SURVIVAL, REPRODUCTION, AND MOVEMENTS OF TRANSLOCATED NUISANCE BLACK BEARS IN VIRGINIA

by

Lisa M. Comly

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE

in

Fisheries and Wildlife Sciences

APPROVED:

Michael R. Vaughan, Chair

Dean F. Stauffer

James D. Fraser

May, 1993
Blacksburg, Virginia

c.2

LD
5655
V855
1993
C657
c.2

SURVIVAL, REPRODUCTION, AND

MOVEMENTS OF TRANSLOCATED NUISANCE

BLACK BEARS IN VIRGINIA

by

Lisa M. Comly

Michael R. Vaughan, Chair

Fisheries and Wildlife Sciences

(ABSTRACT)

Forty-three radiocollared black bears (Ursus americanus) captured in northwestern Virginia were released in the Mt. Rogers National Recreation Area (MRA) in southwestern Virginia, and monitored from June 1990-March 1992. Survival was 0.23 over the 22 month study; male (0.12) and female (0.37) survival rates were not different ($P = 0.16$). Vehicle collisions caused most of the mortality (53%), but legal harvest outside of the study area (16%) and illegal kills in the study area (11%) also were important.

Female bears failed to reproduce in the first winter following translocation, but during the second winter mean litter size was 2.75 ($n = 4$). A computer simulation of the female segment of the translocated population at the MRA predicted 45 females in the population in 1992, but only 29 females by 2002. The instantaneous rate of increase of the simulated population was -0.05 from 1993-2002.

Mean distance translocated from capture to release was

297.7 km. Eleven bears remained in their release areas (i.e., moved <10 km from release), while 32 left their release areas. The mean distance moved from release to recovery/last location was 3.6 km for the former and 48.8 km for the latter. There was no difference ($P > 0.05$) in the probability of remaining in or leaving the study area for either sex. Bears recovered dead were more frequently outside the study area than in the study area ($P < 0.01$).

For bears that left their release areas, the mean direction of travel from release to recovery/last location relative to the capture location (i.e., release to capture direction = 0°) was 31° and did not differ ($P > 0.05$) from the homeward direction. Despite some homeward orientation, no bears returned to their capture areas during this study.

ACKNOWLEDGEMENTS

I would like to thank my major advisor, Michael R. Vaughan, for his advice, support, and critical review throughout all phases of this study. I also thank graduate committee members James D. Fraser and Dean F. Stauffer for their assistance and advice throughout the project.

Funding for this research was provided by the Virginia Department of Game and Inland Fisheries (VDGIF). Additional support was provided by the Virginia Cooperative Fish and Wildlife Research Unit and the Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University.

Assistance was provided by many VDGIF employees. Thanks to Denny Martin for assistance in all phases of the study, and Dave Steffen for assistance with the survival analysis. Special thanks to Larry Crane and Jerry Blank, Jr. for innumerable hours of assistance in the field under what was usually less-than-ideal conditions. Additional field assistance was provided by technicians Jason Humble and Charles Comly.

I greatly appreciate the friendship and support of my fellow graduate students. They made these last 3 years more enjoyable and kept me focused on the things that really matter. Special thanks to fellow "bear people" John Kasbohm and Mike Schrage for their assistance and friendship.

Last but not least, I would like to thank my family for their love and support and for encouraging me to follow my dreams. Their faith in me and my abilities continually inspires me to be all that I can be.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

TRANSLOCATION

Translocation is the purposeful transport and introduction or reintroduction of wildlife into new or previously occupied habitats in an attempt to establish, reestablish, or augment a population (Griffith et al. 1989). Historically, translocation has been used to introduce nonnative species for hunting opportunities, to restore native species decimated by uncontrolled hunting, and, more recently, to restore populations of threatened or endangered species that have succumbed to various maladies.

Translocation may be used to bolster the genetic heterogeneity of critically low populations, to establish satellite populations and reduce the risk of species loss due to catastrophic events, and to speed the recovery of species whose habitats have recovered or where limiting factors have been brought under control. Translocation is expensive, may risk rare organisms, and is subject to intense public scrutiny.

In the face of escalating habitat fragmentation and extinction rates, use of translocation to assist in the maintenance of biological diversity of native species has become more important as a conservation tool. Translocation may be necessary to maintain community composition in isolated habitat fragments that have high extinction rates and limited natural interchange with adjacent similar habitats.

In the broadest context, translocations are considered successful if they result in the establishment of a self-sustaining population. Griffith et al. (1989) analyzed the factors affecting success of native terrestrial vertebrate translocations. They drew the following conclusions: native game species were more likely to be successfully translocated than were threatened and endangered species; translocation into a species' historical range was more successful than translocation outside of the species range; wild-caught animals were more often successfully translocated than were captive-reared animals; and more animals were released in successful translocations. Number of release events, habitat improvement, and average physical condition of animals at release displayed no consistent relationship to translocation success.

Black bears (Ursus americanus) were successfully reintroduced into Arkansas through releases of 20-40 wild-caught bears per year for 8 years between 1958-1968. They were nearly extirpated from Arkansas by the turn of the century, and the population may have been as low as 25 bears during the 1940's (Smith et al. 1990). Bears were released into high quality habitat within historical black bear range. Despite initial indications that the reintroduction was failing (i.e., reports of broad dispersal, mortalities, and few sightings), there were over 2,200 bears in Arkansas in 1990 (Smith et al. 1990).

Many state wildlife agencies use translocation as a means of nuisance animal management, especially for dealing with black bears. In a survey of 45 states conducting translocations during 1985 (Boyer and Brown 1988), black bears were the most commonly translocated mammal (156 animals in 10 states). Relocation of nuisance animals was the most frequently cited reason for bear translocation; restoration of bears to historical habitat also was cited.

An alternative option to translocation of nuisance animals is to give the landowner a damage permit allowing him/her to kill the nuisance animal. Bears killed on damage permits by landowners provide no recreational sporting opportunity and are seldom used for meat (Fies et al. 1987). Rogers et al. (1976) suggested that it may be a better policy to relocate nuisance bears to preserve the animals until the harvest. In Virginia, at least 24% of 300 bears translocated during 1970-1984 were legally harvested (Fies et al. 1987). Despite the high cost of capture and translocation of nuisance bears, the general public is usually supportive of such programs (Fies et al. 1987).

JUSTIFICATION

Black bears historically ranged throughout the forested areas of North America (Hall 1981:950). Hunting and habitat destruction have reduced the bears' range across all of North America, but the reduction is probably most apparent in the East where bears exist mainly in small isolated populations (Brody 1984). Black bears presently occupy only 5-10% of their former range in the Southeast (Maehr 1984). The majority of remaining bear habitat in the Southeast is on public lands administered by the U.S. Forest Service, National Park Service, and U.S. Fish and Wildlife Service (Pelton 1986).

Since 1988, the Virginia Department of Game and Inland Fisheries (VDGIF) has translocated nuisance black bears captured in northwestern Virginia, primarily near Shenandoah National Park (SNP; Figure 1), to southwestern Virginia in an attempt to reestablish a viable bear population there and to reduce nuisance activity near the SNP periphery. Like most southeastern black bear populations (Pelton 1986), the bear population in southwestern Virginia has declined, presumably due to habitat alteration and overexploitation.

Areas east of Interstate 81 in southwestern Virginia were closed to bear hunting in 1988 and 1989 (Figure 2). Grayson and Carroll counties were closed in 1988, and 33 nuisance bears were translocated to Grayson County that

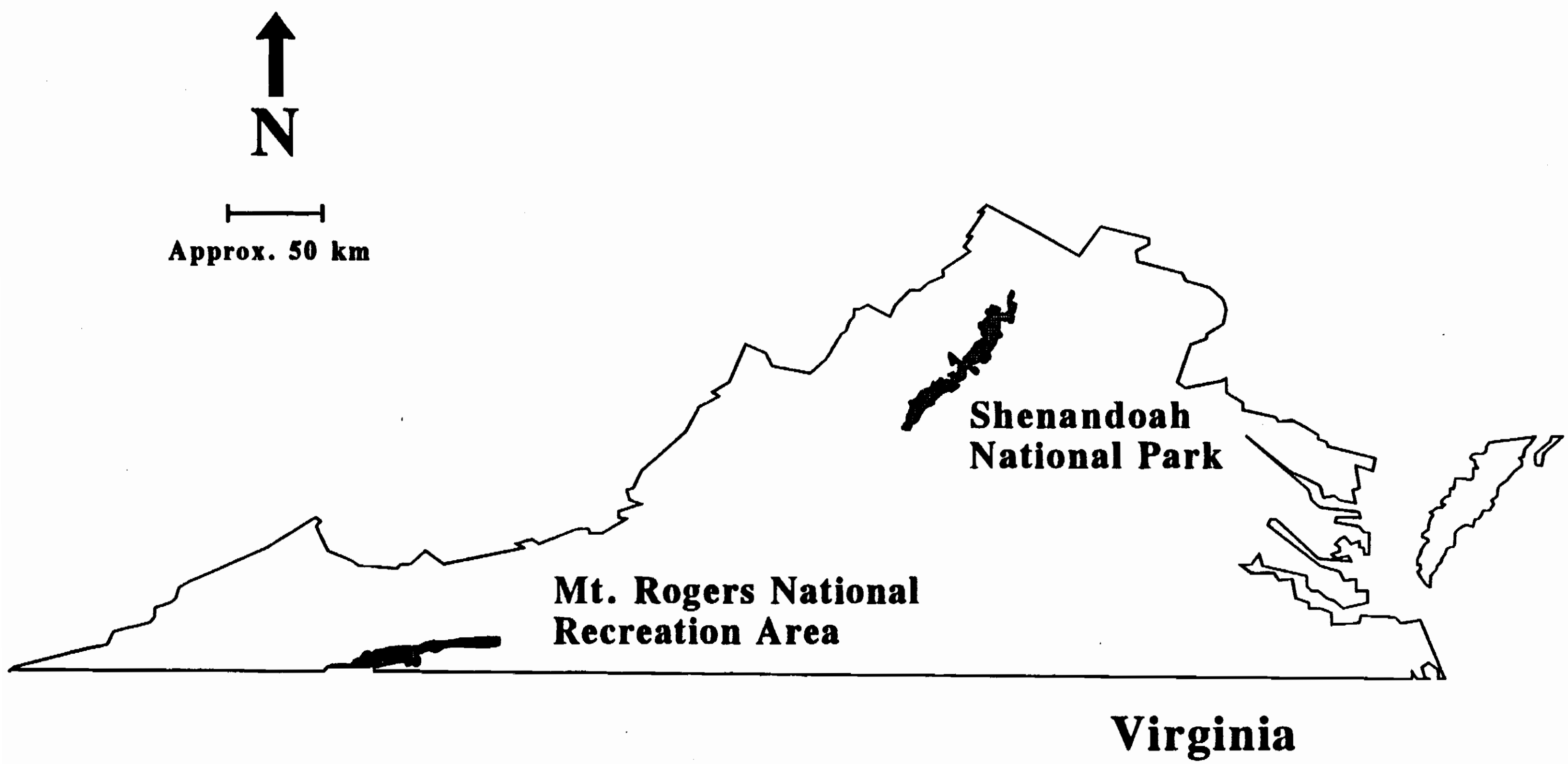

Figure 1. Location of Mt. Rogers National Recreation Area and Shenandoah National Park, Virginia.

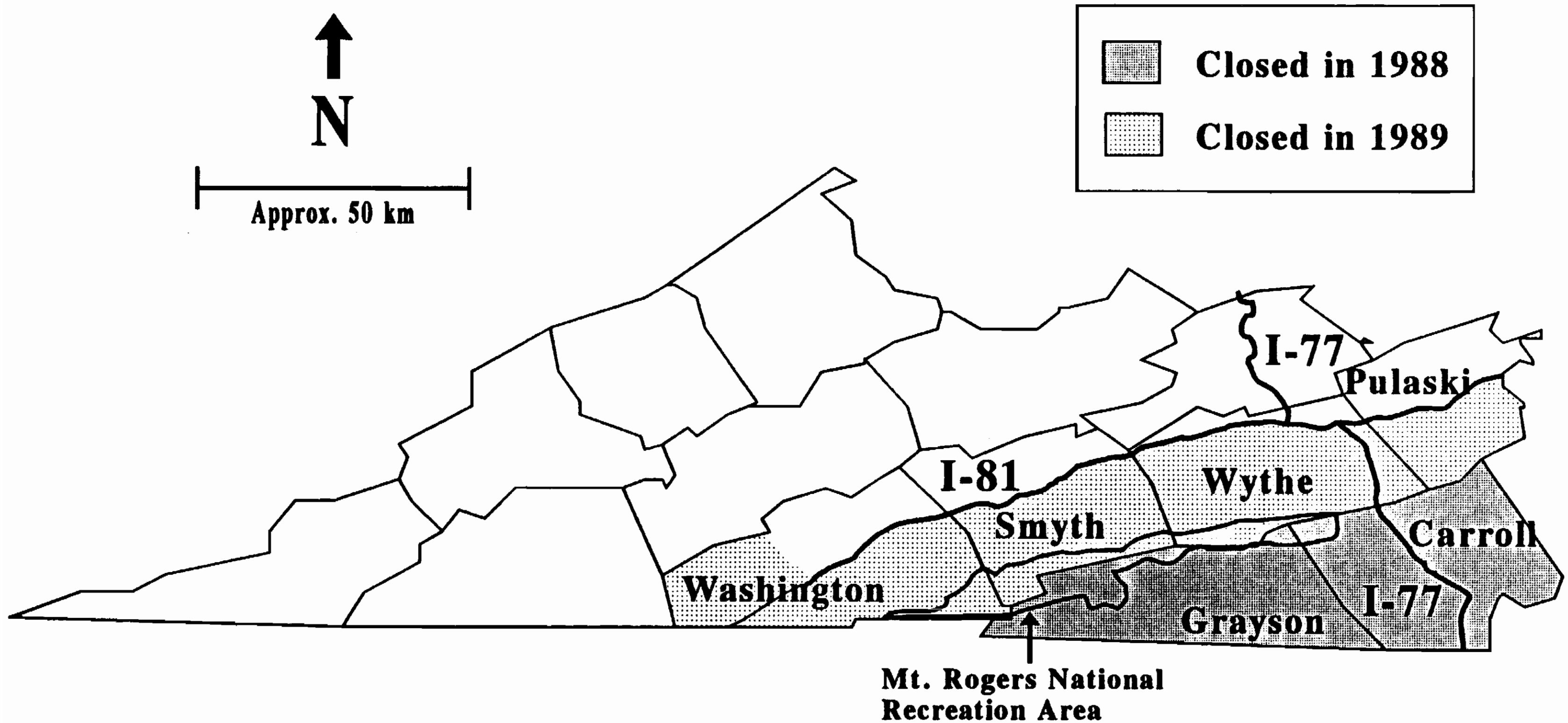

Figure 2. Year of closure to black bear hunting in counties near the Mt. Rogers National Recreation Area, Virginia.

year. The following year, the other counties east of Interstate 81 were closed, and 48 bears were released into Grayson, Smyth, Washington, Wythe, and Pulaski counties.

Thirteen (16%) of the 81 bears released over this 2-year period were recovered prior to this study. Two were legally harvested, 7 were illegally killed, and 4 were killed by vehicles. The fates of the remaining 68 bears (84%) were unknown.

The objectives of this research were to determine the fates, demographic parameters, and movements of bears translocated to the Mt. Rogers National Recreation Area during 1990 and 1991, and to predict the rate at which the population might be expected to grow after the initial releases. An additional objective was to determine the cost of the translocation management strategy on a per bear basis.

STUDY AREA

This study was conducted on the 62,330 ha Mt. Rogers National Recreation Area (MRA), in southwestern Virginia from June 1990 to March 1992. The MRA is within the confines of the Jefferson National Forest and includes parts of Carroll, Grayson, Smyth, Washington, and Wythe counties. The terrain is mountainous (610-1,525 m) with open meadows interspersed with spruce-fir (Picea rubens, Abies fraseri) and northern hardwood forests (Fagus spp., Betula spp., and Acer spp.) at higher elevations (>1,070 m). Cove hardwood (Liriodendron tulipifera, Quercus alba, Q. rubra) and upland hardwood (Quercus spp. and Carya spp.) stands characterize the lower elevations. Steep slopes and shallow, stony soils predominate throughout the MRA. The highest peak (1,746 m) in Virginia, Mt. Rogers, is within the study area.

The management directive of the MRA is "to provide for a variety of outdoor recreation activities and for the conservation of scenic, scientific, historic, and other values of the area" (USDA 1980:5). The primary management objectives on the MRA during the study period were to provide recreation, to enhance wildlife populations, and to provide grazing benefits thereby maintaining the rural character of the area. Timber harvest was a secondary management objective. In 1990, the Forest Service reported 723,000 visitor days (12 hours of use) on the MRA (P. Dorr, U.S. Forest Serv., pers. commun.).

Several small rural communities and the incorporated town of Troutdale are located within the boundary of the MRA. A few independent businesses provide the basic necessities for residents. Schools, libraries, and hospitals are available in the larger neighboring towns and cities. Industrial development is concentrated away from the MRA along interstates and other major highways.

Carroll and Grayson counties were closed to bear hunting in 1988, and areas east of Interstate 81 in Smyth, Washington, and Wythe counties were closed in 1989 (Figure 2). These closures remained in effect during the study period.

METHODS

Capture, marking, and release

Nuisance bears, primarily from the SNP periphery, were captured in aluminum culvert traps or Aldrich foot snares by VDGIF personnel. Captured bears were immobilized with etorphine hydrochloride (M-99, Lemmon Co., Sellersville, Pa.) or a 2:1 mixture of ketamine hydrochloride (Ketaset, Aveco Co., Fort Dodge, Iowa) and xylazine (Rompum, Mobay Corp., Shawnee, Kans.). Etorphine hydrochloride was administered at a dosage of 0.7 mg/45 kg for bears ≤68 kg and a dosage of 0.5 mg/45 kg for bears >68 kg. A mixture concentration of 300 mg/ml of ketamine hydrochloride and xylazine was administered at a dosage of 1 cc/45 kg. Diprenorphine (M50-50, Lemmon Co., Sellersville, Pa.) was used as an antagonist to the etorphine hydrochloride at the same dosage as the immobilizing drug. Yohimbine (Yobine, Lloyd Laboratories, Shenandoah, Iowa) was used as an antagonist to the xylazine at a dosage of 5 mg/45 kg. The immobilizing drug was administered by dart pistol; the antagonist was administered with a hand syringe.

