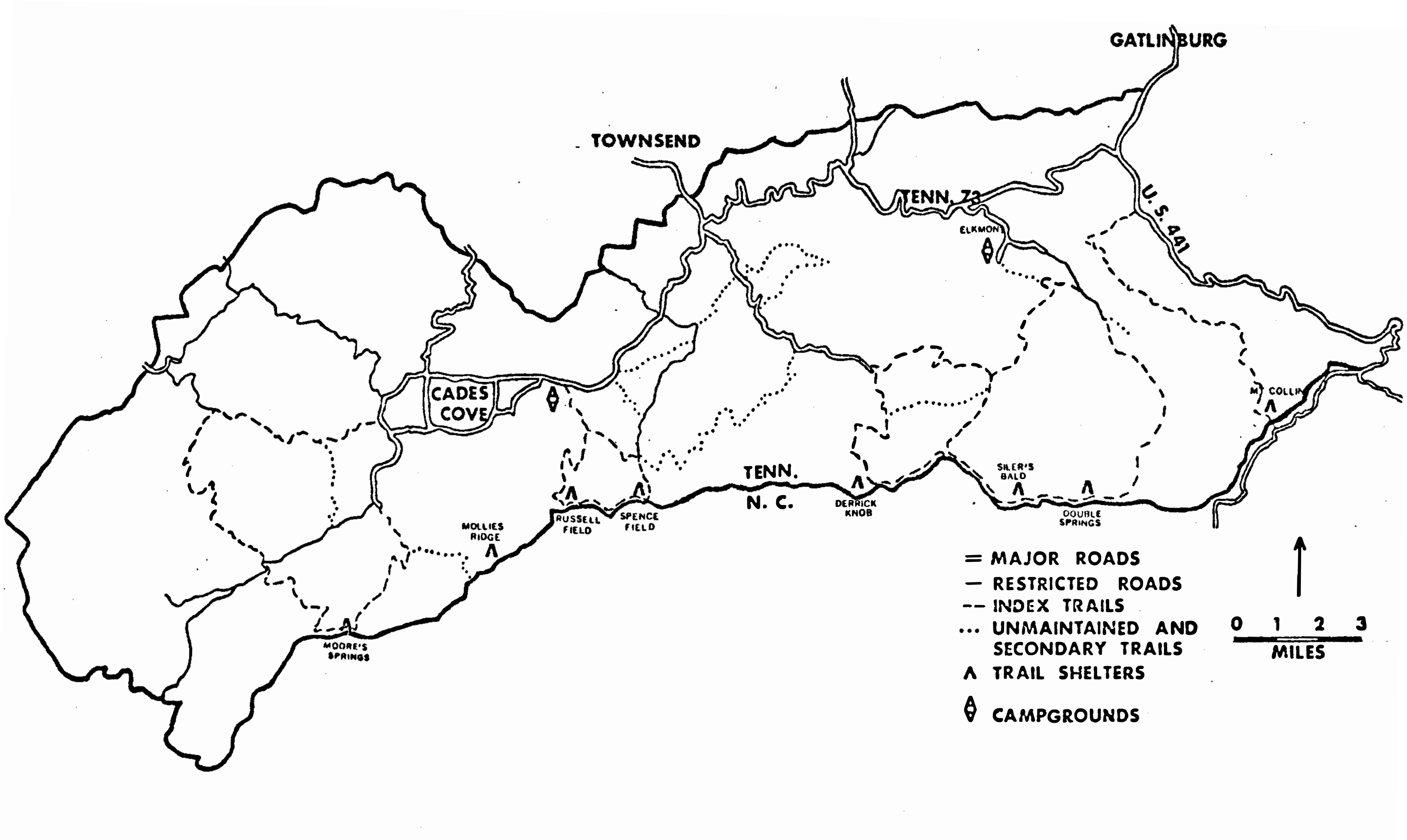

Figure 1. Map of the study area within the Tennessee portion of the Great Smoky Mountains National Park.

B. TOPOGRAPHY

The Great Smoky Mountains National Park is part of the Unaka Mountain Range section of the Blue Ridge Province, located in the southern division of the Appalachian Highlands. The topography of the area is very rugged and is characterized by high mountains and narrow ridges separated by steep-sloped, V-shaped valleys. Most of the valleys are very narrow with the exception of the cove areas which are scattered throughout the area. The majority of the land areas is occupied by the slopes. Elevations range from 888 feet above sea level where Abrams Creek leaves the Park to 6,643 feet at Clingman's Dome. The study area is drained by two major tributaries, the east, middle, and west prongs of the Little River in the East and Abrams Creek in the West.

C. CLIMATE

Due to the high relief, the climate of the Park is quite variable. Generally, the area is characterized by cool temperatures in relation to the surrounding regions and by high amounts of precipitation. Temperatures average some 10 to 15 degrees cooler at high elevations than in the lower valleys. Mean temperatures decrease at an average rate of 2.23 degrees Farenheit for every 1,000 feet gain in elevation. Average temperatures for low lying areas range from 39.3 degrees in January to 73.7 degrees in July. Precipitation averages from 50 to 55 inches annually in the valleys to 85 inches or more at the highest elevations. The Clingman's Dome-Newfound Gap area (5,000-6,600 feet) has the highest annual mean precipitation of any area in the Eastern

United States. Precipitation and temperature data for Gatlinburg and Newfound Gap are given in Tables 1 and 2.

D. VEGETATION

The vegetation of the Park is quite variable. There are more than 1,300 species of flowering plants, 350 species of mosses and liverworts, 230 lichens, and more than 2,000 kinds of fungi (Stupka 1960). Classification of the vegetation patterns in the Park has been attempted by many taxonomists with the works of Shanks (1954), Cain (1935), and Whitaker (1956) being the noteworthy. Shanks lumped the numerous specific forest vegetation types into six broad physiognomic types which are relatively distinct in species composition, especially in the minor vegetation, and which occupy obviously different sites.

Approximately 85 percent of the study area is comprised of the Eastern Deciduous Forest and includes six vegetation types: (1) cove hardwood forest association (approximately 15 percent), 2) hemlock forest association (approximately 5 percent), 3) northern hardwood forest association (approximately 25 percent), 4) closed oak forest association (approximately 25 percent), 5) open oak and pine forest association (approximately 20 percent), and 6) spruce-fir forest association (approximately 10 percent). Table 3 lists the general forest associations and their related plant species.

The remaining part of the study area, less than 5 percent, is in agricultural land in the Cades Cove area. The major agricultural practices include grazing of cattle (1,600 head) and horses (50 head) and hay production. Row cropping is excluded in the area.

TABLE 1

MONTHLY AVERAGE TEMPERATURES WITHIN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

	Average Monthly Temperature in °F			
	Gatlinburg (1460 ft.)			Newfound Gap (4950 ft.)
Month	1923-1967 Average	1972	1973	1973[a]
January	39.3	41.2	36.5	30.1
February	41.9	36.2	36.8	28.1
March	47.8	45.7	52.8	43.4
April	56.8	55.6	54.0	42.0
May	64.8	61.5	59.2	51.5
June	72.0	65.6	70.7	61.9
July	73.6	71.1	73.1	63.5
August	73.7	71.8	71.8	62.7
September	68.9	68.4	69.0	57.6
October	57.9	53.9	59.4	53.0
November	46.7	46.1	49.6	43.4
December	40.2	44.0	39.5	31.2

[a]Long term data not available.

Source: National Park Service records.

TABLE 2

MONTHLY PRECIPITATION WITHIN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

	Total Monthly Precipitation in Inches					
	Gatlinburg (1460 ft.)			Newfound Gap (4950 ft.)		
Month	Average	1972	1973	Average	1972	1973
January	4.83	6.53	4.25	8.00	11.40	6.50
February	5.02	4.88	2.43	6.94	7.37	7.40
March	5.58	5.40	9.98	8.04	10.45	14.90
April	4.57	3.28	5.45	6.19	5.00	9.80
May	4.17	6.75	7.55	6.57	8.30	9.30
June	5.16	6.29	6.85	7.32	8.10	7.90
July	6.60	6.21	4.85	10.24	8.30	5.80
August	5.41	4.29	5.51	7.61	5.00	6.96
September	2.98	7.57	4.79	4.54	7.80	5.01
October	3.01	6.17	1.77	6.68	9.60	2.69
November	3.76	3.20	5.44	6.53	8.70	10.70
December	4.10	6.33	4.64	10.59	11.90	13.56
Annual	55.19	67.20	63.51	89.25	101.92	100.52

Source: National Park Service records.

TABLE 3

FOREST ASSOCIATIONS AND THEIR IMPORTANT SPECIES IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Forest Association Type	Important Species
Cove hardwood	Eastern hemlock (Tsuga canadensis) Silverbell (Halesia monticola) Yellow buckeye (Aesculus octandra) Sugar maple (Acer saccharum) Yellow birch (Betula alleghaniensis) Tulip poplar (Liriodendron tulipifera) Beech (Fagus grandifolia) Black cherry (Prunus serotina) Basswood (Tilia heterophylla) Hydrangea (Hydrangea arborescens) Rhododendron (Rhododendron maximum) Dog hobble (Leucothoe editorum) Sweetshrub (Calycanthus floridus) Mountain laurel (Kalmia latifolia)
Hemlock	Eastern hemlock Yellow birch Silverbell Frazier magnolia (Magnolia fraseri) Rhododendron (Rhododendron catawbiense and R. maximum) Mountain laurel Dog hobble
Northern hardwood	Beech Yellow birch Yellow buckeye Sugar maple Mountain maple (Acer spicatum) Hydrangea Witch-hobble (Viburnum alternifolium) Dogwood (Cornus alternifolia)
Closed oak	White oak (Quercus alba) Chestnut oak (Q. prinus) Northern red oak (Q. rubra) Black oak (Q. velutina) Pignut hickory (Carya glabra) Mockernut hickory (C. tomentosa) Sourwood (Oxydendrum arboreum) Black locust (Robinia pseudoacacia) Mountain laurel Catbrier (Smilax rotundifolia)

TABLE 3 (continued)

Forest Association Type	Important Species
Open oak and pine	Scarlet oak (Quercus coccinea) Sassafras (Sassafras albidum) Pitch pine (Pinus rigida) Table mountain pine (P. pungens) Virginia pine (P. virginiana) Mountain laurel High bush blueberry (Vaccinium simulatum) Hairy blueberry (V. hirsutum) Huckleberry (Gaylussacia baccata)
Spruce-fir	Red spruce (Picea rubens) Fraser fir (Abies fraseri)
Heath bald	Mountain laurel Rhododendron (R. catawbienese, R. carolinianum, and R. maximum Pepperbush (Clethra acuminata) Blueberries (Vaccinum species) Huckleberry Lyonia (Lyonia ligustrina) Sand-myrtle (Leiophyllum buxifolium) Minnie-bush (Menziesia pilosa) Witherod (Viburnum cassinoides) Fetter-bush (Pieris floribunda)
Grassy bald	Serviceberry (Amelanchier laevis) Blueberries Mountain oatgrass (Danthonia compressa) Blackberry (Rubus sp.) Pin cherry (Prunus pennsylvanica)

Sources: R. E. Shanks, "Reference list of native plants in the Great Smoky Mountains," and National Park Service, "Resource Management plan--GSMNP."

CHAPTER III

MATERIALS AND METHODS

A. CAPTURE OF BLACK BEARS

Baits

Cured ham scraps were used in the majority of trap sets for black bear and offered many advantages over other baits. Ham scraps were easily obtained on a weekly basis from local restaurants in Townsend, Tennessee. Because the ham was cured, it could be stored without refrigeration for several days before use; it did not become rancid even after used as bait. Previous researchers indicated that rancid or putrid bait becomes unattractive to bears (Erickson 1957). Sardines were used occasionally as bait, especially in snare sets. Cans of sardines were easily carried into the backcountry and appeared to be effective in attracting bears. However, after four or five days the sets had to be rebaited because the sardines became rancid. Fresh animal kills were not used because they were generally not available to the researchers.

In backcountry areas the practice of prebaiting, or "baiting in" of bears before a trap was set was used in an effort to increase trapping efficiency (in terms of man-hours expended per bear captured). Prebaits consisted of four or five cans of opened sardines wrapped in burlap or approximately five pounds of ham scraps tied eight to ten feet off the ground from a tree branch. Prebaits seemed to be more successful when located in the upper reaches of small drainages or at

small gaps along ridges. Once a prebait was disturbed by a bear, a trap was set within a few feet of the site. Using the above technique it was possible to trap over a much greater area.

Traps

Two culvert traps constructed and maintained by the National Park Service were available for use. These traps were similar to those described by Erickson (1957), Stickley (1957), and Barnes and Bray (1967) (Figure 2).

Culvert traps were used exclusively for trapping in campgrounds, picnic areas, and along roadsides and for the transport of nuisance bears from one area to another. Traps were usually set with the treadle end of the trap slightly elevated as suggested by Erickson (1957). Bait was placed inside the trap on the treadle, along the floor of the trap back to the door, and outside the trap on the ground and in the trees and bushes. No particular effort was made to conceal the trap since bears did not seem to hesitate entering an exposed set. In 1973 (records for 1972 were incomplete), 64 trapnights using the culvert trap resulted in the capture of 13 bears.

Due to the presence in the Park of the European wild hog (*Sus scrofa*) and the policy of the National Park Service to control the animal, several hog traps were stationed on the study area. The traps were constructed of 10 gauge chain link fencing welded to 3/4 inch iron pipe framing. The door was constructed of 3/4 inch plywood. The traps were six feet long, three feet wide, and three feet high and were of similar design as those described by Williamson and Pelton (1971).

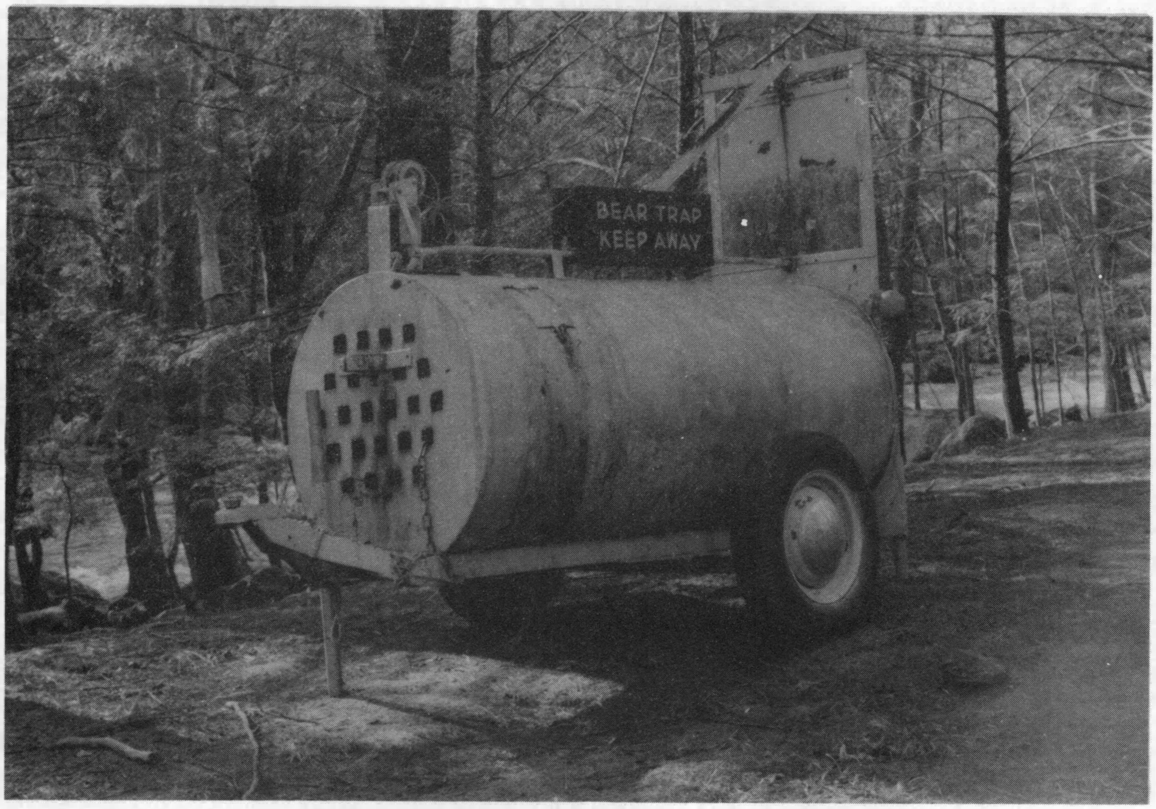

Figure 2. Culvert trap used to capture black bears in the Great Smoky Mountains National Park.

Hog traps were set for black bear in the same manner described by Fox (1972) with bait tied to the trigger mechanism so that the door closed when the bait was pulled. Ten bears were captured in 1972 in hog traps, although six of these animals escaped before being tagged by breaking the fencing material or the plywood door. Due to the high rate of escape, hog traps were not used in 1973.

