

TESTING ASSUMPTIONS IN BEAR RESEARCH: USING STATISTICAL POWER ANALYSIS TO ESTIMATE EFFECTS OF DEN TYPE ON BLACK BEAR CUB SURVIVAL

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Abstract: Statistical tests on data from black bear (*Ursus americanus*) research often have low power because of limited sample sizes and sometimes subtle effects. We used the assumption that den type (open nest, hollow tree, excavation, etc.) has some effect on first year cub survival to illustrate the use of statistical power in black bear research. We tested the hypotheses that den type does not affect minimum first-year cub survival (MFYS) in Massachusetts (MA) or Minnesota (MN), demonstrated the necessary sample sizes to conduct high power tests (≥ 0.80) of these hypotheses, and illustrated the use of power analysis in the design of bear research. Dens were assigned to 1 of 3 categories based on assumed thermal advantage. We used single factor analysis of variance to estimate effect of natal den type on MFYS with $\alpha \leq 0.05$ and to confidently conclude no effect with power ≥ 0.80 . We obtained data on 47 litters in MA (1985–95) and 85 litters in MN (1982–94). For both states, we failed to reject the hypothesis that den type does not affect MFYS (MA: $F = 0.63$; 2,44 df; $P = 0.539$, power = 0.139; MN: $F = 1.26$; 2,82 df; $P = 0.291$, power = 0.258). However, the low power in each case precluded definitive conclusions regarding the effect of den type on MFYS. Achievement of power = 0.80, given the actual sample sizes in each case and $\alpha = 0.05$, would have required large effect sizes. Given the observed effect sizes (MA = 0.155, MN = 0.166) and $\alpha = 0.05$, total sample sizes of 395 litters in MA and 345 litters in MN would have been required to obtain power = 0.80. Our example illustrates the difficulty in testing hypotheses in black bear research. Although the MA and MN data represent 11 and 13 years of data collection respectively, neither generated sufficient sample sizes to adequately test a simple hypothesis with the design and analytical methods used in this study. Black bear researchers must consider power and draw only conclusions that are substantiated by their data.

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Key words: black bear, cubs, denning, Massachusetts, Minnesota, statistical power, survival, *Ursus americanus*.

Data from black bear research projects are often subjected to *a posteriori* statistical hypothesis testing, usually comparing data among years, seasons, or groups of individuals. Because bears occur at relatively low densities, small samples are usually obtained. This has resulted in many widely held assumptions about black bear biology and management based on limited data sets. One such assumption is the importance of den type to black bear fitness (Lentz et al. 1983, Hayes and Pelton 1994).

Denning behavior has been extensively reviewed and researched throughout black bear range (Kolenosky and Strathearn 1987, Schooley et al. 1994). Typically, attributes such as den structure, dimensions, time of entry and emergence, slope, and aspect of the den site have been reported. Because black bears may spend ≥ 6 months in dens and give birth while denning, researchers assume that the den is a critical habitat feature. During dormancy black bears do not eat, drink, urinate or defecate, except for females ingesting cub waste (Folk et al. 1972, Oftedal et al. 1993). Unlike some hibernators, black bears do not drastically lower their body temperature and are eas-

ily aroused; thus they maintain relatively high metabolic rates and energy demands (Folk et al. 1980).

Females give birth while denning, usually in mid- to late-January (Alt 1983). Cubs are altricial, and females remain denning 2–4 months after giving birth; milk is the only food for the cubs (Rogers 1976). Female black bears may produce >25 kg of milk while denning and fasting (Oftedal et al. 1993). In-den milk is derived from body fat stores as is the metabolic energy of the female. Given these competing demands for stored fat of parturient females, thermally efficient (i.e., covered) dens have been assumed to provide several advantages to bears (Johnson et al. 1978).