Bears were marked with 2 numbered metal ear tags measuring 4 cm x 1 cm each (National Band and Tag Co., Newport, Ky.) and a lip tattoo, and equipped with a bimodal radio collar (Advanced Telemetry Systems, Inc., Isanti, Minn.) in the 164-165 Mhz frequency range. A breakaway cotton spacer was inserted in each collar to minimize neck injury and to allow for collar retrieval prior to battery failure (Hellgren et al. 1988). Additionally, female bears were marked with plastic orange ear tags, as requested by hunters, to differentiate sex. Each bear was weighed, its sex determined, and a premolar extracted for aging by cementum annuli (Willey 1974). For analysis, bears <3 years old were classified as subadults; bears ≥3 years were classified as adults (Carney 1985, Hellgren and Vaughan 1989, Seibert 1989).

Bears were transported in cages to the MRA by VDGIF personnel and released at predetermined sites along Forest Service roads or gated roads. Bear releases were spaced throughout the MRA.

LITERATURE CITED

Boyer, D. A., and R. D. Brown. 1988. A survey of translocations of mammals in the United States, 1985. Pages 1-11 in L. Nielsen and R. D. Brown, eds. Translocation of wild animals. Wis. Humane Soc., Milwaukee.

Brody, A. J. 1984. Habitat use by black bears in relation to forest management in Pisgah National Forest, North Carolina. M.S. Thesis, Univ. Tenn., Knoxville. 123pp.

Carney, D. W. 1985. Population dynamics and denning ecology of black bears in Shenandoah National Park, Virginia. M.S. Thesis, Va. Polytechnic Inst. and State Univ., Blacksburg. 84pp.

Fies, M. L., D. D. Martin, and G. T. Blank, Jr. 1987. Movements and rates of return of translocated black bears in Virginia. Int. Conf. Bear Res. and Manage. 7:369-372.

Griffith, B., J. M. Scott, J. W. Carpenter, and C. W. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245:477-480.

Hall, E. R. 1981. The mammals of North America. Vol. II. John Wiley and Sons, New York, N.Y. 1181pp.

_____, and M. R. Vaughan. 1989. Demographic analysis of a black bear population in the Great Dismal Swamp. J. Wildl. Manage. 53:969-977.

Hellgren, E. C., D. W. Carney, N. P. Garner, and M. R. Vaughan. 1988. Use of breakaway cotton spacers on radio collars. Wildl. Soc. Bull. 16:216-218.

Maehr, D. S. 1984. Distribution of black bears in eastern North America. Proc. East. Workshop Black Bear Manage. Res. 7:74.

Pelton, M. R. 1986. Habitat needs of black bears in the East. Pages 49-53 in D. L. Kulhavy and R. N. Conner, eds. Wilderness and natural areas in the eastern United States: a management challenge. Center for Applied Studies, School of Forestry, Stephen F. Austin State Univ., Nacogdoches, Tex.

Rogers, L. L., D. W. Kuehn, A. W. Erickson, E. M. Harger, L. J. Verme, and J. J. Ozoga. 1976. Characteristics and management of black bears that feed in garbage dumps, campgrounds or residential areas. Int. Conf. Bear Res. and Manage. 3:169-175.

Seibert, S. G. 1989. Black bear habitat use and response to roads on Pisgah National Forest, North Carolina. M.S. Thesis, Univ. Tenn., Knoxville. 144pp.

Smith, K. G., J. D. Clark, and P. S. Gipson. 1990. History of black bears in Arkansas: over-exploitation, near elimination, and successful reintroduction. East. Workshop Black Bear Res. and Manage. 10:5-14.

United States Department of Agriculture (USDA). 1980. Mount Rogers National Recreation Area final management plan and environmental impact statement. U.S.D.A., Forest Service, Jefferson National Forest. 163pp.

Willey, C. H. 1974. Aging black bears from first premolar tooth sections. J. Wildl. Manage. 38:97-100.

CHAPTER 1: SURVIVAL AND REPRODUCTION

Black bears historically occurred in southwestern Virginia, but, like most southeastern U.S. bear populations (Pelton 1986), their numbers have declined, presumably due to habitat loss and overexploitation. Since 1988, the Virginia Department of Game and Inland Fisheries (VDGIF) has translocated nuisance black bears from northwestern Virginia to southwestern Virginia to reestablish a self-sustaining bear population there. The objective of this segment of the study was to determine the fates of bears translocated to the Mt. Rogers National Recreation Area (MRA) and estimate their survival and reproductive rates.

METHODS

Survival

Monthly survival was estimated using Pollock et al.'s (1989) modification of the Kaplan-Meier procedure (Kaplan and Meier 1958). Survival for radiocollared bears was estimated using data from this study; survival for uncollared bears was estimated from tag returns to VDGIF. A Z-statistic was used to compare survival rates between collared male and female bears and 1990 and 1991 releases. Survival rates were compared over the full term of the study and for the 9 month July-March interval, the interval common to the 1990 and 1991 releases. Mortality was plotted at 30-

day intervals post-release to look for trends.

Because translocated bears were from the bear population in the Shenandoah National Park (SNP) area, and that population, like the MRA population, is unexploited, survival rates of the translocated bears were compared to rates for the SNP population. Survival rates for the SNP bear population were calculated using the data of Kasbohm (Va. Polytechnic Inst. and State Univ., unpubl. data.) and compared to survival rates of this study using a Z-statistic.

Some bears were not monitored the full term of the study due to loss of radio contact. Following the medical and engineering terminology (Kalbfleisch and Prentice 1980, Cox and Oakes 1984), bears with which contact was lost for >4 months and thus their fates were unknown, were classified as censored. Survival estimates for collared bears were calculated using only the time periods when bears were actively monitored. A lower bound for the survival curve was generated assuming that every censored observation was actually a death. Upper bounds were generated assuming that every censored bear survived until the end of the study, 17 March 1992. Survival estimates for uncollared bears represent maximum survival since tags not returned to VDGIF were assumed to be on bears that were still alive.

Two-sample proportion tests were used to test for differences in recovery rates between sexes, differences in mortality sources among collared and uncollared bears, and differences in proportions of collared and uncollared bears by sex. Statistical significance was tested at the 0.05 level for all analyses.

Reproduction

During the 1990-91 and 1991-92 denning periods, den sites were visited and accessible bears immobilized. Denned bears were weighed and categorized in good, fair, or poor condition based on appearance and palpation for body fat. Radiocollars were checked for fit during the 1990-91 period and removed during the 1991-92 period. Litter size was determined by den observation of family groups. If present, cubs were weighed, measured, and their sex determined. Numbered metal ear tags (National Band and Tag Co., Newport, Ky.) were attached to the ears of larger cubs; small cubs were not marked. Dens of female bears in inaccessible locations were monitored for cub vocalizations.

Virginia bears breed in June-July and have a 2-year birth interval (Carney 1985). Based on this, and the fact that no females in SNP skipped an opportunity to breed (Kasbohm, Va. Polytechnic Inst. and State Univ., unpubl. data.), female bears captured and moved after 1 August that were not lactating or accompanied by cubs, were assumed to be pregnant. No assumption was made about the reproductive status of females moved prior to 1 August because it was unknown if these females were in estrus at time of capture (i.e., estrus was not recorded by VDGIF trapping personnel), nor was the density of bears in the release area, and thus the probability of a mating encounter, known. Mean litter size was compared to mean litter sizes in SNP (Carney 1985), and Great Dismal Swamp, Virginia-North Carolina (GDS; Hellgren 1988), using t-tests.

RESULTS

Survival - Radiocollared bears

During 1987-91, 212 (134M:78F) nuisance bears were translocated to southwestern Virginia; 168 (100M:68F) were released in the 5 counties of the study area during 1988-91 (Tables 1, 2). Forty-three (24M:19F; Table 3) of the 168 bears were radiocollared, released in the MRA in 1990-91, and their fates determined over the 22 months of the study (Table 4). Mortality was confirmed for 19 (11M:8F; 44%) of the collared bears. Radio contact was lost with 10 bears (7M:3F; 23%) for >4 months (these bears were classified as censored). Two females dropped their radiocollars, and 1 female was recaptured due to nuisance activity. Collars were removed from 5 bears (1M:4F; 12%) during the 1991-92 denning period, and 6 bears (5M:1F; 14%) remained equipped

Table 1. Age and sex of black bears released in the 5 counties of the Mt. Rogers National Recreation Area, Virginia, 1988-91.

	1988	1989	1990	1991	Totals
MALE					
Cub	1	2	8	3	14
1 year	0	1	1	1	3
2 year	5	6	3	1	15
Adult	16	17	25	10	68
Total	22	26	37	15	100
FEMALE					
Cub	2	4	4	6	16
1 year	2	0	0	0	2
2 year	2	3	1	0	6
Adult	6	13	17	8	44
Total	12	20	22	14	68
TOTALS	34	46	59	29	168

Table 2. Year and county of release for black bears released in the 5 counties of the Mt. Rogers National Recreation Area, Virginia, 1988-91.

County	1988	1989	1990	1991	Totals
Carroll	0	0	1	0	1
Grayson	33	10	10	3	56
Smyth	1	15	27	11	54
Washington	0	12	14	4	30
Wythe	0	9	7	11	27
Totals	34	46	59	29	168

Table 3. Age and sex of radiocollared black bears released in the 5 counties of the Mt. Rogers National Recreation Area, Virginia, 1990-91.

	Males		Females		
	Subadult	Adult	Subadult	Adult	Totals
1990 Releases	5	7	2	11	25
1991 Releases	3	9	1	5	18
Totals	8	16	3	16	43

Table 4. Fates of radiocollared black bears released in the Mt. Rogers National Recreation Area, Virginia, 1990-1991.

	Males		Females		
	Subadult	Adult	Subadult	Adult	Totals
Known mortality	3	8	0	8	19
Alive[1]	1	4	1	0	6
Collar retrieved[2]	0	1	1	3	5
Censored	4	3	0	3	10
Dropped collar[3]	0	0	1	1	2
Recapture/nuisance	0	0	0	1	1
Totals	8	16	3	16	43

[1]Alive and collared as of 17 March 1992, last date transmitters were monitored.
[2]Collars removed from bears during the 1991-92 denning period.
[3]Collars dropped >1 week post-release.

with radiocollars at the end of the study.

Eight of the 43 collared bears were subadult males. Four were censored with the last known location 0-48 days after release. Two subadults were killed outside of the study area, and 1 died within the study area from unknown causes. One subadult male was actively monitored and known to have survived throughout the study.

Vehicle collisions accounted for 10 (4M:6F) of the 19 confirmed mortalities (Table 5). Three males were legally harvested outside the study area, and 2 (1M:1F) bears were illegally killed in the study area. Four (3M:1F) bears died of unknown causes (i.e., cause of death could not be determined at recovery). Recovery rates for male (46%) and female (42%) bears were not different (Z = 0.24; P = 0.81).

Fourteen (74%) of the 19 mortalities occurred within 120 days post-release, while only 3 (16%) occurred >150 days after release (Figure 3). The greatest number of mortalities within an interval (n = 4) occurred during the 60-90 day and 90-120 day intervals.

Cumulative survival over the 22 months of the study was 0.23 for all collared bears (Table 6). Estimated minimum and maximum survival was 0.05 and 0.34, respectively. There was no difference (Z = 1.41; P = 0.16) between male (0.12) and female (0.37) survival nor in survival over the first 9 months (July-March) post-release between the 1990 (0.53) and

Table 5. Cause of death for radiocollared black bears released in the Mt. Rogers National Recreation Area, Virginia, 1990-91.

Cause	Males		Females		Totals
	Subadult	Adult	Subadult	Adult	
Vehicle collisions	1	3	0	6	10
Legal harvest	1	2	0	0	3
Illegal kills	0	1	0	1	2
Unknown[1]	1	2	0	1	4
Totals	3	8	0	8	19

[1] 1 suspected auto related mortality, 2 recoveries of skeletal remains and collar only, 1 possible handling related mortality.

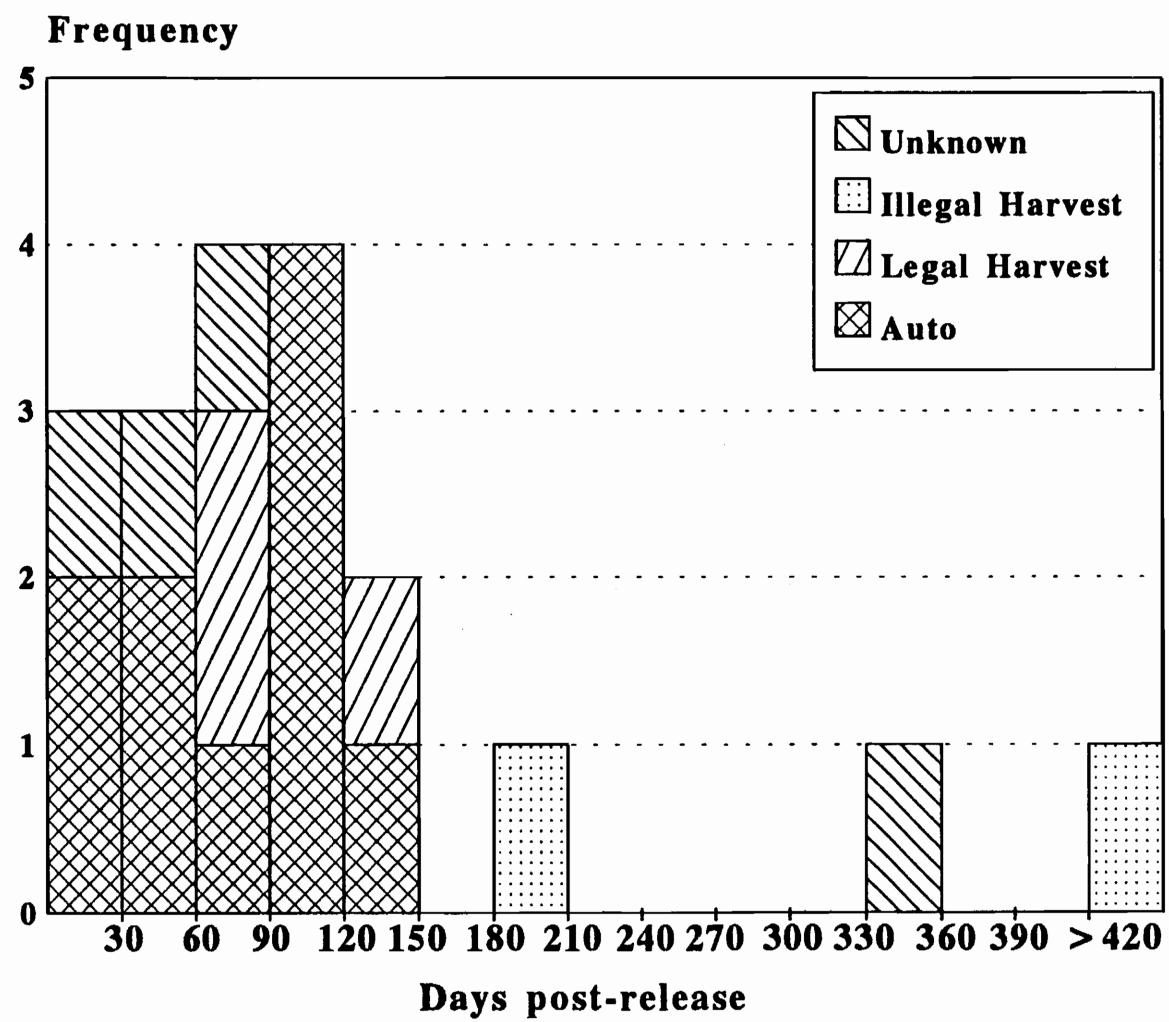

Figure 3. Distribution of mortality over 30-day intervals post-release for radiocollared black bears released in the Mt. Rogers National Recreation Area, Virginia, 1990-91.

Table 6. Monthly survival estimates, June 1990-March 1992, for radiocollared black bears released in the Mt. Rogers National Recreation Area, Virginia, 1990-91.

Month	All Bears (n=43)	Males (n=24)	Females (n=19)	1990 Releases (n=25)	1991 Releases (n=18)
June 1990	1.00		1.00	1.00	
July 1990	1.00		1.00	1.00	
Aug. 1990	0.71	0.50	1.00	0.71	
Sept. 1990	1.00	1.00	1.00	1.00	
Oct. 1990	0.95	1.00	0.92	0.95	
Nov. 1990	0.83	0.88	0.80	0.83	
Dec. 1990	0.93	0.83	1.00	0.93	
Jan. 1991	1.00	1.00	1.00	1.00	
Feb. 1991	1.00	1.00	1.00	1.00	
Mar. 1991	1.00	1.00	1.00	1.00	
Apr. 1991	0.92	0.80	1.00	0.92	
May 1991	1.00	1.00	1.00	1.00	
June 1991	1.00	1.00	1.00	1.00	1.00
July 1991	0.90	0.75	1.00	0.89	1.00
Aug. 1991	0.93	0.86	1.00	1.00	0.83
Sept. 1991	0.95	0.90	1.00	1.00	0.92
Oct. 1991	0.90	0.90	0.90	1.00	0.83
Nov. 1991	0.72	0.78	0.67	0.88	0.60
Dec. 1991	0.92	1.00	0.83	1.00	0.80
Jan. 1992	1.00	1.00	1.00	1.00	1.00
Feb. 1992	1.00	1.00	1.00	1.00	1.00
Mar. 1992	1.00	1.00	1.00	1.00	1.00
<u>Survival</u>					
Cumulative	0.23	0.12	0.37	0.38	0.31
Standard Error	0.07	0.05	0.17	0.13	0.15
Minimum[1]	0.05	0.04	0.02	0.08	0.11
Maximum[2]	0.34	0.21	0.53	0.46	0.45

[1]Assumes censored, recaptured, dropped collars, and collar retrievals are dead as of last date located.

[2]Assumes censored, recaptured, dropped collars, and collar retrievals are alive until study end, 17 March 1992.

1991 (0.31) releases (Z = 1.24; P = 0.22). Survival of bears released in 1990 did not differ (Z = 1.31; P = 0.19) between July 1990-March 1991 (0.53) and July 1991-March 1992 (0.78). However, survival over the July 1991-March 1992 interval was greater (Z = 2.14; P = 0.03) for bears released in 1990 (0.78) than for bears released in 1991 (0.31).

Survival rates for all radiocollared bears (Table 6) were lowest in August 1990 (0.71) and November 1991 (0.72). Survival was 100% for radiocollared bears during January-March 1991 and 1992.

Survival of collared bears translocated to the MRA (0.23) was lower (Z = 2.05; P = 0.04) than for bears in SNP (0.87; n = 40) over a comparable 22 month interval from July 1988-March 1990. Female survival in the MRA (0.37) was lower (Z = 3.17; P < 0.01) than female survival in SNP (0.96; n = 35). Male survival between the 2 areas was not compared due to the small number (n = 5) of male bears collared in SNP.

Survival - All bears released in the 5 counties of the MRA

Forty-four of the 168 bears (26%; Table 7) released in the 5 counties of the MRA were reported mortalities during the study. This includes the 19 collared bears reported above. Vehicle collisions (5M:8F) and legal harvest (9M:4F) were the major mortality sources, followed by illegal kill

Table 7. Cause of death for black bears released in the 5 counties of the Mt. Rogers National Recreation Area, Virginia, 1988-91.