The Aldrich spring-activated foot snare was used in backcountry situations, especially in 1973, and only occasionally near roadsides and campgrounds. The snare consists of two parts: a 1/4 inch steel spring and a 3/16 inch diameter steel cable. Each snare set was made by placing the spring in the ground with the trigger centered over a small (1 inch) depression in the ground; this procedure insured proper release of the trigger. The cable was then placed as a loop around the depression and the trigger mechanism. The loose end of the cable was then firmly attached to a tree; care was taken to set snares as close to the anchor tree as possible. It was felt that if the snare were anchored close to the tree injury to the animals would be less likely to occur because their movements would be more limited and also, a tree is needed for the construction of the wedge which aids in guiding the bear into the snare set (Figure 3).

Each wedge was constructed of two to six inch diameter logs. A wedge was necessary to insure that the bear would enter the set from the front side. Bait was placed in the rear of the wedge just back of the steel spring (Figure 3). Care was taken to insure that the wedge was stable and that there were no holes through which the bear could reach the bait without entering the set. Small sticks, approximately

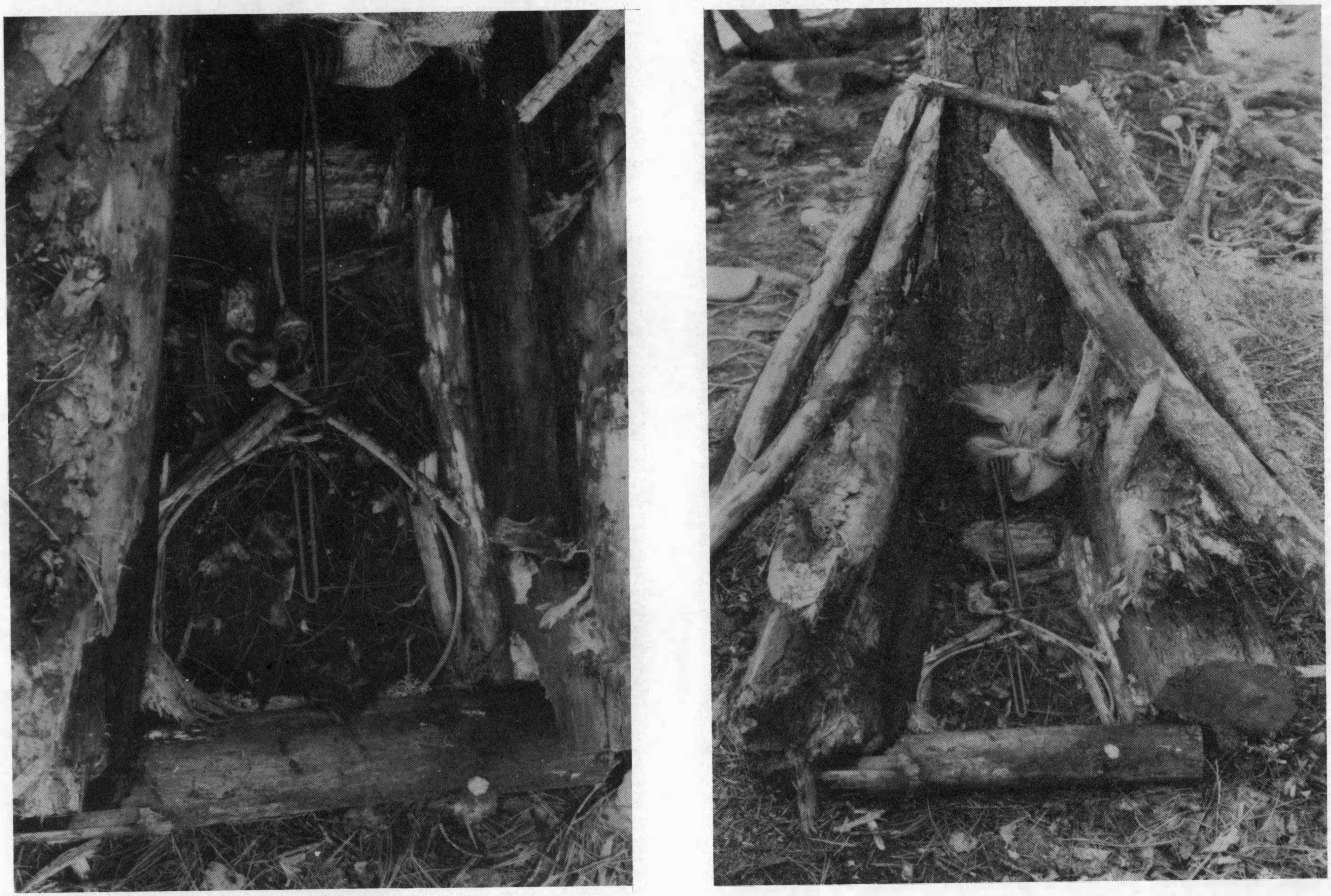

Figure 3. Snare set used to capture black bears in the Great Smoky Mountains National Park.

one inch in diameter were placed around the cable loop with a two to three inch diameter log being placed in front of the loop. The above was done in an effort to encourage the bear to step on the trigger but not on the cable. In addition, a small stick was placed under the loop at the front of the set to insure that the cable would tighten around the bear's foot above the pad. From one-half to one hour was required to build a wedge and set a snare, depending upon the amount of construction material available in the immediate area. In 1973, 135 trapnights resulted in the capture of 29 bears.

In 1972, four of the springs of the snares were modified so that the bear had to pull up rather than push down on the trigger to activate the spring. Bait was tied to the trigger mechanism. Using the modified snare, four bears were captured in 1972 in a total of eight trapnights. However, in 1973, after eight unsuccessful attempts to capture bears, the modified snares were abandoned. Three springs were lost when bears carried them away from the snare site. Snare sets, as with other trap sets, were checked on a daily basis in an effort to minimize injuries to the animals.

Projectile Syringe Gun

In certain instances where bears were accustomed to the presence of humans, it was convenient to capture animals using an immobilizing drug administered by means of a projectile syringe and gun. One, two, three, or five cc capacity, rapid-injection syringes fired from a powder-charged Cap-Chur gun were used to deliver the drug. Needle length ranged from 3/8 to 1-1/8 inches depending upon the size of the bear. Equipment was obtained from Palmer Chemical and Equipment

Company of Douglasville, Georgia. The gun had an effective range of 20 to 75 yards depending upon the size of powder charge used. Caution was exercised to prevent using high charges at close range. Most bears were shot from a distance of less than 30 yards. After the bears were immobilized, they were either tagged at that time or, in the case of nuisance bears, placed in a culvert trap, transported to another area, and then tagged. The Cap-Chur gun was very effective at roadsides, shelters, and campgrounds where bears were accustomed to feeding around people. In 1972, 23 of 27 bears were successfully immobilized by this method. No bears were immobilized in 1973 using this method since very few captures were made in these areas where bears were accustomed to people.

Immobilization

Bears were immobilized using either Sernylan (phencyclidine hydrochloride) or M-99 (etorphine). The drugs were delivered using a powder-charged syringe rifle (for free-roaming animals) or by a CO_2 powered syringe pistol (for trapped animals). The most effective dosages for Sernylan ranged from 0.8 to 1.0 mg per pound of animal, while the most effective dosages for M-99 ranged from 0.45 to 1.0 mg per 100 pounds of animal weight (Table 4). Immobilization time was similar for both drugs, ranging from 4.5 to 9.5 minutes in most cases with an extreme range of 1.0 to 30 minutes. Using the dosages given, most of the animals were completely immobilized while a few were able to move to a limited degree. Overdosing by as much as twice the desired dosage did not seem to drastically affect the animals although with M-99 respiration rate decreased to as low as one breath per minute. However,

TABLE 4

DOSAGES, IMMOBILIZING TIME, AND RECOVERY TIME OF ETORPHINE AND SERNYLAN ON BLACK BEARS DURING 1969-1973 IN THE SMOKY MOUNTAINS OF TENNESSEE AND NORTH CAROLINA

	Drug					
	Etorphine			Sernylan		
Number of bears	Cubs and Yearlings (10)	Adult Females (8)	Adult Males (20)	Cubs and Yearlings (4)	Adult Females (2)	Adult Males (7)
Dosages Range (mg/lb)	.016 (.008- .030)	.011 (.009- .05)	.010 (.006- .031)	1.6 (.77- 3.00)	1.37 (1.33- 1.41)	0.85 (.40- 1.31)
Immobilizing time Range (minutes after initial injection)	4.4 (2.5- 6.0)	9.6 (3.0- 30.0)	9.9 (3.5- 30.5)	6.3 (1.0- 13)	7.8 (5.0- 10.5)	9.7 (8.0- 13)
Recovery time[a] Range (minutes)	9.3 (6.0- 15)	14.7 (8.0- 30)	23.7 (8.0- 105)	104.8 (97- 230)	303.5 (180- 427)	221.3 (110- 367)

[a]After injection of antagonist (for Etorphine only).

Source: Beeman, Pelton, and Marcum (1974).

overdosing greatly increased the recovery time, especially with Sernylan. Both drugs worked well and produced good results with little apparent side effect to the animals. M-99 showed a slight advantage due to the fact that an antagonistic drug (M-50-50) could be used to effect a faster recovery after the tagging operation was over. A more complete account of the use of these drugs was reported by Beeman, Pelton, and Marcum (1974).

Ear Tagging

After immobilization, each bear was examined closely, several basic skull and body measurements were taken, and the animal was weighed using portable spring scales and a hoist (the weights of 12 backcountry bears were estimated). A 1-1/2 inch plastic, color coded, numbered tag was placed in each ear for future identification. Tag colors included red, blue, white, and yellow. (Green and pink tags were used before 1972 by other researchers, but these colors were often confused with white and blue tags at night.) A number was tatooed on the smooth inner surface of the lower lip for further identification in the event that the ear tags were lost. The lower right first premolar was extracted and later sectioned for aging purposes. External examinations were made for parasites and injuries as well as examination for dental malformations and tooth wear. Radio transmitters were placed on selected individuals as part of another study on bear movements and activities.

B. RADIOISOTOPE SELECTION AND INJECTION

In the spring of 1972 radioisotopes were selected for use in the study based on the following criteria: 1) the isotope had to emit gamma rays in the decay process since gamma rays are less damaging to biological tissue and are easily detectable using scintillation analysis, 2) the isotope had to have a biological half-life long enough to allow detection of the radioisotopes in the scat material through the time of the study (but not so long that the excretion rate would be too slow and render detection in the scats difficult or to make the animal radioactive for an undue length of time after completion of the study), and 3) the major route of elimination of the radioactive materials had to be through the scats. Zinc-65 (^{65}Zn), Manganese-54 (^{54}Mn), Cadmium-109 (^{109}Cd), and Cerium-144 (^{144}Ce) appeared favorable in meeting the above criteria (Nellis, et al. 1967; Miller and Byrne 1970; Miller, et al. 1968). Prior to the study one millicurie of each of the isotopes was obtained from the New England Nuclear Corporation (Boston, Massachusetts). Isotopes were shipped as chloride compounds in 0.5N HCl at concentrations ranging from 3 to 10 millicuries per ml. Table 5 summarizes the basic properties of the isotopes.

Isotopes were diluted using an isotonic saline solution (0.9%) so that the final solution of isotope and saline were equal to 50 ml in volume for each isotope; this dilution resulted in an initial activity of 20 μc (microcuries) per ml of solution. All of the radioactive materials were stored in a room specified for such purposes at the University of Tennessee at Knoxville and later at a field lab in the

TABLE 5

BASIC PROPERTIES AND CHARACTERISTICS OF THE RADIOISOTOPES USED AS BLACK BEAR SCAT TAGS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Isotope[a]	Physical Half-life (d)	Biological Half-life (d)	Effective Half-life (d)	Gamma Energy (Mev)	MPBB[b] (μc)	Critical Organs
^{54}Mn	312	17	16	0.83	40	Gastrointestinal Liver
^{65}Zn	245	930	193	1.12	60	Total body Prostate Liver
^{109}Cd	475	200	140	0.08	200	Liver Kidney Gastrointestinal
^{144}Ce	285	563	193	0.13	20	Bone Liver Gastrointestinal

[a]International Congress on Radiological Protection 1959.

[b]Data based on "standard man."

Park. The field lab was used only by project personnel and total visitation time in this storage facility was usually less than three hours per week. No material for shielding was used to surround the radioactive materials due to the small amounts of radiation emitted. From 150 to 200 μc of each isotope were taken from the original solutions and put into rubber-capped serum bottles and kept with field equipment carried by research personnel. The rubber-capped bottles made it possible to fill syringes easily by pushing the needle through the cap and extracting the amount of isotope needed; this greatly minimized the chance of spillage or contamination of the solutions. At the end of each trapping season (1972 and 1973) one microcurie of each isotope was kept in the lab for the purpose of making counting standards for the radioactive scat samples.

Bears were injected with radioactive materials using a 2-1/2 cc disposable syringe with a 1-1/4 inch, 18 gauge needle. Injections were given intramuscularly in the shoulder area. The amount of isotope injected ranged from 40 to 60 μc in most instances although some injections contained as much as 100 μc. In 1972 various combinations of the four selected radioisotopes were injected in varying concentrations. This was done in an effort to individualize the radioactive tag of each animal. In 1973, ^{65}Zn and ^{54}Mn were injected in equal concentrations.

It was desired to have some indication as to how long and in what amounts isotopes would be excreted by black bears. Two penned bears used for research by the University of Tennessee, Department of Psychology, and located at the Tremont Environmental Education Center

within the Park were injected with radioactive isotopes. One bear was injected with 50 μc of ^{65}Zn and 50 μc of ^{54}Mn. The other bear was injected with similar amounts of ^{144}Ce and ^{109}Cd. Scat samples were collected on a daily basis for two weeks after injection and then on a bi-weekly basis for the duration of the study.

C. INDEX TRAILS AND SCAT COLLECTION

Black bear scats were collected during June to October of each year. Scat samples were collected from five previously established index trails (Figure 1, page 6) on a bi-weekly basis and from abandoned and unmaintained trails on an irregular basis. Whenever possible, scat samples were collected incidental to other research operations. An effort was made to collect as much of each sample as possible without collecting a lot of debris. Each sample was placed in a 1/2 gallon plastic bag and labeled with the date and exact location of collection. All samples were frozen until late fall of each year at which time they were prepared for isotope analysis.

Approximately 10 cc of each scat sample were dried in a drying oven at 50 degrees Centigrade for two days. Each dried sample was then broken into small particles and placed in 25 x 150 mm culture tubes. Height of the sample in the tube was approximately one inch. Each tube was weighed before and after filling in order to determine the exact dry weight of the sample to the nearest 1/100 of a gram. Cotton was placed over the samples in the tubes to prevent spillage and contamination of one sample by another. In 1972 samples were placed in one pint, cylindrical, ice cream containers for drying in the oven, then analyzed in the same containers without any further preparations.

D. BEAR SIGHTINGS

Bear sightings by research and National Park Service personnel were recorded for both 1972 and 1973 with special note being made regarding the presence or absence of ear tags. In addition, postcard questionnaires (with instructions on how to complete them) were given by Park Rangers to several hundred backpackers when they applied for backcountry camping permits. Backpackers were requested to record all locations where they observed bears, numbers of bears observed, size of the animal(s), the presence or absence of ear tags, and, if the animal was tagged, the colors of the tags and in which ear each color was located. The postcards were pre-addressed and post-paid so that the backpacker had only to drop it in the mail once his trip was completed. Although these postcards provided observational data of black bears for the entire Park, only the data taken from the study area was tabulated for this study.

