To the Graduate Council:

I am submitting herewith a thesis written by Thomas Hunter Eason entitled "Weights and Morphometrics of Black Bears in the Southeastern United States." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Dr. Michael R. Pelton, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor
and Dean of The Graduate School

WEIGHTS AND MORPHOMETRICS OF BLACK BEARS IN THE SOUTHEASTERN UNITED STATES

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Thomas H. Eason

December 1995

DEDICATION

This thesis is dedicated to Danielle;

my heart,
my soul,
my strength
and
my salvation.

ACKNOWLEDGMENTS

This thesis is the culmination of years of hard work and would not have been possible without the help and support of many. Dr. Pelton laid the groundwork for this study and gave me the opportunity to work in the profession that I love; thanks for your constant encouragement and suggestions throughout. I also thank my committee members: Dr. Buehler, Dr. Bozdogan, and Dr. Kennedy who always had open ears and minds and offered invaluable assistance in the drafting of my thesis. Additionally, I thank Frank Teunissen van Manen for his many critiques of my writing and his selfless help whenever I asked (which was almost always!).

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ABSTRACT

Weights and body size measurements (morphometrics) of mammals may vary throughout the range of a species for different reasons. Populations may vary genetically, demographically, or nutritionally, any 1 of which (or combination thereof) could alter the weights and morphometrics of its constituents. The objectives of my study were to determine if black bear (*Ursus americanus*) populations vary in weights and morphometrics and, if so, to determine if these differences correspond to current subspecies demarcations or, alternatively, to regional habitat quality indices. I also determined the level of variation introduced into morphometric data when multiple researchers collect field data.

I compared the summer weights and morphometrics of 260 adult black bears, collected from 20 locations throughout the Southeast and selected other areas in the United States from 1992 to 1994. I estimated missing data points using multiple regression analyses and combined the sexes using sexual dimorphism correction factors. I partitioned the 20 populations based on 1) traditional subspecies demarcations of black bears and 2) Bailey's (1980) ecoregion province delineations. Then, I determined the optimal clusterings of these partition schemes using the minimum of Akaike's information criterion (AIC) and information complexity based on the inverse-Fisher information matrix (ICOMPIFIM) in multi-sample cluster analyses.

Black bears in both the subspecies and ecoregion province partition schemes grouped separately based on their weights and morphometrics in the multi-sample cluster

analyses. Therefore, there was evidence supporting the subspecies demarcations, but there was also evidence that this classification may not account for all of the morphometric variation found in black bears in the eastern United States. I concluded that *U. a. americanus*, *U. a. luteolus* and *U. a. floridanus* were morphometrically distinct subspecies, but that there may be additional morphometric differences within the range of *U. a. americanus*.

The weight and morphometric differences indicated by the multi-sample cluster analyses, however, were not correlated with regional habitat quality indices as measured by: crop yields, latitude, actual evapotranspiration, and soil fertility. Additionally, in Great Smoky Mountains National Park (TN) and Neuse-Pamlico Peninsula (NC), black bears exhibited inter-year differences in weights and morphometrics. Therefore, I hypothesized that black bears may respond temporally to habitat quality at a sub-regional level.

I estimated the variation in morphometrics of black bears (Ursus americanus) taken by 6 field researchers. Eight body measurements were recorded by 3 teams of 2 researchers on a total of 70 black bears in Great Smoky Mountains National Park in Tennessee and North Carolina. Measurements were summarized to determine the intra- and inter-researcher variation present in the morphometrics. I then ran simulations on predictive equations to determine how the observed variation affected the results. The intra-researcher simulations differed from one another by 1.5 - 2.6% of the average of the predicted parameters and the inter-researcher simulations differed from one another by 3.4 - 8.1% of the average of the predicted parameters. These differences may explain some of the error associated with analyses and predictive equations based on morphometrics. Consequently, it is imperative for researchers to minimize the error of taking measurements by developing stringent standards for data collection and by reducing the number of personnel involved in data collection.

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WEIGHTS AND MORPHOMETRICS OF BLACK BEARS IN THE SOUTHEASTERN UNITED STATES AND SELECTED OTHER AREAS.

CHAPTER I

INTRODUCTION

General Problem Statement

Black bears (*Ursus americanus*) historically ranged throughout the southeastern United States and were characterized by 3 subspecies in this region (Hall 1981) (Fig. 1.1). The Louisiana subspecies (*U. a. luteolus*) occupied all of Louisiana, eastern Texas, and southern Mississippi, whereas the Florida subspecies (*U. a. floridanus*) ranged throughout Florida, southern Georgia, and southern Alabama. The more widespread *U. a. americanus* occupied the rest of the Southeast.

Over the past 100 years, the range of black bears in the Southeast has contracted by 90% (Maehr 1984), bringing attention to the subspecies in this region. Responding to petitions requesting the protection of *U. a. floridanus* and *U. a. luteolus*, the United States Fish and Wildlife Service (USFWS) listed the Louisiana subspecies as "threatened" and placed the Florida subspecies in the "warranted but precluded" category of the Endangered Species Act of 1973. Thus, *U. a. luteolus* gained protection, whereas *U. a. floridanus* did not. During the listing process, however, the USFWS investigated the status of black bears in the Southeast and encountered questions regarding the classification of these bears.

Griffith (1821) originally named the Louisiana black bear (*U. luteolus*) and Merriam (1893) described the taxon based on the morphological characteristics of 5 skulls