Among the specific advantages that energy conservation has been assumed to confer to bears is increased cub survival (Hellgren and Vaughan 1989, Hayes and Pelton 1994). Most black bear cub mortality appears to occur in the 3 months immediately following den emergence (Elowe 1987, LeCount 1987), and lightweight cubs may have higher mortality rates than heavier cubs (Rogers 1976, Noyce and Garshelis 1994); thus

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increased growth may enhance cub survival during this period. This increased growth would be achieved by allowing females to allocate more depot fat to lactation than to their own metabolism, thus increasing nutrient transfer to cubs. First-year cub survival is extremely variable, with reported rates ranging from 0.52 to 0.94 (Beck 1991). Cub survival rates have been reported as the most sensitive variables in population models (Fuller 1993). Thus factors affecting cub survival are important to bear managers. No study has directly investigated the effect of den type on cub survival. Our objectives were to (1) test the null hypotheses that den type does not affect mean minimum first-year cub survival (MFYS) in Massachusetts (MA) and Minnesota (MN), (2) demonstrate the necessary sample sizes to conduct powerful (≥ 0.80) tests of these hypotheses, and (3) illustrate the use of power analysis in designing and evaluating bear research.

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STUDY AREA

We collected data on 2 study areas in western MA (42°27'N, 72°41'W) 20-km apart. The 150-km² Conway-Williamsburg study area was 70% forested and >90% privately owned with elevations ranging from 30 m to 450 m (Fuller 1993). Hardwood-dominated forests consisted of northern red oak (*Quercus rubra*), red maple (*Acer rubrum*), black birch (*Betula lenta*), sugar maple (*A. saccharum*), and hickories (*Carya* spp.). Major softwoods were eastern white pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*). The 160-km² Savoy-Hawley study area was 90% forested and >60% was state-owned (Fuller 1993). Elevations ranged from 180 m to 790 m, and the forest was more typical of the northern hardwood type. Major hardwood species were American beech (*Fagus grandifolia*), yellow birch (*B. alleghaniensis*), and sugar maple. Softwoods included eastern white pine, eastern hemlock, red spruce (*Picea rubens*), and balsam fir (*Abies balsamea*).

Data collected in northcentral MN (47°35'N, 93°37'W) on the Chippewa National Forest and adjacent George Washington State Forest (Noyce and Garshelis 1994) were also analyzed. Northern hardwood and boreal forest types made up most of the area. Major species included aspens (*Populus* spp.) and paper birch (*B. papyrifera*) on uplands with some red pine (*Pinus resinosa*), eastern white pine, and white spruce (*Picea glauca*). Also present were sugar maple, basswood (*Tilia americana*), and northern red oak. Nearly 33% of the forest was comprised of lowland black spruce (*Picea mariana*), tamarack (*Larix laricina*), and northern white cedar (*Thuja occidentalis*).

METHODS

Capture

In MA bears were captured during 1980–94 using foot snares and trained bear hounds (Elowe 1984, Fuller 1993). MN bears were captured using foot snares and barrel traps during 1981–94 (Noyce and Garshelis 1994). Adult and yearling females were fitted with radiocollars and tracked to winter dens. We immobilized bears in MA using a mixture of ketamine hydrochloride (10–17 mg/kg body weight) and xylazine hydrochloride (1–2 mg/kg body weight) or ketamine (6–10 mg/kg body weight) alone on small bears (<50 kg). In MN bears were immobilized using either ketamine hydrochloride (11–13 mg/kg body weight) and promazine (0.6–0.7 mg/kg body weight) or tiletamine hydrochloride (3.9–5.3 mg/kg body weight).

Cub Production and Survival

We attempted to visit dens of all radiocollared females each winter to assess cub production and survival. We calculated MFYS as the percent of cubs in a litter surviving to 1 year. Because cubs normally den with their mother as yearlings, we determined MFYS by visiting female dens in consecutive winters and assuming that cubs missing as yearlings had died. Females with yearlings sometimes abandoned dens when approached, especially in MA. If there was snow, we tracked the bears until the number of yearlings could be determined. We often visually relocated such family groups shortly after den emergence to further assess MFYS. It is possible that the number of yearlings may have been underestimated or missing yearlings may not have actually died; thus, survival rates are minimum estimates. However, we have no knowledge of any marked cubs, assumed dead as yearlings, being captured at a later date

or being reported in the legal harvest. We analyzed only litters first observed in natal dens. Litters that were abandoned by the female after den visits and either died or were transferred to other females and litters of females that received abandoned cubs were not included in analyses.