E. LABORATORY ANALYSIS OF SCAT SAMPLES

Counting equipment used to analyze bear scats collected during the study was made available by the Ecological Sciences Division of the Oak Ridge National Laboratory at Oak Ridge, Tennessee. The counting equipment utilized in 1972 included a 3 x 2 inch NaI solid scintillation crystal and counter coupled with a Packard Model 115 multi-channel analyzer (Figure 4). These instruments were used for counting scat samples in ice cream containers. Each sample had to be manually inserted and removed from the counting chamber. In 1973 a "well type" NaI crystal was used. An auto-gamma spectrometer capable

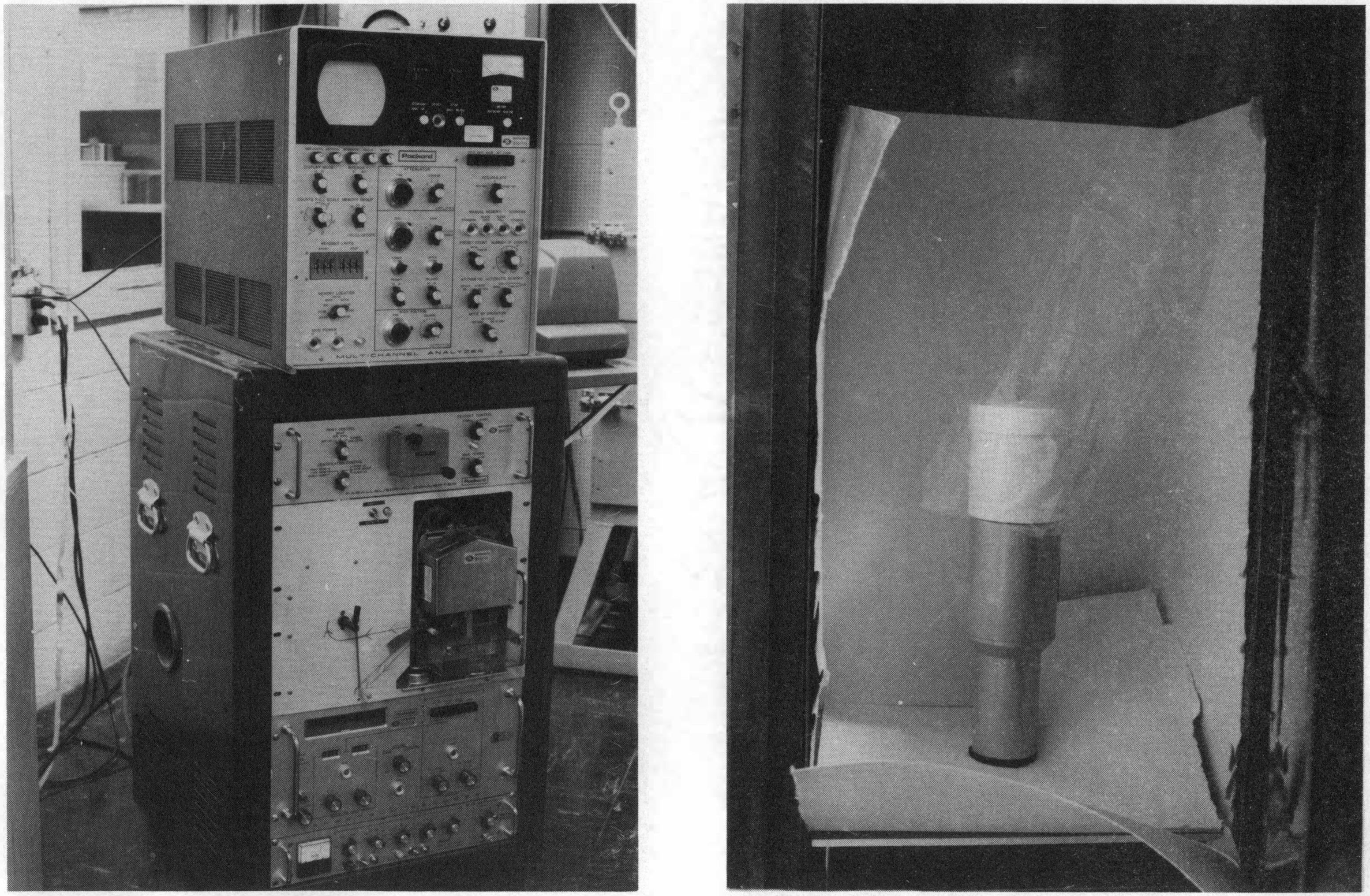

Figure 4. Packard Model 115 multi-channel analyzer and counting chamber used to analyze black bear scat samples in 1972.

of holding 50 samples was used to automatically insert and remove the samples in the culture tubes from the counting chamber. The counter was coupled to a computerized Nuclear Data dual channel analyzer (Figure 5).

In preparation for counting samples, a standard was made for each isotope. Using a 20 λ pipette, isotope material was drawn from aliquots of solution saved for that purpose and mixed with non-tagged fecal material. These standards were used to calibrate all of the counting equipment. In 1972 all samples were counted for 10 minutes, while in 1973 the counting time was increased to 15 minutes. All counts were corrected for decay which occurred between the time of sample collection and counting.

F. POPULATION ESTIMATES

Population estimates were made using the Schnabel method (Schnabel 1938) for multiple sampling. Estimates were made using data collected from the scat-tagging segment of the study for both 1972 and 1973. These estimates were compared to estimates computed from mark-observational data provided by backpackers, National Park Service personnel, and research personnel for the same years.

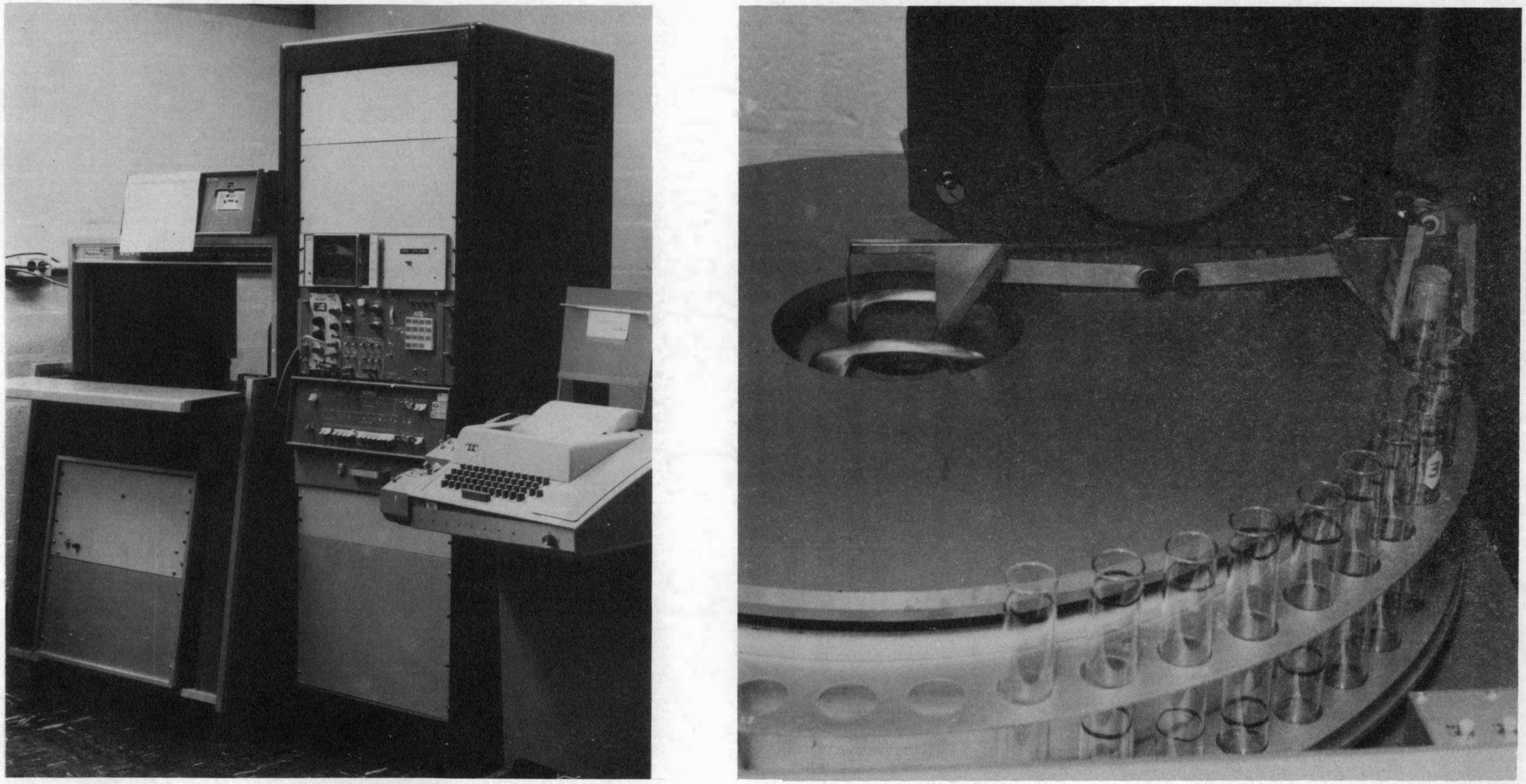

Figure 5. Nuclear Data dual-channel analyzer, computer, and autogamma spectrometer used to analyze black bear scat samples in 1973.

CHAPTER IV

RESULTS AND DISCUSSION

A. EVALUATION OF TRAPPING

In 1972, 31 bears were captured a total of 43 times; 28 of these animals were injected with radioactive isotopes. In 1973, 35 bears were captured a total of 40 times; 32 of these animals were radioactively tagged (Appendix, Table A-1).

Most of the time and effort of the present study was devoted to the capture of bears; this has been the case with earlier researchers primarily involved with population estimates of bears (Erickson and Petrides 1964). Trapping success in 1973 (trapping records for 1972 were incomplete) was lower in August than in other months (Table 6), although success of trapping did not vary greatly from one month to another. Miller, McCaffrey, and Will (1973) reported that trapping efficiency in New York was best in the late spring and fall with a reduction in success during the summer. The above was believed to be related to the fact that baited traps were less attractive to bears during the summer because of abundant berry crops. Although most of the trapping in the present study was conducted during the summer, there was no evidence, based on activity signs, to suggest that spring or fall trapping might be more productive. Erickson (1957) believed that trapping success decreased as the seasons progressed from summer to fall due to the increased food supplies which became available as the mast crop ripened.

TABLE 6

BLACK BEAR TRAPPING RESULTS BY MONTH IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK DURING 1973

Month	Trap Type	Number of Trapnights	Bear Visits	Captures	Misses	Visits by Other Animals	Bear Visits per Capture	Trapnights per Visit	Trapnights per Capture
June	Snare	14	3	2	1	0	1.5	4.7	7.0
	Culvert	16	6	5	1	0	1.2	2.7	3.2
	All	30	9	7	2	0	1.3	3.3	4.3
July	Snare	55	22	15	7	0	1.5	2.5	3.7
	Culvert	16	5	3	2	0	1.7	3.2	5.3
	All	71	27	18	9	0	1.5	2.6	3.9
August	Snare	56	11	8	3	4	1.4	4.7	6.5
	Culvert	14	3	2	1	0	1.5	4.7	7.0
	All	70	14	10	4	4	1.4	4.7	6.6
September	Snare	10	4	4	0	0	1.0	2.5	2.5
	Culvert	18	3	3	0	1	1.0	5.7	5.7
	All	28	7	7	0	1	1.0	3.9	3.9
Total	Snare	135	40	29	11	4	1.4	3.3	4.5
	Culvert	64	17	13	4	1	1.3	3.7	4.8
	All	199	57	42	15	5	1.4	3.4	4.6

Prebaits

It appeared that prebaiting was a successful segment of the trapping program. Traps were set in areas where prebaits had been visited by bears; it appears that the probability of bears visiting traps was increased. The above is reflected in the trapping data; an average of 4.6 trapnights was required for each bear captured (Table 6). The number of trapnights per capture reported by other researchers ranges from 40 to 213 (Table 7). Although differences may exist in densities of bears between the GSMNP and other study areas reported in the literature, it is not reasonable to assume a density 10 to 50 times greater for the Park than that found in the Catskills of New York (Miller, et al. 1973) or in Yellowstone National Park (Barnes and Bray 1967). Therefore, differences in density alone do not explain the differences in trap success. The data suggests that compared to other techniques, prebaiting may be a much more effective method of attracting and trapping bears.

Prebaiting probably did not attract many bears from great distances but likely indicated areas of bear activity and hence areas of high probable trap success. Prebait sites required only three to five minutes to set. Hence, prebaiting made it possible to reduce the effort required to capture bears and also made it possible to trap several different sections within the study area with the limited manpower available.

Culvert Traps

Culvert traps were useful and successful when trapping in areas of high human concentrations and activities. Bears were contained within

TABLE 7

BLACK BEAR TRAPPING RESULTS OF OTHER RESEARCHERS IN THE UNITED STATES

Source	Trap Type	Number of Trapnights	Bear Visits	Captures	Trapnights per Capture
Miller 1973	Snare	3624	-	17	213.1
	Culvert	160	-	4	40.0
Erickson 1957	Steel trap	2393	126	44	54.4
	Culvert	165	11	4	41.2
Barnes and Bray 1967	Snare	15	0	0	-
Black 1958	Steel trap	2732	126	29	94.2

the trap and posed little or no threat to visitors who approached closely. Also, few injuries occurred to the bears; the only injuries observed were occasional breakage of the canine teeth on the grated front and back of the trap. Another advantage of culvert traps was that bears could be held for longer periods of time before handling and/or release. The only disadvantage was that use was restricted to locations accessible by pickup truck.

Foot Snares

Aldrich spring-activated foot snares were also used with a great deal of success. Due to their light weight, snares were used in many backcountry areas which were accessible only by foot trails. Setting of snares was more of an art than setting culvert traps. However, once the technique was mastered, the sets were relatively easy to construct and were very efficient for capturing bears (Table 6, page 31). Previous researchers reported that small animals such as raccoons, skunks, opossums, squirrels, and birds often disturbed snare sets (Jonkel and Cowan 1971; Miller, et al. 1973; and Erickson 1957). This was not a problem in the present study as only 4 of 199 snare sets were disturbed by animals other than bears; in no instances were animals other than bears captured.

The only apparent disadvantage of the foot snare was that the bears were not contained as with the culvert trap and hence there existed a potential danger to humans who might venture too close and injury to the bear was more likely. Approximately 75 percent of all the bears captured in snares sustained some type of minor leg injury. The most common injuries involved swelling of the snared foot with a

small 1/4 inch break in the skin where the cable and the angle iron rubbed against the foot. The injured areas were not treated in any way, but recaptures indicated that the bears had completely recovered. The bears' chewing on the snare cables resulted in the back sides of the canines being grooved on approximately 50 percent of the bears as a result of the abrasive action of the cables. In four cases the canines were broken off about 1/2 inch above the gum line. Although a high percentage of minor injuries occurred, only two instances of serious injury were observed. One bear sustained a broken radius as a result of thrashing around while in the snare. In another case, a female was found dead in a snare with a broken neck and the viscera exposed. Another animal was obviously responsible for many of the wounds, but it was not determined if the bear died as a result of being snared or by the attack of another animal. Although serious injuries to bears occurred in only two cases, there was potential for injury in every case. This has led other researchers to abandon or at least reduce the use of snares (Conley, Raybourne, and Ernst personal communications). Snare sets should be used only in areas where other capture techniques are not possible.

Projectile Syringe Gun

Use of the projectile syringe as a means of capturing bears was limited. In 1972, 23 bears were captured while free-roaming. All 23 bears captured using this technique came from campgrounds, trail shelters, and roadside picnic areas. In 1973 less emphasis was placed on the capture of bears from these areas and no bears were captured in the above manner.

The major problem in using the projectile syring was that some bears were difficult to locate after injection. Four bears shot with the syringe gun near roadsides ran into nearby rhododendron thickets before becoming immobilized and were not captured. In at least four other cases when the bears tried to elude researchers after being shot, the bears were found in an immobile state within a short period of time.

Location of Captures

Figure 6 illustrates the point of capture of the bears in 1972 and 1973 within the study area. In 1973, an intensive effort was made to capture bears in as many parts of the study area as possible. The study area was divided into several units, with each unit receiving a week's trapping effort. As a result, tagged bears were distributed over most of the area. Further distribution of tagged animals was likely obtained as a result of movements of individual bears within the area. A concentration of captures in the Bote Mountain area was a result of a high density of bears and more intensive trapping efforts in this area related to another study on black bear movements and activities.