Cause	Males	Females	Totals
Vehicle collisions	5	8	13
Legal harvest	9	4	13
Illegal kills	4	7	11
Unknown	5	2	7
Totals	23	21	44

(4M:7F). Seven bears (5M:2F) died of unknown causes. The recovery rates of male and female bears did not differ (Z = 0.53; P = 0.60). Excluding collared bears, 25 of 125 translocated bears died (20%). Ten bears (6M:4F) were legally harvested, and 9 (3M:6F) were illegally killed. Three bears (1M:2F) died from vehicle collisions, and 3 (2M:1F) died from unknown causes.

Dates of death were unreported for 13 of the 44 mortalities. Twenty-five of the 31 bears (81%) with a known death date died <210 days post-release (Figure 4). Five bears (16%) died >420 days post-release. Only 1 mortality was reported in the 210-420 day post-release interval. The greatest mortality within a single 30-day interval occurred in the 90-120 day interval (n = 6). Disregarding collared bears, the greatest mortality (n = 2) within a single interval occurred during the 90-120 and 120-150 day intervals (Figure 5).

Using Pollock et al.'s (1989) extension of the Kaplan-Meier procedure (Kaplan and Meier 1958) and deleting bears with unknown death dates, cumulative maximum survival for all bears released from June 1988 until the end of this study (46 months) was 0.54 (Table 8). Annual survival ranged from 0.89 in 1991 to 0.97 in 1989; survival of all bears over the 22 month interval of this study was 0.81. Removing collared bears from this sample, maximum survival

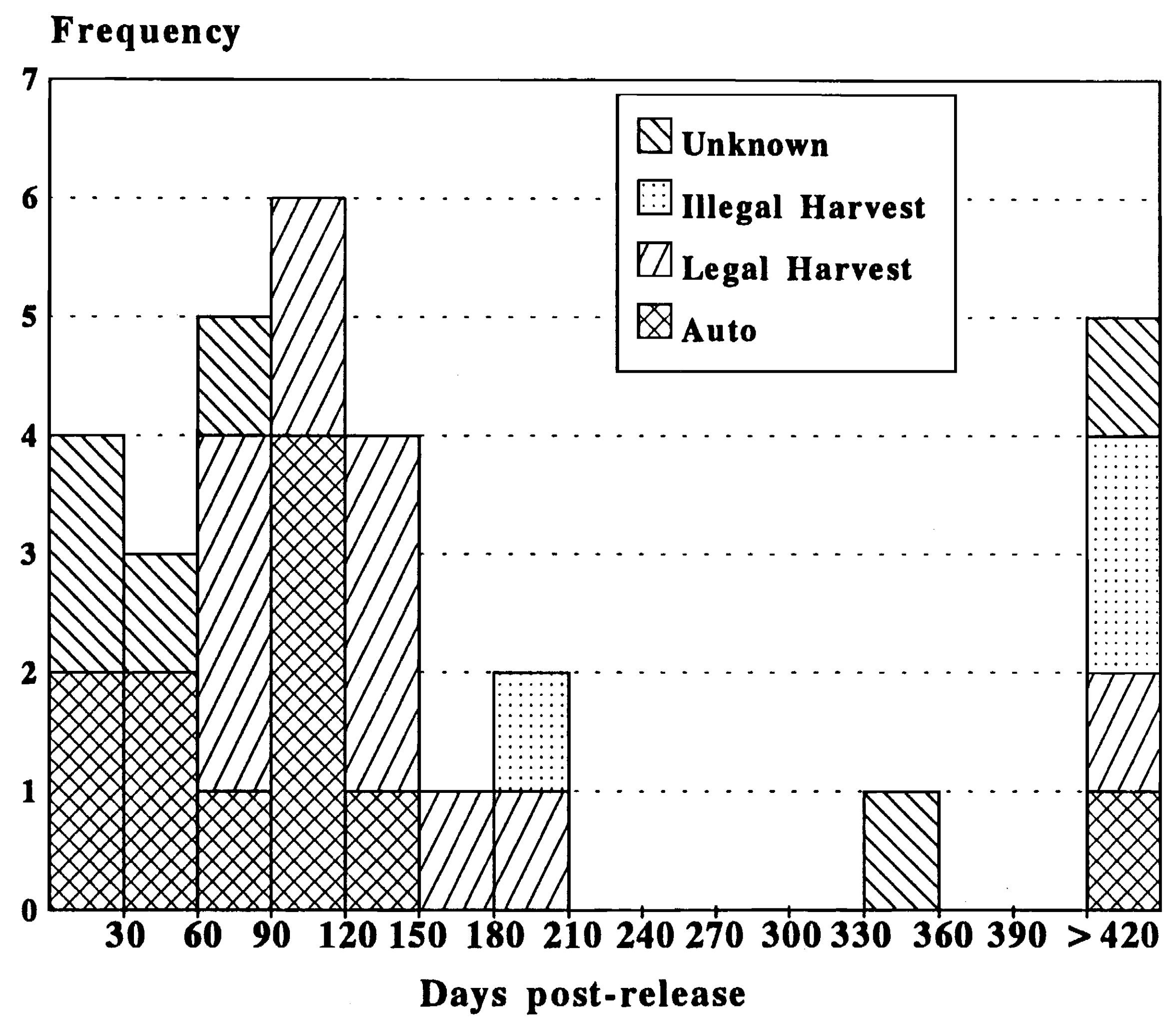

Figure 4. Distribution of mortality over 30-day intervals post-release for black bears released in the 5 counties of the Mt. Rogers National Recreation Area, Virginia, 1988-91.

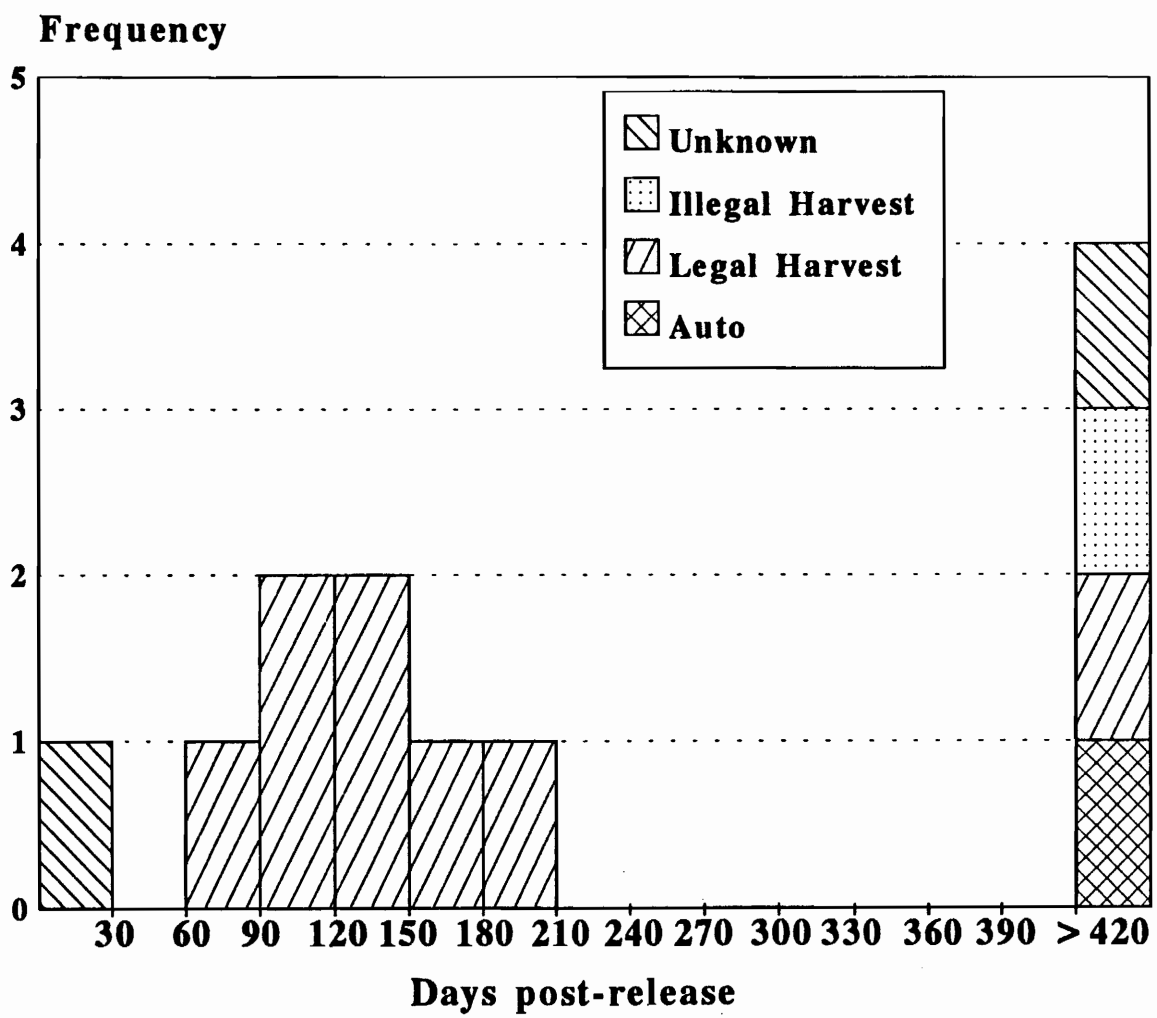

Figure 5. Distribution of mortality over 30-day intervals post-release for uncollared black bears released in the 5 counties of the Mt. Rogers National Recreation Area, Virginia, 1988-91.

Table 8. Maximum survival estimates[1] during 1988-1992, for collared and uncollared black bears released in the 5 counties of the Mt. Rogers National Recreation Area, Virginia, 1988-91.

Year	Survival rate	Interval	Cumulative survival
1988	0.70	7 months	0.70
1989	0.97	12 months	0.68
1990	0.90	12 months	0.61
1991	0.89	12 months	0.54
1992	1.00	3 months	0.54

[1]Dead bears without a death date (n=13) were omitted.

was 0.64 from June 1988 until the study end (Table 9). Annual survival ranged from 0.96 in 1990 to 0.98 in 1991. Survival of this group over the 22 month interval of this study was 0.94. Survival of uncollared bears was greater (Z = 9.49; P < 0.01) than survival of collared bears over the study interval.

Reproduction - Radiocollared bears

Eleven radiocollared adult females were released in 1990; 4 had cubs with them at the time of release. Three were released between 12 June and 13 July, and their reproductive status was unknown. One was censored and another died prior to denning. Two of the adult females released in 1990 that survived until denning were assumed to have been bred, but cubs were not found in dens of these females during the 1990-91 denning period. Cub vocalizations were heard outside the den of a female released on 3 August 1990 with a fostered cub. No other reproduction was documented the first winter of the study.

Five radiocollared adult females were translocated in 1991; 4 died prior to the denning period. The surviving female was assumed to have been bred prior to translocation, but no evidence of cubs was found in her den during winter 1991-92.

During winter 1991-92, cubs were found in 4 dens of

Table 9. Maximum survival estimates[1] during 1988-1992, for uncollared black bears released in the 5 counties of the Mt. Rogers National Recreation Area, Virginia, 1988-91.

Year	Survival rate	Interval	Cumulative survival
1988	0.70	7 months	0.70
1989	0.97	12 months	0.68
1990	0.96	12 months	0.65
1991	0.98	12 months	0.64
1992	1.00	3 months	0.64

[1]Dead bears without a death date ($\underline{n}$=13) were omitted.

radiocollared females released in 1990, indicating that breeding occurred in the study area. Mean litter size was 2.75 (3 litters of 3, 1 of 2). Sexes of cubs in 1 den were unknown. The remaining 3 dens had a sex ratio of 1:1. Cub survival following den observations was unknown because collars were removed from adults in the dens.

DISCUSSION

Survival

Translocated bears were released in unfamiliar territory; their movements following release often put them at risk of encountering mortality sources. Survival of the radiocollared bears appeared to level off by 150 days following release, possibly because they had become familiar with the area and had begun to establish home ranges by this time. This 150-day interval also coincided with the onset of denning; little, if any, mortality is usually reported during the denning period (Jonkel and Cowan 1971; Rogers 1987; Kasbohm, Va. Polytechnic Inst. and State Univ., unpubl. data.). Similar documentation of lower survival in the first several months post-release was reported in Maine (Hugie 1982) and Great Smoky Mountains National Park (GSMNP) in Tennessee (Stiver 1991). Hugie (1982) reported that the highest mortality for bears in Maine was for tagged bears trapped in Baxter State Park and released ≥100 km from the

Park. At least 7 of 19 bears (37%) moved from Baxter were killed by hunters or hit by vehicles within 3 months of being released. None of 11 bears released within Baxter were killed within a year of capture. Most (69%) of the mortality of relocated bears in GSMNP occurred within 172 days of relocation (range 4-1949 days; Stiver 1991).

Annual survival of adult black bears is usually high, e.g., 0.86 for adult bears in Montana (Jonkel and Cowan 1971), 0.78 for adults in GSMNP (Beeman 1975), and 0.74 for males ≥2.5 years and females ≥1.5 years in GDS (Hellgren 1988). Survival of collared bears translocated to the MRA was 0.23 over the entire study; 0.52 for the last 6 months of 1990, 0.44 for 1991, and 1.00 for the first 3 months of 1992. This is lower than survival rates for non-translocated populations discussed above, and also lower than survival rates reported for other translocated populations.

Translocated bears may have lower survival rates due to the stresses of translocation and lack of familiarity with the release area, but the evidence is contradictory. Rogers (1986) summarized 179 black bear translocations in 11 states and provinces and found no increase in natural mortality among translocated bears ≥2 years old. While translocation may not increase natural mortality, it may increase mortality from other sources. Human-induced mortality, especially hunting, is the major mortality source for adult black bears (Rogers 1976). Based on harvest data, translocated bears in Wisconsin (Massopust and Anderson 1984) had a lower survival rate than non-translocated bears (0.56 vs. 0.72); translocation appeared to increase mortality from hunting. Stiver (1991) suggested that GSMNP nuisance bears were habituated to humans, and relocation to unfamiliar areas increased vulnerability to hunting and other human-induced mortality. Harger (1970), however, found similar recovery rates from tag returns (from hunting and shooting of nuisance animals) for translocated (41%) and nontranslocated (38%) bears in Michigan, suggesting no difference in human-induced mortality between the 2 groups.

In this study, there was no difference between female (0.37) and male (0.12) survival. However, male bears typically have lower survival rates than female bears (Bunnell and Tait 1985, Carney 1985, Hellgren and Vaughan 1989). In a review of exploited North American bear populations, Bunnell and Tait (1985) reported that apparent mortality rates of subadult and adult bears combined calculated from harvest data were 0.17 for females and 0.26 for males. On average, the mortality rates of males were 48% higher than the rates of females. Statewide harvest records for Virginia over the past 16 years report a sex distribution skewed toward males and suggest a greater vulnerability of males to hunting. The percentage of females in the harvest has ranged from 29% in 1979 to 43% in 1985 (VDGIF 1987; D. D. Martin, VDGIF, pers. commun.). The mean percentage of females in the harvest over the past 16 years was 38%. Bunnell and Tait (1985) suggested that hunter selectivity, large home ranges, and extensive movements by male bears contribute to the greater mortality rates of males. Timing of the hunting season could also affect the difference in mortality between the sexes.

There was no between sex difference in recovery rates among collared bears (Z = 0.24; P = 0.81) nor among all bears released in the 5 counties of the MRA (Z = 0.53; P = 0.60), suggesting that both sexes were equally vulnerable to mortality. Similar results have been reported for nuisance bears in GSMNP (Stiver 1991) and translocated bears in Michigan (Harger 1970).

Only 1 of the 8 radiocollared subadult males released in the MRA was actively monitored and known to have survived throughout the study. Assuming that bears were censored because they left the study area and adjacent survey area, 6 of the 8 subadult males left the study area within 3 months of release. Resident adult males may encourage subadult male dispersal (Kemp 1976, Young and Ruff 1982) and prevent transient subadult males from establishing home ranges within an area through aggression (Jonkel and Cowan 1971, Rogers 1983). The high rate of subadult male censorship may be the result of forced dispersal from the study area by resident adult males, but there is no information on the male bear density on the study area prior to this study. It is unlikely that the high rate of subadult censorship is due to homing of bears back to their capture sites since subadult males are often transients dispersing through the capture area and have little if any attachment to the capture area (Rogers et al. 1976). If these subadult males were transient bears in their capture area, they may have continued their dispersal upon release at the MRA.

The greater survival of bears released in 1990 versus bears released in 1991 during the July 1991 to March 1992 interval is likely explained by familiarity with the area and home range establishment of the 1990 releases by July 1991. The July 1991-March 1992 interval encompassed the initial 120-day period of lower survival for the 1991 releases, while the same interval exceeded the leveling off survival limit (150 days) for the 1990 releases. Hugie (1982) and Stiver (1991) reported similar results of lower survival the first several months post-release for translocated bears in Maine and GSMNP, respectively.

All collared bears survived during January-March 1991 and 1992, which encompassed part of the denning period for Virginia bears. Typically, little, if any, mortality occurs during the denning period (Jonkel and Cowan 1971; Rogers 1987; Kasbohm, Va. Polytechnic Inst. and State Univ., unpubl. data.), although there are occasional reports of cannibalism of denned black bears (Lindzey et al. 1986, Tietje et. al 1986, Hellgren 1988).

Survival estimates for uncollared bears released in the 5 counties of the MRA were greater than survival estimates for the radiocollared subsample. It is likely that the difference is due to differences in recovery rates between these 2 groups, and does not actually reflect survival differences. Radiocollars facilitated retrieval of a greater percentage of dead and/or injured bears than did ear tags alone, and allowed for tracking and retrieval of dead and injured bears in situations and locations that would have been almost impossible to encounter without the aid of the collar. For example, a partially decomposed bear carcass was found in a stream outside of the study area by a turkey hunter. The hunter noticed the submerged collar, removed it and returned it. On a subsequent visit to the site, I found ear tags on the bear although they were difficult to find given the advanced state of decomposition of the carcass. There were 2 instances where only skeletal remains of radiocollared bears were recovered outside of the study area. In 1 case, visual observation of the radiocollar prompted its return to us; in the other, bear skeletal remains were found through aerial and ground monitoring of the radiocollar. One female bear was shot and killed within the study area, and her carcass was left at the kill site. The radiocollar was still attached to the carcass and allowed me to track the bear and determine the cause of death. These 4 examples demonstrate cases where it is unlikely a bear's death would have been known had the animal not been radiocollared. There was no difference in the proportions of males ($Z = 0.58$; $P = 0.56$) and females ($Z = 0.57$; $P = 0.57$) released among the collared and uncollared bears, and both collared and uncollared bears were released throughout the term of this study. Thus, survival rates calculated from the collared bear sample should be representative of all bears released in the study area.