Den Types

We grouped observed den types by apparent thermal efficiency into 3 categories: open nests (poorest efficiency), brush- or slashpiles (efficiency variable and dependent upon snow cover but better protected than open nests), and covered (including hollow trees, rock dens, and excavations; highest efficiency). We only considered natal dens in our analyses.

Statistical Analyses

We used analysis of variance (ANOVA) to determine if MFYS differed among den types. The Type I error level (α) was set at the conventional 0.05. Power of the tests was derived according to methods in Cohen (1988). We considered power = 0.80 to be the minimum desired. Notation follows Cohen (1988) for abbreviations (e.g., ANOVA effect size = f). We used t -tests to compare MFYS between MA and MN. We considered individual litters to be our sampling unit because all cubs in a litter were born in the same den and thus exposed to the same treatment. We considered multiple litters by individual females to be independent observations. This assumption may not be entirely true; however, we observed variation in both den selection and condition of individual females followed during several years and litters.

We used ANOVA in preference to other methods for several reasons. First, ANOVA is robust to violation of the underlying assumptions, notably lack of normality and heterogenous variances (Neter et al. 1990). Skewness and kurtosis are more critical than mere lack of normality. We examined our data and found it unskewed and moderately kurtotic. Second, we were interested in investigating a commonly accepted assumption in the clearest way possible. Complex statistics would have obscured the basic message of tempering conclusions without sufficient data. Third, some obvious covariates were not measured because testing the hypotheses presented here was not the objective of either the MA or MN research. Such situations commonly arise in long-term research as new ideas emerge from the original objectives or basic assumptions appear less solid.

Statistical power is the probability of rejecting a false null hypothesis (H_0). Power is calculated differently for different statistical analyses but it is in all cases a func-

tion of 3 elements: α , sample size, and effect size (Cohen 1988). Sample size and α are readily understood and reported. The investigator sets α according to either convention (typical, with $\alpha = 0.05$) or by considering the relative cost of making a Type I error (atypical). Sample sizes are usually whatever can be obtained. In bear research small sample sizes are common, especially in tests that categorize bears (e.g., females vs. males).

Effect size (f) is that effect that the investigator wishes to detect. In this paper, effect size can be thought of as the difference in MFYS among den types. The typical H_0 is that of no effect (i.e., all means equal). Usually, H_0 might be more accurately described as no appreciable effect of treatment on the parameter of interest. In an experimental design context, it could be stated that there is some level of effect that would be important to detect (e.g., that MFYS differed by 20% among den types) and then the necessary data collected to evaluate the hypothesis. Because of the relationship among α , power, sample size, and effect size, 1 element can be calculated as a function of the other 3 (Cohen 1988).

Otis (1995) noted the role of population variance in power. We used an effect size (f) for ANOVA that was a standard deviation of standardized group means (weighted for unequal n):

$$f = \frac{\sigma_m}{\sigma}$$

with

$$\sigma_m = \sqrt{\sum_{i=1}^k p_i (m_i - m)^2}$$

where σ_m = the standard deviation of each m category, σ = the population standard deviation, and p_i = the proportion of the total N each m_i category represents (Cohen 1988:359–360). This standardized the group means by point estimates of the population variance; thus, this feature was incorporated into the effect size.

RESULTS

We obtained MFYS estimates for 47 litters in MA during 1985–95 and 85 litters in MN during 1982–94 (Table 1). Overall mean litter sizes were 2.30 (SD = 0.88) in MA and 2.47 (SD = 0.74) in MN. Litter sizes ranged from 1 to 4 in MA and 1 to 5 in MN. Minimum first year survival was higher in MN than MA in each den type (Table 1), and overall MFYS differed between areas ($t = 3.79$, 73 df, $P < 0.05$).