B. ANALYSIS OF SCATS COLLECTED FROM PENNED BEARS

From June, 1972 through May, 1973, a total of 80 samples of scats were collected from two penned black bears at the Environmental Education Center at Tremont in the GSMNP. Since ^{109}Cd and ^{144}Ce proved to be unsuccessful and ^{65}Zn and ^{54}Mn were used exclusively during 1973, only data collected from the bear injected with ^{65}Zn and ^{54}Mn are

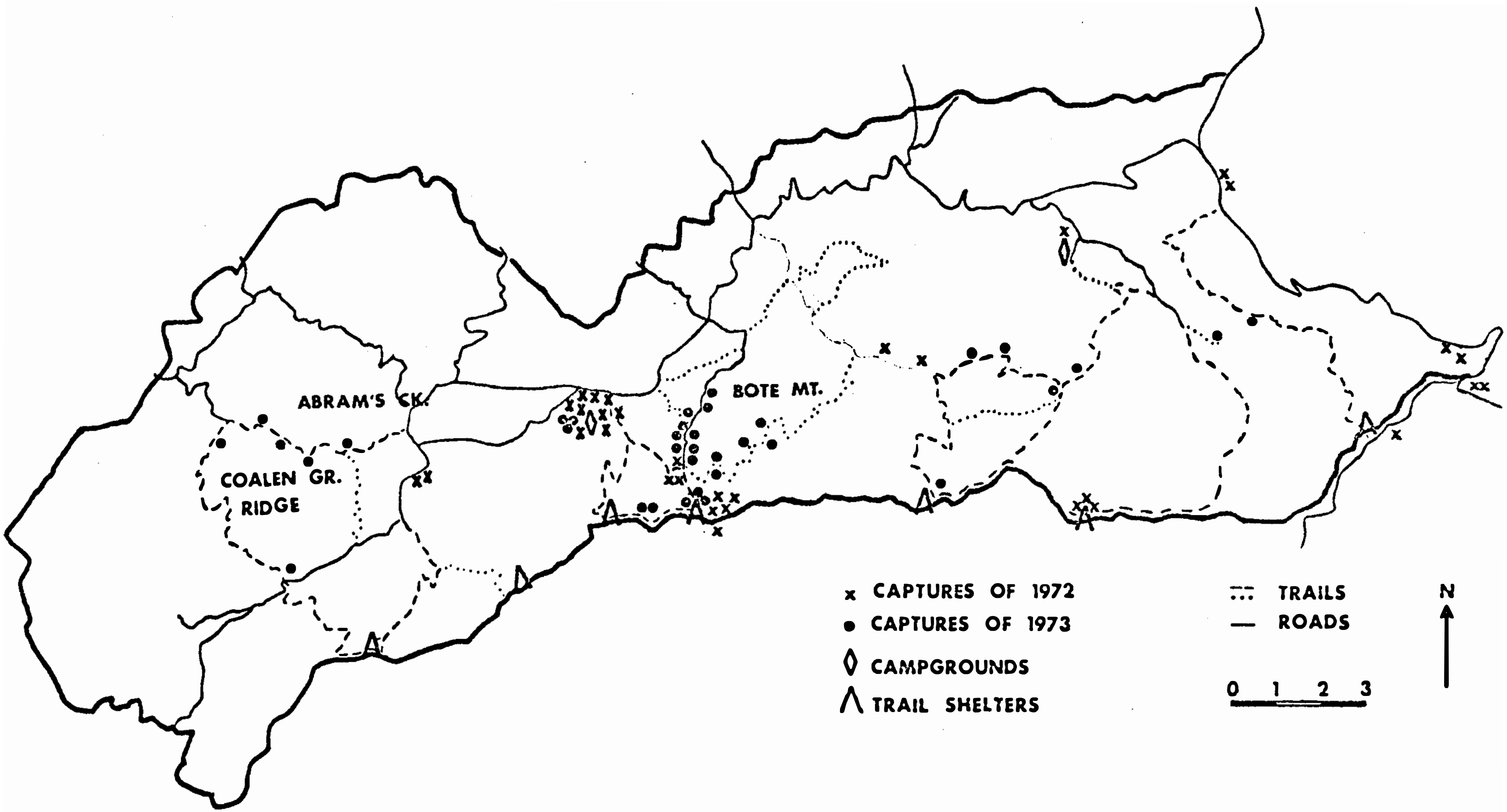

Figure 6. Map of the study area within the Great Smoky Mountains National Park showing the site of capture of black bears during 1972 and 1973.

reported. As illustrated in Figure 7, when radioactivity was plotted against time on a semi-logarithmic scale, the points on the graph form a curvilinear line until late fall (November). Nellis, et al. (1967) used ^{65}Zn in working with rabbits, foxes, and bobcats and reported that activity plotted against time on a semi-logarithmic scale formed a straight line. Beginning in November there was a deviation from the regression pattern of the summer and early fall; activity showed a sharp increase for both ^{65}Zn and ^{54}Mn. By late winter (February) the activity began to decline again, although the study was terminated before enough data were collected to indicate the magnitude of the decline in activity.

Change in the physiology of the penned bears could explain the rise in activity in the late fall. Bacon (personal communication) noted that fecal excretion declined by as much as 90 percent in late fall and winter as the bears went through their winter period of reduced activity and food intake. Folk, Folk, and Minor (1972) noted that although bears reduce food intake during the winter, there is only a slight reduction in basal body temperature during this time; this indicates that there may be only a partial reduction in metabolism. Therefore, it is possible that a continued excretion of metabolic wastes (which includes the radioactive material) coupled with a decrease in the volume of excreta caused by a reduction in food intake could account for the higher activity without a higher excretion rate of the isotopes themselves.

By the fifth day post-injection the radioactivity in the scats of the penned bear was less than one-half that found in the samples

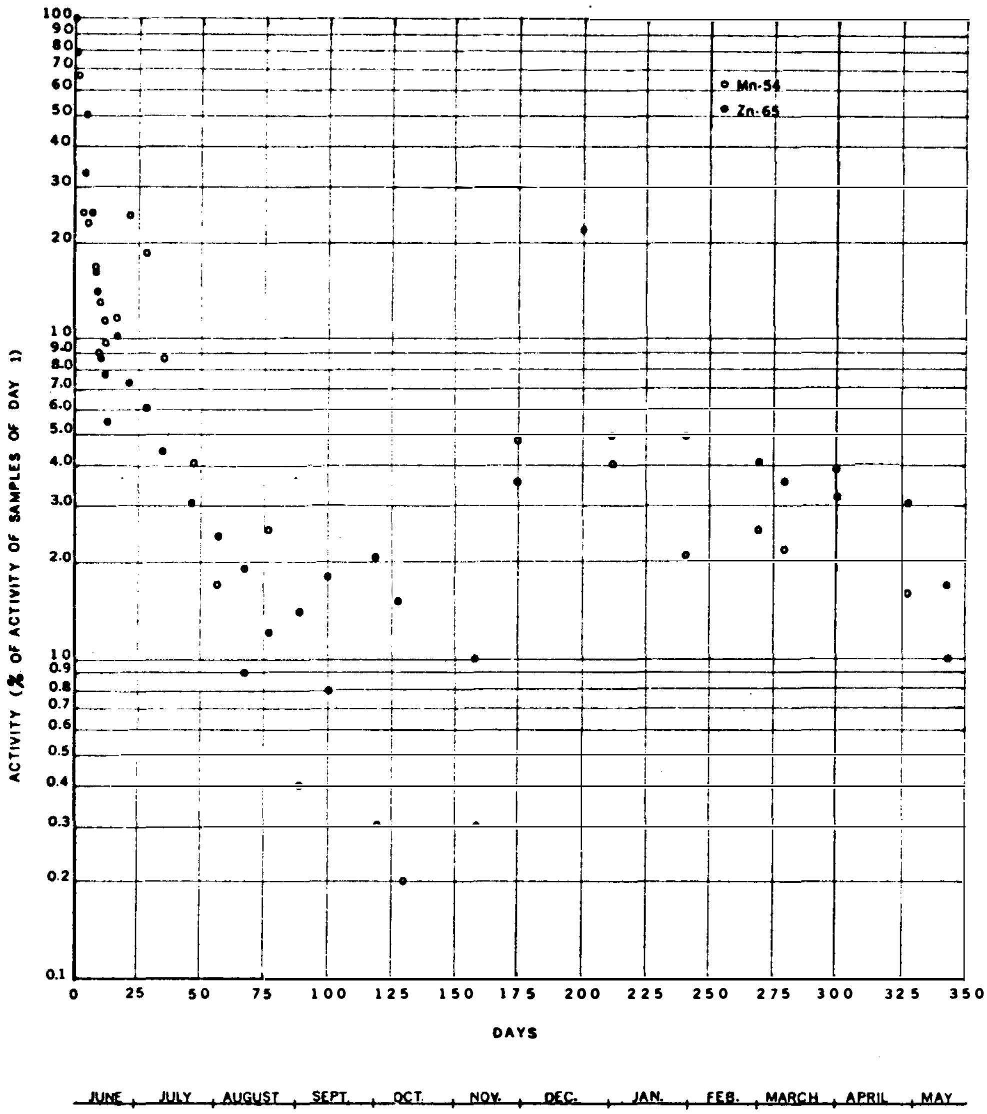

Figure 7. Activity of scats collected from the penned black bear injected with 50 μc each of ^{65}Zn and ^{54}Mn at Tremont Environmental Education Center.

collected on the first day after injection. The above should not be interpreted as indicating that the radioactivity in the body of the bear (body burden) had been reduced to one-half of the amount injected. However, Baker, Dunaway, and Auerbach (1968), working with rats, noted that there was a rapid initial loss of ^{134}Cs within the first two days followed by a lower rate of loss characteristic of this isotope's biological half-life. Odum and Golley (1963) attributed the initial loss to excretion of unassimilated isotope materials.

After 1972, ^{109}Cd and ^{144}Ce were abandoned as feces tags as a result of counts of scats collected from the penned animals. The low-energy rays emitted by these isotopes led to problems in their identification and quantification in the scats, especially when the isotopes were present in low amounts. The major problem in the identification and quantification was due to a region in the energy scale known as backscatter (Figure 8). This backscatter region on the scale was always present and its intensity was dependent upon several factors, including the type and amount of radioactivity present in the samples. There was confusion in interpretation of some counts as to whether the peak was a result of backscatter of a low energy isotope present in small amounts.

Data from the penned bears were collected for one year but it is likely that the isotopes would be detectable for several more months. Nellis, et al. (1967) reported that rabbits injected with ^{65}Zn excreted detectable amounts of radioactive materials for 400+ days. Eight of the 240 scats collected from the trails in 1973 contained ^{65}Zn from the previous year, although the dpm per gram were low. The above

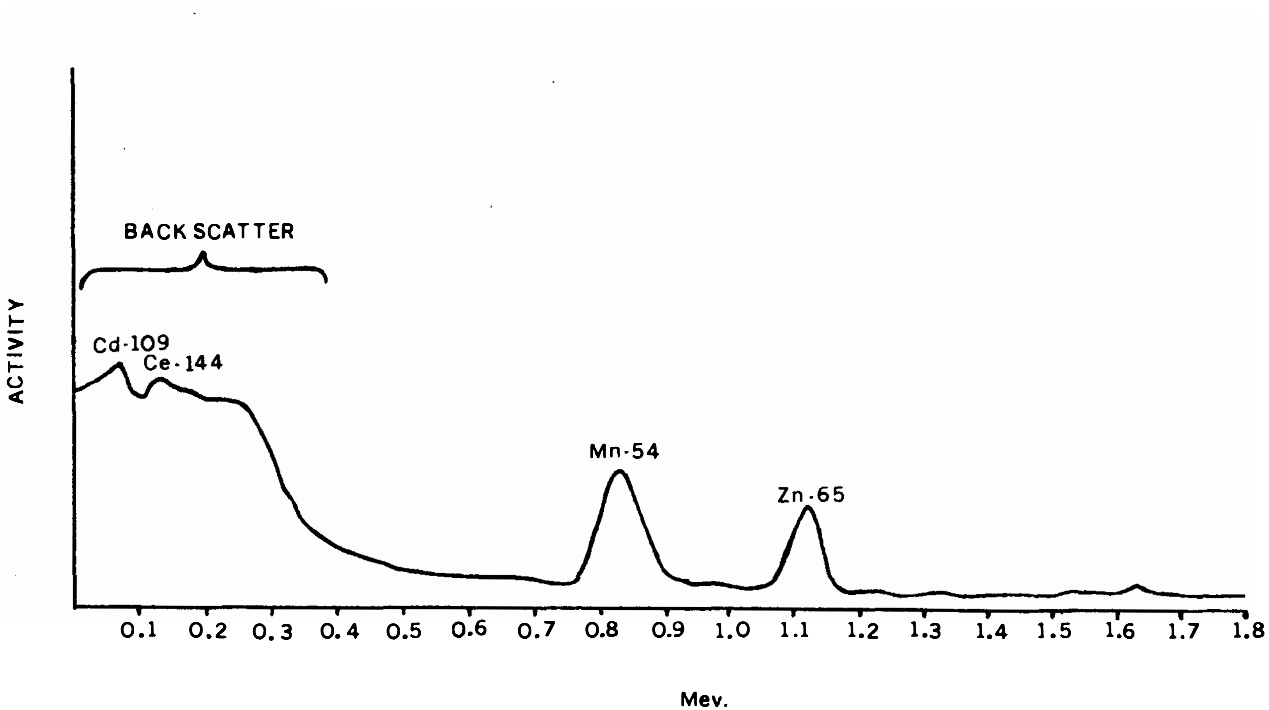

Figure 8. Schematic figure of an energy scale with the peaks formed by ^{109}Cd, ^{144}Ce, ^{54}Mn, and ^{65}Zn and the region of backscatter.

offers a potential technique for determining population mortality from one year to the next by noting the decrease in percentage of scats tagged the previous year from the percentage of scats expected to be tagged. Since several animals tagged in 1972 were retagged in 1973 with the ^{65}Zn, it was not possible to determine the number of scats collected from bears tagged the previous year.

C. EVALUATION OF RADIOACTIVE TAGGING TECHNIQUE

In three cases in 1972 the presence of ^{109}Cd and ^{144}Ce was questionable in scats collected from index trails. In many cases involving these two isotopes, quantification was very difficult because of the backscattering effect. In 1973 when only ^{65}Zn and ^{54}Mn were used as tags, there were no questionable samples.

Dual Tagging

All bears in 1973 were tagged with both ^{65}Zn and ^{54}Mn. Nellis, et al. (1967) reported that ^{65}Zn was extremely resistant to leaching from samples. The dual tagging was undertaken to insure that samples would be recognized as tagged even if the ^{54}Mn were leached out. From results of counting data it was evident that ^{54}Mn was resistant to leaching. In 1973, ^{65}Zn was not used as a single tag because it had been used in combination with ^{109}Cd and ^{144}Ce in 1972. If ^{65}Zn had been used as a single tag, there was the possibility that bears tagged in 1972 with ^{65}Zn might produce misleading data for the 1973 segment of the study. The ^{65}Zn-^{54}Mn combination was not used in 1972 and only two bears were tagged with ^{54}Mn in any combination; both of these animals were removed from the population before 1973. Therefore, there was

no possibility of confusing tagged scats from animals injected in 1973 with those injected in 1972.

In all cases, the ^{54}Mn activity was higher than the ^{65}Zn activity for each tagged scat for the first six months post-injection. It would seem that ^{54}Zn would be more suitable as a single tag, at least for studies which are to last only a few months.

<u>Identification of Individual Bears from Scat Samples</u>

In 1972 an attempt was made to tag bears in such a manner that each radioactive scat collected might be identified as coming from a specific bear. Using four isotopes it was possible to tag 10 bears with different isotopes or combinations of isotopes. However, since 28 bears were captured, it was necessary to vary the ratio of the amounts of isotopes to obtain the number of individualized tags required. (Example, one bear might be injected with 60 μc of ^{65}Zn and 30 μc of ^{54}Mn while another bear might be tagged with 60 μc of ^{54}Mn and 30 μc of ^{65}Zn.) Identity of individual bears from their radioactive scats was extremely difficult due to the variability among the isotopes as to the amount of radioactive material excreted in the first few days after injection, variability of excretion among isotopes due to daily changes in metabolism, and the changes in the ratios of the isotopes due to time. Therefore, the amount of data on movement of individual bears collected by this technique was negligible. However, by radioactively tagging sub-populations of animals with different isotopes, the technique definitely has potential in the study of sub-population dispersal, mixing, and interactions.

<u>Public Health Aspects</u>

Although the black bear population in the Park is completely protected by National Park Service regulations, the possibility exists that tagged bears could be harvested illegally inside the Park, or, if the bears moved out of the Park, legally on an open hunt. The possibility of tagged bears being harvested and part of their carcasses eaten should be given consideration.

The International Congress on Radiological Protection (1959) set limits for the maximum permissible body burden (MPBB) allowed for various groups of the human population. The MPBB for ^{65}Zn, ^{54}Mn, ^{109}Cd, and ^{144}Ce are 60, 40, 200, and 20 microcuries, respectively. Assuming that a bear was killed and muscle tissues salvaged for food the day the bear was injected, approximately 30 percent of the animal's body burden of ^{65}Zn would be incorporated in the muscle tissues (ICRP 1959). Data from analysis of tissues taken from injected bears in the Park indicate that ^{109}Cd and ^{144}Ce have a lower concentration in muscle tissues (tissues tagged with ^{54}Mn were not available). Of the amount of radioactive material ingested by the human body, 10 percent of the ^{65}Zn and ^{54}Mn, 0.25 percent of the ^{109}Cd, and 0.1 percent of the ^{144}Ce would be retained by the body with the rest passing out of the body by way of the excretory system. The highest effective energy is found in ^{144}Ce and ^{65}Zn. If the bear killed were injected with 50 μc of ^{65}Zn and 50 μc of ^{144}Ce, then no more than 15 μc of each isotope would be available for consumption in the muscle tissues. Of the 15 μc of each isotope consumed (assuming that one person consumed all of the meat), 1.5 μc of ^{65}Zn and less

than 0.015 μc of ^{144}Ce would be incorporated into body tissues. The above would result in an internal radiation dose of 0.004 rems per week from the accumulated body burden plus 0.6 rems to the gastrointestinal tract from the radioactive materials as they pass through the digestive tract. The total radiation dose for one year would be approximately 1 rem.