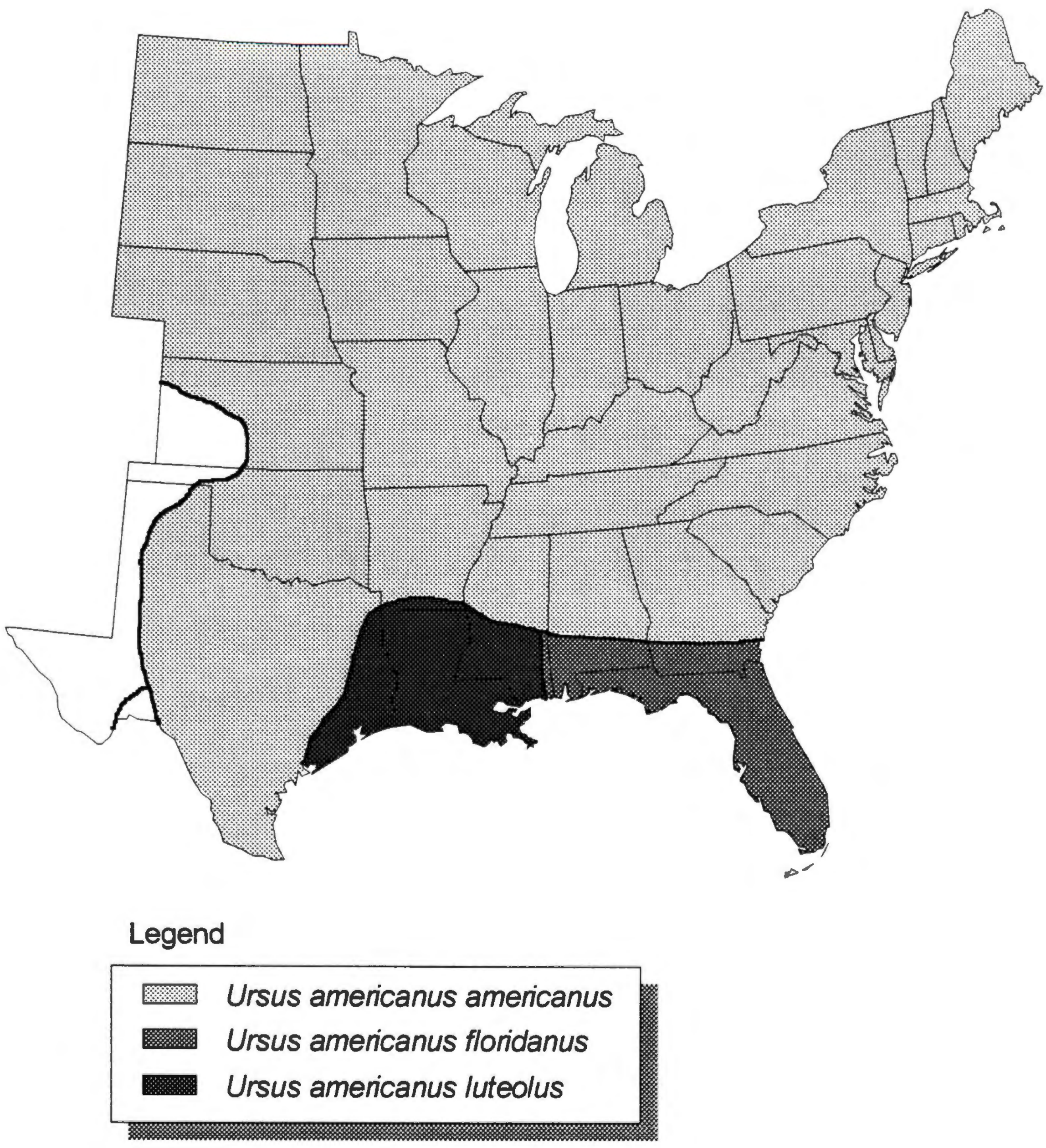


Figure 1.1. Traditional subspecies ranges of black bears in the Southeast (from Hall 1981).

from 1 parish in Louisiana. Similarly, Merriam (1896) described the Florida black bear (*U. floridanus*) based on 1 skull which came from southern Florida. Later, Hall and Kelson (1959) treated both taxa as subspecies, and this classification has been used since (Hall 1981). Pelton (1989), however, questioned the validity of the taxonomic grouping of the Louisiana and Florida subspecies in a study that employed skull measurements and genetic characteristics (isoenzyme and mitochondrial DNA) to determine the taxonomic status of black bear populations in Louisiana, Arkansas, Florida, West Virginia, Virginia, Minnesota, and Tennessee. Skull measurements supported *U. a. luteolus* as a distinct subspecies but also showed that the Louisiana and Florida subspecies may be morphologically similar. Genetic analyses, however, did not detect any clear differences among the 3 subspecies.

Small sample sizes in the aforementioned study prohibited a thorough analysis and left many questions unanswered (Pelton 1989). Thus, the United States Fish and Wildlife Service (USFWS) in 1992 funded a 3-year study to clarify the taxonomy of black bears in the southeastern United States. Led by researchers at Virginia Polytechnic Institute and State University (Virginia Tech), investigators used genetic characteristics, skull morphology, weights, and morphometrics to assess the taxonomic relationships between *U. a. americanus*, *U. a. floridanus*, and *U. a. luteolus*. I focused on the weight and morphometric aspect of the study, and investigated regional habitat quality as a possible factor driving any differences found among the populations in the southeastern United States and selected other areas.

Theoretical Framework

Geographic Variation. Geographic variation of many traits is common in black bears across North America. For instance, the predominant color phase of bears in the East is black, whereas non-black color phases are increasingly common from east to west across North America (Rounds 1987). In the West, color phases range from black to cinnamon brown, bluish-gray, and even white (Pelton 1982). Skull measurements also vary across the range of the species. Harlow (1962) found that Florida black bear (*U. a. floridanus*) skulls were larger than (*U. a. americanus*) skulls from Virginia in both sexes. Based on similar skull measurements, Kennedy (1989) reported that black bears in southeastern localities (eastern Texas, Alabama, Florida, Louisiana, and Mississippi) clustered together and grouped differently from bears in other areas (Mexico, New York, Minnesota, Virginia, Tennessee, and Arkansas). Body size also varies in black bears. McLean (1990) found significant body size differences in wild and nuisance black bears within Great Smoky Mountains National Park (GSMNP) and between bears in an adjacent national forest and those in the park.

The identification of 16 subspecies of black bears (Hall 1981) over the past 2 centuries further illustrates the variations found in this species. Mayr (1969) defined a subspecies to be a group of individuals of a species that are phenotypically distinct from other such groups and that occupy a discrete geographic area. This concept was further defined by Amadon (1949), who considered a population a distinct subspecies if 75% of its individuals varied from another population in at least 1 character. Using Amadon's 75% rule, Kennedy (1989) illustrated that the Louisiana black bear would be considered a distinct subspecies. Genetic and biochemical procedures, however, failed to support this finding (Pelton 1989). Variation in weights and morphometrics (N.B. for the purposes of this thesis, morphometrics are defined as external body measurements) among the 3 southeastern subspecies of black bear would lend support to the findings of Kennedy (1989).