We failed to reject the H_0 that MFYS did not differ among den types for both MA ($F = 0.627$; 2,44 df; $P = 0.539$, power = 0.139) and MN ($F = 1.255$; 2,82 df; $P = 0.291$, power = 0.258). Because power was <0.80 in each case, we could not confidently accept H_0 . Thus, 11 and 13 years of data collection were inadequate to test the hypotheses.

The observed effect size was 0.155 for MA data and 0.166 for the MN data. In terms of MFYS, these f seemed large enough to be important to bear population trends. However, given the observed sample sizes we could not detect a difference. Because the data were from long-term data sets that we believed would be adequate to test the H_0 , we were interested in the f that we could have detected with the observed n and statistical criteria ($P = 0.05$, power = 0.80). For MA, $f = 0.464$ was necessary to reject the H_0 ; for MN $f = 0.341$ was required.

Conversely, the required n to reject H_0 given the observed f values and statistical criteria were also of interest. For MA data, $n = 395$ litters were necessary to reject H_0 ($f = 0.155$); $n = 345$ was required for the MN data ($f = 0.166$). Relaxing the Type I error level to 0.10 lowered the required n to 314 and 274 litters in MA and MN, respectively.

DISCUSSION

In wildlife research logistical and financial constraints often prevent the acquisition of sufficient (i.e., large) sample sizes. Power analysis then becomes important in data analysis and interpretation of results. Tests of hypotheses that fail to reject at the specified α rarely have the associated power reported (The Wildl. Soc. 1995). However, Type II errors can be as costly as Type I errors if management decisions are based on the conclusions (Peterman 1990) or if they lead to pooling of results for further analyses. Pooling data to increase sample size

after failing to reject a H_0 without examining the power of the test can compound errors. Judgement and experience may often lead researchers to believe (correctly) that there really was no difference among the tested entities. However, statistical power should be reported to allow readers to better interpret published results and to understand why certain decisions were made.

We were unable to detect any difference in MFYS among 3 types of black bear dens in this study despite differences large enough to appear meaningful. We also could not confidently conclude there was no difference. Standard statistical methodology, with Type I error rates = 0.05, required such large sample sizes (>300) to adequately test H_0 that it is unlikely that such samples could ever be attained. Alt (1989) and McLaughlin et al. (1994) come closest of all published accounts to meeting the required sample sizes 122 and 154 litters, respectively. Most studies of black bear reproduction have observed <50 litters in dens (Eiler et al. 1989, Beck 1991, Samson and Huot 1995). Others have combined in-den observations with summer observations of females with cubs (Clark and Smith 1994). Synthesis of such studies can provide useful, descriptive information; indeed, the volume and geographic scope of black bear research programs has provided biologists with a clear picture of the life history of the species. However, such programs are inadequate to test many basic hypotheses.

Hellgren and Vaughan (1989) stated that investigations on den type-productivity interactions should include female characteristics (e.g., age, nutritional status) to properly evaluate a H_0 as stated in this study. Hayes and Pelton (1994) also state that long-term research is needed to evaluate such a H_0 . We agree that individual female characteristics play a substantial role in MFYS of offspring. For example, first litters had lower MFYS rates than subsequent litters in Maine (McLaughlin et al. 1994) and Massachusetts (J. McDonald and T. Fuller unpubl.

Table 1. Mean litter size and percent minimum first-year cub survival (MFYS) from each den type in Massachusetts (1985–95) and Minnesota (1982–94).