The survival rate of radiocollared bears in SNP was 3.8 times greater than the survival rate of the collared translocated bears. Survival of females in SNP was 2.6 times greater than female survival in the MRA; too few males were collared in SNP to make valid comparisons. Both SNP and MRA are closed to bear hunting. Shenandoah National Park is long and narrow in shape, and female home ranges generally fall within SNP boundaries, thereby reducing exposure to risks such as hunting, poaching, and removal following damage complaints outside of SNP (Carney 1985). The MRA and adjacent areas closed to bear hunting are larger and less linear in shape than SNP and should offer translocated female bears the same, if not additional, protection. The reduced survival of females in the MRA may be due to increased movements, unfamiliarity with the area, and other effects of the translocation effort.

Causes of mortality

Vehicle collisions were the major mortality source for radiocollared male and female bears, and one of the major mortality sources for all 168 bears released in the 5 counties of the MRA. Although all mortality of collared bears from vehicle collisions occurred within 150 days post-release, there was no clear relationship between cause of death and time since release. Seven of the 10 radiocollared bears killed by vehicles were killed on Interstates 77 and 81, adjacent to the study area (Figure 6).

High traffic volumes inhibited bear movements in western North Carolina, and bears avoided roads with traffic volumes >10,000 vehicles per day (Beringer et al. 1990). Similar results were found in GSMNP (Quigley 1982). Since both groups were resident bears in the area, road avoidance may have been a learned behavior. Bears translocated to the MRA did not appear to avoid roads with high traffic volumes. Harger (1970) reported that translocation stimulated movements of Michigan bears, and Pelton (1982) concluded

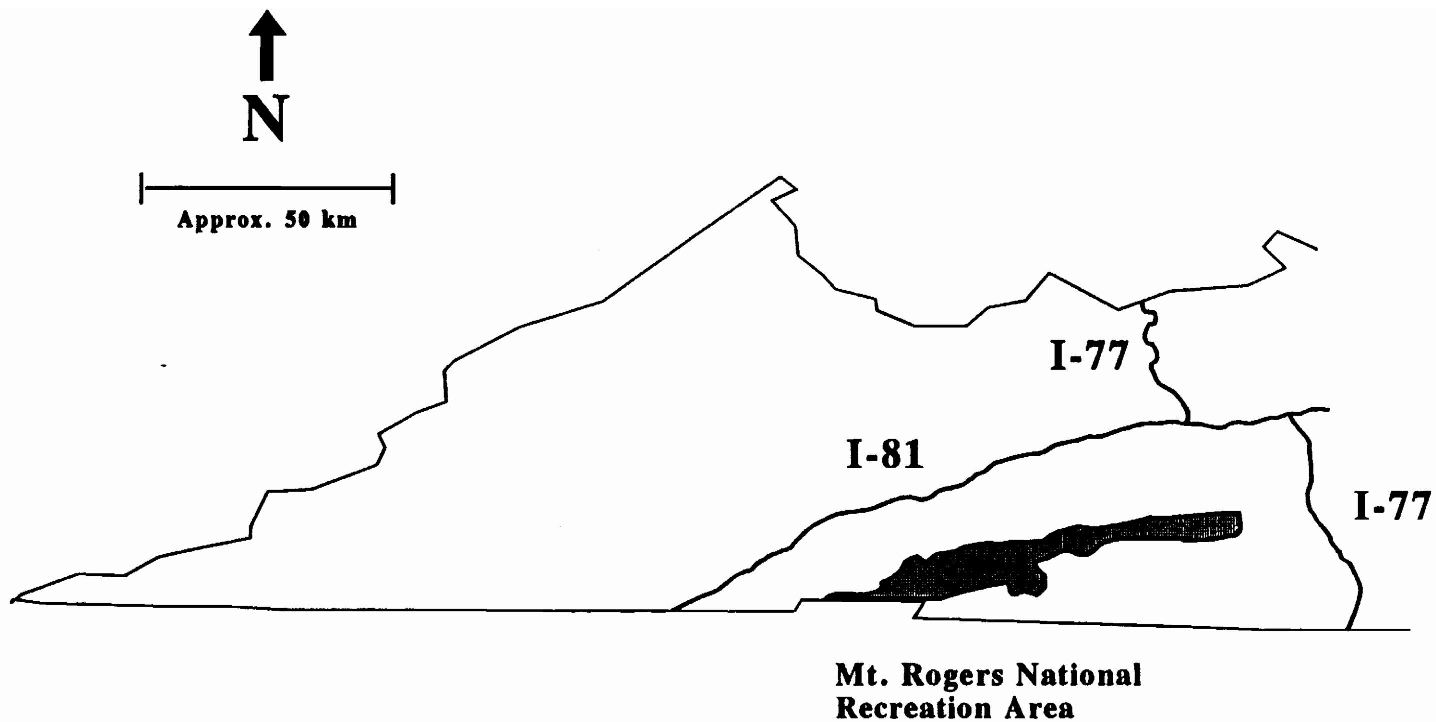

Figure 6. Location of Mt. Rogers National Recreation Area and Interstates 77 and 81 in southwestern Virginia.

that high mobility of bears in general may result in an increased mortality rate. Greater movements would increase the likelihood of encountering mortality sources such as roads, leading to greater mortality rates from such human-induced sources for translocated bears.

Vehicle collisions were a significant mortality source for Pennsylvania black bears during 1971-79, accounting for 65% of the total bear loss in years when there was no bear hunting and 7-20% of the total bear loss in years when bear hunting was permitted (Lindzey et al. 1983). Bear mortality from vehicle collisions appeared related to population levels and increased in years of low natural food availability (Lindzey et al. 1983). In the GDS, 7 of 8 bear mortalities resulting from vehicle collisions were on major highways bounding the GDS (Hellgren 1988).

Vehicle collisions may be a more significant mortality source for Virginia black bears than is commonly recognized. Translocated collared bears were killed by vehicle collisions (10 of 43; 23%) at a higher rate ($Z = 4.42$; $P < 0.01$) than uncollared translocated bears (3 of 125; 2%), which may be explained by greater visibility of radiocollars over ear tags. All translocated bears were tagged with small metal ear tags. From handling bears in dens, it was obvious that the small metal tags were not always immediately visible as they were often covered with hair.

It is unknown how thoroughly the person finding the dead bear and/or investigating the scene (game warden, state police, or highway road crew) examined the bear for ear tags. In at least 1 case of a collared bear mortality on Interstate 81, the state trooper investigating the scene did not check the carcass for ear tags or a radiocollar. The ear tags and radiocollar were returned by the person who towed the damaged vehicle from the scene.

The major mortality source (10 of 25 mortalities; 6M:4F) for uncollared bears released in the 5 county study area (n = 125) was legal harvest. Since the release area of the bears was closed to hunting, these bears had presumably traveled outside of the study area. Five bears were harvested in the areas of Washington, Wythe, and Smyth counties that remained open to bear hunting and did not necessarily travel very far from the study area boundaries. One bear was harvested in Pulaski County, a county adjacent to the 5 counties of the study area. The remaining 4 bears were harvested in North Carolina, West Virginia, and Craig County, Virginia. At least 9 (3M:6F) of the 125 bears released without collars were illegally killed. Records are incomplete as to the location of kill, therefore it is unknown if these bears were killed inside or outside of the study area.

Information about mortalities of tagged, collared bears was more likely to be quickly received than information about mortalities of tagged, uncollared bears. The procedures and channels of communication for reporting bear mortalities among the VDGIF and other agencies (e.g., state and local police departments, Virginia Transportation Department) are not well defined. Procedures have been in place for reporting tagged bear mortalities, but through employee attrition they have become less clear and are infrequently followed (D. D. Martin, VDGIF, pers. commun.). Although bear mortality reports may have been given to a VDGIF employee, the information was not always reported in a timely fashion to the VDGIF Staunton office where all bear records are maintained. This was demonstrated by several instances where records of bear mortalities within the study area obtained from VDGIF employees were not consistent with mortality reports received from the Staunton office. Thus, due to inconsistent reporting procedures and failure of people on the scene to check killed bears for tags, the number of tagged bears killed by vehicles and other sources in southwestern Virginia is believed to be under-reported.

Radiocollars also facilitated retrieval of bears that were hit by cars but not immediately killed. One collared bear reported hit by an automobile on a secondary road in Wythe County was subsequently found injured a short distance from the road. The injuries were extensive and the bear was euthanized. Had this bear not been collared, it is unlikely it would have been found or its death recorded.

Censored bears

Ten (7M:3F) of the 43 collared bears were censored when radio contact was lost for >4 months. Possible causes for censoring included a bear leaving the study area and surrounding search area, transmitter malfunction, or transmitter failure due to a destroyed collar. Four censored bears were subadult males, 3 were adult males, and 3 were adult females. The larger number of censored males may be due to their larger home ranges and wider movement patterns (Alt et al. 1980, Reynolds and Beecham 1980, Pelchat and Ruff 1986), increasing the likelihood that they left the search area. Homing of bears back to their capture sites may have contributed to the high rate of censorship (see Chapter 3).

Resumed nuisance activity

Only 1 of the 43 collared translocated bears (2%) resumed nuisance activity; 5 of the 125 uncollared translocated bears (4%) were recaptured for nuisance activity. Trapping and moving bears may reduce further nuisance activity. In an earlier Virginia study, Fies et al. (1987) found that only 3% of relocated nuisance bears were known to resume nuisance activity. McLaughlin et al. (1981) reported that 15% of 75 nuisance bears translocated in northcentral Pennsylvania resumed nuisance activity. In contrast, 32% of 333 nuisance bears captured and relocated in GSMNP were recaptured due to further nuisance activity (Stiver 1991). Nuisance bears were successfully moved to the MRA and created very few nuisance problems in the release area.

Reproduction

None of the females assumed to have been bred prior to translocation (2 in 1990-91, 1 in 1991-92) produced viable cubs the first winter following release (i.e., no cubs or evidence of cubs was observed at dens). The stress of translocation to an unfamiliar territory may have caused female bears with viable blastocysts to fail to implant or resorb/abort their young. Successful cub production has been linked to female nutritional status in that failure to gain sufficient weight prior to denning often results in failure to produce cubs or immediate neonate mortality induced by the female. Rogers (1976) found that female bears in Minnesota ≥3.5 years old failed to produce cubs when they weighed <67 kg on 1 October ($\underline{n}$ = 16). Females weighing >80 kg on 1 October produced cubs in 28 of 30 cases. Females weighing >67 kg and <80 kg had variable success. Kolenosky (1990) found a similar relationship between minimum fall weights and successful reproduction for bears in west-central Ontario. Females in GSMNP delayed reproduction when white oak acorn production was poor (Pozzanghera 1990). It is possible that translocated bears are nutritionally stressed and thus fail to implant or resorb/abort their cubs, or consume them at birth, although no bears examined in the dens appeared to be in exceptionally poor nutritional condition. Lindzey et al. (1986) concluded that failure of nutritionally stressed females to implant would be a sound strategy for a long-lived species like the black bear. Failure to implant due to stresses related to the translocation effort such as physical or psychological trauma from the capture and release procedure also would be a reasonable response for bears.

Cub vocalizations were heard outside the den of a female released on 3 August 1990 with a fostered cub. At the time of initial capture, the female appeared to be lactating although no cubs were captured at the site. An orphan cub was fostered to this female and released with her. This bear may have lost her own cubs, come into estrus, and bred prior to her capture and translocation. The fate of the fostered cub is unknown. Immediately following den emergence on 10 April 1991 this female made a

46-km movement. No evidence of cubs was found in the den the following day. It is unlikely that the cubs heard in the den survived since the presence of cubs usually restricts females' movements for a short period immediately following den emergence (Alt et al. 1980, Reynolds and Beecham 1980, Rogers 1987). Although visual observations of females released with cubs were attempted, none of the observations were successful, thus the fates of cubs released with females are unknown.

The 1:1 sex ratio observed in this study is commonly reported for black bear cubs (Jonkel and Cowan 1971, Kemp 1972, Reynolds and Beecham 1980, Alt 1982, Carney 1985, Rogers 1987). The mean litter size of 2.75 cubs was not different from the average litter sizes reported in SNP ($\bar{x}$ = 2.0, $\underline{P}$ = 0.08; Carney 1985) or GDS ($\bar{x}$ = 2.3, $\underline{P}$ = 0.17; Hellgren and Vaughan 1989). Greater average litter sizes have been reported in Pennsylvania ($\bar{x}$ = 2.9; Alt 1982) and in Michigan for bears feeding at dumps ($\bar{x}$ = 3.1; Rogers et al. 1976). The average litter size determined from den observations for 352 litters from 8 eastern bear populations was 2.5 cubs (Table 10). The greater mean litter size of this study may be a reflection of the small sample size of only 4 litters.

The reproductive success of uncollared female bears is unknown. Based on the frequency of reported sightings of

Table 10. Mean litter sizes of eastern black bear populations based on den observations.

Location	Litter Size	n[1]	Source
Michigan	2.2	20	Erickson et al. 1964
Maine	2.5	154	C. R. McLaughlin, Maine Dep. Inland Fish. and Wildl., pers. commun., 1992.
Massachusetts	2.3	27	Elowe and Dodge 1989
Pennsylvania	2.9	68	Alt 1982
Virginia	2.0	21	Carney 1985
Great Dismal Swamp (VA/NC)	2.3	7	Hellgren and Vaughan 1989
Tennessee	2.6	45	Eiler et al. 1989
Florida	2.2	10	Harlow 1961
	$\bar{x}$ = 2.5	352	

[1]Number of litters.

females with cubs in the Mt. Rogers area, reproduction probably occurred among some of the uncollared females.

LITERATURE CITED

Alt, G. L. 1982. Reproductive biology of Pennsylvania's black bear. Pa. Game News 53(2):9-15.

______, G. J. Matula, Jr., F. W. Alt, and J. S. Lindzey. 1980. Dynamics of home range and movements of adult black bears in northeastern Pennsylvania. Int. Conf. Bear Res. and Manage. 4:131-136.

Beeman, L. E. 1975. Population characteristics, movements and activities of the black bear (Ursus americanus) in the Great Smoky Mountains National Park. Ph.D. Diss., Univ. Tenn., Knoxville. 218pp.

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

Bunnell, F. L., and D. E. N. Tait. 1985. Mortality rates of North American bears. Arctic 38:316-323.

Carney, D. W. 1985. Population dynamics and denning ecology of black bears in Shenandoah National Park, Virginia. M.S. Thesis, Va. Polytechnic Inst. and State Univ., Blacksburg. 84pp.

Cox, D. R., and D. Oakes. 1984. Analysis of survival data. Chapman and Hall, New York, N.Y. 201pp.

Eiler, J. H., W. G. Wathen, and M. R. Pelton. 1989. Reproduction in black bears in the southern Appalachian Mountains. J. Wildl. Manage. 53:353-360.

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

Erickson, A. W., J. Nellor, and G. A. Petrides. 1964. The black bear in Michigan. Mich. State Univ. Agric. Exp. Stn. Res. Bull. 4. 102pp.

Fies, M. L., D. D. Martin, and G. T. Blank, Jr. 1987. Movements and rates of return of translocated black bears in Virginia. Int. Conf. Bear Res. and Manage. 7:369-372.

Harger, E. M. 1970. A study of homing behavior of black bears. M.A. Thesis, Northern Mich. Univ., Marquette. 81pp.

Harlow, R. F. 1961. Characteristics and status of Florida black bear. Trans. North Am. Wildl. and Nat. Resource Conf. 26:481-495.

Hellgren, E. C. 1988. Ecology and physiology of a black bear (Ursus americanus) population in Great Dismal Swamp and reproductive physiology in the captive female black bear. Ph.D. Diss., Va. Polytechnic Inst. and State Univ., Blacksburg. 231pp.

______, and M. R. Vaughan. 1989. Demographic analysis of a black bear population in the Great Dismal Swamp. J. Wildl. Manage. 53:969-977.

Hugie, R. D. 1982. Black bear ecology and management in the northern conifer-deciduous forests of Maine. Ph.D. Diss., Univ. Montana, Missoula. 203pp.

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

Kalbfleisch, J. D., and L. Prentice. 1980. The statistical analysis of failure data. John Wiley and Sons, New York, N.Y. 321pp.

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. J. Am. Stat. Assoc. 53:457-481.

Kemp, G. A. 1972. Black bear population dynamics at Cold Lake, Alberta, 1968-70. Int. Conf. Bear Res. and Manage. 2:26-31.

______. 1976. The dynamics and regulation of black bear, Ursus americanus, populations in northern Alberta. Int. Conf. Bear Res. and Manage. 3:191-197.

Kolenosky, G. B. 1990. Reproductive biology of black bears in east-central Ontario. Int. Conf. Bear Res. and Manage. 8:385-392.

Lindzey, F. G., K. R. Barber, R. D. Peters, and E. C. Meslow. 1986. Responses of a black bear population to a changing environment. Int. Conf. Bear Res. and Manage. 6:57-63.

Lindzey, J. S., G. L. Alt, C. R. McLaughlin, and W. S. Kordek. 1983. Population response of Pennsylvania black bears to hunting. Int. Conf. Bear Res. and Manage. 5:34-39.

Massopust, J. L., and R. K. Anderson. 1984. Homing tendencies of translocated nuisance black bears in northern Wisconsin. Proc. East. Workshop Black Bear Manage. and Res. 7:66-73.

McLaughlin, C. R., C. J. Baker, A. Sallade, and J. Tamblyn. 1981. Characteristics and movements of translocated nuisance black bears in northcentral Pennsylvania. Pa. Game Comm. Rep., Harrisburg. 31pp.

Pelchat, B. O., and R. L. Ruff. 1986. Habitat and spatial relationships of black bears in boreal mixedwood forest of Alberta. Int. Conf. Bear Res. and Manage. 6:81-92.

Pelton, M. R. 1982. Black bear. Pages 504-514 in J. A. Chapman and G. A. Feldhammer, eds. Wild mammals of North America: biology, management, and economics. Johns Hopkins Univ. Press, Baltimore, Md.

______. 1986. Habitat needs of black bears in the East. Pages 49-53 in D. L. Kulhavy and R. N. Conner, eds. Wilderness and natural areas in the eastern United States: a management challenge. Center of Applied Studies, School of Forestry, S. F. Austin State Univ., Nacogdoches, Tex. 416pp.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. J. Wildl. Manage. 53:7-15.

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

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

Reynolds, D. G., and J. J. Beecham. 1980. Home range activities and reproduction of black bears in west-central Idaho. Int. Conf. Bear Res. and Manage. 4:181-190.

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

______. 1983. Effects of food supply, predation, cannibalism, parasites, and other health problems on black bear populations. Pages 194-211 in F. L. Bunnell, D. S. Eastman, and J. M. Peek, eds. Symposium of natural regulation of wildlife populations. For. Wildl. and Range. Exp. Station, Univ. Idaho, Moscow.