Habitat Qualtiy. Much of the weight and morphometric variation of mammals can be explained by differing nutritional levels among populations. Pelton (1970) found that Georgia cottontail rabbit (*Sylvilagus floridanus*) weights and morphometrics varied among mountain, piedmont, and coastal plain populations. He found that coastal plain cottontails were the heaviest and largest, whereas mountain cottontails were the lightest and smallest. Piedmont cottontails were intermediate in weight and size between coastal plain and mountain cottontails. Pelton attributed these differences in weight and size to increased nutrition due to land use practices in Georgia. Another example of morphometric variation was discussed by Dozier (1950). He trapped muskrats on the Montezuma Wildlife Refuge in New York from 1943-1948 and showed that muskrats living in habitats with good food conditions weighed more and were larger than those living in habitats with poor food conditions (Dozier 1950). Dozier's findings were supported by Schacher and Pelton (1976), who found that body weights of river muskrats were greater than those for creek muskrats in eastern Tennessee. This correlated with the nutritional quality of forages between the two study areas. Additionally, Rayor (1985) found that Gunnison's prairie dogs living in irrigated fields were significantly heavier than those living in the open prairie. This weight difference correlated with the greater availability of lush vegetation and water in the irrigated fields as opposed to the dry vegetation growing in the open range.

McLean (1990) found that nuisance black bears were larger and heavier than wild black bears in GSMNP, and that national forest bears were larger and heavier than bears living in the park. He attributed these size differences to the better nutrition of nuisance bears eating human foods high in energy and also to more oak trees (*Quercus spp.*) and consequently better hard mast crops in the national forests as compared to the adjacent park. Similarly, Rogers (1976) discovered that captive black bears receiving rich diets grew faster than free-ranging bears. Again, this difference was attributed to the increased nutrition of the captive black bears as compared with wild bears.

Based on the above general pattern of body size and weight response to nutritional quality, black bear weights, morphometrics, and fat levels may vary among populations in the Southeast. Thus, bears living in areas with good habitat likely will be heavier, larger and have more fat than bears from areas with lower habitat quality.

Black bear habitat quality is difficult to quantify without intensive, time consuming, and costly habitat inventories. Many indirect methods, however, can be employed to measure habitat levels: general habitat parameters, bear-specific habitat parameters, physiological parameters, agriculture/soil parameters, and expert knowledge. These methods and the underlying confounding factors common to all of them are discussed below.

<u>General Habitat Parameters.</u> General habitat parameters give a sense of the overall quality of an area. Net primary productivity (NPP) measures the total energy converted to

plant matter at a particular site. Generally, the more plant matter that is produced, the better the quality of that habitat. Net primary productivity may be estimated using measures of evapotranspiration (Rosenzweig 1968a) or values of NPP may be obtained from the literature. Site indices may also indicate the potential habitat quality of an area by relating tree height and age to soil nutritional levels. The diversity, interspersion, and juxtaposition of habitats in conjunction with the above measures may also provide an idea of the general quality of an area.

Bear-Specific Habitat Parameters. Species-specific habitat parameters impart finer detail to habitat quality than do general habitat parameters. For black bears, these parameters include vegetation surveys emphasizing soft- and hard-mast production, cover, water, and den sites. Other vegetation parameters focusing on foods commonly eaten by black bears would also be beneficial. Habitat Suitability Indices (HSI's), such as that derived by Van Manen (1991) for the Big South Fork National River and Recreation Area, may be used for this purpose. However, due to the variety of physiographic regions and habitats inhabited by black bears, different HSI models would be necessary for many of the populations across the Southeast. To date, these HSI's have not been developed.

Physiological Parameters. Physiological parameters of bears may be used to measure habitat quality. As discussed previously, larger, heavier, fatter mammals come from areas of high habitat quality (Dozier 1950, Marchinton et. al. 1987, Pelton 1970, Rayor 1985, Rogers 1976, Schacher and Pelton 1976). Thus, weights, morphometrics, fat levels and weight/body length ratios may be used to determine if bears are larger in one area than in another. Blood parameters such as hemoglobin, globulin, alpha 1 globulin, calcium, packed cell volume, and sodium can also be used as indicators of black bear health and consequently of black bear habitat quality. Additionally, animals that are healthier, as measured by soil fertility, tend to have more offspring (Albrecht 1944, Denney 1944, Hill 1972, Stevens 1962, Williams and Caskey 1965), so fecundity may also be considered.

Soil-Agriculture Parameters. Soil-agriculture parameters may indicate the habitat quality of an area. Parent materials of an area determine many characteristics of a soil, which in turn determine much about the vegetation. Fertile parent materials yield more and healthier crops than infertile parent materials, however, soil fertility is a more direct measure of soil nutrition than is parent material (Brady 1990). Parameters such as pH, calcium levels, magnesium levels, and organic matter can be used to rank soils according to soil fertility (Crawford 1950, Williams 1964, Williams and Caskey 1965). Lastly, the percent sand, silt, and loam fraction of a soil dictates much of a soil's ability to hold water and release nutrients.

General agriculture practices may also be studied to determine if bears are gaining significant portions of their diet from these sources. Bears ranging in areas adjacent to large agricultural crops such as corn and sugar cane have access to large, stable food sources which other bears may not. The length of the growing season may also be an index of habitat quality, as food will be available throughout more of the year with longer growing seasons.

Expert Knowledge. Black bear biologists and soil biologists can be interviewed and their opinions recorded as a means of quantifying habitat quality. Experienced biologists usually have a "feel" for intangibles like habitat quality that can be used when other data are unavailable.

Confounding Factors. There are many confounding factors involved in using the above indirect methods of quantifying habitat quality. Many definitions of habitat quality exist and may cause confusion among researchers. For this study, I defined habitat quality to be the capability of the environment to provide essential biotic and abiotic factors (focusing on nutrition) necessary for the maintenance of a black bear population. Such assessment of habitat quality on a population level introduces many difficulties into relating black bear nutritional levels to their weights and morphometrics.

The age and sex of bears can affect their growth rate because older, larger, more aggressive males tend to chase off subadult males and possibly even females who then may be excluded from the prime habitat areas (van Manen 1994). Male bears also grow larger than females and may therefore exhibit different growth patterns. The genetics of a bear population can also affect its response to habitat parameters, as certain "strains" of bears may inherently grow faster and attain larger sizes than others. Similarly, certain populations may naturally retain more fat than other populations.

The status of a bear population can influence black bear nutritional levels as well. Whether a population is increasing, stable, or decreasing may alter its density and consequently its response to habitat quality. Lastly, the time of year and season may affect nutritional status because black bear habitat use varies due to the dynamics of natural systems. Thus, bears sampled during a "good" or "bad" year will not represent the true habitat quality of an area. Data need to be collected over many years and averaged to develop a representative estimate of an area's habitat quality.

Within-year variation of weights and morphometrics also occurs in black bears. Bears emerging from winter dormancy usually have exhausted their fat reserves and are leaner and smaller than when they entered dormancy. This condition may persist into early summer while food sources may be deficient. Consequently, bears eat more during the late summer and fall and gain weight in fat preparing for winter hibernation. Thus, a bear in early summer will have different nutritional parameters than in the late fall.