In a more realistic example, one might assume that a bear would not likely be harvested on the day of injection of radioactive materials. Illegal hunting pressures are low during the summer months but increase during the fall. Also, it is not likely that all of the muscle tissues would be salvaged for food or that all of the tissues would be consumed by the same person. Under the above conditions the radiation dose would approximate 10 percent (0.1 rem per year) of the dose given in the previous discussion. The hazards of consuming flesh of radioactively tagged bears are essentially insignificant, even under the worst situations. However, situations where consumption of contaminated flesh could occur should be avoided, if possible.

D. COLLECTION OF SCATS

In 1972 and 1973, 189 and 240 scat samples, respectively, were collected from designated index and abandoned trails. In 1972, 630 index-trail-miles accounted for 171 scats, 61 of which came from trail shelter areas, while 25 miles of abandoned trail-miles produced 8 bear scats. Ten scats were collected from the Cades Cove Campground. In 1973, 810 index-trail-miles resulted in the collection of 141 scats, 55 of which came from areas around trail shelters. Ninety-nine scats

were collected from approximately 140 miles of abandoned trails. The most productive time in terms of scat per miles hiked was late August through the middle of September for both years. Abandoned trails were more productive than maintained trails since an average of 1 scat per 3.12 miles and 1 scat per 1.41 miles were collected from these trails in 1972 and 1973 as compared to 1 scat per 3.68 miles and 1 scat per 5.74 miles from maintained trails. The above is believed to be due to the bears utilization of abandoned trails to a greater extent than maintained trails.

There appeared to be a linear relationship between the number of scat collected per mile and elevation. Pelton (1972) noted that in the GSMNP there was an increase in the number of scats per mile at higher elevations; 56 percent of all scats collected were above 4,500 feet. Reasons for the above relationship could be density dependent or it could be the result of heavier utilization of trails by bears at higher elevations. However, data supporting either idea are inconclusive at this time.

E. POPULATION ESTIMATES

Population estimates for 1972 and 1973 were 102 and 132 animals, respectively, using the data obtained from radioactive scat analysis. Estimates were 43 and 54 animals using mark-observation data for the two respective years (Tables 8, 9, 10, and 11).

Population estimates were made using the method of Schnabel (1938), since this technique made it possible to collect data continuously throughout each summer. Estimates were obtained by the formula:

TABLE 8

BLACK BEAR POPULATION ESTIMATE AS DETERMINED BY MARK-OBSERVATION DATA USING THE SCHNABEL METHOD FOR 1972

Date (Period)	Mt	Ct	Rt	Ct Mt
July 2-July 8	9	15	6	135
July 9-July 15	13	25	15	325
July 16-July 22	17	27	8	459
July 23-July 29	18	20	12	360
July 30-August 5	22	25	12	550
August 6-August 12	21	10	4	210
August 13-August 19	21	15	7	315
August 20-August 26	24	28	20	672
August 27-September 2	25	14	5	350
September 3-September 9	25	15	8	375
September 10-September 16	28	30	10	840
September 17-September 23	28	11	4	308
September 24-September 30	28	1	1	28
October 1-October 7	28	4	1	112
October 8-October 14	28	4	3	112
October 15-October 21	28	7	7	196
October 22-October 28	28	7	6	196
October 29-November 4	28	1	1	28
Σ		259	130	5571

$$\hat{N} = \frac{\Sigma(Ct\ Mt)}{\Sigma Rt} = \frac{5571}{130} = 42.85$$

$$P(36 < \hat{N} < 52) = 0.95$$

TABLE 9

BLACK BEAR POPULATION ESTIMATE AS DETERMINED
BY MARK-OBSERVATION DATA USING THE
SCHNABEL METHOD FOR 1973

Date (Period)	Mt	Ct	Rt	Ct Mt
June 17-June 23	9	16	8	144
June 24-June 30	13	13	5	169
July 1-July 7	13	19	4	247
July 8-July 14	18	5	3	90
July 15-July 21	19	6	3	114
July 22-July 28	24	2	0	48
July 29-August 4	27	4	0	108
August 5-August 11	28	20	9	560
August 12-August 18	33	5	2	165
August 19-August 25	35	3	1	103
August 26-September 1	35	10	9	350
September 2-September 8	35	2	0	70
September 9-September 15	35	7	1	245
September 16-September 22	35	4	3	140
September 23-September 30	35	0	0	0
October 1-October 6	35	0	0	0
October 7-October 13	35	1	0	35
Σ		117	48	2606

$$\hat{N} = \Sigma(Ct\ Mt)/\Sigma Rt = \frac{2606}{48} = 54$$

$$P(42 < \hat{N} < 75) = 0.95$$

TABLE 10

BLACK BEAR POPULATION ESTIMATE AS DETERMINED BY RADIOACTIVE SCAT TAGGING USING THE SCHNABEL METHOD FOR 1972

Date (Period)	Mt	Ct	Rt	Ct Mt
July 2-July 8	5	14	0	70
July 9-July 15	9	5	0	45
July 16-July 22	12	28	6	336
July 23-July 29	13	0	0	0
July 30-August 5	17	19	3	323
August 6-August 12	19	0	0	0
August 13-August 19	19	17	2	323
August 20-August 26	22	0	0	0
August 27-September 2	23	41	7	943
September 3-September 9	23	27	15	621
September 10-September 16	26	17	0	442
September 17-September 23	26	0	0	0
September 24-September 30	26	0	0	0
October 1-October 7	26	15	1	390
October 8-October 14	26	0	0	0
October 15-October 21	26	0	0	0
October 22-October 28	26	3	0	0
October 29-November 4	26	3	1	78
Σ		189	35	3571

$\hat{N} = \frac{\Sigma(Ct\ Mt)}{\Sigma Rt}$ $\quad \hat{N} = \frac{3571}{35}$ $\quad \hat{N} = 102$

$P(77 < \hat{N} < 153) = 0.95$

TABLE 11

BLACK BEAR POPULATION ESTIMATE AS DETERMINED BY RADIOACTIVE SCAT TAGGING DATA USING THE SCHNABEL METHOD FOR 1973

Date (Period)	Mt	Ct	Rt	Ct Mt
June 17-June 23	0	31	0	0
June 24-June 30	4	8	0	32
July 1-July 7	5	19	0	95
July 8-July 14	10	15	0	150
July 15-July 21	11	6	0	66
July 22-July 28	16	0	0	0
July 29-August 4	21	0	0	0
August 5-August 11	22	1	0	22
August 12-August 18	28	2	0	56
August 19-August 25	29	12	1	348
August 26-September 1	31	34	12	1054
September 2-September 8	32	31	6	992
September 9-September 15	32	0	0	0
September 16-September 22	32	43	14	1376
September 23-September 29	32	8	4	256
September 30-October 6	32	17	2	544
October 7-October 13	32	13	2	416
Σ		240	41	5407

$$\hat{N} = \frac{\Sigma(Ct\ Mt)}{\Sigma Rt} = \frac{5407}{41} = 132$$

$$P(101 < \hat{N} < 190) = 0.95$$

$$\hat{N} = \Sigma(Ct\ Mt)/\Sigma Rt$$

where

$\hat{N}$ = population estimate

Ct = total sample taken in the t^{th} period

Mt = total number of marked animals in the population at the start of the t^{th} period

Rt = number of marked samples in Ct.

In using the above method of population estimation certain assumptions about the population and its members have to be made (Ricker 1955): 1) mortality rates among marked and unmarked members of the population are equal, 2) marks are not lost, 3) marks are recognizable, 4) recruitment is negligible, 5) marked and unmarked animals are randomly mixed, and 6) every member of the population has an equal chance of contributing to the estimate.

A seventh assumption must be made when computing estimates based on radioactively tagged and untagged scat samples. One must assume that the ratio of tagged to untagged scats collected from the study area is proportional to the ratio of tagged to untagged bears in the study area. Martin (1972) reported that marked and unmarked animal track observations could be substituted for animal captures or observations in the population estimating formula.

Flyger (1959) using the Schnabel formula obtained estimates which he believed to be very accurate in instances where he could eliminate most of the situations where violations of the assumptions occurred. Certainly, in no natural situation can all of the above assumptions be met completely. However, by minimizing the degree of separation between the ideal and the actual, one can minimize the

degree of error in the population estimate. Hornocker (1962) was able to correlate estimates obtained by the Schnabel method with direct counts where direct counts were feasible. Troyer and Hensel (1964), working with Kodiak bears, obtained estimates 20 percent higher using the Schnabel method than with direct counts, but they believed that poor visibility caused by inclement weather may have resulted in fewer sightings.

Since the Schnabel method is a statistical estimation based on probabilities, the greater the percentage of the estimated population sampled the less the sampling error. Redd (1956) stated that estimates were questionable if less than 40 percent of the estimated population were sampled. Mosby (1969) believed that at least one-half of the population should be sampled while Strangaard (1967) stated that two-thirds of the population should be sampled to provide acceptable results.

The Lincoln Index has been used by several researchers to estimate black bear populations (Kemp 1972, Erickson and Petrides 1964). Although the Schnabel method is only a modification of the Lincoln Index, the Schnabel method has the advantage of allowing continuous sampling and an averaging of the estimations; this generally tends to generate a larger sample and thereby reduce the sampling error.

Brady (1973) in working with cottontail populations in enclosures observed that the Schnabel method yielded estimates as much as 50 percent less than the actual population. He attributed the error to inherent individual behavior of the rabbits and/or learning through experience with the traps which resulted in trap shyness and/or trap proneness among the members of the population. Brady also postulated

that some rabbits would have a greater probability of capture simply through greater contact with the traps. Huber (1962) basing his report on similar evidence, stated that the use of the mark-recapture methods should be ruled out as accurate techniques for censusing cottontails. Flyger (1959) noted in censusing squirrel populations using capture-recapture data and the Schnabel formula that estimates were low due to many animals becoming trap prone and others becoming trap shy.

The problems mentioned above are not restricted to those species, and certainly must also be considered in censusing black bear populations using the Schnabel method. Marten (1972) stated that non-recapture sampling techniques had the advantage of eliminating problems due to low or unequal catchability as well as generating a large sample size.

Kemp (1972) was able to obtain estimates of a black bear population near Cold Lake, Alberta, using a multiple recapture technique as well as Schnabel and Lincoln Index methods. However, he was working in a study area roughly 40 percent the size of the study area in the GSMNP. In such an area he was able to greatly intensify his trapping efforts which resulted in an average of 70 captures per year over a three year period in an area with a density of 1 bear per 1.02 square miles. To obtain a comparable sample from the present study would require 175 to 200 captures per year. Although the multiple recapture technique has, in several instances, proven very useful for estimating populations with an apparent high degree of accuracy (Brady 1973), the manpower and resources needed to adequately sample an area of 210 square miles (or greater) would be

considerable and unrealistic for censusing most large carnivore populations.

Evaluation of Mark-Observation Estimates

It was felt that the mark-observation data yielded population estimates much lower than actual numbers of bears present in the study area during the two years of the study. Over the two year period 66 different animals were tagged with a minimum of 35 additional bears being removed or killed during the fall of 1972. Assuming recruitment to be minimal, the above would indicate a minimum black bear population of at least 100 animals in 1972. The low mark-observation estimates were probably due to a gross failure of the assumption that every animal had an equal chance of being observed. In 1972 greater than 90 percent of all observations recorded were made at roadsides, campgrounds, and trail shelters with very few bears observed in back-country areas. To assume that 90 percent of the bear population occupied these areas of high visitor-use would not be valid. A more likely explanation would be that a few bears became habituated to the presence of humans, spent a lot of time in these areas in search of artificial foods, became exposed to a great number of people, and hence were observed a greater number of times. The above is supported by the fact that more than 80 percent of the observations of tagged bears in 1972 included only six different bears. Roadside and trail shelter bears were usually easy to capture and recapture and this further added to the bias as a greater percentage of these bears were tagged.

In one sense, the study area can be viewed as being comprised of

two sub-populations, one population which frequents areas of artificial foods while another sub-population never or only rarely visits such areas. One sub-population had a higher proportion of marked animals and also a greater influence on the population estimate by the fact that this sub-population afforded more opportunities for observations to be made.

On occasion other assumptions regarding the estimate of population density were violated. However, the extent to which these violations affected the estimates were difficult to evaluate. Instances of bears losing tags were noted although it was not common. The loss of tags would tend to increase the estimate by yielding a lower tagged to untagged ratio. In other instances it was observed that a tagged animal was noted as being untagged by the observer because the observer could not see the tags. Also, it was believed that occasionally some backpackers may have reported tagged animals which were not tagged.

Evaluation of Population Estimates from Radioactive-Tagging Technique

The estimates obtained from data on radioactive-tagging for 1972 and 1973 were more than double the estimates from mark-observation data for each year. The major reason for the higher estimates was probably due to the removal of the bias caused by unequal vulnerability of individual bears within the population to the data-collecting process. The bias caused by animals becoming trap shy or trap prone was removed since recapture was not necessary. Mark-recapture data (unpublished) indicated that some bears, especially around campgrounds, became extremely trap prone and thus created a major bias in the mark-recapture data.

The bias introduced by differential vulnerability to observation was also removed. The probability of observing a bear on a trail was dependent on the presence of a bear in the area, an observer in the area at the same time, and the bear not eluding the observer. The presence of an observer in an area was greatly influenced by the fact that a majority of the backpackers (observers) tended to prefer to hike along the Appalachian Trail and its access trails. Also, bears which were accustomed to foraging for artificial foods around high visitor-use areas became less elusive than "wild" bears. The above two biases were removed when data were collected by means of radioactively tagged scats. Distribution of the trails used for scat collection was such that it was reasonable to assume that a high percentage of the bears in the population had their home ranges traversed by one or more of these trails. Further, factors determining whether or not a bear near one of the trails defecated on that trail was probably little influenced by any factor other than chance.

The technique of radioactive-tagging appeared to give proportional representation in the estimation of the two sub-populations described earlier. In certain areas more scat samples were collected than in other areas. Pelton (1972) believed that to a great extent the number of scats collected in an area per unit effort of searching was an index to the bear density in that area. As pointed out earlier, the above probably is not true of bear observations. Hence, the collection of several scats in one area or trail did not introduce the bias that occurred when many observations were made in one area.

Other biases caused by the loss of tags or the failure to

recognize tags were completely removed using the technique of radioactive-tagging. Since bears were trapped near trails and scats were collected on trails there exists a possibility that the radioactive tag data was biased due to differential utilization of trails by tagged and untagged bears. However, there was no data to indicate that a bias did exist.

Confidence intervals computed for the four estimates (Tables 8, 9, 10, and 11; pages 47, 48, 49, and 50) indicate that the two estimates based on mark-observation data were more precise. The above was due to the fact that 66 animals were eartagged while only 60 animals were radioactively tagged during the two years of the study. Also, since the mark-observation estimates were lower, this resulted in a greater percentage of the estimated population being tagged. Although confidence intervals are a measure of precision of the population estimates based on the quantity of data, it does not reflect the quality (methods of data collection) of the data in any way. Evaluation of the scat tagging data seem to indicate that these data provided a more realistic and accurate estimate of the population density.

Evaluation of 1972 and 1973 Estimates

The population estimate in 1973 (using radioactively tagged scats) was approximately 30 percent higher than the estimate in 1972. Introduced into the 1972 estimate was a bias due to a concerted effort to collect scats near campgrounds and shelters as well as a concerted effort to trap animals in these areas. The above factors probably resulted in an underestimate of the population of 1972. Also, in 1973

the overall distribution of tagged bears and collection of scats was much more random than the previous year. Thus, it was felt that the 1973 estimate was more accurate.

There was probably a population reduction in the fall of 1972 due to high mortality in bears which moved outside the Park and the removal of several bears in the Gatlinburg area by the Tennessee Game and Fish Commission. The high mortality and removal was not compensated for by reproduction in the winter. The above decline in numbers is based on data from the National Park Service and the Tennessee Game and Fish Commission which accounted for a minimum of 40 bears killed or removed from the study area. Data indicate that fewer cubs were present in 1973 than in 1972 (Beeman, personal communication). Assuming that the 1973 estimate is indeed accurate, then the bear population was probably higher in 1972 than in 1973.

Although the study was restricted to one-fourth of the land area of the Park, it is hoped that some type of index may eventually be used throughout the Park which will allow comparisons to be made between the study area and the entire Park. Also, it is hoped that a suitable index can be found which will show definite and precise population fluctuations from year to year (Pelton 1972). From the observational data collected for 1972 and 1973, it appeared that observations along roadsides and near shelters and campgrounds do not provide an adequate index of population density. The number of bears observed near these areas appeared to be related primarily to food availability and only secondarily to density.