Den type	Mean litter size						MFYS					
	Massachusetts			Minnesota			Massachusetts			Minnesota		
	n	\bar{x}	SD	n	\bar{x}	SD	n	\bar{x}	SD	n	\bar{x}	SD
Open nest	9	2.11	0.93	8	2.33	0.50	9	0.67	0.50	8	0.79	0.35
Brushpile	21	2.48	0.87	19	2.28	0.69	21	0.61	0.35	19	0.93	0.24
Covered ^a	17	2.18	0.88	58	2.55	0.77	17	0.50	0.42	58	0.81	0.30

^a Includes hollow trees, excavations, and rock caves.

data). However, a multifactorial design would further reduce the sample size in each cell of the statistical model. Unless the effect size increased enough to compensate for the decrease in n (or to reject the H_0), power would also decrease.

We agree with Smith et al. (1994) that black bears will use any materials available to create a den. Johnson et al. (1978) hypothesized that black bears select dens to minimize energy losses and that this would provide some survival advantages. Subsequently, this untested hypothesis has been accepted as intuitively logical. We demonstrate that in 2 environments with potentially harsh winter conditions no detectable survival differences were evident among cubs born in 3 den types ranging in thermal efficiency from poor to excellent. Indeed, the observed trends in MFYS were counter to those predicted. In MA, cubs born in open nest dens had the highest mean MFYS rates and cubs born in covered dens had the lowest mean MFYS rates. In MN, cubs born in brushpiles (moderate efficiency) had the highest mean MFYS rates and cubs born in open nest and covered dens had the lowest rates. Thus, denning habitat and bear populations may not be as closely linked as has been believed (Johnson and Pelton 1981, Lentz et al. 1983, Goodrich and Berger 1994). Beck (1991) hypothesized that individual bears had enough insulation (body fat and pelage) from the elements that they could over-winter without the structural assistance of a den. Weaver and Pelton (1994) recognized that den sites did not appear to limit Louisiana black bear populations yet despite the lack of evidence, they stressed the importance of den sites in conservation planning.

Factors often cited as negatively affecting the quality of a denning site include flooding (Alt 1984), human disturbance (Elowe and Dodge 1989), and presence of predators such as wolves (*Canis lupus*, Paquet and Carbyn 1986), brown bears (*Ursus arctos*, Smith and Follmann 1993), and other black bears (Alt and Grattadauria 1984). Smith et al. (1994) provide some evidence to discount extreme cold as a survival-related factor. They documented black bears in interior Alaska that successfully used surface dens despite temperatures ≤ -50 C. Most risks may be more related to poor site selection by individual bears, unpredictable weather, and chance human disturbances than thermal deficiencies of den type.

Alt (1984) cited excavated dens as being most prone to cub mortality from flooding, yet these would be among the den types that bears acting under the energy hypothesis should select. Manville (1983) noted 2 female bears denned <100 m from active snowmobile trails without

abandoning dens; one of the 2 did flee when approached on foot. In Massachusetts, female bears with new cubs have denned in open nests and brushpiles ≤ 50 m from snowmobile trails, secondary paved roads, and interstate highways with 100% MFYS (J. McDonald and T. Fuller unpubl. data). Other types of disturbance (e.g., logging, construction) can not be anticipated by bears prior to denning and are unavoidable from a den selection standpoint, as heavy equipment will destroy surface, brushpile, and excavated dens alike.

Predation may be partially avoidable by selecting secure den sites and not reusing previous dens (i.e., avoiding certain sites [Alt and Grattadauria 1984]). However, in Alaska high reuse (29%–75%) of dens was reported (Schwartz et al. 1987). By selecting cryptic or defensible (Beck 1991) dens, female black bears may enhance both their survival and MFYS of cubs. By selecting easy-to-flee dens (i.e., open nests), bears may enhance their own survival.

Ruggerio et al. (1994) addressed several factors that limit the state of knowledge on forest carnivores. These included extensive information from few studies, small sample sizes, variable results, and inappropriate inference and methods. Several of these factors also hinder progress in bear research. As wildlife research in general and bear research in particular progresses from where and when questions to how and why, the inferential standards must be raised as well (Romesburg 1981, Hunter 1989).