The above confounding factors illustrate the difficulties involved in using indirect methods to assess habitat quality on a population level. However, if these factors can be addressed, strong correlations between habitat quality and black bear weights and morphometrics may emerge.

Scope of Study

In this study, I explored the relationships among the summer weights and morphometrics of adult black bears (≥ 4 yrs.) across the Southeast and selected other areas by comparing them at the subspecies and ecoregion province levels. I also determined if black bear weights, morphometrics, and fat levels correlated with regional indices of habitat quality. Because of the difficulty in quantifying habitat quality on a regional scale, however, I focused on only a few of the indexing methods discussed above. Weights and fat levels of bears, evapotranspiration rates of forests, soil fertility rankings, crop acreage estimates, and latitudinal positions were all used to index the relative habitat qualities of the various study areas. Even though they were not utilized, the other methods of indexing habitat quality were mentioned to give an overview of the subject and so that other researchers may incorporate them into future studies. I attempted to account for the confounding factors that were resolvable.

The objectives of this study were to: (1) compare weights and morphometrics (total body length, chest girth, neck girth, forearm girth, head width, and zygomatic circumference) of black bear (*Ursus americanus*) populations in the southeastern United States and selected other North American black bear populations, (2) determine if *U. a. luteolus* and *U. a. floridanus* are distinctive from the more widespread *U. a. americanus* based on weights and morphometrics, and (3) determine if black bear weights, morphometrics and fat levels correlate with habitat quality. These objectives were investigated by testing the following research hypotheses: (1) weights and morphometrics differ among black bears (*Ursus americanus*) grouped by ecoregion province in the southeastern United States and selected other areas, (2) weights and morphometrics differ among black bears (*Ursus americanus*) grouped by subspecies in the southeastern United States and selected other areas, and (3) black bear weights, morphometrics and fat levels increase proportionally with regional indices of habitat quality.

CHAPTER II

STUDY AREA

The study area for the entire taxonomic project included locations across the entire southeastern United States and selected other sites across the United States, Canada, and Mexico. Because of data limitations, however, only 20 locations could be incorporated into the weight and morphometric portion of the study (Fig. 1.2). To classify these locations, I chose a physiographic approach in which similar areas were lumped into regions (Fig. 1.3). The following descriptions follow Bailey's ecoregion delineations of the United States (Bailey 1980).

Humid Temperate Domain (2000)

The Humid Temperate Domain is bounded by the 30° and 60° N. latitudes. Strong seasonality with cold winters and warm summers characterizes this domain. Precipitation is also strongly seasonal. Broadleaf deciduous and needleleaf evergreen species dominate the forests of this domain.

Warm Continental Division (2100). The warm continental division comprises the northern portion of the humid temperate domain. It falls between the 40° and 55° latitudes and exhibits strong seasonal variations in temperature. Needleleaf and mixed needleleaf-deciduous forests dominate the vegetation in this division. Soils are generally acidic with an upper organic layer, but are not productive for cropping.

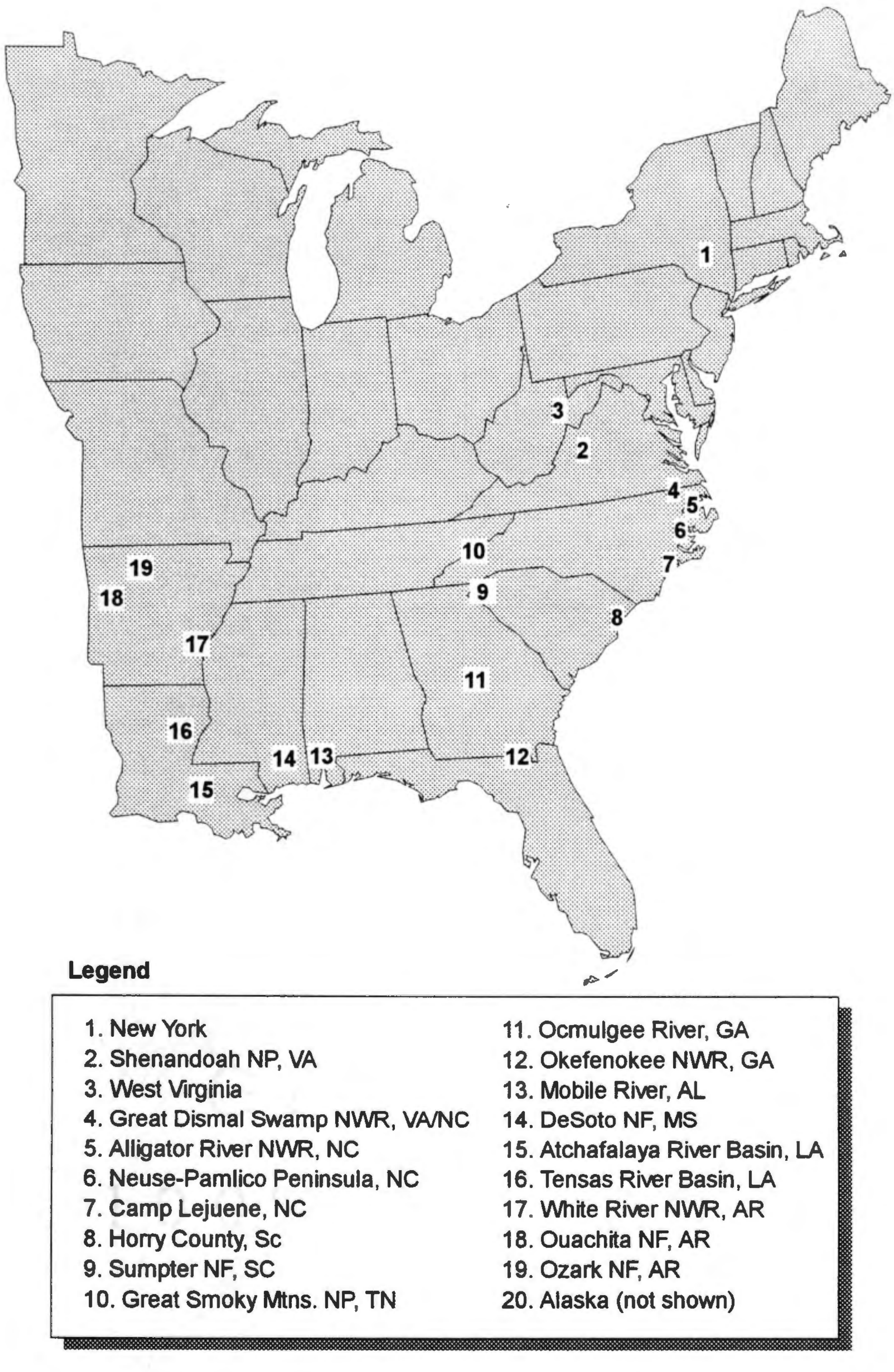


Figure 1.2. Populations sampled for morphometric study of black bears, 1992-1994.