Pelton (1972) indicated that the incidence of bear scat could

provide a suitable index for monitoring fluctuations in black bear populations in the GSMNP. Although the incidence of bear scat is affected by factors other than bear density such as precipitation and trail use by visitors and horses, this index does not possess some of the shortcomings of the other indices and, with refinement, may prove to be useful. The number of prebaits utilized by bears during trapping operations might also be adapted for use as an index providing drastic changes in the animal's natural food supplies do not occur from year to year.

Population Density

In determining the population density of the study area, portions of the areas north of Cades Cove and north of Highway 73 were excluded because no data were collected from these areas. The area censused was approximately 90,000 acres (140 square miles) and densities are based on this acreage.

In 1973 estimates resulted in a population density of 1 bear per 1.06 square miles or 1 bear per 680 acres. Jonkel and Cowan (1971) reported a density of 1 bear per 0.8 square miles using the Lincoln Index and direct counts in an area of high black bear density in Montana while Erickson and Petrides (1964) reported a density of 1 bear per 3.0 square miles in good black bear habitat in Michigan. Barnes and Bray (1967) indicated a bear density of 1 bear per 20.7 square miles in Yellowstone National Park, although they believed this estimate was low. Spencer (1955) calculated a density of 1 bear per 5.6 square miles in Maine from data obtained from a cruise line census.

Within the study area in the GSMNP an area encompassing the Bote

Mountain region (Figure 6, page 37) was intensively trapped in conjunction with another study on the movements and activities of black bears. As a result, 15 individual bears were trapped in this area. Using the Schnabel formula, an estimate of 40 animals was obtained for this 17 square mile area. The above represents a density of 1 bear per 0.42 square miles (1 bear per 275 acres) or a density 2-1/2 times greater than that of the entire study area.

This high bear density could be a result of at least two factors. Large acreages of the Bote Mountain area are comprised of almost pure stands of wild cherry (*Prunus* spp.) and other berry species which are heavily utilized by bears as food. Numerous scats collected in this area from late August through September consisted totally of cherries. The abundance of these summer foods could have contributed to the high bear density in the area. However, the area does not have a great number of mast producing trees such as oaks, hickories, and beech. Beeman (1974) noted that when the berry crop was gone, many bears left the Bote Mountain area, perhaps in search for food, in early October but returned in late November. Beeman also noted that the bears seemed to prefer trees for dens in the winter and since the Bote Mountain area does have a large number of over-mature trees, this could also help explain the high bear density in the area.

Another factor which could contribute to the higher population density is the relative isolation of the Bote Mountain area. This isolation provides the bears in the area with almost total protection from illegal hunting and harassment by dogs.

The Abrams Creek area (Figure 6, page 37) comprised approximately

50 square miles of black bear habitat within the study area which was not censused. However, this area appears to be good habitat for black bears and capable of supporting high populations. The area is comprised of large areas of oak and hickory stands which are highly utilized in the fall by bears (Beeman 1971). In addition, large areas are occupied by pine stands with the ground species consisting largely of blueberry species, a preferred food of bears in the summer. However, the Abrams Creek area is subject to illegal hunting pressures which could limit the population in the area, although the extent of the hunting or its effects on the population is not known and is difficult to evaluate.

The Coalen Ground Ridge area (Figure 6, page 37) is adjacent and very similar to the Abrams Creek area in regard to habitat and food composition. Limited data from this area (approximately 15 square miles) yielded a population of 28 bears or 1 bear per 0.54 square miles (340 acres).

In comparison to other regions it would appear that the GSMNP has one of the highest black bear densities in the United States. This is to be expected since most of the Park is considered "prime" black bear habitat with a variety of food producing plant species and large areas offering relative protection from hunting.

CHAPTER V

SUMMARY

A study to determine the density of a black bear population using radioactively tagged scats was conducted in the GSMNP from June through October of 1972 and 1973. The major objectives of the study were: to evaluate the technique of radioactively tagging bears as a means of providing reliable data for population estimates and to delineate the density of the black bear population in the GSMNP.

The GSMNP consists of 800 square miles of mountainous terrain characterized by a diversity of plant and animal species. There is considerable variability in both temperature and precipitation from areas of low elevation to areas of high elevation. The study area consisted of 200 square miles within the Tennessee portion of the Park lying west of U.S. 441.

During the two-year period a total of 66 individual bears were captured and ear-tagged while 60 of these animals were injected with radioisotopes.

Capture techniques included: free-roaming capture, hog traps, culvert traps, and Aldrich foot snares. In 1973, 199 trapnights resulted in 57 bear visits and 42 captures which yielded a trapnights per capture ratio of 4.6. The technique of prebaiting was believed to be responsible for the high degree of efficiency in trapping.

Two confined bears were injected with 50 μc of ^{65}Zn and ^{54}Mn and ^{109}Cd and ^{144}Ce. Scats collected from these bears were analyzed

to determine how long and in what amounts the radioactive materials would be excreted. Based on data collected from the above bears, ^{65}Zn and ^{54}Mn were satisfactory as radioactive tags. Both ^{65}Zn and ^{54}Mn appeared to be resistant to leaching in the fecal material and were easily identified and quantified.

Bear scats were collected from previously established index trails and from abandoned and unmaintained trails. One hundred and eighty-nine scats from 655 miles of trails and 240 scats from 950 miles of trails were collected in 1972 and 1973, respectively. In addition, black bear observations by researchers, National Park Service Personnel, and backpackers totaled 259 and 117 for the two years.

Population estimates were obtained by the Schnabel method using mark-observation data and radioactive-non-radioactive scat data for both 1972 and 1973. Estimates using mark-observation data were 43 and 54 animals, respectively, for the two years. Estimates using radioactive-scat tag data were 102 and 132 animals for the two years. The estimate for 1973 using radioactive tags was believed to be more accurate than for 1972 due to a better distribution of tagged animals.

The black bear density for the study area in 1973 was computed to be 1 bear per 1.06 square miles (680 acres) while areas of higher density within the study area included one 17 square mile area with a density of 1 bear per 0.42 square miles (275 acres) and another 15 square mile area with a density of 1 bear per 0.54 square miles (342 acres).

In attempting to correlate density with certain indices, it was determined that observational indices are probably not suitable as

indicators of population trends. The incidence of bear scats on trails as an indicator of population density should be given further study. Prebait utilization by bears also has potential as a suitable index.

The radioactive-tagging technique used to provide data for the Schnabel method appeared to be a much more accurate technique than conventional mark-observe or mark-recapture techniques for censusing the black bear population. The above appears to be true for several reasons: 1) biases introduced by loss of or failure to recognize tags were completely removed; 2) since the animals did not have to be retrapped, the bias introduced by animals becoming trap shy or trap prone was removed; 3) since bears did not have to be re-observed, the bias introduced by animals becoming habituated to the presence of humans and hence becoming observation-prone was eliminated; 4) since scats were collected randomly over the study area, the bias introduced by non-random recaptures or sightings (specifically the disproportionate number of sightings and captures at trail shelters, campgrounds, and roadsides) was removed; 5) the radioactive-tagging technique tended to generate a large sample size; 6) although difficult to evaluate, it was believed that the radioactive-tagging technique utilized a much greater percentage of the total population in the data collection process; and 7) the radioactive-tagging technique required less expenditures of time and resources in the collection of data when compared to the amount of reliable data obtained.

Radioactive-tagging should prove to be useful for estimating populations of many carnivores since these animals are seldom utilized for food by humans. The technique also has potential for monitoring population mixing, dispersal, movements, and mortality.

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APPENDIX

TABLE A-1

BLACK BEAR TAGGING DATA 1972-1973

Date	Ear Tags[a] Right	Ear Tags[a] Left	Sex	Weight (Pounds)	Drug[b]	Bait[c]	Trap[d]	Capture Point	Release Point	Isotopes (μc)
5-4-72	B-7	B-8	M	348	M-99	-	FR	Cades Cove Campground	Parson's Branch Road	-
6-9-72	W-26	Y-26	M	347	M-99	H	C	Cades Cove Campground	Parson's Branch Road	Zn-48
6-14-72	B-26	Y-27	M	260	M-99	H	C	Cades Cove Campground	Cooper Road	Ce-40 and Mn-40
6-13-72	B-7	B-8	M	-	M-99	-	FR	Cades Cove Campground	Indian Camp Road	Zn-50 and Cd-50
6-20-72	R-27	R-26	M	250	M-99	H	C	Bote Mountain	Bote Mountain	Zn-44 and Ce-44
6-23-72	W-28	W-27	M	260	M-99	H	C	McCaully Place	McCaully Place	Cd-42 and Mn-52
7-3-72	W-36	W-37	M	50	S	H	HT	McCaully Place	McCaully Place	Zn-40 and Mn-48
7-6-72	Y-28	Y-29	M	190	M-99	H	C	Bote Mountain	Bote Mountain	Zn-24 and Mn-58
7-6-72	R-29	Y-30	F	120	M-99	H	HT	Spence Field	Spence Field	Cd-50 and Ce-50
7-7-72	B-27	B-28	M	30	M-99	-	FR	Spence Field	Spence Field	Ce-50
7-11-72	R-27	R-26	M	203	M-99	H	C	Bote Mountain	Bote Mountain	-
7-12-72	R-28	W-30	M	60	M-99	H	HT	Spence Field	Spence Field	Zn-20 and Cd-56
7-13-72	B-31	Y-31	M	60	M-99	H	HT	Bote Mountain	Bote Mountain	Mn-90
7-12-72	W-29	B-29	F	20	S	-	FR	Spence Field	Spence Field	Cd-40
7-17-72	Y-28	Y-29	M	195	M-99	H	C	Bote Mountain	Bote Mountain	-
7-19-72	8-8	B-30	M	337	S	-	FR	Cades Cove	Indian Camp Road	-
7-20-72	Y-32	W-31	M	255	S	-	FR	U.S. 441	Tremont Road	Zn-20 and Ce-40
7-20-72	B-11	P-7	M	-	-	H	C	Cades Cove	Tremont Road	-
7-27-72	W-32	R-30	F	150	S	-	FR	Siler's Bald	Siler's Bald	Zn-20 and Ce-60
7-28-72	Y-33	R-31	M	15	S	-	FR	Siler's Bald	Siler's Bald	Ce-20 and Cd-10
7-28-72	B-32	R-35	F	13	S	-	FR	Siler's Bald	Siler's Bald	Zn-20 and Cd-16
7-28-72	R-34/Y	R-33/Y	F	142	S	-	FR	U.S. 441	Tremont Road	Zn-60 and Ce-20
8-4-72	Y-38/R	Y-37/R	M	255	S	-	FR	Cades Cove	Tremont Road	Zn-20 and Ce-80
8-4-72	R-38/W	R-39/W	M	400	S	-	FR	Cades Cove	Bunker Hill	Zn-40 and Ce-20
8-4-72	Y-36/B	Y-35/B	M	365	M-99	-	FR	Cades Cove	Bunker Hill	Zn-80 and Ce-20
8-9-72	Y-32	W-31	M	268	M-99	-	FR	U.S. 441	Parson's Branch Road	-
8-14-72	Y-38/R	Y-37/R	M	-	S	S	S	Cades Cove	Bunker Hill	-
8-14-72	B-37/R	B-36/R	M	318	M-99	-	FR	Cades Cove	Cooper Road	Ce-20 and Cd-80
8-15-72	B-34/Y	B-35/Y	M	125	S	S	S	Cades Cove	Tremont Road	Zn-20 and Cd-40
8-16-72	R-37/B	R-47/B	M	385	M-99	Unknown	C	Elkmont	Cooper Road	Zn-20 and Cd-80
8-17-72	B-26	Y-27	M	312	M-99	-	FR	Cades Cove	Cooper Road	-
8-18-72	B-37/R	B-36/R	M	318	S	S	S	Cades Cove	Bunker Hill	-
8-21-72	Y-32	W-31	M	-	M-99	S	S	U.S. 441	Cooper Road	-
8-23-72	R-38/W	R-39/W	M	-	M-99	-	FR	Cades Cove	Parson's Branch Road	-

TABLE A-1 (continued)

Date	Ear Tags[a]		Sex	Weight (Pounds)	Drug[b]	Bait[c]	Trap[d]	Capture Point	Release Point	Isotopes (μc)
	Right	Left								
8-23-72	W-26	Y-26	M	342	M-99	-	FR	Cades Cove	Parson's Branch Road	-
8-25-72	R-50	B-50	F	150	M-99	-	FR	Spence Field	Spence Field	-
8-28-72	R-50	B-50	F	150	M-99	-	FR	Spence Field	Spence Field	Ce-20 and Cd-20
9-6-72	R-44	R-45	F	12	M-99	S	HT	Tremont	Tremont	Zn-40 and Cd-20
9-8-72	B-42	R-43	M	163	M-99	Unknown	C	Walnut Bottoms	Tremont	Zn-60 and Cd-20
9-8-72	B-40	W-33	M	180	M-99	-	FR	U.S. 441	U.S. 441	Ce-58 and Cd-20
9-14-72	R-48	W-48	M	93	M-99	-	FR	Newfound Gap	Newfound Gap	Zn-18 and Ce-12 and Cd-18
11-7-72	Y-40	None	M	22	M-99	S	HT	Sugarlands	U.S. 441	-
11-7-72	W-42	None	F	102	M-99	S	HT	Sugarlands	U.S. 441	-
11-14-72	B-41	B-46	M	25	M-99	-	FR	Newfound Gap	Tremont	-
11-14-72	B-39	None	F	16	M-99	Unknown	C	Newfound Gap	Tremont	-
6-11-73	W-55	Y-26	M	280	M-99	H	C	Cades Cove	Tremont	Mn-80
6-19-73	Y-51	R-55	M	87	M-99	H	C	Cades Cove	Cades Cove	Zn-40 and Mn-40
6-17-73	W-51	W-52	F	115	M-99	H	C	Bote Mountain	Bote Mountain	Zn-40 and Mn-40
6-17-73	B-52	Y-27	M	320	M-99	H	C	Cades Cove	Tremont	Zn-40 and Mn-40
6-19-73	W-53	R-53	F	72	M-99	-	S	Defeat Ridge	Defeat Ridge	Zn-40 and Mn-40
6-19-73	-	-	F	120[e]	-	-	S	Bote Mountain	Dead	-
6-29-73	R-51	R-26	M	243	M-99	H	C	Bote Mountain	Bote Mountain	Zn-40 and Mn-40
7-3-73	B-53/55	Y-52	F	71	M-99	H	C	Bote Mountain	Bote Mountain	Zn-40 and Mn-40
7-4-73	W-54	B-54	F	100[e]	M-99	H	S	Defeat Ridge	Defeat Ridge	Zn-40 and Mn-40
7-4-73	Y-53	B-51	F	40[e]	M-99	H	S	Defeat Ridge	Defeat Ridge	Zn-40 and Mn-40
7-5-73	W-56	Y-56	F	105[e]	M-99	H	S	Defeat Ridge	Defeat Ridge	Zn-40 and Mn-40
7-5-73	R-52	R-54	F	100[e]	M-99	H	S	Defeat Ridge	Defeat Ridge	Zn-40 and Mn-40
7-12-73	B-56	R-56	M	93	M-99	H	C	Bote Mountain	Bote Mountain	Zn-40 and Mn-40
7-17-73	Y-55	Y-54	F	70[e]	M-99	H	S	Bent Arm	Bent Arm	Zn-40 and Mn-40
7-18-73	W-57	B-57	F	110[e]	M-99	-	S	Miry Ridge	Miry Ridge	Zn-40 and Mn-40
7-18-73	B-60	W-60	F	65[e]	M-99	-	S	Miry Ridge	Miry Ridge	Zn-40 and Mn-40
7-19-73	Y-59	W-59	F	40[e]	M-99	-	S	Jakes Gap	Jakes Gap	Zn-40 and Mn-40
7-21-73	B-58	Y-58	F	120[e]	M-99	-	S	Jakes Gap	Jakes Gap	Zn-30 and Mn-14
7-24-73	W-62	W-58	M	105	M-99	-	S	Little Bald	Little Bald	Zn-30 and Mn-30
7-24-73	Y-57	Y-60	M	73	M-99	H	C	Bote Mountain	Bote Mountain	Zn-30 and Mn-30
7-27-73	R-29	Y-30	F	140	M-99	-	S	Spence Field	Spence Field	Zn-30 and Mn-30
7-28-73	B-65	Y-65	M	185	M-99	-	S	Little Bald	Little Bald	Zn-30 and Mn-30

TABLE A-1 (continued)

Date	Ear Tags[a] Right	Ear Tags[a] Left	Sex	Weight (Pounds)	Drug[b]	Bait[c]	Trap[d]	Capture Point	Release Point	Isotopes (μc)
7-28-73	R-65	B-50	F	150	M-99	-	S	Spence Field	Spence Field	Zn-30 and Mn-30
7-31-73	R-61	B-61	M	100[e]	M-99	-	S	Derrick Knob	Derrick Knob	Zn-30 and Mn-30
8-7-73	R-62	Y-62	M	110	M-99	-	S	Rabbit Creek Road	Rabbit Creek Road	Zn-30 and Mn-30
8-8-73	W-63	B-63	F	119	M-99	-	S	Rabbit Creek Road	Rabbit Creek Road	Zn-30 and Mn-30
8-8-73	R-63	Y-63	M	158	M-99	-	S	Rabbit Creek Road	Rabbit Creek Road	Zn-30 and Mn-30
8-9-73	W-61	Y-61	F	120	M-99	-	S	Rabbit Creek Road	Rabbit Creek Road	Zn-30 and Mn-30
8-9-73	R-64	W-64	M	145	M-99	-	S	Rabbit Creek Road	Rabbit Creek Road	Zn-30 and Mn-30
8-9-73	Y-57	Y-64	M	80	M-99	H	C	Bote Mountain	Bote Mountain	Zn-30 and Mn-30
8-16-73	R-66	Y-66	M	250[e]	M-99	-	S	Huskey Gap	Huskey Gap	Zn-30 and Mn-30
8-18-73	R-66	Y-66	M	250[e]	M-99	-	S	Huskey Gap	Huskey Gap	-
8-19-73	W-55	Y-26	M	300	M-99	S	S	Caged since June at Tremont	Tremont	-
8-23-73	B-67	Y-67	F	85	M-99	-	S	Sam's Gap	Sam's Gap	Zn-20 and Mn-32
8-28-73	B-66	Y-68	M	55	M-99	H	C	Bote Mountain	Bote Mountain	Zn-20 and Mn-30
9-3-73	B-66	Y-68	M	55	M-99	-	S	Bote Mountain	Bote Mountain	-
9-4-73	R-67	-	F	75[e]	M-99	-	S	Bote Mountain	Bote Mountain	-
9-6-73	R-65	B-51	F	173	M-99	H	C	Bote Mountain	Bote Mountain	-
9-7-73	W-66	Y-70	F	120[e]	M-99	-	S	Spence Field	Spence Field	-
9-12-73	W-53	R-53	F	95	M-99	H	C	Bote Mountain	Bote Mountain	-

[a]B - Blue
W - White
Y - Yellow
R - Red

[b]S - Sernylan

[c]H - Ham
S - Sardines

[d]FR - Free-roaming
HT - Hog trap
S - Aldrich foot snare
C - Culvert trap

[e]Weights were estimated.