______. 1986. Effects of translocation distance on frequency of return by adult black bears. Wildl. Soc. Bull. 14:76-80.

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

______, D. W. Kuehn, A. W. Erickson, E. M. Harger, L. J. Verme, and J. J. Ozoga. 1976. Characteristics and management of black bears that feed in garbage dumps, campgrounds or residential areas. Int. Conf. Bear Res. and Manage. 3:169-175.

Stiver, W. H. 1991. Population dynamics and movements of problem black bears in Great Smoky Mountains National Park. M.S. Thesis, Univ. Tenn., Knoxville. 134pp.

Tietje, W. D., B. O. Pelchat, and R. L. Ruff. 1986. Cannibalism of denned black bears. J. Mamm. 67:762-766.

Virginia Department of Game and Inland Fisheries (VDGIF). 1987. Virginia wildlife investigations. Fed. Aid in Wildl. Restor. Annu. Rep., July 1, 1987-June 30, 1988.

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

CHAPTER 2: POPULATION MODEL

The primary objective of the translocation effort was to reestablish a self-sustaining bear population in southwestern Virginia for recreational purposes, with the possibility of reopening the area to bear hunting in the future. A population model was used to predict the rate at which the translocated population in the 5 counties of the Mt. Rogers National Recreation Area (MRA) might be expected to grow after the initial releases.

METHODS

RAMAS/age (Ferson and Akcakaya 1991), a single-species, age-structured population model, based on a modified Leslie matrix, was used to model fluctuations in the translocated black bear population in the 5 counties of the MRA. Based on the lack of estimates of bear numbers in the release area prior to the translocation effort, and speculation by VDGIF (Virginia Department of Game and Inland Fisheries) personnel that there were very few bears in the area, I assumed there were no bears present in the study area prior to the translocations. Consequently, density dependence was not included in the model.

Given the breeding biology of bears, the large home ranges of males, and the preponderance of male bears released in the MRA (100M:68F), only the female segment of the population was modeled. Thus, I assumed that the density of male bears in the release area was sufficient to ensure that all females in estrus were bred.

Age classes used in the model were cubs, 1-year olds, 2-year olds, and adults (denoted below by subscripts 0, 1, 2, and 3, respectively). The numbers of individuals at the end of each year were calculated by the RAMAS software from the following formulas:

Cubs $N_0 = F_3N_3 + M_0$

1-year olds $N_1 = S_0N_0 + M_1$

2-year olds $N_2 = S_1N_1 + M_2$

Adults $N_3 = S_2N_2 + M_3 + S_3N_3$

where F, M, and S represent fecundity, migration (i.e., bears leaving, entering, or translocated into the area), and survival, respectively. The model treats all immigrants (i.e., translocated bears) as having 100% survival their first year. Because mortality occurred in the first year following translocation, the numbers of bears input into the model were reduced to account for first year mortality. Reproduction of the adult age class was calculated prior to survival by RAMAS, thus true cub survival was reduced to account for adult mortality occurring after reproduction within the model. Demographic and environmental stochasticity were included in the model, and results were summarized over 50 replications of the model.

Input parameters for the model (Table 11) were derived from this and other Virginia bear studies (Carney 1985, Hellgren 1988). The fecundity rate was based on the mean litter size of 32 litters from this study, SNP (Carney 1985), and the Great Dismal Swamp (GDS; Hellgren 1988). The translocated bear population was simulated for 4 years (1989-92) with bears added each year (1988-91), representing the actual translocations that occurred from 1988-91. The mean number of females released was 17 per year (4 cubs, 1 1-year old, 1 2-year old, and 11 adults); the actual numbers added into the model each year were reduced to account for first year mortality rate in each age class. Fecundity was reduced during this 4-year period to account for a 1-year lag in reproduction after translocation.

I assumed that, after an initial adjustment period, survival and fecundity approximated other unexploited, established populations. Thus, at the end of the initial 4-year simulation period, the population was simulated for an additional 10 years (1993-2002) using a survival rate of 0.85 for adult females and the average fecundity for 3 Virginia bear populations (this study, Carney 1985, Hellgren 1988). The adult survival rate was based on estimates of second-year adult female survival of 0.80 in this study (n = 5), survival of 0.84 for females >1.5 years in GDS (Hellgren 1988), and survival of 0.93 for adult females in SNP (Carney

Table 11. Input parameters used for population model simulating the translocated female black bear population at Mt. Rogers National Recreation Area, Virginia.

Parameter			Source
Years to run	4 years	10 years	
Migration or Translocation			
(females)			This study
Cubs	2.80	0	
1-year olds	0.46	0	
2-year olds	0.61	0	
Adults	5.39	0	
Annual survival			Adults for first 4
Cubs	0.343	0.595	years, this study.
1-year olds	0.460	0.460	Remaining data from
2-year olds	0.610	0.610	Carney (1985)
Adults	0.490	0.850	
Adult fecundity			
(female cubs/			
litter/year)	0.43	0.54	This study, Carney (1985), Hellgren (1988)

1985). No additional bears were added through translocation during the 10-year simulation, representing the discontinuation of bear translocations to the MRA in 1992.

RESULTS

After 4 years of translocations into the MRA, there were 45 (SD = 10) females in the simulated population (Figure 7). The number of individuals in each age class remained the same or increased throughout the 4-year period (Figure 8). The instantaneous rate of increase (r) during this period was 0.40. At the end of 10 additional years, the simulated population contained 29 (SD = 8) females (Figure 7). The number of cubs and adults continually decreased throughout the 10-year period; the number of 1- and 2-year olds increased early in the interval and then remained the same or decreased (Figure 8). The instantaneous rate of increase (r) of the simulated population over 10 years was -0.05.

DISCUSSION

The 2 major assumptions in this simulation were that the male bear density was sufficient to ensure that all females in estrus were bred and that there were no bears in the release area prior to translocation. The former is most likely valid given bear breeding biology and the large

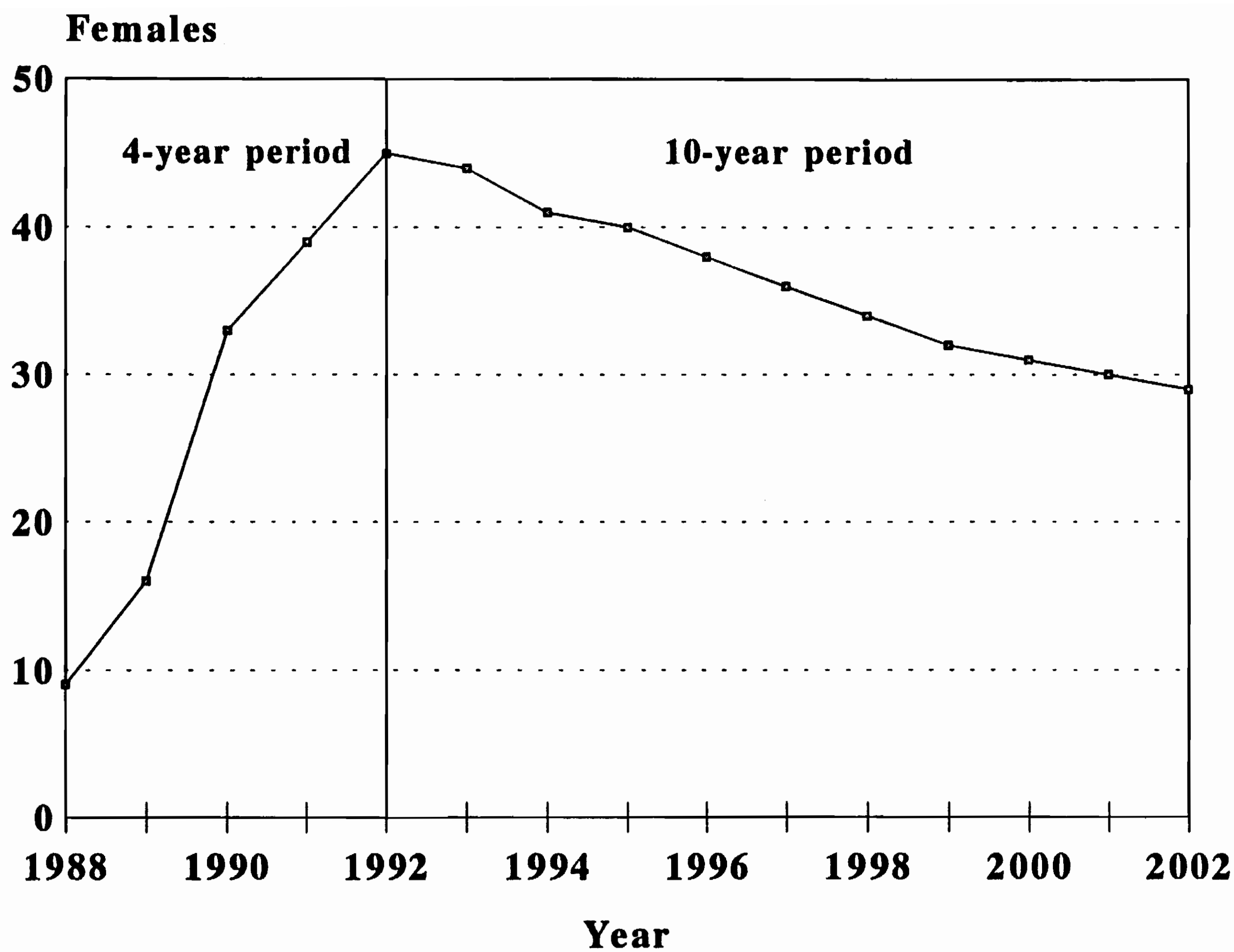

Figure 7. Predicted number of female black bears in simulated population at Mt. Rogers National Recreation Area, Virginia.

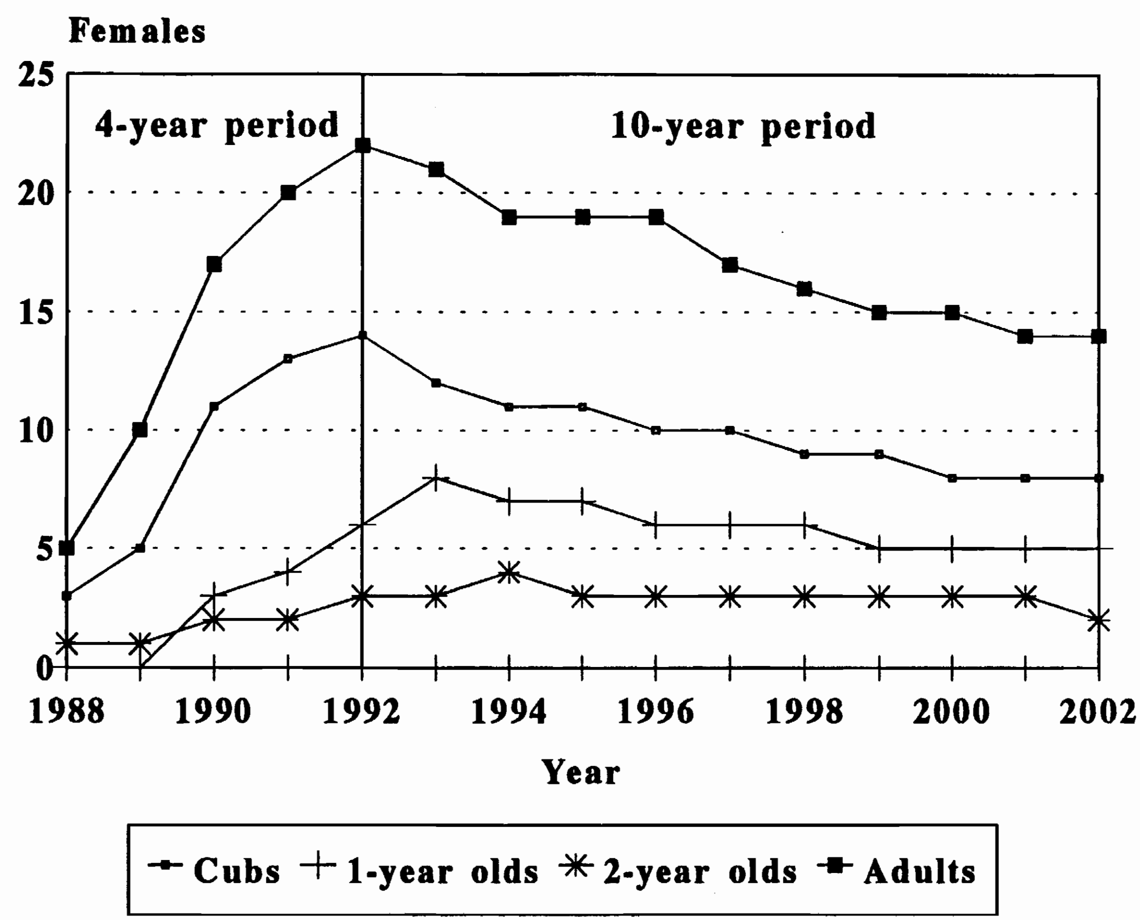

Figure 8. Predicted number of female black bears by age class in simulated population at Mt. Rogers National Recreation Area, Virginia.

number of males released. The validity of the latter assumption is questionable. There were no formal estimates of bear numbers in the release area prior to the translocation effort, and it is possible that a small bear population existed in the MRA. Violation of this latter assumption would result in underestimation of the population size and growth rate.

The simulated population grew exponentially over the first 4 years due primarily to the addition of bears to the population each year through translocation. If bears had not been added beyond the first year, the population would have decreased (i.e., $r = -0.44$) for the first 4 years.

Computer simulation indicated a slowly decreasing ($r = -0.05$) female population over 10 years, if the input population parameters prevail. Both adult and cub survival, as input in the model, nearly doubled from the initial 4-year period to the 10-year period, without a corresponding increase in the population. The population decrease during the 10-year period is due to the discontinuation of translocations into the population and the low survival of the 1- and 2-year old classes.

The 1- and 2-year old survival rates used in the model were the converse of the mortality/disappearance rates calculated by Carney (1985) through life table analysis for the combined sexes. These probably underestimated female survival since males typically have greater subadult mortality/disappearance rates than females due to the dispersing nature of the males (Bunnell and Tait 1985). Female subadult survival rates from this study were not used in the model due to the small number ($\underline{n}$ = 3) of subadult females collared.

In a review of several exploited North American black bear populations, Bunnell and Tait (1985) reported apparent subadult mortality rates of 15-35% annually for male and female bears; male rates were greater than female rates. I ran the population simulation using the lower extreme of Bunnell and Tait's (1985) mortality range based on the knowledge that female mortality is less than male mortality and the fact that Bunnell and Tait's (1985) rates were derived from exploited populations while the MRA population is unexploited. This simulation resulted in 70 (SD = 16; r = 0.05) female bears in the translocated population after 10 years.

In reality, the true female subadult survival probably falls somewhere between the estimates of Carney (1985) and the upper extreme of Bunnell and Tait (1985). At a low population density, survival rates should be greater than they would be once the population becomes more concentrated. I examined the effect different subadult survival would have on the model by decreasing subadult survival incrementally over the 10 years between the estimates of Bunnell and Tait (1985) and Carney (1985). This simulation resulted in 48 (SD = 5; r = 0.01) female bears at the end of 10 years.

Bears (*Ursus* species) have the lowest reproductive rate of all terrestrial mammals in North America (Jonkel and Cowan 1971). Age at first reproduction, litter size, and breeding interval determine a population's reproductive rate, and these factors appear to be dictated by nutrition (Bunnell and Tait 1981). The average litter size of bears in this study was 2.75 cubs (n = 4 litters), however due to the small sample size, an average litter size ($\bar{x}$ = 2.16; n = 32) based on den observations in MRA, SNP, and GDS was used to calculate fecundity for the model. It is possible that the increased litter size observed in this study was the result of low bear density and good nutrition. The average litter size of 3.0 cubs reported for Pennsylvania black bears (Alt 1980), has been attributed to an abundant and dependable natural food supply in addition to food sources provided intentionally or inadvertently by humans. Increased growth rates and larger fat reserves, and thus larger litters have been reported for female bears with access to food sources of human origins (Rogers 1976, Rogers et al. 1976).

Bears released in the MRA may have a higher litter size as a result of low densities, abundant resources, and little, if any, intraspecific competition. Over time, the mean litter size would be expected to decrease as bear density increased. I examined the effect such a mechanism would have on the translocated population by basing input fecundity estimates on an average litter size of 3.0 for the first 4 years and then decreasing mean litter size from 3.0 to 2.0 in 0.1 increments over the 10-year period. This simulation resulted in 33 (SD = 4; r = -0.04) female bears in the population after 10 years.

Models are simplifications of reality. While they are quicker and less costly than extensive field research, the question remains about how adequately they represent reality. Given the potential adjustments to this model, the female segment of the MRA bear population is expected to be somewhere between 29 and 70 bears by the year 2002 if there are no major changes in adult and cub survival or fecundity. The results reported here ignore bears entering or leaving the study area. Because many bears left the study area (see Chapter 3), the number of bears predicted to be in the population is likely overestimated.

LITERATURE CITED

Alt, G. L. 1980. Rate of growth and size of Pennsylvania black bears. Pa. Game News 51(12):7-17.

Bunnell, F. L., and D. E. N. Tait. 1981. Population dynamics of bears - implications. Pages 75-98 in C. W. Fowler and T. D. Smith, eds. Dynamics of large mammal populations. John Wiley and Sons, Inc. New York, N.Y.

______, and ______. 1985. Mortality rates of North American bears. Arctic 38:316-323.

Carney, D. W. 1985. Population dynamics and denning ecology of black bears in Shenandoah National Park, Virginia. M.S. Thesis, Va. Polytechnic Inst. and State Univ., Blacksburg. 84pp.

Ferson, S. and H. R. Akcakaya. 1991. RAMAS/age user manual. Modeling fluctuations in age-structured populations. Exeter Software, Inc. New York. 146pp.

Hellgren, E. C. 1988. Ecology and physiology of a black bear (*Ursus americanus*) population in Great Dismal Swamp and reproductive physiology in the captive female black bear. Ph.D. Diss., Va. Polytechnic Inst. and State Univ., Blacksburg. 231pp.

Jonkel, C. J., and I. McT. Cowan. 1971. The black bear in the spruce-fir forest. Wildl. Monogr. 27.

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

______, D. W. Kuehn, A. W. Erickson, E. M. Harger, L. J. Verme, and J. J. Ozoga. 1976. Characteristics and management of black bears that feed in garbage dumps, campgrounds or residential areas. Int. Conf. Bear Res. and Manage. 3:169-175.

CHAPTER 3: BEAR MOVEMENTS

The ability of translocated black bears to return to their capture sites has been reported in New York (Sauer et al. 1969), Michigan (Harger 1970), Newfoundland (Payne 1975), Great Smoky Mountains National Park (GSMNP; North Carolina-Tennessee; Beeman and Pelton 1976), northeastern (Alt et al. 1977) and northcentral Pennsylvania (McLaughlin et al. 1981), British Columbia (Rutherglen and Herbison 1977), Montana (McArthur 1981), Minnesota (Rogers 1986b), and Virginia (Fies et al. 1987). The exact mechanism of homing is poorly understood. It is uncertain whether bears home by random movements, familiarity with large areas, traveling along a particular compass bearing, or by some other means of navigation (Rogers 1988).