Explanation of Demarcations

- **2000** Humid Temperate Domain
  - **2100** Warm Continental Division
    - **2110** Laurentian Mixed Forest Province
      - **2111** Spruce-Fir Forest Section
      - **2112** Northern Hardwoods-Fir Forest Section
      - **2113** Northern Hardwoods Forest Section
      - **2114** Northern Hardwoods-Spruce Forest Section
  - **2200** Hot Continental Division
    - **2210** Eastern Deciduous Forest Province
      - **2211** Mixed Mesophytic Forest Section
      - **2212** Beech-Maple Forest Section
      - **2213** Maple-Basswood Forest and Oak Savanna Section
      - **2214** Appalachian Oak Forest Section
      - **2215** Oak-Hickory Forest Section
  - **2300** Subtropical Division
    - **2310** Outer Coastal Plain Forest Province
      - **2311** Beech-Sweetgum-Magnolia-Pine-Oak Forest Section
      - **2312** Southern Flood Plain Forest Section
    - **2320** Southeastern Mixed Forest Province
  - **2400** Marine Division
    - **M2410** Pacific Forest Province (Highland)
  - **2500** Prairie Division
    - **2510** Prairie Parkland Province
      - **2511** Oak-Hickory-Bluestem Parkland Section
    - **2530** Tall-Grass Prairie Province
      - **2531** Bluestem Prairie Section
- **4000** Humid Tropical Domain
  - **4100** Savanna Division
    - **4110** Everglades Province

Figure 1.3. Ecoregions of the eastern United States (from Bailey 1980) with study sites super-imposed.

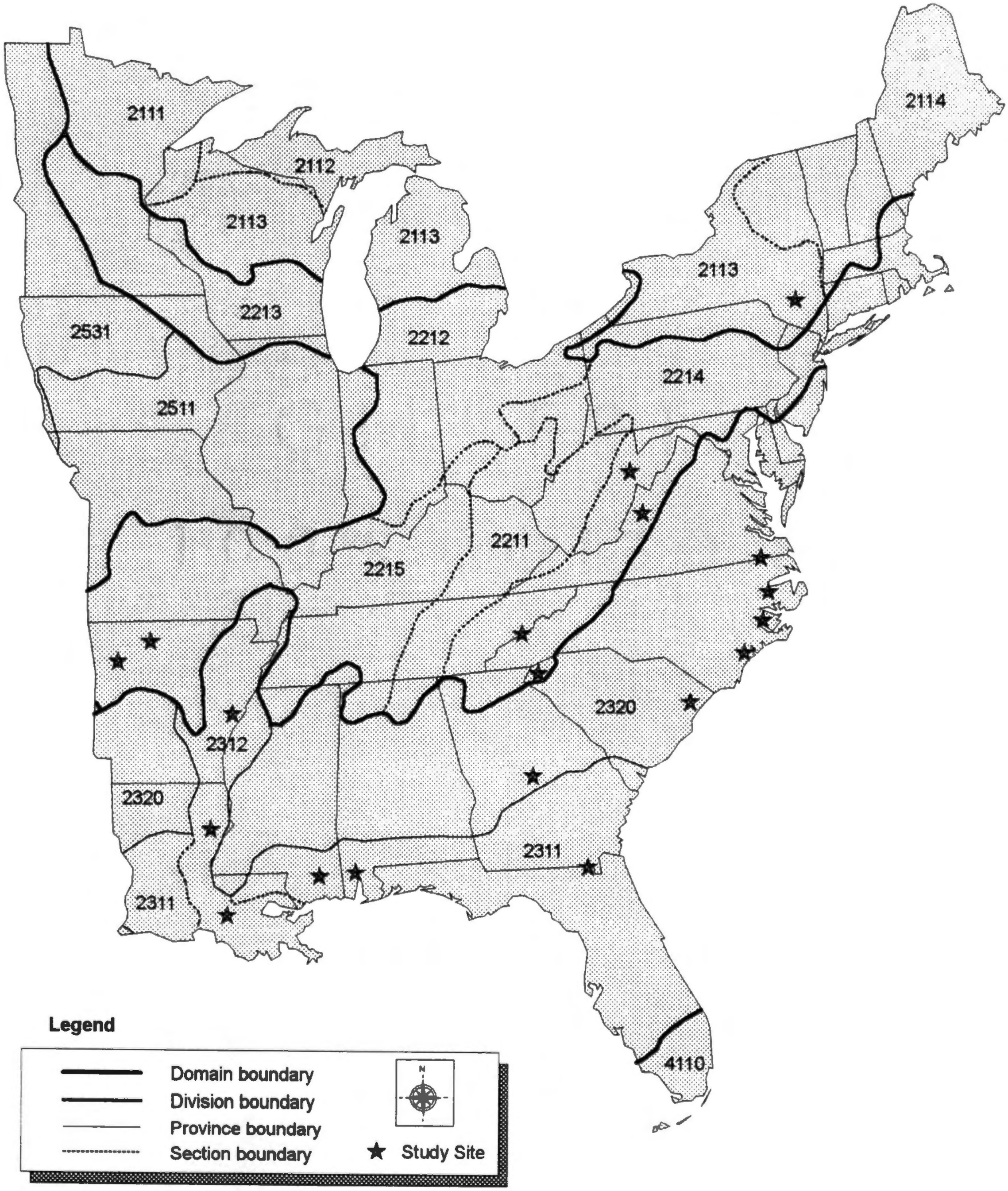


Figure 1.3. (continued).

Laurentian Mixed Forest Province (2110). Rolling hills and low mountains interrupt the otherwise low relief of this province. Elevations range from sea level to 1,200 m, with a few isolated peaks higher than 1,500 m. Winters are long and cold, while summers are short and cool. Average annual temperatures range between 2°-10° C. Precipitation averages 600-1,150 mm annually. Mixed forests of coniferous and deciduous species cover the province. Soils vary greatly but are dominated by Spodosols, Incepticols, and Alfisols in New England, along the Great Lakes, and further inland, respectively. A short growing season of 100-140 frost-free days restricts agriculture in this province. A study site in New York, located in the Northern Hardwoods Forest (2113), represents 1 of the 4 sections in this province.