In discussing the effect of habitat quality on black bear natality, Beck (1991:35) quoted Krebs (1979): “the strength of belief is often confused with the strength of the evidence.” This also seems to apply to our discussion of den type effects on cub survival. Although the energy demands of metabolic maintenance and lactation during a prolonged fast under the harshest annual climatic conditions make the hypothesis of a positive relationship between den thermal efficiency and cub survival plausible, the evidence does not support this hypothesis. Further, using the design and analytical methods described in this study, it is doubtful the hypothesis can be tested unambiguously simply due to the logistical and financial constraints involved with capturing the number of bears required.

Researchers should keep in mind the types of questions that need to be asked and try to identify effects that would be meaningful to detect. Consideration of only Type I error rates can lead to spurious conclusions (Petterman 1990) and keep unfounded dogma from being replaced by actual knowledge.

LITERATURE CITED

- ALT, G.L. 1983. Timing of parturition of black bears (*Ursus americanus*) in northeastern Pennsylvania. *J. Mammal.* 64:305-307.
- . 1984. Black bear cub mortality due to flooding of dens. *J. Wildl. Manage.* 48:1432-1434.
- . 1989. Reproductive biology of female black bears and early growth and development of cubs in northeastern Pennsylvania. Ph.D. Diss., West Virginia Univ., Morgantown. 116pp.
- , AND J.M. GRATTADURIA. 1984. Reuse of black bear dens in northeastern Pennsylvania. *J. Wildl. Manage.* 48:236-239.
- BECK, T.D.I. 1991. Black bears of west-central Colorado. *Colo. Div. Wildl. Tech. Pub.* 39. 86pp.
- CLARK, J.D., AND K.G. SMITH. 1994. A demographic comparison of two black bear populations in the interior highlands of Arkansas. *Wildl. Soc. Bull.* 22:593-603.
- COHEN, J. 1988. Statistical power analysis for the behavioral sciences. Second ed. Lawrence Erlbaum Assoc. Inc., Hillsdale, N.J. 567pp.
- 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. 1984. Home range, movements, and habitat preferences of black bears (*Ursus americanus*) in western Massachusetts. M.S. Thesis, Univ. Massachusetts, Amherst. 112pp.
- . 1987. Factors affecting black bear reproductive success and cub survival in Massachusetts. Ph.D. Diss., Univ. Massachusetts, Amherst. 71pp.
- , AND W.E. DODGE. 1989. Factors affecting black bear reproductive success and cub survival. *J. Wildl. Manage.* 53:962-968.
- FOLK, G.E., JR., M.A. FOLK, AND J.J. MINOR. 1972. Physiological condition of three species of bears in winter dens. *Int. Conf. Bear Res. and Manage.* 2:107-124.
- , J.M. HUNT, AND M.A. FOLK. 1980. Further evidence for hibernation of bears. *Int. Conf. Bear Res. and Manage.* 3:43-47.
- FULLER, D.P. 1993. Black bear population dynamics in western Massachusetts. M.S. Thesis, Univ. Massachusetts, Amherst. 136pp.
- GOODRICH, J.M., AND J. BERGER. 1994. Winter recreation and hibernating black bears *Ursus americanus*. *Biol. Cons.* 67:105-110.
- HAYES, S.G., AND M.R. PELTON. 1994. Habitat characteristics of female black bear dens in northwestern Arkansas. *Int. Conf. Bear Res. and Manage.* 9(1):411-418.
- HELLGREN, E.C., AND M.R. VAUGHAN. 1989. Denning ecology of black bears in a southeastern wetland. *J. Wildl. Manage.* 53:347-353.