Because the objective of the translocation effort was to reestablish a viable bear population in southwestern Virginia, it was essential to know whether the translocated bears remained in their release areas. The incidence of homing or bears dispersing from their release areas was necessary for evaluation of the translocation management strategy. This segment of the research focused on analyzing movements of the bears translocated to the Mt. Rogers National Recreation Area (MRA).

METHODS

Bears were located from fixed-wing aircraft with directional yagi antennas mounted under each wing and by ground triangulation with hand-held yagi antennas. Ground locations were plotted on 7.5 minute United States Geological Survey topographical maps and recorded as Universal Transverse Mercator (UTM) coordinates. Aerial locations were recorded as LORAN-C coordinates and converted to UTM coordinates. The study area and areas south of it were regularly flown to search for bears. Areas to the north of the study area were less frequently monitored from the air.

Bears were classified as censored, alive, or dead on their recovery or last location. Censored bears included bears with which radio contact was lost, recaptured bears removed from the study, and bears that dropped their collars. Bears classified as alive survived throughout the study or had their collars removed during winter 1992.

Only bears that moved >10 km from their release sites were included in the distance, directional, and time monitored analyses. Bears that moved <10 km from release sites were not considered to have left their release areas.

Distances between capture, release, and recovery or last locations of bears were calculated using the Pythagorean theorem. Differences in distance moved as well as differences in number of days between release and recovery/last location among sex and fate classes were tested using the Wilcoxon rank sum test and the Kruskal-Wallis test (Hollander and Wolfe 1973). Distances between recovery/last location and release were broken into the following intervals: 0-10 km, >10 km, >20 km, >30 km, and >40 km. The proportions of males and females within each interval were compared using 2-sample proportion tests. Significance was tested at the 0.05 level for all statistical analyses. Following the protocol of Fies et al. (1987) for translocated Virginia bears, bears successfully returned home if they were recovered within 15 km (males) or 10 km (females) of their original capture sites.

Angles between capture, release, and recovery locations were calculated using trigonometric functions. Directional data were analyzed using circular statistics (Batschelet 1981). The V test, a modification of the Rayleigh test (Batschelet 1981:58), was used to test the null hypothesis that bear movements were randomly distributed for bears that left their release areas.

Bears were classified as in or out of the MRA as of their last location. Given the small area of the MRA (62,330 ha) and the need to approach the translocation project from a larger scale, bears also were classified as in or out of the area in southwestern Virginia bounded by

Interstates 81 and 77 and the Virginia state line (81-77-state line area; 316,400 ha; Figure 9). Bears killed on the interstates were classified as out of that area. Proportions of bears by sex, age, and fate classes that remained in the MRA and the 81-77-state line area were compared with 2-sample proportion tests. Z tests on binomial parameters were used to test the null hypothesis that the proportions of bears that remained in the MRA (or 81-77-state line area) were not different from 0.50 (i.e., bears were equally likely to stay or leave the area). Since the proportion of bears that left these areas is the converse of those that remained, it was not necessary to run tests on the proportions leaving.

RESULTS

Eleven bears (6M:5F) survived the study, while 19 (11M:8F) were recovered dead during the study. Thirteen bears (7M:6F) were censored (radio contact lost with 10, 1 removed from study area, 2 dropped collars).

Eleven bears (7M:4F) did not leave their release areas (i.e., moved <10 km from release site). Four of the 11 were censored at locations <10 km from release, 1 was never found after release, 2 were recovered dead, and 4 survived throughout the study. The remaining 32 bears (17M:15F) moved >10 km from their release sites.

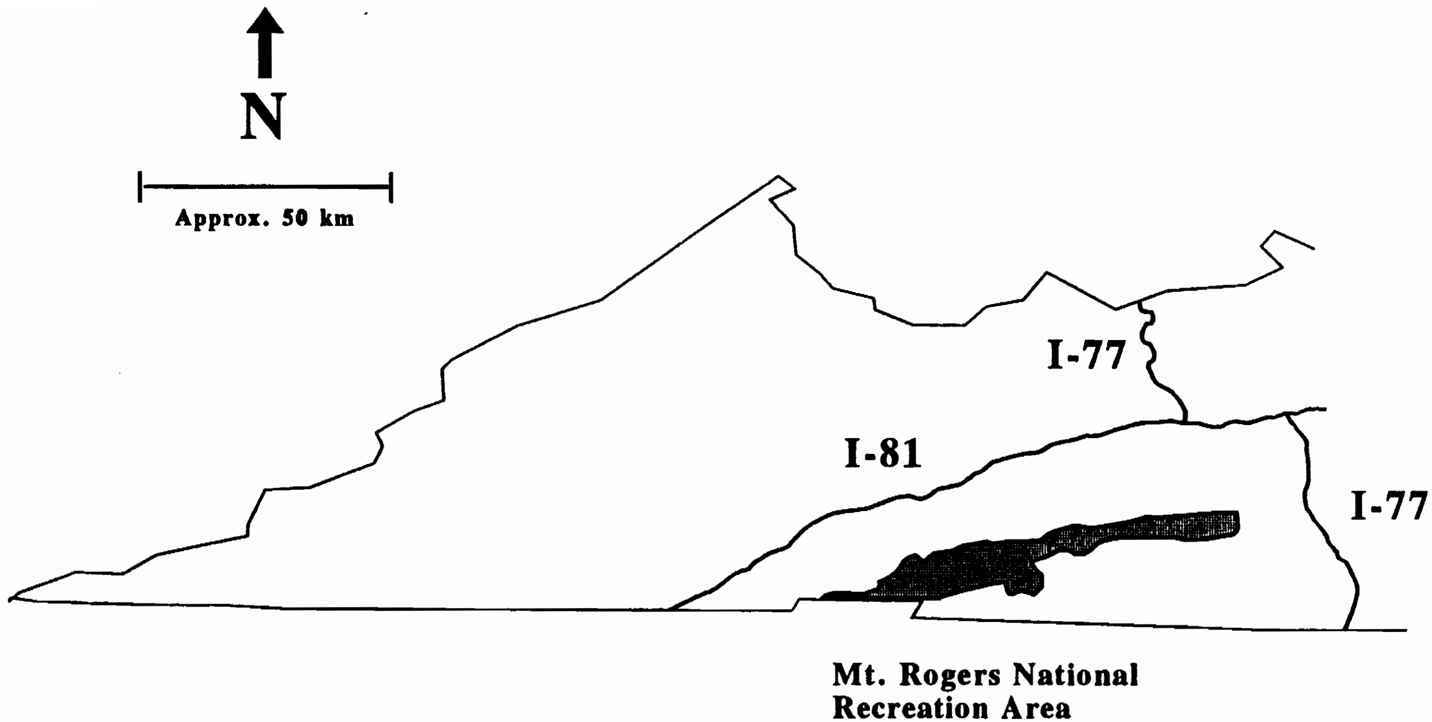

Figure 9. Location of Mt. Rogers National Recreation Area and Interstates 77 and 81 in southwestern Virginia.

Time monitored

The mean time between release and recovery/last location was 276 days (*n* = 10; median = 227 days; range = 2-593 days) for bears that remained in their release areas and 169 days (*n* = 32; median = 92 days; range = 11-598 days; Table 12) for bears that left their release areas. Days elapsed between release and recovery/last location of bears that left their release areas were not different for males and females (Z = 0.79; P = 0.43), or for bears recovered dead and censored bears (Z = 0.61; P = 0.54). More days elapsed from release to recovery/last location for bears that survived the study than for bears that did not (Z = 3.40; $P < 0.01$) or for censored bears (Z = 2.49; P = 0.01).

Distances moved

Radiocollared bears were released on average 297.7 km from their capture sites (*n* = 43; Table 13). Translocation distance did not differ by sex (P = 0.41) or fate (P = 0.83).

The mean distance from release site to recovery/last location was 3.6 km (*n* = 10; median = 4.5 km; range = 1.3-5.6 km) for bears that remained in their release areas but 48.8 km (*n* = 32; median = 45.1 km; range = 11.3-192.8; Table 12) for bears that left their release areas. Release-to-recovery distance for bears that left their release areas

Table 12. Distance (km) and days from release to recovery for radiocollared black bears that moved >10 km from their release sites in the Mt. Rogers National Recreation Area, Virginia, 1990-91.

		Release-recovery distance (km)				Release-recovery days			
	n	Median	Mean	SE	Range	Median	Mean	SE	Range
All bears	32	45.1	48.8	6.3	11.3-192.8	92	169	29.9	11-598
Sex[1]									
Males	17	49.2	60.2	10.1	14.0-192.8	87	162	43.8	11-598
Females	15	32.2	36.0	5.5	11.3-81.0	113	177	41.5	47-558
Fate[2]									
Dead	17	45.5	61.1	10.1	16.0-192.8	87a	103	19.6	17-351
Censored	8	18.1	30.0	8.1	11.3-71.4	77a	106	36.2	11-279
Alive	7	49.2	40.8	6.0	17.9-53.5	512	401	73.4	171-598

[1]No difference between males and females for distance ($Z = 1.81$; $P = 0.07$) or days ($Z = 0.79$; $P = 0.43$), Wilcoxon rank sum test.
[2]No differences between fate groupings for distance ($\chi^2 = 5.68$; 2 df; $P = 0.06$), Kruskal-Wallis test. Differences exist between fate groupings for days ($\chi^2 = 12.16$; 2 df; $P < 0.01$), Kruskal-Wallis test. Medians within a column followed by the same letter are not different ($P > 0.05$) according to the Wilcoxon rank sum test.

Table 13. Distance (km) from capture site to point of release for radiocollared black bears released in the Mt. Rogers National Recreation Area, Virginia, 1990-91.

	n	Median	Mean	SE	Range
All bears	43	313.9	297.7	10.5	62.3-382.6
Sex[1]					
Males	24	305.3	291.7	14.1	62.7-359.9
Females	19	322.7	305.3	15.9	62.3-382.6
Fate[2]					
Dead	19	309.2	304.0	14.8	62.3-368.0
Censored	13	313.9	305.7	14.0	193.4-382.6
Alive	11	319.8	277.4	27.9	62.7-360.4

[1]No difference between males and females, Wilcoxon rank sum test (Z = 0.83; P = 0.41).
[2]No difference between fate groupings, Kruskal-Wallis test (χ^2 = 0.38; 2 df; P = 0.83).

did not differ by sex ($\underline{P}$ = 0.07) or fate ($\underline{P}$ = 0.06). In addition, there was no difference ($\underline{P}$ > 0.05) between the proportions of males and females whose recovery/last location from release was within each predefined distance interval (Table 14).

Direction of movement

The mean direction of travel from release to recovery location relative to capture location (i.e., release to capture direction = 0°) for bears that left their release areas was 31° (Table 15; Figure 10). These movements were not randomly distributed ($\underline{P}$ < 0.01), and the mean angle did not differ ($\underline{P}$ > 0.05) from the homeward direction.

The directions of travel for females and bears surviving the study were randomly distributed ($\underline{P}$ > 0.10 and 0.10 > $\underline{P}$ > 0.05, respectively); they were not oriented in the homeward direction. Mean directions of travel for censored bears ($\bar{x}$ = 32°; Figure 11) and bears recovered dead ($\bar{x}$ = 28°; Figure 11) were not random (0.05 < $\underline{P}$ < 0.01) and were homeward ($\underline{P}$ > 0.05), while male movements ($\bar{x}$ = 28°; Figure 10) were not random ($\underline{P}$ < 0.01), but differed from homeward ($\underline{P}$ < 0.05).

Following the criteria of Rogers (1987b) and Fies et al. (1987), bears in this study were oriented homeward if they were within 22.5° of the homeward direction. Nine

Table 14. Proportions of radiocollared black bears released in the Mt. Rogers National Recreation Area, Virginia, with a recovery/last location within specified distance intervals from release site, 1990-91.

Distance from release	Males	Females	Proportions Males	Proportions Females	Z	P
0-10 km	7	4	0.292	0.211	-0.606	0.54
>10 km	17	15	0.708	0.789	0.606	0.54
>20 km	15	10	0.625	0.526	-0.651	0.52
>30 km	15	8	0.625	0.421	-1.332	0.18
>40 km	13	6	0.542	0.316	-1.481	0.14

Table 15. Mean angle (°) from release to recovery site relative to homeward direction (0°) for radiocollared black bears that moved >10 km from their release sites in the Mt. Rogers National Recreation Area, Virginia, 1990-91.

	n	Mean Angle	u^1	V test for randomness Conclusion	P
All bears	32	31.2	3.09	Movements not random	<0.01
Sex					
Males	17	27.9	3.96	Movements not random	<0.01
Females	15	58.8	0.31	Movements random	>0.10
Fate					
Dead	17	27.9	1.90	Movements not random	<0.05
Censored	8	31.8	2.02	Movements not random	<0.05
Alive	7	36.2	1.49	Movements random	>0.05

[1]Test statistic for the V test, a modification of the Rayleigh test (Batschelet 1981:58).

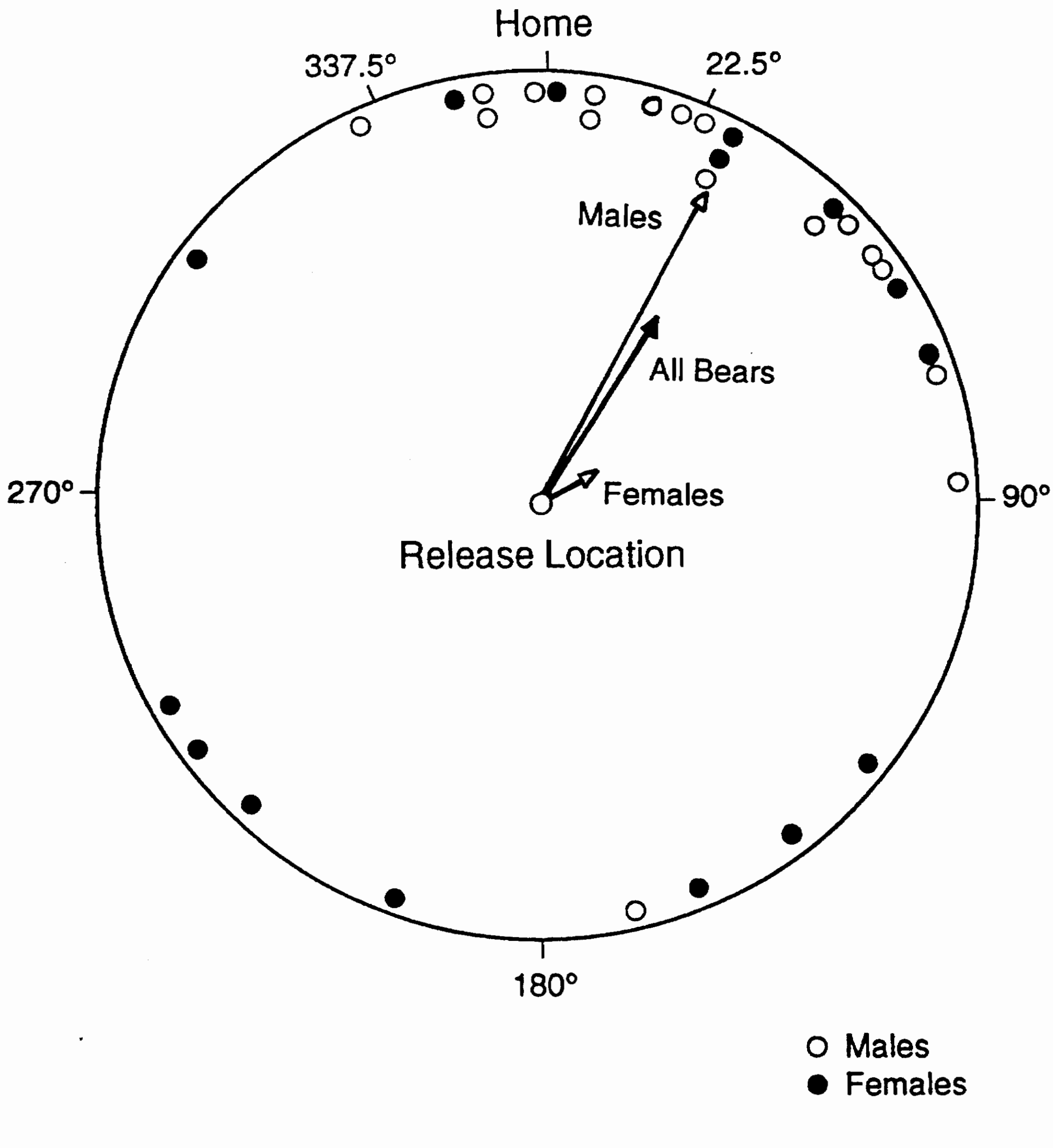

Figure 10. Directional movements of radiocollared male and female black bears that moved >10 km from their release sites in the Mt. Rogers National Recreation Area, Virginia, 1990-91. Arrows represent mean vectors.