Hot Continental Division (2200). This division lies south of the Warm Continental Division and exhibits similar characteristics except for hotter summers and milder winters. Tall, broadleaf tree species dominate the natural vegetation. Inceptisols, Ultisols, and Alfisols make up the majority of soils in this division.

Eastern Deciduous Forest Province (2210) Elevations in this province range form sea level to 760 m with a few isolated peaks higher than 1,370 m. Topography is mostly rolling, but some areas are nearly flat whereas other areas are mountainous. Cold winters and warm summers mark this region, with average annual temperatures ranging between 4°-15° C. Precipitation is seasonal but averages 900-1,500 mm per year. Tall, broadleaf trees with dense canopies dominate the forests of this province. Soils are characteristically Alfisols. Two of the 5 sections in this province were represented in this study: locations in Virginia, West Virginia, Tennessee, and South Carolina were in the Appalachian Oak

Forest (2214) and 2 locations in northwestern Arkansas were in the Oak-Hickory Forest (2215).

Subtropical Division (2300). Hot, humid summers and moderate winters characterize this division. Deciduous forests cover the inland regions, whereas pine forests cover the sandy soils of the coastal region. Soils are predominantly strongly leached Ultisols.

Outer Coastal Plain Forest Province (2310). Topography of this area is flat with elevations reaching only 90 m. Average annual temperatures range moderately from 15°-21°C and precipitation is abundant, averaging 1,000-1,525 mm per year. Temperate rainforests grow in this province with pines predominating. Soils consist of wet, acidic, and sandy Ultisols, Spodosols, and Entisols. Both of the sections were represented by 6 study sites: 3 locations in Florida/Georgia, Mississippi and Alabama were in the Beech-Sweetgum-Magnolia-Pine-Oak Forest (2311) and 3 locations in Louisiana and Arkansas were in the Southern Flood Plain Forest (2312).

Southeastern Mixed Forest Province (2320). Gently sloping hills cover most of this province, with elevations ranging from 30-180 m in the Gulf Coastal Plains and from 90-300 m in the Piedmont. Mild winters and hot summers give rise to average annual temperatures ranging from 15° to 21°C. Rainfall is plentiful, averaging 1,000-1,500 mm per year. The forests of this region consist of broadleaf deciduous trees and evergreen trees. Ultisols dominate the soils; however, Vertisols and Inceptisols also are represented. Six study sites in Virginia, North Carolina, South Carolina, and Georgia were in this province.

Marine Division (2400). Situated on the Pacific west coast between the 40° and 60° N. latitudes, this division is temperate and rainy with warm summers. Dense needleleaf forests cover the marine division and harbor some of the world's largest trees. The strongly leached Inceptisol and Ultisol soils are acidic.

Pacific Forest Province (Highland) (M2410). The Pacific forest province is characterized by steep, rugged mountains rising 1,500 - 2,700 m above sea level. The climate is mild with temperatures averaging between 2° to 10° C. throughout the year. Precipitation is heavy, 750 - 3,800 mm a year, and switches from rain to a rain/snow mix in the northern latitudes. Montane vegetation predominates in the Inceptisol and Ultisol soils of the pacific forest province. One study site in Alaska was in this province.

CHAPTER III

METHODS

Data Collection

Summer weights and morphometrics were collected on 260 adult black bears ($\geq$ 4 yrs.) from 20 locations throughout the southeastern United States and selected other areas outside the region (Table 1.1). Project personnel from Virginia Tech and the University of Tennessee trapped and measured black bears in White River National Wildlife Refuge [NWR] (AR), Great Dismal Swamp NWR (VA and NC), Ocmulgee River (GA), Okefenokee NWR (GA), Mobile River (AL), DeSoto National Forest (MS), the lower Atchafalaya Basin (LA), and coastal South Carolina. Cooperating researchers collected samples and information from the other 13 populations and sent the data to this project. Data were accepted for bears sampled during the summer only (late May through August).

Project personnel captured black bears by use of Aldrich spring-activated foot snares (Aldrich Animal Trap Co., Clallam Bay, WA) or culvert traps following standard protocols (Johnson and Pelton 1980). Captured bears were immobilized by injection of a 2:1 mixture of ketamine hydrochloride (Ketaset) (Aveco Co., Inc., Fort Dodge, IA) and xylazine hydrochloride (Rompun) (Miles, Inc., Shawnee Mission, KS). Personnel administered this mixture at 1 cc per 45 kg of estimated bear weight via a jab pole syringe, CO_2 pistol dart, or blowpipe dart. Researchers then measured, weighed, ear-tagged, and

Table 1.1. Sample sizes of populations sampled for morphometric study of adult black bears in the Southeast and selected other areas, 1992-1994.

Population	Number of adult bears sampled
Alaska	8
Alligator River NWR, NC	24
Atchafalaya River, LA	24
Camp Lejeune Marine Base, NC	8
DeSoto NF, MS[a]	2
Great Dismal Swamp NWR, VA/NC	10
Great Smoky Mountains NP, TN	42
Horry County, SC	4
Mobile River, AL[a]	7
Neuse-Pamlico Penninsula, NC	39
New York	13
Ocmulgee River, GA	10
Okefenokee NWR, GA	5
Ouachita Mountains, AR[b]	5
Ozark Mountains, AR[b]	6
Shenandoah NP, VA	4
Sumpter NF, SC	16
Tensas River, LA	9
West Virginia	5
White River NWR, AR	19
total	260

[a]DeSoto NF bears were pooled with Mobile River bears because of close proximity and small sample sizes.
[b]Ouachita Mountain bears were pooled with Ozark Mountain bears because of close proximity and small sample sizes.

lip tattooed immobilized bears. The 6 measurements (chest girth, forearm girth, head width, neck girth, total body length, and zygomatic circumference) (Table 1.2), were recorded to the nearest 0.5 cm holding the tape firmly to the hide. Also, a premolar tooth was extracted from each bear for aging by use of cementum annuli (Wiley 1974). Blood and tissue samples were also taken for the genetic investigations. Lastly, immobilized bears were injected with Yohimbine (Sigma Chemical Co.) to reverse the effect of the xylazine hydrochloride.

I restricted my analyses to adult bears (≥ 4 yrs.) to reduce the variation associated with growth in young bears. Similarly, I also limited my analyses to bears caught in the summer to minimize the intra-year variation in body size of the bears. Thus, even though my sample sizes were reduced, I attempted to abate 2 of the confounding factors involved with analyzing black bear weights and morphometrics.