- HUNTER, M.L., JR. 1989. Aardvarks and Arcadia: two principles of wildlife research. *Wildl. Soc. Bull.* 17:350-351.
- JOHNSON, K.G., D.O. JOHNSON, AND M.R. PELTON. 1978. Simulation of winter heat loss for a black bear in a closed tree den. *Proc. Fourth East. Work. Black Bear Res. and Manage.* 4:155-166.
- , AND M.R. PELTON. 1981. Selection and availability of dens for black bears in Tennessee. *J. Wildl. Manage.* 45:111-119.
- KOLENOSKY, G.B., AND S.M. STRATHEARN. 1987. Black bear. Pages 442-455 in M. Novak, J.A. Baker, M.E. Obbard, and B. Mallock, eds. *Wild furbearer management and conservation in North America.* Ont. Minist. Nat. Resour., Toronto, Can.
- LECOUNT, A.L. 1987. Causes of black bear cub mortality. *Int. Conf. Bear Res. and Manage.* 7:75-82.
- LENTZ, W.M., R.L. MARCHINTON, AND R.E. SMITH. 1983. Thermodynamic analysis of northeastern Georgia black bear dens. *J. Wildl. Manage.* 47:545-550.
- MANVILLE, A.M., II. 1983. Human impact on the black bear in Michigan's lower peninsula. *Int. Conf. Bear Res. and Manage.* 5:20-33.
- MCLAUGHLIN, C.R., G.J. MATULA, JR., AND R.J. O'CONNOR. 1994. Synchronous reproduction by Maine black bears. *Int. Conf. Bear Res. and Manage.* 9(1):471-479.
- NETER, J., W. WASSERMAN, AND M.H. KUTNER. 1990. Applied linear statistical models. Third ed. Irwin, Homewood, Ill. 1181pp.
- NOYCE, K.V., AND D.L. GARSHELIS. 1994. Body size and blood characteristics as indicators of condition and reproductive performance in black bears. *Int. Conf. Bear Res. and Manage.* 9(1):481-496.
- OFTEDAL, O.T., G.L. ALT, E.M. WIDDOWSON, AND M.R. JAKUBASZ. 1993. Nutrition and growth of suckling black bears (*Ursus americanus*) during their mothers' winter fast. *Brit. J. Nutr.* 70:59-79.
- OTIS, D.L. 1995. Journal news. *J. Wildl. Manage.* 59:630.
- PAQUET, P.C., AND L.N. CARBYN. 1986. Wolves, *Canis lupus*, killing denning black bears, *Ursus americanus*, in the Riding Mountain National Park area. *Can. Field-Nat.* 100:371-372.
- PETERMAN, R.M. 1990. Statistical power analysis can improve fisheries research and management. *Can. J. Fish. Aquatic Sci.* 47:2-15.
- 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.
- ROMESBURG, H.C. 1981. Wildlife science: gaining reliable knowledge. *J. Wildl. Manage.* 45:293-313.
- RUGGERIO, L.F., K.B. AUBRY, S.W. BUSKIRK, J.L. LYON, AND W.J. ZIELINSKI, TECHNICAL EDITORS. 1994. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. RM-254. 184pp.
- SAMSON, C., AND J. HUOT. 1995. Reproductive biology of female black bears in relation to body mass in early winter. *J. Mammal.* 76:68-77.
- SCHOOLEY, R.L., C.R. MCLAUGHLIN, G.J. MATULA, JR., AND W.B. KROHN. 1994. Denning chronology of female black bears:

- effects of food, weather, and reproduction. *J. Mammal.* 75:466–477.
- SCHWARTZ, C.C., S.D. MILLER, AND A.W. FRANZMANN. 1987. Denning ecology of three black bear populations in Alaska. *Int. Conf. Bear Res. and Manage.* 7:281–291.
- SMITH, M.E., AND E.H. FOLLMANN. 1993. Grizzly bear, *Ursus arctos*, predation of a denned adult black bear, *U. americanus*. *Can. Field-Nat.* 107:97–99.
- , J.L. HECHTEL, AND E.H. FOLLMAN. 1994. Black bear denning ecology in interior Alaska. *Int. Conf. Bear Res. and Manage.* 9(1):513–522.
- THE WILDLIFE SOCIETY. 1995. Journal news. *J. Wildl. Manage.* 59:196–198.
- WEAVER, K.M., AND M.R. PELTON. 1994. Denning ecology of black bears in the Tensas River basin of Louisiana. *Int. Conf. Bear Res. and Manage.* 9(1):427–433.