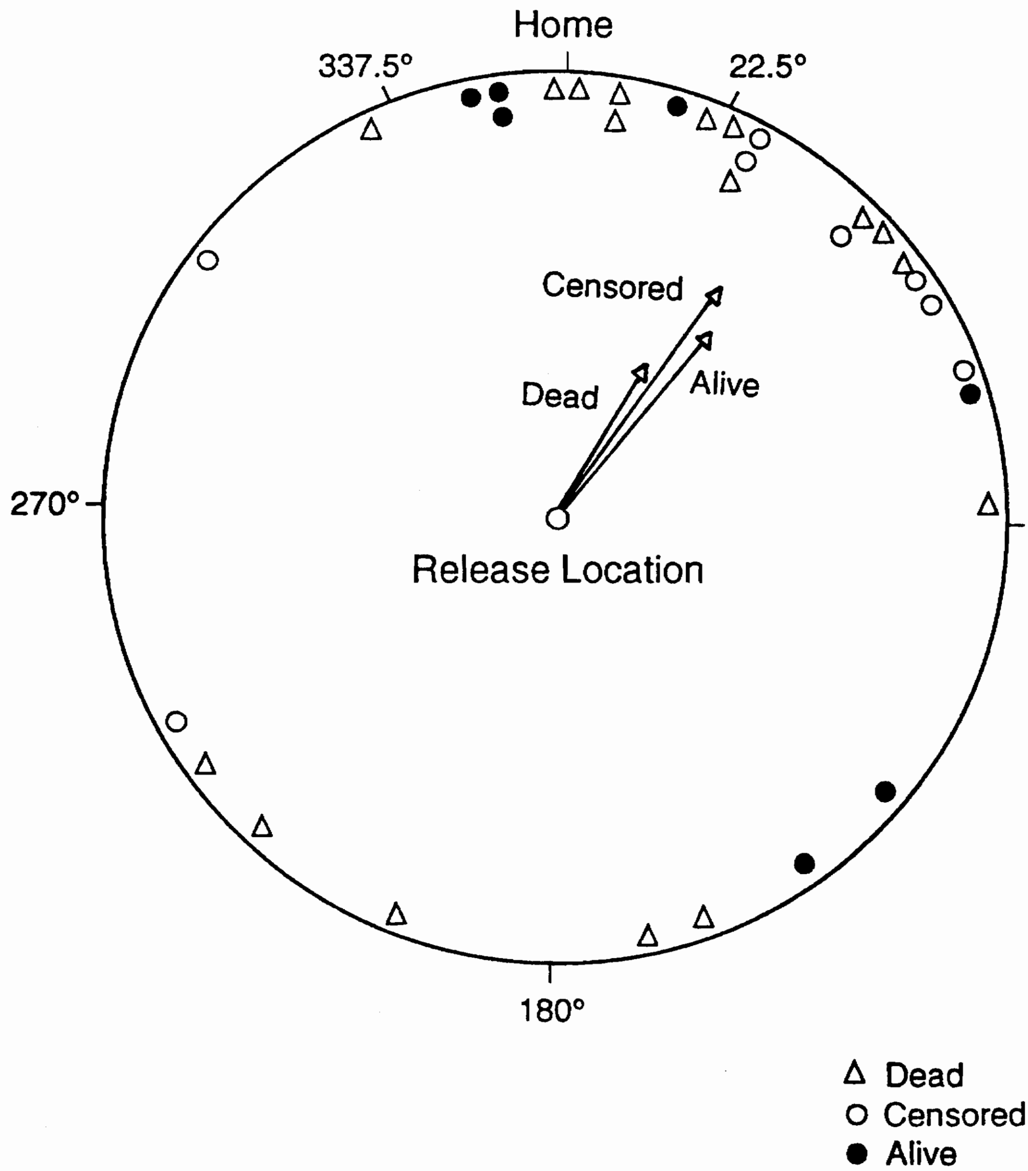

Figure 11. Directional movements of radiocollared black bears (by fate group) that moved >10 km from their release sites in the Mt. Rogers National Recreation Area, Virginia, 1990-91. Arrows represent mean vectors.

(7M:2F; 28%) of the 32 bears that left their release areas were oriented in the homeward direction at time of recovery/last location. Four (3M:1F) survived throughout the study and established home ranges oriented in their homeward directions. The remaining 5 (4M:1F) were oriented homeward at their time of death. No censored bears that left their release areas were oriented homeward at their last location.

Movements from the study area

Twenty-one of the 43 radiocollared bears (49%; Table 16) were within the 81-77-state line area at recovery or last location; 17 (40%) were also within the MRA. The probability of a bear leaving the MRA or 81-77-state line area was equivalent to the probability of remaining within each area (MRA: $P = 0.17$; 81-77-state line area: $P = 0.88$). The probability of leaving or remaining in the MRA was equal for males ($P = 0.41$) and females ($P = 0.25$), as was their probability of leaving or remaining in the 81-77-state line area (males: $P = 0.68$; females: $P = 0.49$). There was no difference in the proportions of males and females remaining in the MRA (42% vs. 37%; $P = 0.75$; Table 16) or in the 81-77-state line area (54% vs. 42%; $P = 0.43$; Table 16).

Bears recovered dead were more frequently recovered outside the MRA ($P < 0.01$) or the 81-77-state line area ($P =$

Table 16. Proportion of radiocollared male and female black bears released in the Mt. Rogers National Recreation Area, Virginia, that remained within that area and the 81-77-state line area, 1990-91.

	Males	Females	Total
MRA			
In	10	7	17
Out	14	12	26
Totals	24	19	43
Proportion in	0.417[1]	0.368[1]	0.395
Z[2]	-0.82	-1.15	-1.37
P	0.41	0.25	0.17
81-77-state line area			
In	13	8	21
Out	11	11	22
Totals	24	19	43
Proportion in	0.542[3]	0.421[3]	0.488
Z[2]	0.41	-0.69	-0.15
P	0.68	0.49	0.88

[1]No difference in proportions of males and females remaining in the MRA (Z = 0.32; P = 0.75).

[2]Tests of null hypothesis that the proportion of bears remaining in each area was equivalent to 0.50.

[3]No difference in proportions of males and females remaining in the 81-77-state line area (Z = 0.79; P = 0.43).

0.01) than in these areas (Table 17). The probability of remaining in or leaving the MRA or the 81-77-state line area was not different for bears that survived the study (P = 0.36 and P = 0.36, respectively) and censored bears (P = 0.41 and P = 0.05, respectively).

Movements of subadult males

Five subadult males moved <10 km from their release sites (1 established a home range <10 km from release site, 1 died of unknown causes 1.3 km from release, 3 were censored). Subadult males that left their release areas moved shorter (Z = 2.08; P = 0.04) distances from release to recovery/last location ($\bar{x}$ = 30.4 km; n = 3; range = 15.7-40.3 km) than adult males ($\bar{x}$ = 66.6 km; n = 14; range = 14.0-192.8 km).

Regardless of the distance moved from release site, no subadult males were oriented homeward at recovery/last location. The proportions of adult and subadult males remaining in the MRA (31% vs. 63%) and in the 81-77-state line area (44% vs. 75%) were not different (P = 0.14 and P = 0.15, respectively; Table 18).

Home range establishment

Eighteen bears established home ranges during the study; 12 were within the 81-77-state line area, and 11 of

Table 17. Proportion (by fate group) of radiocollared black bears released in the Mt. Rogers National Recreation Area, Virginia, that remained within that area and the 81-77-state line area, 1990-91.

	Alive	Dead	Censored
MRA			
In	7	2	8
Out	4	17	5
Totals	11	19	13
Proportion in	0.636	0.105	0.615
Z^1	0.91	-3.44	0.83
P	0.36	<0.01	0.41
81-77-state line area			
In	7	4	10
Out	4	15	3
Totals	11	19	13
Proportion in	0.636	0.211	0.769
Z^1	0.91	-2.52	1.94
P	0.36	0.01	0.05

[1]Tests of null hypothesis that the proportion of bears remaining in each area was equivalent to 0.50.

Table 18. Proportion (by age class) of radiocollared male black bears released in the Mt. Rogers National Recreation Area, Virginia, that remained within that area and the 81-77-state line area, 1990-91.

	Subadults	Adults
MRA		
In	5	5
Out	3	11
Totals	8	16
Proportion in	0.625[1]	0.313[1]
81-77-state line area		
In	6	7
Out	2	9
Totals	8	16
Proportion in	0.750[2]	0.438[2]

[1]No difference in proportions of subadult and adult males remaining in the MRA (Z = 1.46; P = 0.14).
[2]No difference in proportions of subadult and adult males remaining in the 81-77-state line area (Z = 1.45; P = 0.15).

these were within the MRA. Two home ranges were established in Virginia outside of the 81-77-state line area, 1 was established in Tennessee, and 3 were established in North Carolina. The remaining 25 bears did not survive long enough to establish home ranges, were not monitored long enough to determine if home ranges were established, or did not establish home ranges.

DISCUSSION

Despite some orientation in the homeward direction, no bears reached home by the study end. Five bears (4M:1F) that left their release areas, however, were moving in a homeward direction at the time of their death. Translocated bears should be highly motivated to return to their former home ranges since home ranges may provide psychological as well as physical needs for a bear (Beeman and Pelton 1976). The psychic role of the home range may allow a bear to move about familiar areas with assurance and efficiently use the resources there. The energy expenditure and risks associated with returning the long distances from release to capture sites in this study may have exceeded the physical and psychic benefits of returning to familiar areas.

An inverse relationship between distance translocated and probability of returning to the capture area was reported for bears in GSMNP (Beeman and Pelton 1976, Singer and Bratton 1980), Glacier National Park (McArthur 1981), New York (Sauer et al. 1969), and Virginia (Fies et al. 1987). In Roger's (1986a) summary of 179 bears ≥2 years old translocated from 11 states and provinces, 81% translocated <64 km returned home, but only 43% translocated >64 km returned home.

Translocation distances of >64 km appeared to be adequate for reducing homing among translocated bears in this study. With the exception of 2 bears (1M:1F) moved 62.3 and 62.7 km from capture location in this study, all radiocollared bears were moved >145 km from their capture sites (Figure 12), thus a low incidence of homing was expected. No bears reached home during the study, but the adult male translocated 62.3 km from capture to release traveled homeward (351°) and was 16.0 km from his capture site at the end of the study. This bear had been monitored for 598 days. Another adult male was harvested in October 1992, after the study ended, 13.1 km from his original capture site. This 10-year old bear was 355.8 km from his 31 July 1991 release site. He was last located on 12 August 1991, 71.4 km from his release site, traveling 27° east of his homeward direction.

The longest distance moved by a bear during this study was 192.8 km from release site. This 3 year old male traveled homeward (359°) and was legally harvested 84 days

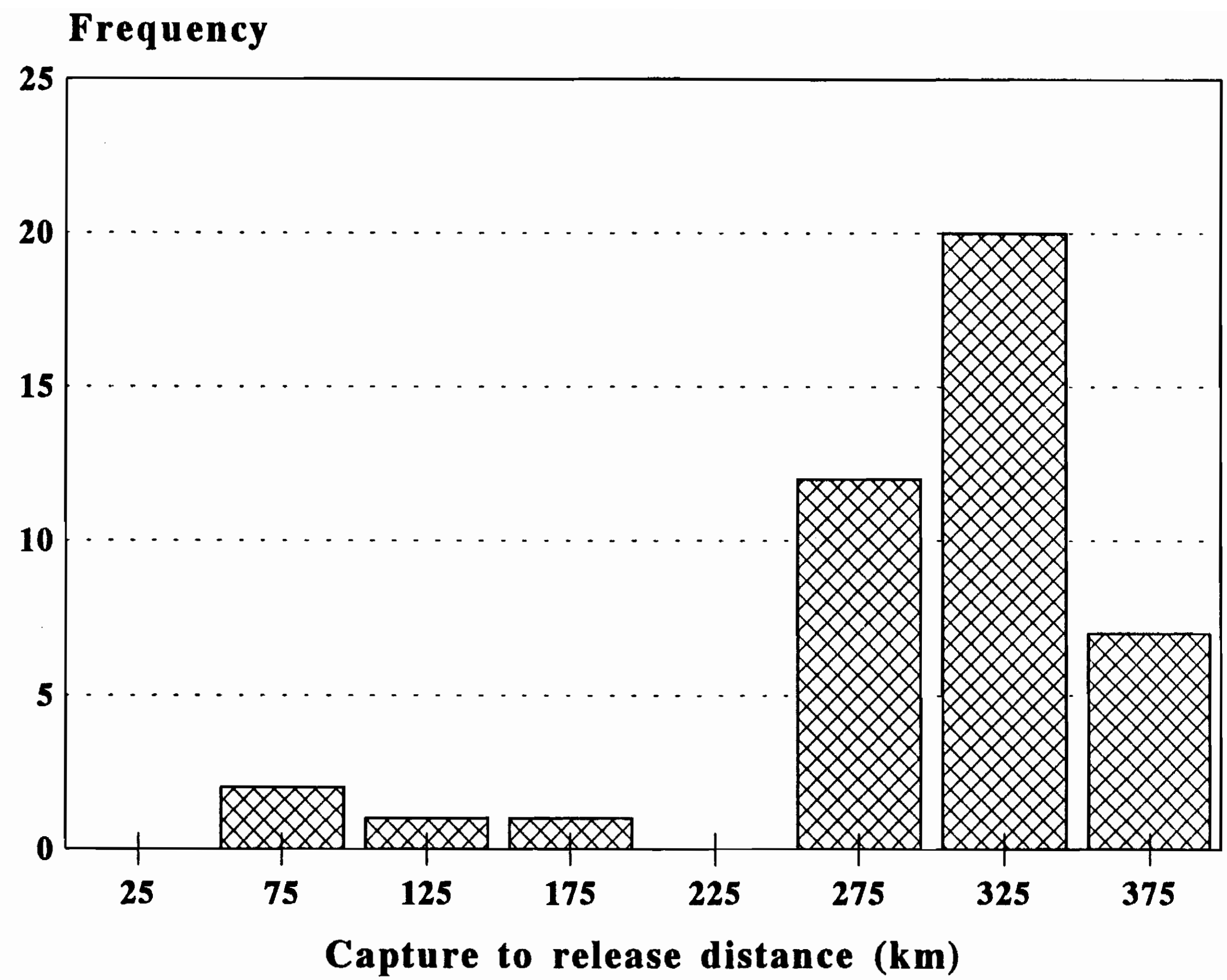

Figure 12. Distribution of capture to release distances for radiocollared black bears released in the Mt. Rogers National Recreation Area, Virginia, 1990-91.

after release, 77.6 km from his original capture site.

Males appeared to have a stronger homing orientation/ ability than females, as more males were oriented homeward at recovery/last location than were females. In contrast to an earlier Virginia study (Fies et al. 1987), I found no statistical difference in the average distance traveled from release to recovery/last location between the sexes. Fies et al. (1987) reported shorter dispersal distances from release sites and less frequent homing among females. The lack of statistical significance in this study, however, may be the result of small sample sizes and does not necessarily imply lack of biological significance. The mean distance between release and recovery/last location was 60% greater for males than females in this study. Males typically exhibit more widespread movements than females (Alt et al. 1980, Reynolds and Beecham 1980, Pelchat and Ruff 1986), as was evidenced in this study. Given the larger home ranges of males in general, males may have had to move farther from release sites than females to find unoccupied territories.

The timing of bear releases also may have contributed to the lack of homing observed in this study. Most bears were released in late summer or fall, a time when bears are in a hyperphagic state. Food sources are generally abundant during this period, and bears expend large amounts of energy building fat stores for hibernation. If homing and denning are innate behaviors, the predisposition to store fat for hibernation may be stronger than the drive to return to an established home range. Additionally, if a bear did successfully return to its capture area, it is likely that the bear would be in a reduced nutritional state after traveling a long distance and might not have enough time to build fat stores prior to denning.

Initial movements following release were random for most bears. While some bears were recovered or last located in a homeward orientation, this did not imply that their movements were necessarily directed homeward. Most bears appeared to wander at random without directed orientation until they established a home range, were recovered dead, or contact was lost with them. It is unlikely that these initial random movements were search patterns in an attempt to orient homeward since most bears did not move homeward after these initial random movements and random movements or expanding search patterns are not the primary mechanisms of mammalian homing (Robinson and Falls 1965; Rogers 1986b, 1987b).

Translocated bears typically leave release sites within a few days of release and move widely, regardless of whether they return home (Harger 1970, McCollum 1974, Alt et al. 1977, McLaughlin et al. 1981, Massopust and Anderson 1984). This was not true for translocated bears in this study; 11

bears apparently never left their release areas. Four bears (2M:2F) that survived this study were 1.1-5.6 km from their release sites at last location, and a female bear shot within the study area was only 4.7 km from her release site at death. All 5 of these bears had established home ranges in the vicinities of their release sites prior to their last location/death.

Telemetry data indicate that most bears that home do so within a month following their release (Rogers 1986a). While no successful homing was detected during the 22 months of this study, the potential for undetected homing does exist. Radio contact was lost with 8 bears, 2 in their first month post-release. None of these bears, however, were oriented homeward at the time of their last location. A male bear that did return home to his capture area was not detected for 26 months after release, exceeding the study period. This bear had been censored at 12 days post-release and was not oriented homeward at that time. It is possible that more of the bears with which we lost radio contact returned to their capture areas undetected. The areas in northwestern Virginia where the translocated bears were captured were not regularly monitored for presence of bears returning to their capture areas.

The 9 radiocollared bears (9 of 43; 21%) that left their release areas oriented in a homeward direction in this study was similar to 23% of translocated bears recovered in a homeward direction in an earlier Virginia study (Fies et al. 1987). The actual number of bears moving homeward in that study may have been greater since bears were not radiocollared, and recoveries were based solely on tag returns by hunters. Despite a high frequency of homeward movement, no bears translocated >64 km from their capture sites returned home (Fies et al. 1987), similar to this study. Thus, translocating Virginia black bears >64 km from capture appears to be effective at reducing homing.

Like bears transplanted into Arkansas (Rogers 1974), there was no relationship between bear sex and the likelihood of remaining in the release area in this study. Neither sex was more likely to leave the MRA or 81-77-state line area than the other. There also was no relationship between month or year of release and the likelihood of remaining in the release area. It is impossible to isolate the factors that caused bears to leave or remain in these areas. Leaving the defined areas could be a response to an existing high bear density in the area, but such a hypothesis fails to explain why some bears remained in the areas. The movements out of these areas were more likely a consequence of random movements in response to translocation.

Adult and subadult males responded differently to translocation. Adults moved greater distances from release to recovery/last location and had a stronger inclination/ ability to orient homeward than did subadults. Since adult males tend to have the greatest homing ability of any sex/age class of bears (Alt et al. 1977, McLaughlin et al. 1981, Fies et al. 1987), results from this study were not surprising. Adults may have an increased drive to return to an area where they have been successful breeders and have established breeding territories. Subadult males likely were in a dispersal phase at the time of translocation. Unlike adults, subadults usually do not have established home ranges and thus should have little motivation to return to their capture areas.

Adult males appeared more highly motivated to make wider movements after release than subadults. Resident adult males may encourage subadult male dispersal (Kemp 1976, Young and Ruff 1982) and prevent transient subadult males from establishing home ranges within an area through aggression (Jonkel and Cowan 1971, Rogers 1983). The short distances moved by subadults following release suggests that there were not many adult males with established territories in the release areas or that adult males there were not territorial. The latter is contradictory to reports of territoriality in bears (Jonkel and Cowan 1971, Young and Ruff 1982, Pelchat and Ruff 1986, Rogers 1987a), while the former is consistent with the speculation of the Virginia Department of Game and Inland Fisheries (VDGIF) personnel that there were very few bears in the MRA prior to the translocation effort.

Translocation of subadult males versus adult males may be preferable when the goal of the translocation effort is to reestablish a bear population in an area devoid or nearly devoid of bears. Summary statistics of translocations in 11 states and provinces (Rogers 1986a) suggest that translocation distances of ≤32 km may be effective for translocating subadult males. This distance seems consistent with results of this study, since only 2 subadults moved distances >32 km from release, and neither was in the homeward direction.

Translocating adult females with cubs may encourage the adults to remain in their release areas since the presence of cubs restricts family group movements. Four females with cubs were translocated in this study, and all established home ranges. Three did not leave their release areas, and 1 established a home range 17.9 km from release. Survival rates of the translocated cubs was not determined.