Missing Data Estimation

Because of the difficulty in collecting data from 20 localities throughout the United States, there were missing data points from 14 populations sampled. Moreover, 13 of the populations contained 10 or fewer individuals and the information that was obtained was crucial. Thus, it was imperative to fill in the missing data points so that all of the eligible bears could be incorporated into the analyses.

I used multiple regressions of weight and morphometric parameters to estimate the missing data points, a method similar to that used by Schnell et.al. (1986). Because of the limited sample sizes available to me, I used the largest data set (Great Smoky Mountains

Table 1.2. Description of weight and morphometric parameters taken for morphometric study of adult black bears in the southeastern United States and selected other areas, 1992-1994.

Morphometric	Code	Description
Chest Girth	CG	-the circumference of the chest (directly behind the front legs) on the exhale
Forearm Girth	FG	-the circumference of the thickest part of the forearm
Head Width	HW	-straight line distance between zygomatic arches
Neck Girth	NG	-the circumference of the neck
Total Body Length	TBL	-from the tip of the nose, along the backbone, to the tip of the most distal tail vertebra
Weight	WT	-total body weight of bear taken with hanging scale
Zygomatic Circuference	ZC	-the circumference of the head over the zygomatic arches

National Park) to determine the best fitting model for each parameter. I regressed each parameter against all of the other weight and morphometric parameters in the Great Smoky Mountain National Park data set. I used Bozdogan's (1990) information theory based multiple regression modules in the MATLAB environment to compare all possible combinations of subsets of the weight and morphometric parameters. In this procedure, all possible subsets of the parameters were compared using information theory criteria: Akaike's Information Criterion (AIC) (Akaike 1973), Information Complexity (ICOMP) (Bozdogan 1990), and Information Complexity based on the inverse-Fisher information matrix (ICOMPIFIM) (Bozdogan 1990).

$$AIC = -2 LogL(\hat{\underset{\sim}{\beta}}) + 2(k+1),$$

where

$$-2\, LogL(\hat{\underset{\sim}{\beta}}) = n \log_e(2\pi) + n \log_e(\frac{RSS_k}{n}) + n,$$

k is the number of parameters estimated, and RSS_k is the Residual Sum of Squares from a model with k-coefficients. The first term, $-2 LogL(\hat{\underset{\sim}{\beta}})$, measures the lack of fit of each model and the data, whereas the second term, 2(k+1), penalizes each model based on the number of parameters included in the model. Thus, AIC provides a tradeoff between the accuracy and size of each model. AIC, with its 2(k+1) penalty term, adheres to the principle of parsimony and chooses the optimum model as that one which best fits the data with the fewest number of parameters. The model with the minimum AIC score is chosen as the optimum model since it provides the most information about the data. Models that vary by less than e (2.7183), however, can not be distinguished statistically using the information theory criteria (Bozdogan 1986).

ICOMP and ICOMPIFIM follow the same principles as AIC, but utilize different techniques for deriving the penalty term. ICOMP is computed as follows:

$$ICOMP = -2\,LogL(\hat{\underset{\sim}{\beta}}) + 2C_1(\mathrm{cov}\,\hat{\underset{\sim}{\beta}}),$$

where

$$C_1(\mathrm{cov}\,\hat{\underset{\sim}{\beta}}) = \frac{k}{2}\log_e\left[\frac{tr(\mathrm{cov}\,\hat{\underset{\sim}{\beta}})}{k}\right] - \frac{1}{2}\log_e\left|\mathrm{cov}\,\hat{\underset{\sim}{\beta}}\right|,$$

and

$$\mathrm{cov}\,\hat{\underset{\sim}{\beta}} = \frac{RSS_k}{n} inv(X'X),$$

and

$$\mathrm{cov}\,\hat{\underset{\sim}{\beta}} = \text{the covariance } \hat{\underset{\sim}{\beta}} \text{ matrix},$$

and the loglikelihood term and RSS_k are the same as for AIC. As with AIC, the first term measures the lack of fit and the second term penalizes each model, adhering to the principle of parsimony. Instead of counting the number of parameters, however, ICOMP measures the complexity of the parameter estimates and penalizes more as the interdependency of the data increases.

ICOMPIFIM is similar to ICOMP, but employs a different method of measuring the interdependency of the data.

$$ICOMPIFIM = -2LogL(\hat{\underset{\sim}{\beta}}) + 2C_1(\hat{F}^{-1}),$$

where

$$C_1(\hat{F}^{-1}) = 2[\frac{\dim \hat{F}^{-1}}{2}\log(\frac{tr\,\hat{F}^{-1}}{\dim \hat{F}^{-1}}) - \frac{1}{2}\log\left|\hat{F}^{-1}\right|],$$

and

$$\hat{F}^{-1} = \begin{bmatrix} \hat{\sigma}^2(X'WX)^{-1} & \underset{\sim}{0} \\ \underset{\sim}{0'} & \frac{2\hat{\sigma}^2}{N} \end{bmatrix},$$

and the loglikelihood term is the same as AIC and ICOMP. ICOMPIFIM uses the inverse-Fisher information matrix ($\hat{F}^{-1}$) to measure the interdependency of the data and penalizes the models accordingly.

The information theory criteria provided a tradeoff between the precision and bias of each model and the model with the minimum information theory score is chosen as the optimal model (Bozdogan 1986 and Bozdogan et.al. 1993). When AIC, ICOMP, and ICOMPIFIM did not agree, I chose the simplest model or, when that model did not account for a large amount of the variation, the one that explained the most variation in the data as the optimum model.

Once the optimal model was chosen for each parameter, I then ran individual regressions with the proc GLM procedure in Statistical Analysis System software (SAS Institute, Inc., Cary, NC) (SAS Institute, Inc. 1990) for each parameter in every population that had missing data points. I did so to estimate coefficients for the parameters in the models that would be individualized for each population. After deriving the individualized models for each population, I used the equations to estimate the missing data points.

Eighty-seven of the 1,820 data points (4.5%) for the 260 adult black bears had missing values. The multiple regressions (from the weights and morphometrics of black bears in Great Smoky Mountains National Park, 1992-1993) used to estimate these missing data points yielded a variety of best fitting models (Appendix A). The individualized regression coefficients for the best fitting models, however, seemed effective as they accounted for a large proportion of the variation in the estimated parameters ($\bar{r}^2 = 0.960$; range = 0.797 - 0.999) (Appendix B). All of the 87 missing data points were estimated using the individualized equations from Appendix B.