TABLE A-2

BLACK BEAR OBSERVATION DATA IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK - 1972-1973

Date	Location	Tagged
7-3-72	McCaully Place	X
7-5-72	Birch Springs	
7-6-72	Spence Field	X
7-6-72	Bote Mountain	X
7-6-72	Spence Field	
7-7-72	Spence Field	X
7-7-72	Spence Field	
7-7-72	Cucumber Gap	
7-8-72	Spence Field	X
7-8-72	Spence Field	
7-8-72	Spence Field	
7-8-72	Spence Field	
7-8-72	Spence Field	X
7-8-72	Siler's Bald	
7-8-72	Siler's Bald	
7-9-72	Abram's Creek	
7-9-72	Huskey Gap	
7-9-72	Siler's Bald	
7-9-72	Mollie's Ridge	X
7-9-72	Mollie's Ridge	
7-9-72	Spence Field	X
7-10-72	Spence Field	X
7-10-72	Spence Field	X
7-11-72	Dome Road	
7-11-72	Dome Road	
7-11-72	Dome Road	X
7-11-72	Bote Mountain	X
7-11-72	Bote Mountain	X
7-12-72	5 miles below Spence Field	
7-12-72	Bote Mountain	
7-12-72	Newfound Gap	
7-12-72	Dome Road	X
7-12-72	Spence Field	X
7-12-72	Spence Field	X
7-12-72	Bote Mountain	X
7-12-72	Spence Field	X
7-13-72	Spence Field	X
7-13-72	Spence Field	X
7-13-72	Bote Mountain	
7-14-72	Cades Cove	X

TABLE A-2 (continued)

Date	Location	Tagged
7-17-72	Bote Mountain	X
7-17-72	Cades Cove	X
7-19-72	Siler's Bald	
7-19-72	Siler's Bald	
7-19-72	Siler's Bald	
7-19-72	Siler's Bald	
7-19-72	Spence Field	
7-19-72	Spence Field	
7-19-72	Spence Field	X
7-19-72	Spence Field	
7-19-72	Spence Field	
7-19-72	Spence Field	
7-20-72	Spence Field	
7-20-72	Spence Field	
7-20-72	Spence Field	
7-20-72	Cades Cove Campground	X
7-20-72	U.S. 441	X
7-20-72	Newfound Gap	X
7-20-72	Siler's Bald	X
7-20-72	Siler's Bald	
7-20-72	Siler's Bald	
7-20-72	Siler's Bald	
7-20-72	Double Springs	
7-20-72	Double Springs	
7-21-72	Spence Field	X
7-21-72	Spence Field	
7-21-72	Spence Field	
7-22-72	Spence Field	X
7-23-72	Cades Cove Campground	
7-25-72	Spence Field	X
7-25-72	Spence Field	X
7-26-72	Spence Field	X
7-27-72	Walker Prong	
7-27-72	Walker Prong	
7-27-72	Siler's Bald	X
7-27-72	Siler's Bald	
7-27-72	Siler's Bald	
7-27-72	Siler's Bald	
7-28-72	Siler's Bald	X
7-28-72	Siler's Bald	X
7-28-72	Walker Prong	X
7-28-72	Spence Field	X
7-28-72	Dome Road	
7-28-72	Dome Road	

TABLE A-2 (continued)

Date	Location	Tagged
7-28-72	U.S. 441	X
7-28-72	U.S. 441	X
7-29-72	U.S. 441	X
7-29-72	U.S. 441	X
8-1-72	Spence Field	X
8-1-72	Siler's Bald	X
8-1-72	Siler's Bald	
8-1-72	Siler's Bald	
8-1-72	Siler's Bald	
8-1-72	Spence Field	X
8-1-72	Walker Prong	
8-2-72	Cades Cove Campground	X
8-3-72	Cades Cove Campground	X
8-3-72	Spence Field	X
8-3-72	Spence Field	X
8-4-72	Spence Field	
8-4-72	Spence Field	
8-4-72	Mt. Collins	
8-4-72	Cades Cove Campground	X
8-4-72	Cades Cove Campground	X
8-4-72	Spence Field	X
8-4-72	Russell Field	X
8-4-72	Double Springs	
8-4-72	Double Springs	
8-5-72	Russell Field	X
8-5-72	Siler's Bald	
8-5-72	Siler's Bald	
8-5-72	Siler's Bald	
8-5-72	Siler's Bald	
8-6-72	Moore's Spring	
8-6-72	Spence Field	X
8-7-72	Spence Field	X
8-8-72	Russell Field	
8-8-72	Russell Field	
8-8-72	Russell Field	
8-9-72	U.S. 441	X
8-9-72	Sam's Gap	
8-10-72	Dome Road	X
8-12-72	Dome Road	
8-13-72	Meigs Mountain	
8-14-72	Cades Cove Campground	X
8-14-72	Cades Cove Campground	X
8-14-72	Cades Cove Campground	X
8-14-72	Cades Cove Campground	

TABLE A-2 (continued)

Date	Location	Tagged
8-14-72	Double Springs	
8-15-72	Cades Cove Campground	X
8-15-72	Dome Road	
8-16-72	Elkmont	X
8-17-72	Dome Road	
8-17-72	Double Springs	
8-17-72	Spence Field	
8-17-72	Spence Field	
8-17-72	Cades Cove Campground	X
8-18-72	Cades Cove Campground	X
8-20-72	Cades Cove Campground	X
8-20-72	Thunderhead Mountain	
8-20-72	Russell Field	
8-20-72	Spence Field	X
8-20-72	Spence Field	X
8-21-72	U.S. 441	X
8-21-72	Cades Cove Campground	X
8-21-72	Russell Field	X
8-21-72	Spence Field	X
8-22-72	Siler's Bald	
8-22-72	Siler's Bald	
8-22-72	Cades Cove Campground	X
8-23-72	Cades Cove Campground	X
8-23-72	Cades Cove Campground	X
8-23-72	Cades Cove Campground	X
8-23-72	Tremont	X
8-23-72	Spence Field	
8-24-72	Spence Field	X
8-24-72	Tremont	X
8-25-72	Spence Field	X
8-25-72	Spence Field	X
8-25-72	Russell Field	
8-25-72	Russell Field	
8-25-72	Russell Field	
8-25-72	Russell Field	X
8-25-72	Spence Field	X
8-25-72	Spence Field	X
8-25-72	Thunderhead Mountain	X
8-27-72	Spence Field	X
8-27-72	Gregory Bald	
8-28-72	Spence Field	X
8-28-72	Spence Field	X
8-29-72	Mt. Collins	
8-29-72	Cades Cove Campground	X

TABLE A-2 (continued)

Date	Location	Tagged
9-2-72	Spence Field	
9-2-72	Spence Field	
9-2-72	Spence Field	
9-2-72	Spence Field	X
9-2-72	Siler's Bald	
9-2-72	Siler's Bald	
9-2-72	Siler's Bald	
9-2-72	Siler's Bald	
9-3-72	Spence Field	
9-3-72	Spence Field	X
9-3-72	U.S. 441	
9-3-72	U.S. 441	
9-3-72	U.S. 441	
9-3-72	Dome Road	X
9-5-72	Cades Cove Campground	X
9-6-72	Cades Cove Campground	X
9-6-72	Tremont	X
9-8-72	U.S. 441	X
9-9-72	Siler's Bald	X
9-9-72	Siler's Bald	
9-9-72	Siler's Bald	
9-9-72	Siler's Bald	X
9-9-72	Siler's Bald	
9-10-72	Spence Field	X
9-10-72	Spence Field	
9-11-72	Siler's Bald	X
9-11-72	Siler's Bald	X
9-11-72	Siler's Bald	X
9-11-72	Siler's Bald	
9-11-72	Siler's Bald	
9-11-72	Cades Cove Campground	
9-12-72	Siler's Bald	
9-12-72	Russell Field	
9-12-72	Russell Field	
9-13-72	Birch Springs	
9-13-72	Siler's Bald	
9-13-72	Siler's Bald	X
9-13-72	Siler's Bald	
9-13-72	Siler's Bald	
9-13-72	Siler's Bald	
9-13-72	Spence Field	
9-14-72	Dome Road	X
9-14-72	Moore's Springs	X
9-15-72	Moore's Springs	X

TABLE A-2 (continued)

Date	Location	Tagged
9-15-72	Cades Cove Campground	X
9-15-72	Jakes Gap	
9-15-72	Siler's Bald	
9-15-72	Siler's Bald	
9-15-72	Siler's Bald	
9-15-72	Siler's Bald	
9-16-72	Spence Field	X
9-16-72	Spence Field	
9-16-72	Spence Field	
9-17-72	Leadbetter Ridge	
9-17-72	Spence Field	X
9-17-72	Spence Field	
9-17-72	Spence Field	
9-17-72	Dome Road	
9-18-72	Cades Cove Campground	X
9-19-72	Cades Cove Campground	X
9-20-72	Cades Cove Campground	
9-21-72	Tremont	
9-23-72	Spence Field	X
9-23-72	Spence Field	
9-29-72	U.S. 441	X
10-1-72	Newfound Gap	X
10-1-72	Sugarlands	
10-1-72	Sugarlands	
10-2-72	Hannah Mountain	
10-9-72	Dome Road	
10-10-72	Cades Cove Campground	X
10-11-72	Cades Cove Campground	X
10-12-72	Cades Cove Campground	X
10-16-72	Cades Cove Campground	X
10-17-72	Cades Cove Campground	X
10-18-72	Cades Cove Campground	X
10-19-72	Cades Cove Campground	X
10-20-72	Cades Cove Campground	X
10-21-72	Cades Cove Campground	X
10-21-72	Gregory Bald	X
10-22-72	Cades Cove Campground	X
10-23-72	Spence Field	X
10-25-72	Spence Field	X
10-26-72	Cades Cove Campground	X
10-27-72	Cades Cove Campground	X
10-27-72	Spence Field	X
10-28-72	Spence Field	
10-29-72	Cades Cove Campground	X
6-17-73	Cades Cove Campground	

TABLE A-2 (continued)

Date	Location	Tagged
6-17-73	Cades Cove Campground	
6-18-73	Spence Field	X
6-18-73	Dome Road	X
6-18-73	Russell Field	
6-18-73	Spence Field	X
6-18-73	Spence Field	X
6-18-73	Spence Field	
6-19-73	Siler's Bald	X
6-19-73	Siler's Bald	X
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-20-73	Spence Field	X
6-21-73	Little Bald	X
6-24-73	Spence Field	X
6-24-73	Spence Field	X
6-24-73	Little Bald	
6-23-73	Double Springs	
6-23-73	Birch Springs	
6-25-73	Siler's Bald	
6-27-73	Siler's Bald	X
6-27-73	Siler's Bald	
6-27-73	Siler's Bald	
6-29-73	Double Springs	
6-29-73	Bote Mountain	
6-30-72	Mt. Collins	
6-30-73	Bote Mountain	
6-30-73	Bote Mountain	X
6-30-73	Dome Road	X
7-1-73	Spence Field	X
7-2-73	Spence Field	
7-2-73	Siler's Bald	
7-2-73	Spence Field	
7-2-73	Bote Mountain	
7-3-73	Spence Field	X
7-4-73	Spence Field	
7-4-73	Spence Field	
7-4-73	Spence Field	
7-4-73	Spence Field	X
7-4-73	Derrick Knob	
7-5-73	Double Springs	
7-5-73	Double Springs	
7-5-73	Spence Field	X
7-6-73	Jakes Gap	
7-6-73	Spence Field	X

TABLE A-2 (continued)

Date	Location	Tagged
7-7-73	Miry Ridge	
7-7-73	Double Springs	
7-7-73	Double Springs	
7-8-73	Spence Field	X
7-10-73	Spence Field	X
7-11-73	Little Bald	
7-13-73	Russell Field	
7-14-73	Spence Field	X
7-16-73	Dome Road	X
7-16-73	Dome Road	
7-16-73	Dome Road	
7-16-73	Dome Road	
7-16-73	Spence Field	X
7-18-73	Siler's Bald	X
7-23-73	Double Springs	
7-23-73	Double Springs	
7-31-73	Birch Springs	
8-1-73	Anthony Creek	
8-2-73	Mollie's Ridge	
8-3-72	Dome Road	
8-6-73	Double Springs	
8-6-73	Spence Field	X
8-7-73	Siler's Bald	
8-7-73	Spence Field	
8-7-73	Spence Field	X
8-7-73	Spence Field	X
8-7-73	Spence Field	X
8-8-73	Bote Mountain	X
8-8-73	Bote Mountain	
8-8-73	Bote Mountain	
8-8-73	Siler's Bald	X
8-9-73	Mt. Collins	
8-9-73	Spence Field	X
8-10-73	Spence Field	
8-10-73	Dome Road	X
8-10-73	Dome Road	
8-10-73	Dome Road	
8-10-73	Dome Road	
8-10-73	Mt. Collins	
8-11-73	Double Springs	X
8-13-73	Siler's Bald	X
8-17-73	Russell Field	
8-18-73	Double Springs	
8-18-73	Double Springs	

TABLE A-2 (continued)

Date	Location	Tagged
8-18-73	Double Springs	
8-20-73	Mt. Collins	
8-21-73	Spence Field	X
8-23-73	Mollie's Ridge	
8-26-73	Siler's Bald	X
8-28-73	Siler's Bald	X
8-28-73	Spence Field	X
8-28-73	Spence Field	X
8-28-73	Spence Field	X
8-28-73	Spence Field	X
8-30-73	Spence Field	X
8-30-73	Spence Field	X
9-1-73	Mollie's Ridge	
9-1-73	Siler's Bald	X
9-6-73	U.S. 441	
9-8-73	Sam's Gap	
9-9-73	Dome Road X Appalachian Trail	
9-10-73	Double Springs	
9-10-73	Double Springs	
9-10-73	Double Springs	
9-10-73	Spence Field	X
9-11-73	Siler's Bald	
9-13-73	Townsend Y	
9-17-73	Elkmont	X
9-17-73	Elkmont	X
9-17-73	Cades Cove	
9-20-73	Spence Field	X
10-12-73	Birch Springs	