Bears that left the MRA or 81-77-state line area were exposed to more risks. The high mobility of black bears results in a significantly increased mortality rate (Pelton 1982), and thus it follows that bears in this study that moved farther (i.e., out of the defined areas) would experience higher mortality rates. More bears died outside of the MRA and 81-77-state line area than within these areas. Bears recovered dead moved greater distances from release and were more likely to leave the MRA or the 81-77-state line area than bears surviving the study or censored. The study area may have acted as a refuge for bears. Counties within the 81-77-state line area were closed to bear hunting, and only 4 bears died within that area during the study. Two of the mortalities were from illegal kills, 1 from an auto collision on a secondary road, and 1 from unknown causes. In contrast, 15 bears died outside of the 81-77-state line area. Causes of mortality for these bears included auto collisions on the interstates and legal harvest.

Bears that remained in their release areas were monitored longer than bears that left their release areas. Two main factors contributed to this difference. Bears that remained within 10 km of their release sites were exposed to fewer risks than bears moving out of these areas and thus survived longer (i.e., were monitored longer). Bears that did not leave their release areas were more easily and more often successfully monitored than bears that left their release areas. The random movements of bears that left their release areas were difficult to monitor.

The 2 4-lane interstates in southwestern Virginia did not inhibit bear movements; bears did not appear to avoid the interstates. Although 7 mortalities occurred on the interstates, more bears successfully (i.e., without being hit and killed) crossed the interstates than did not.

Resident bears have been reported to avoid roads in western North Carolina (Brody 1984), GSMNP (Quigley 1982), Cherokee National Forest (Villarrubia 1982), West Virginia (Miller 1975), and Maine (Hugie 1982). In North Carolina, resident bears avoided an interstate with >10,000 vehicles per day (Brody and Pelton 1989, Seibert 1989, Beringer et al. 1990). Translocation stimulates bear movements (Harger 1974), and that may explain why translocated bears in this study did not exhibit the same road avoidance strategy as resident bears.

LITERATURE CITED

Alt, G. L., G. J. Matula, F. W. Alt, and J. S. Lindzey. 1977. Movements of translocated nuisance black bears of northeastern Pennsylvania. Trans. Northeast Fish and Wildl. Conf. 1977:119-126 and Trans. Appendum 1977:61-66.

______, ______, ______, and ______. 1980. Dynamics of home range and movements of adult black bears in northeastern Pennsylvania. Int. Conf. Bear Res. and Manage. 4:131-136.

Batschelet, E. 1981. Circular statistics in biology. Academic Press, New York, N.Y. 371pp.

Beeman, L. E., and M. R. Pelton. 1976. Homing of black bears in the Great Smoky Mountains National Park. Int. Conf. Bear Res. and Manage. 3:87-95.

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

Brody, A. J. 1984. Habitat use by black bears in relation to forest management in Pisgah National Forest, North Carolina. M.S. Thesis, Univ. Tenn., Knoxville. 123pp.

______, and M. R. Pelton. 1989. Effects of roads on black bear movements in western North Carolina. Wildl. Soc. Bull. 17:5-10.

Fies, M. L., D. D. Martin, and G. T. Blank, Jr. 1987. Movements and rates of return of translocated black bears in Virginia. Int. Conf. Bear Res. and Manage. 7:369-372.

Harger, E. M. 1970. A study of homing behavior of black bears. M.A. Thesis, Northern Mich. Univ., Marquette. 81pp.

______. 1974. Homing behavior of the black bear. Proc. East. Workshop Black Bear Manage. and Res. 2:128-129.

Hollander, M., and D. A. Wolfe. 1973. Nonparametric statistical methods. John Wiley and Sons, Inc., New York, N.Y. 503pp.

Hugie, R. D. 1982. Black bear ecology and management in the northern conifer-deciduous forests of Maine. Ph.D. Diss. Univ. Montana, Missoula. 203pp.

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

Kemp, G. A. 1976. The dynamics and regulation of black bear, Ursus americanus, populations in northern Alberta. Int. Conf. Bear Res. and Manage. 3:191-197.

Massopust, J. L., and R. K. Anderson. 1984. Homing tendencies of translocated nuisance black bears in northern Wisconsin. Proc. East. Workshop Black Bear Manage. and Res. 7:66-73.

McArthur, K. L. 1981. Factors contributing to effectiveness of black bear transplants. J. Wildl. Manage. 45:102-110.

McCollum, M. T. 1974. Research and management of black bears in Crater Lake National Park, Oregon. U.S. Natl. Park Serv. Prog. Rep., Crater Lake Natl. Park, Oreg. 74pp.

McLaughlin, C. R., C. J. Baker, A. Sallade, and J. Tamblyn. 1981. Characteristics and movements of translocated nuisance black bears in northcentral Pennsylvania. Pa. Game Comm. Rep., Harrisburg. 31pp.

Miller, T. O. 1975. Factors influencing black bear habitat selection on Cheat Mountain, West Virginia. M.S. Thesis, West Virginia Univ., Morgantown. 61pp.

Payne, N. F. 1975. Unusual movements of Newfoundland black bears. J. Wildl. Manage. 39:812-813.

Pelchat, B. O., and R. L. Ruff. 1986. Habitat and spatial relationships of black bears in boreal mixedwood forest. Int. Conf. Bear Res. and Manage. 6:81-92.

Pelton, M. R. 1982. Black bear. Pages 504-514 in J. A. Chapman and G. A. Feldhammer, eds. Wild mammals of North America: biology, management, and economics. Johns Hopkins Univ. Press, Baltimore, Md.

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

Reynolds, D. G., and J. J. Beecham. 1980. Home range activities and reproduction of black bears in west-central Idaho. Int. Conf. Bear Res. and Manage. 4:181-190.

Robinson, W. L., and J. L. Falls. 1965. A study of homing of meadow mice. Am. Midl. Nat. 73:188-224.

Rogers, L. L. 1983. Effects of food supply, predation, cannibalism, parasites, and other health problems on black bear populations. Pages 194-211 in F. L. Bunnell, D. S. Eastman, and J. M. Peek, eds. Symposium of natural regulation of wildlife populations. For. Wildl. and Range. Exp. Station, Univ. Idaho, Moscow.

______. 1986a. Effects of translocation distance on frequency of return by adult black bears. Wildl. Soc. Bull. 14:76-80.

______. 1986b. Homing by radio-collared black bears, Ursus americanus, in Minnesota. Can. Field Nat. 100:350-353.

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

______. 1987b. Navigation by adult black bears. J. Mamm. 68:185-188.

______. 1988. Homing tendencies of large mammals: a review. Pages 76-92 in L. Nielsen and R.D. Brown, eds. Translocation of wild animals. Wis. Humane Soc., Milwaukee.

Rogers, M. J. 1974. Movements and reproductive success of black bear introduced into Arkansas. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 27:307-308.

Rutherglen, R. A., and B. Herbison. 1977. Movements of nuisance black bears (Ursus americanus) in southeastern British Columbia. Can. Field-Nat. 91:419-422.

Sauer, P. R., S. L. Free, and S. D. Browne. 1969. Movement of tagged black bears in the Adirondacks. N. Y. Fish and Game J. 16:205-223.

Seibert, S. G. 1989. Black bear habitat use and response to roads on Pisgah National Forest, North Carolina. M.S. Thesis, Univ. Tenn., Knoxville. 144pp.

Singer, F. J., and S. P. Bratton. 1980. Black bear/human conflicts in the Great Smoky Mountains National Park. Int. Conf. Bear Res. and Manage. 4:137-139.

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

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

CHAPTER 4: COST ESTIMATE

The cost incurred by the Virginia Department of Game and Inland Fisheries (VDGIF) to capture and translocate nuisance black bears is the sum of fixed and variable costs. The fixed costs remain relatively constant regardless of the number of bears translocated and include components such as overhead, employee benefits, administrative costs, and equipment. Variable costs change in relationship to the number of bears translocated. Personnel time, mileage, and handling expenses fall into the variable cost category.

The depth of any cost analysis is limited by the time and money available. Even with unlimited time and money, all the relevant aspects can never be included because some of them are intangible (Goldman 1967). The scope of this study was primarily biological, however a cost estimation of the translocation effort was conducted as an additional part of the study. Since fixed costs must be paid regardless of the output (number of bears moved), only variable costs should be considered when analyzing the costs of a management strategy (Gould and Lazear 1989). Thus, the estimate of the cost of this translocation management strategy was calculated on a per bear basis using variable costs.

METHODS

Variable costs were estimated in 3 major categories: personnel time, travel, and handling expenses. The time category reflected the time spent trapping and handling a bear and transporting it to the release site. This category also included time associated with round-trip travel to the complaint location, investigating the complaint, talking with landowner, setting the trap or snare, obtaining bait, round-trip travel to move the bear from capture site to transfer site, and processing the bear for release. This component of the time category was based on estimates by Gerald T. Blank, Jr., VDGIF Trapping Specialist (Pers. commun.). Round-trip time for personnel to transport the bear from the transfer site to release area also was included in this category. The time costs were based on salaries of personnel involved in the translocation effort.

Miles traveled round-trip to capture a bear were calculated from yearly mileage and work records for the Trapping Specialist. Round-trip mileage from the transfer site to release area was based on actual mileage between the 2 areas. Costs of travel were determined using the VDGIF equipment rental rate for a 3/4 ton pickup truck. Handling expenses included costs for drugs, ear tags, and miscellaneous items used in the handling process. Meat scraps were donated by restaurants for use as bait, thus no expense was associated with it. Travel time and mileage to pick up bait were included in the time and travel categories. Mileage and time estimates were adjusted to account for the fact that 2 bears were transported to the Mt. Rogers National Recreation Area (MRA) in 1 trip 50% of the time.

RESULTS

The cost estimate of capturing and translocating a nuisance bear to the MRA during 1990-91 was $349 (Table 19). This cost included $177 for personnel time, $163 for travel, and $9 in handling expenses.

DISCUSSION

The $349 estimate per bear translocated to the MRA is a conservative estimate. The estimate reflects only the variable costs to capture and translocate a bear. The fixed costs of administration (e.g., secretarial time and equipment, employee benefits), capture and handling equipment (e.g., traps, snares, carrying cages, rifles, darts), purchases of customized trucks for bear trapping, and overhead were not included. While these fixed costs are real and may be a significant amount, they must be paid regardless of whether bears are moved to the MRA. Additionally, these costs can not be properly allocated on a

Table 19. Cost estimate to capture and move a nuisance black bear from northwestern Virginia to the Mt. Rogers National Recreation Area, Virginia, during 1990-91.

	Unadjusted Total	Adjustments[1]	Adjusted Total
TIME			
To catch bear and transport it to transfer site 9.5 hours x $13.50/hour	$128		$128
To transport bear from transfer site to Mt. Rogers Area 10 hours x $6.50/hr	65	-16	49
TRAVEL (Round-trip)			
Miles to capture and transport bear to transfer site 155 miles x $0.33/mile	51		51
Miles to transport bear from transfer to release site 452 miles x $0.33/mile	149	-37	112
HANDLING			
Drugs $5			
Ear tags 1			
Misc. 3	9		9
TOTAL PER BEAR ESTIMATE			$349

[1]Adjustment factor of 0.25 to reduce unadjusted total to account for the fact that 50% of the time 2 bears are transported to release area in 1 trip.

per bear basis. They are incurred for a variety of VDGIF projects and wildlife species, and allocating these fixed costs according to specific tasks is beyond the scope of this project.

One component of the variable costs that could be tracked was personnel time for transporting a bear from the transfer site to release area. The cost of this time was calculated based on the hourly rate for a seasonal employee. The majority of the time, a seasonal employee transported the bear. However, it was not uncommon for an employee at a higher pay level to transport the bear, another reason the estimate is conservative.

It is the present policy of VDGIF to capture and relocate nuisance bears ≥100 miles from their capture sites. Given this policy, the cost estimate derived for capture and translocation to the MRA may be misleading. Component parts of the estimate are not exclusive to the translocation to the MRA, since nuisance bears would be captured and relocated anyway. An evaluation of a management strategy should be based on the difference between the net benefits (benefits-costs) with the management strategy and the net benefits without the management strategy (OECD 1986).

Under current VDGIF management strategy, the variable cost of capturing and moving a nuisance bear is $290 per bear (Table 20). This estimate reflects adjustments to

Table 20. Cost estimate to capture and move a nuisance black bear in northwestern Virginia under current VDGIF policy during 1990-91.

	Unadjusted Total	Adjustments[1]	Adjusted Total
TIME			
To catch bear and transport it to transfer site			
9.5 hours x $13.50/hour	$128		$128
To transport bear from transfer to release site			
4 hours x $13.50/hr	54	-8	46
TRAVEL (Round-trip)			
Miles to capture and transport bear to transfer site			
155 miles x $0.33/mile	51		51
Miles to transport bear from transfer to release site			
200 miles x $0.33/mile	66	-10	56
HANDLING			
Drugs $5			
Ear tags 1			
Misc. 3	9		9
TOTAL PER BEAR ESTIMATE			$290

[1]Adjustment factor of 0.15 to reduce unadjusted total to account for the fact that 30% of the time 2 bears are transported to release area in 1 trip.

account for the fact that 2 bears were transported in 1 trip from capture to release 30% of the time. While bears captured under current VDGIF policy are not moved as far as bears translocated to the MRA, the cost difference between these 2 groups is not simply a function of the difference in miles moved. Transport to release site of bears not translocated to the MRA is usually done by the Trapping Specialist who is paid an hourly rate more than double that of the seasonal employee who transports bears to the MRA. Also, the adjustment factors to account for multiple bears moved per trip are not equivalent for these 2 strategies.

The additional cost for the translocation effort to the MRA was $59 per bear. This represents the variable costs associated with moving the bear to the MRA. It is the difference between the cost of capturing and translocating a bear to the MRA and the cost associated with capturing and moving a nuisance bear under current VDGIF policy.

In order to properly evaluate a management strategy, the additional benefits of the strategy must also be quantified (Mishan 1976, Stokey and Zeckhauser 1978). No attempt was made to evaluate the additional benefits of moving bears to the MRA. Thus, no evaluation of the economic efficiency of the translocation management strategy can be made.

These cost estimates are just that - estimates. There may be additional costs that should be included that have been inadvertently omitted. "If the economist is unwilling to make some bold simplifications, the job of determining "true" marginal costs may be highly complex, time-wasting, and too expensive" (Gould and Lazear 1989:249).

The per bear cost estimate provided here should be interpreted cautiously. It was based on limited written records of time and mileage with associated tasks. The indirect costs associated with the translocation were not addressed and could include vehicle damage, corpse disposal of road-killed bears, and crop depredation by bears in southwestern Virginia. A full specification of all the costs associated with this management strategy are beyond the scope of this study.

LITERATURE CITED

Goldman, T. A. 1967. Cost-effectiveness analysis. Frederick A. Praeger, Publishers, New York, N.Y. 231pp.

Gould, J. P., Jr., and E. P. Lazear. 1989. Microeconomic theory. Sixth ed. Richard D. Irwin, Inc. Boston, Mass. 640pp.

Mishan, E. J. 1976. Cost-benefit analysis. Praeger Publishers, New York, N.Y. 454pp.

Organisation for Economic Co-operation and Development (OECD). 1986. The public management of forestry projects. OECD Publications, Paris, France. 99pp.

Stokey, E., and R. Zeckhauser. 1978. A primer for policy analysis. W. W. Norton & Co., Inc. New York, N.Y. 356pp.

SUMMARY/CONCLUSIONS

Forty-three radiocollared bears were released in the Mt. Rogers National Recreation Area (MRA) and monitored from June 1990-March 1992. Eleven bears survived throughout the study, 19 were recovered dead during the study, and 13 were censored. Survival of the bears was 0.23 over the 22 months of this study. This is lower than survival rates of other translocated populations and lower than survival of non-translocated bears in Virginia. Nuisance bears translocated to unfamiliar areas should be expected to have lower survival rates than non-translocated bears, especially during the initial 150 days following release. After that time, mortality should decrease, allowing survival to approach survival of similar non-translocated populations. There was no difference between male and female survival.

Survival of uncollared translocated bears released in the 5 counties of the MRA was greater than survival estimates for the radiocollared subsample. Low recovery rates of uncollared bears and inconsistent reporting of bear mortality suggest that actual mortality of tagged, but uncollared bears, translocated to southwestern Virginia during 1988-1991, was greater than reported.

Vehicle collisions were the major mortality source for radiocollared bears, and bears did not appear to avoid roads with large traffic volumes. Other mortality sources included legal harvest of bears that left the study area and illegal kills of bears within the study area.

Translocated female bears should be expected to exhibit a 1-year lag in reproduction following translocation if moved during the late summer or early fall. After this lag, reproductive rates should approximate rates of other similar populations. The mean litter size of 4 litters was 2.75 cubs with a 1:1 sex ratio. Most females translocated with cubs established home ranges in their release areas.

Fifty-one percent of the radiocollared bears left the 81-77-state line area. Of the 21 bears whose recovery/last location was in the 81-77-state line area, 4 were recovered dead and 10 were censored. Only 7 within the 81-77-state line area survived the 22 months of the study.

A computer simulation of the female segment of the translocated population at the MRA, ignoring movements out of the area, predicted 45 females in the population in 1992 and 29 females by 2002. The population decreased ($r = -0.05$) from 1993-2002.

The distance bears were moved from capture to release in this study ($\bar{x}$ = 297.7 km) appears to be effective at reducing homing by translocated bears since no translocated bears returned to their capture areas during this study. Bears wandered at random without directed orientation after release until they established a home range, were recovered dead, or were censored. Eleven of 43 bears did not leave their release areas (i.e., moved <10 km from release site). These bears were monitored longer than bears that left their release areas. The mean distance from release to recovery/ last location for bears leaving their release areas was 48.8 km; there was no difference in the distance by sex. Males appeared to have a stronger homing orientation/ability than females, and adult males moved greater distances from release to recovery/last location and had a stronger inclination/ability to orient homeward than did subadult males.

The variable cost estimate to capture and move a nuisance bear under current Virginia Department of Game and Inland Fisheries (VDGIF) policy was $290; the cost to capture and translocate a bear to the MRA was $349. The additional variable costs associated with moving a bear to the MRA over the current VDGIF policy was $59 per bear.

Trapping and relocation of nuisance black bears in Virginia appears to be a successful management strategy in terms of reducing further nuisance activity by translocated bears. The long distances bears were moved in this study were effective at reducing homing of the translocated bears. Given the low survival and high frequency of bears leaving the release area, it may take many years for a self-sustaining bear population to be established in the 5 counties of the MRA.

VITA

Lisa Marie Comly was born in Point Pleasant, New Jersey on December 18, 1965. In 1983, she graduated from Palisades High School in Kintnersville, Pennsylvania. She attended Chestnut Hill College, Rutgers University, Bucks County Community College, and the University of Maine. She received a B.S. degree in Wildlife Management from the University of Maine at Orono in 1989. Following graduation, she worked for the Maine Audubon Society surveying marshes for rare birds and the Maine Cooperative Fish and Wildlife Research Unit compiling an annotated bibliography on wildlife translocations. In July 1990, she became a candidate for a M.S. degree in Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University.

Lisa M. Comly