TABLE A-3

BLACK BEAR SCAT COLLECTIONS
FOR 1972-1973

Date	Location	Radioactively Tagged
7-8-72	Buckeye Gap	
7-8-72	Siler's Bald	
7-8-72	Siler's Bald	
7-8-72	Siler's Bald	
7-8-72	Siler's Bald	
7-8-72	Siler's Bald	
7-8-72	1-1/2 miles past Siler's	
7-8-72	Double Springs	
7-8-72	Double Springs	
7-8-72	1-1/2 miles from Double Springs	
7-8-72	Goshen Ridge	
7-8-72	Goshen Ridge	
7-8-72	Sam's Gap	
7-8-72	Sam's Gap	
7-11-72	Spence Field	
7-11-72	Spence Field	
7-11-72	Spence Field	
7-11-72	Spence Field	
7-12-72	Bote Mountain	Ce, Mn
7-17-72	Bote Mountain	
7-22-72	Bent Arm	
7-22-72	Bent Arm	
7-22-72	Bent Arm	
7-22-72	Bent Arm	
7-22-72	Bent Arm	
7-22-72	Bent Arm	
7-22-72	Miry Ridge	
7-22-72	Miry Ridge	
7-22-72	Miry Ridge	
7-22-72	Sugarlands Mountain	
7-22-72	Sugarlands Mountain	
7-22-72	Sugarlands Mountain	
7-22-72	Double Springs	
7-22-72	Siler's Bald	
7-22-72	Siler's Bald	
7-22-72	Siler's Bald	
7-22-72	Siler's Bald	
7-22-72	Spence Field	Ce, Cd

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
7-22-72	Spence Field	
7-22-72	Spence Field	Ce, Cd
7-22-72	Spence Field	Zn
7-22-72	Spence Field	Ce, Cd
7-22-72	Spence Field	Cd
7-22-72	Gregory Bald	
7-22-72	Hannah Mountain	
7-22-72	Siler's Bald	
7-22-72	Double Springs	
8-5-72	Sugarlands Mountain	
8-5-72	Sugarlands Mountain	
8-5-72	Huskey Gap	
8-5-72	Huskey Gap	
8-5-72	Bent Arm	
8-5-72	Miry Ridge	
8-5-72	Siler's Bald	
8-5-72	Siler's Bald	
8-5-72	Siler's Bald	Zn
8-5-72	Double Springs	
8-5-72	Spence Field	Cd, Ce
8-5-72	Spence Field	Cd, Ce
8-5-72	Sam's Gap	
8-5-72	1-1/2 miles from Sam's Gap	
8-5-72	Hannah Mountain	
8-5-72	Hannah Mountain	
8-5-72	Hannah Mountain	
8-5-72	Flint Gap	
8-14-72	Flint Gap	Zn, Ce
8-19-72	Sugarlands Mountain	
8-19-72	Sugarlands Mountain	
8-19-72	Goshen Ridge	
8-19-72	Goshen Ridge	
8-19-72	Goshen Ridge	
8-19-72	Siler's Bald	
8-19-72	Bent Arm	
8-19-72	Bent Arm	
8-19-72	Miry Ridge	
8-19-72	Jeep trail to Derrick Knob	
8-19-72	Russell Field	
8-19-72	Between Russell Field and Spence Field	
8-19-72	Spence Field	
8-19-72	Spence Field	

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
8-19-72	Spence Field	
8-19-72	Spence Field	Zn
9-2-72	Sugarlands Mountain	
9-2-72	Sugarlands Mountain	
9-2-72	2 miles above Huskey Gap	
9-2-72	1 mile above Huskey Gap	
9-2-72	1 mile above Huskey Gap	
9-2-72	Bent Arm	Ce, Zn
9-2-72	Bent Arm	
9-2-72	Miry Ridge	
9-2-72	Miry Ridge	
9-2-72	Miry Ridge	
9-2-72	Miry Ridge	
9-2-72	Miry Ridge	
9-2-72	Miry Ridge	
9-2-72	Miry Ridge	
9-2-72	Siler's Bald	
9-2-72	Siler's Bald	
9-2-72	Siler's Bald	
9-2-72	Siler's Bald	
9-2-72	Siler's Bald	
9-2-72	Between Siler's and Double Springs	
9-2-72	Between Siler's and Double Springs	
9-2-72	Between Siler's and Double Springs	
9-2-72	Between Siler's and Double Springs	
9-2-72	Goshen Ridge	
9-2-72	Goshen Ridge	
9-2-72	Goshen Ridge	
9-2-72	Goshen Ridge	
9-2-72	Goshen Ridge	
9-2-72	Goshen Ridge	
9-2-72	Goshen Ridge	
9-2-72	Anthony Creek Trail	
9-2-72	Bote Mountain	Zn
9-2-72	Spence Field	
9-2-72	Spence Field	Cd, Zn
9-2-72	Between Spence and Russell	Ce
9-2-72	Between Spence and Russell	Ce, Zn
9-2-72	Between Spence and Russell	Ce, Zn

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
9-2-72	Russell Field	Ce
9-2-72	Sam's Gap	
9-2-72	Hannah Mountain	
9-2-72	Hannah Mountain	
9-5-72	Cades Cove Campground	Zn
9-5-72	Cades Cove Campground	Zn
9-5-72	Cades Cove Campground	
9-5-72	Cades Cove Campground	Ce, Zn
9-5-72	Cades Cove Campground	Zn
9-5-72	Cades Cove Campground	Zn
9-5-72	Cades Cove Campground	Zn
9-5-72	Cades Cove Campground	
9-5-72	Cades Cove Campground	Zn
9-6-72	Spence Field	
9-6-72	Spence Field	
9-6-72	Spence Field	
9-6-72	Spence Field	Cd, Zn
9-6-72	Spence Field	
9-6-72	Spence Field	Cd, Ce
9-6-72	Spence Field	
9-6-72	Spence Field	Cd, Ce
9-6-72	Spence Field	Cd, Ce
9-6-72	Spence Field	Zn
9-6-72	Spence Field	Cd, Ce
9-6-72	Spence Field	
9-7-72	Spence Field	Cd, Zn
9-7-72	Spence Field	Cd
9-7-72	Russell Field	
9-7-72	Russell Field	
9-7-72	Russell Field	
9-7-72	Russell Field	
9-16-72	Sugarlands Mountain	
9-16-72	Miry Ridge	
9-16-72	Huskey Gap	
9-16-72	Siler's Bald	
9-16-72	Siler's Bald	
9-16-72	Between Siler's and Double Springs	
9-16-72	Between Siler's and Double Springs	
9-16-72	Between Siler's and Double Springs	
9-16-72	Goshen Ridge	

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
9-16-72	Jeep trail to Derrick Knob	
9-16-72	Sam's Gap	
9-16-72	Sam's Gap	
9-16-72	Miry Ridge	
9-16-72	Jakes Gap	
9-16-72	Sam's Gap	
9-16-72	Sam's Gap	
10-2-72	Sugarlands Mountain	
10-2-72	Miry Ridge	
10-2-72	Siler's Bald	
10-2-72	Siler's Bald	
10-2-72	Siler's Bald	
10-2-72	Goshen Ridge	
10-2-72	Sam's Gap	Cd
10-2-72	Moore's Spring	
10-2-72	Moore's Spring	
10-2-72	Moore's Spring	
10-4-72	Spence Field	
10-4-72	Defeat Ridge	
10-4-72	Defeat Ridge	
10-4-72	Defeat Ridge	
10-4-72	Defeat Ridge	
10-27-72	Spence Field	
10-27-72	Spence Field	
10-27-72	Rocky Top	
10-29-72	Dome Road	
10-29-72	Dome Road	
10-29-72	U.S. 441	Ce
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-19-73	Siler's Bald	
6-19-73	Double Springs	
6-19-73	Double Springs	
6-19-73	Bent Arm	
6-19-73	Bent Arm	
6-19-73	Bent Arm	

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
6-19-73	Bent Arm	
6-19-73	Bent Arm	
6-19-73	Goshen Ridge	
6-19-73	Buckeye Gap	
6-20-73	Bote Mountain	
6-20-73	Bote Mountain	Zn
6-20-73	Bote Mountain	
6-21-73	Bote Mountain	
6-21-73	Bote Mountain	
6-21-73	Bote Mountain	
6-23-73	Spence Field	
6-23-73	Spence Field	
6-23-73	Spence Field	
6-23-73	Spence Field	
6-23-73	Spence Field	
6-23-73	Spence Field	
6-25-73	Bote Mountain	
6-26-73	Defeat Ridge	
6-26-73	Defeat Ridge	
6-27-73	Defeat Ridge	Zn
6-28-73	Defeat Ridge	
6-28-73	Defeat Ridge	
6-29-73	Defeat Ridge	Zn
6-29-73	Defeat Ridge	
7-1-73	Sam's Gap	
7-4-73	Bent Arm	
7-4-73	Miry Ridge	
7-4-73	Bent Arm	
7-5-73	Derrick Knob	
7-5-73	1/4 mile from Siler's	
7-6-73	Siler's Bald	
7-6-73	Siler's Bald	Zn
7-6-73	Siler's Bald	
7-6-73	Siler's Bald	Zn
7-6-73	Siler's Bald	
7-6-73	Siler's Bald	
7-6-73	Siler's Bald	
7-6-73	Siler's Bald	
7-6-73	Siler's Bald	
7-6-73	1/4 mile from Siler's	Zn
7-6-73	1/4 mile from Siler's	
7-6-73	Double Springs	
7-6-73	Goshen Ridge	

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
7-9-73	Sugarlands Mountain	
7-9-73	Sugarlands Mountain	
7-9-73	Sugarlands Mountain	
7-9-73	Sugarlands Mountain	
7-9-73	Sugarlands Mountain	
7-9-73	Sugarlands Mountain	
7-10-73	Spence Field	
7-10-73	Spence Field	
7-10-73	Spence Field	
7-10-73	Spence Field	
7-10-73	Spence Field	
7-10-73	Spence Field	
7-10-73	Spence Field	
7-10-73	Bote Mountain	
7-10-73	Bent Arm	
7-16-73	Flint Gap	
7-16-73	Sam's Gap	
7-17-73	Siler's Bald	
7-17-73	Russell Field	
7-17-73	Bent Arm	
7-18-73	Sugarlands Mountain	
8-9-73	Flint Gap	
8-16-73	Sam's Gap	
8-17-73	Miry Ridge	
8-20-73	1/2 mile from Double Springs	
8-20-73	Double Springs	
8-20-73	Double Springs	
8-20-73	Double Springs	
8-20-73	Bent Arm	
8-20-73	Bent Arm	
8-20-73	Bent Arm	
8-20-73	Bent Arm	
8-22-73	Coalen Ground Ridge	
8-22-73	Coalen Ground Ridge	
8-22-73	Coalen Ground Ridge	
8-22-73	Coalen Ground Ridge	Mn, Zn
8-26-73	Sugarlands Mountain	
8-26-73	Sugarlands Mountain	
8-27-73	Sugarlands Mountain	
8-27-73	Sugarlands Mountain	
8-27-73	Sugarlands Mountain	
8-28-73	Russell Field	
8-28-73	Spence Field	

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
8-28-73	Spence Field	
8-29-73	Defeat Ridge	
8-29-73	Defeat Ridge	
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Bote Mountain	Mn, Zn
8-29-73	Defeat Ridge	
8-29-73	Defeat Ridge	
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Defeat Ridge	
8-29-73	Defeat Ridge	
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Defeat Ridge	
8-29-73	Defeat Ridge	
8-29-73	Defeat Ridge	Mn, Zn
8-29-73	Defeat Ridge	
8-29-73	Defeat Ridge	
8-30-73	Fish Camp Prong	
8-30-73	Fish Camp Prong	
8-30-73	Fish Camp Prong	
8-30-73	Fish Camp Prong	
8-30-73	Miry Ridge	
9-2-73	Siler's Bald	
9-2-73	Siler's Bald	
9-2-73	Siler's Bald	
9-2-73	Siler's Bald	
9-2-73	Goshen Ridge	
9-2-73	Bent Arm	
9-2-73	Bent Arm	
9-2-73	Bent Arm	
9-2-73	Bent Arm	
9-2-73	Bent Arm	
9-2-73	Bent Arm	
9-2-73	Goshen Ridge	Mn, Zn
9-2-73	Siler's Bald	
9-2-73	Siler's Bald	
9-2-73	Goshen Ridge	
9-2-73	Goshen Ridge	

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
9-2-73	Goshen Ridge	
9-2-73	Siler's Bald	
9-2-73	Double Springs	
9-2-73	Elkmont Road	Mn, Zn
9-4-73	Bote Mountain	Mn, Zn
9-4-73	Ekaneetlie Gap	
9-6-73	Sam's Gap	Mn, Zn
9-6-73	Coalen Ground Ridge	Mn, Zn
9-6-73	Coalen Ground Ridge	
9-6-73	Defeat Ridge	
9-6-73	Defeat Ridge	
9-6-73	Defeat Ridge	
9-6-73	Defeat Ridge	Mn, Zn
9-6-73	Defeat Ridge	
9-20-73	Giant Poplar	
9-20-73	Sam's Gap	
9-20-73	Flint Gap	
9-21-73	Andrew's Bald	
9-21-73	Chimney's Picnic Area	
9-21-73	Andrew's Bald	
9-21-73	Bull Branch	
9-21-73	Rich Mountain	
9-21-73	Lumber Ridge	
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	Mn, Zn

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	Mn, Zn
9-21-73	Defeat Ridge	Zn, Mn
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	
9-21-73	Defeat Ridge	
9-22-73	Bent Arm	
9-22-73	Bent Arm	
9-22-73	Bent Arm	
9-22-73	Bent Arm	
9-22-73	Bent Arm	Mn, Zn
9-22-73	Goshen Ridge	
9-22-73	Goshen Ridge	
9-22-73	Goshen Ridge	
9-24-73	Mark's Cove	
9-24-73	Mark's Cove	Mn, Zn
9-24-73	Mark's Cove	
9-25-73	Jenkins Ridge	Mn, Zn
9-25-73	Jenkins Ridge	
9-25-73	Hickory Tree Gap	
9-26-73	Bote Mountain	
9-27-73	Lumber Ridge Trail	Mn, Zn
10-4-73	Cades Cove	
10-4-73	Bote Mountain Road	Zn
10-4-73	Cades Cove	
10-5-73	Laurel Creek	
10-5-73	Laurel Creek	
10-5-73	Laurel Creek	
10-5-73	Laurel Creek	
10-5-73	Laurel Creek	Mn, Zn
10-5-73	Miry Ridge	
10-5-73	Miry Ridge	
10-5-73	Jakes Gap	
10-5-73	Bent Arm	
10-5-73	Bent Arm	Mn, Zn
10-5-73	Bent Arm	
10-6-73	Sugarlands Mountain	
10-6-73	Sugarlands Mountain	
10-6-73	Sugarlands Mountain	
10-10-73	Hannah Mountain	
10-10-73	Hannah Mountain	
10-10-73	Hannah Mountain	
10-10-73	Hannah Mountain	

TABLE A-3 (continued)

Date	Location	Radioactively Tagged
10-10-73	Hannah Mountain	
10-11-73	Defeat Ridge	Mn, Zn
10-11-73	Defeat Ridge	Mn, Zn
10-11-73	Defeat Ridge	
10-11-73	Defeat Ridge	
10-11-73	Defeat Ridge	
10-11-73	Defeat Ridge	
10-11-73	Gregory Bald	
10-11-73	Defeat Ridge	

TABLE A-4

RADIOACTIVE ANALYSIS OF FECES COLLECTED FROM CONFINED BLACK BEAR INJECTED WITH ^{65}ZN AND ^{54}MN

Date of Collection	dpm/g ^{54}MN	dpm/g ^{65}Zn
6-6-72	13099	5859
6-6-72	11081	2591
6-7-72	6989	2429
6-7-72	8996	4151
6-9-72	2974	1462
6-9-72	3118	1609
6-10-72	21500	2076
6-11-72	2838	1050
6-12-72	2029	695
6-13-72	1090	601
6-13-72	33708	1673
6-14-72	1609	374
6-14-72	1747	484
6-17-72	1050	333
6-17-72	2210	469
6-18-72	1353	233
6-21-72	1413	425
6-27-72	2932	307
7-3-72	2219	257
7-10-72	1055	189
7-21-72	502	136
8-1-72	202	102
8-10-72	107	82
8-21-72	305	51
9-1-72	54	58
9-13-72	92	74
10-1-72	41	88
10-11-72	26	63
11-11-72	37	41
11-28-72	580	150
1-5-73	672	238
1-5-73	332	185
2-3-73	258	211
3-3-73	302	174
3-13-73	266	150
4-2-73	383	166
4-30-73	189	130
5-15-73	126	73

VITA

Larry Calvin Marcum was born in Oneida, Tennessee on November 30, 1950. He graduated from Oneida High School in May of 1968. In June of 1968 he entered the University of Tennessee and received a Bachelor of Science degree in Liberal Arts in December of 1971. In January of 1972 he accepted a Graduate Research Assistantship in the Department of Forestry, University of Tennessee. He received his Master of Science degree in Wildlife Management in March, 1974. He is married to the former Patricia Lee Warfield of Heiskell, Tennessee.