Sexual Dimorphism Correction Factors

After estimating the missing data points, 13 populations still had small sample sizes of bears. In addition, black bears exhibit sexual dimorphism in size and weight, which precluded me from analyzing males and females together. To overcome these deficiencies, I analyzed both sexes together, thus doubling my sample sizes in most cases. I developed a correction factor for each sex, similar to Schnell et. al.'s (1985) method for spotted dolphins (*Stenella attenuata*), that allowed for direct comparison of both sexes. Schnell et. al. termed this correction factor a zwitter from a German word for hermaphrodite or hybrid (Douglas et.al. 1985). My approach was to partition the bears in my study into geographic regions based on where they were sampled. I then computed the difference between males and females as a percent of the female character for each character in each region. To derive an overall difference for each character, I used harmonic means of the number of each sex in each area that had at least 5 males and 5 females to weight the difference for each region. Next, I computed the zwitters as one-half of the weighted proportional difference and one-half of the weighted proportional difference divided by 100 + the weighted proportional difference for females and males respectively (Appendix C). These zwitters were then added to the characters of the smaller sex and subtracted from the characters of the larger sex.

I utilized weighted proportions instead of weighted differences because there was not a standard size difference between the male and female bears. This enabled me to determine 2 different percentages; one that could be subtracted from male characters and another that could be added to female characters (Appendix C). Thus, as the size of the bears increased, a larger value was added or subtracted from the female and male characters respectively.

The correction factors, or zwitters, which were calculated for the weight and morphometric variables, varied from 7.8- 24.5% and 9.3- 48.1% for males and females respectively (Appendix D). Overall, the zwitters brought the mean male and female weights and morphometrics closer together, thereby reducing the variation, as measured by the coefficient of variation (CV), around the variables (Appendix E). Male and female weights and morphometrics generally displayed equal coefficients of variation (CV), but the male CV's tended to be larger (Appendix E). Even so, the zwitter correction factors reduced the variation around the combined male and female means of all of the variables (Appendix E). When viewed by population, however, the zwitters yielded mixed results. The correction factors worked best for the Neuse-Pamlico Peninsula, Ocmulgee River, and White River NWR black bears, which displayed very large reductions in the CVs of the variables (Appendix E). However, the zwitters worked worst for the Alaska, Okefenokee NWR, and Shenandoah NP black bears, which displayed increases in the CV's of their variables (Appendix E). All of the other populations displayed small to moderate reductions in the CV's of the variables (Appendix E).

Inter-Year Variability

After all of the data from the 20 study areas were collected, the missing data points estimated, and the adult males and females adjusted using the modified zwitter operation, I investigated the inter-year variation of black bear morphometrics. Because of small sample sizes at most study sites, I used the 2 largest data sets (Great Smoky Mountains National Park, TN and Neuse-Pamlico Peninsula, NC) for the analysis. I increased sample sizes by using the sexually corrected data (zwitters), which allowed me to compare males and females in the same analysis. I categorized adult bears into those captured in 1992 and those captured in 1993 and compared morphometrics to determine if they would cluster together or separately. I employed Bozdogan et.al.'s (1993) information theory based multi-sample cluster analysis in the MATLAB environment to accomplish the clustering. Based on the minimum of the scoring criteria, I selected the best clustering of the 2 years of data: each year separately or both years together.

Multi-sample Cluster Analysis

In addition to investigating the inter-year variability in black bear weights and morphometrics, I determined the optimal grouping of the populations. Because of their close proximity and small sample sizes, I pooled the Ozark Mountain and Ouachita Mountain bears and the DeSoto NF and Mobile River bears, respectively, for this analysis. Thus, I had 18 groups of black bears for the cluster analysis. I used multi-sample cluster analysis (MSCA) in an information theory approach (Bozdogan 1986 and Bozdogan et.al. 1993), which allowed for the comparison of all possible subsets of a group of observations. For the 18 populations of black bears, there were exponentially more unique combinations of populations than the 115,975 calculated for 10 groups by Bozdogan (1986). Therefore, I grouped the populations into more manageable units. I ran 2 cluster analyses, one on the populations lumped into their respective subspecies (Table 1.3) and another one on the populations lumped into their respective ecoregion provinces (Table 1.4). I ran the MSCA with modules developed by Bozdogan (1992) in the MATLAB environment.

The AIC and ICOMPIFIM scoring criteria for the MSCA are interpreted in the same manner as they are for the multiple regression analysis shown above. For MSCA,

Table 1.3. Subspecies groupings of study areas for the multi-sample cluster analysis, 1992-1994.

Code	Populations by Subspecies		Number of Adult Bears Sampled
1	American black bear (Ursus americanus americanus)		
	Alligator River NWR, NC		24
	Camp Lejeune Marine Base, NC		8
	Great Dismal Swamp NWR, VA/NC		10
	Great Smoky Mountains NP, TN		42
	Horry County, SC		4
	Neuse-Pamlico Peninsula, NC		39
	New York		13
	Ocmulgee River, GA		10
	Ozark/Ouachita Mountains, AR		11
	Shenandoah NP, VA		4
	Sumpter NF, SC		16
	West Virginia		5
		subtotal	186
2	Florida black bear (U. a. floridanus)		
	Mobile River, AL/DeSoto NF, MS		9
	Okefenokee NWR, GA		5
		subtotal	14
3	Louisiana black bear (U. a. luteolus)		
	Atchafalaya River, LA		24
	Tensas River, LA		9
	White River NWR, AR		19
		subtotal	52
4	Alaska black bear (U. a. emmonsii)		
	Alaska		8
		subtotal	8
		grand total	260

Table 1.4. Ecoregion province groupings of study areas for the multi-sample cluster analysis, 1992-1994.

Code	Populations by Ecoregion Province		Number of Adult Bears Sampled
1	Laurentian Mixed Forest Province		
	New York		13
		subtotal	13
2	Eastern Deciduous Forest Province		
	Great Smoky Mountains NP, TN		42
	Ozark/Ouachita Mountains, AR		11
	Shenandoah NP, VA		4
	Sumpter NF, SC		16
	West Virginia		5
		subtotal	78
3	Outer Coastal Plain Province		
	Atchafalaya River, LA		24
	Mobile River, AL/DeSoto NF, MS		9
	Okefenokee NWR, GA		5
	Tensas River, LA		9
	White River NWR, AR		19
		subtotal	66
4	Southeastern Mixed Forest Province		
	Alligator River NWR, NC		24
	Camp Lejeune Marine Base, NC		8
	Great Dismal Swamp NWR, VA/NC		10
	Horry County, SC		4
	Neuse-Pamlico Peninsula, NC		39
	Ocmulgee River, GA		10
			95
5	Pacific Forest Province		
	Alaska		8
		subtotal	8
		grand total	260

however, there are 3 models under which the data may be analyzed: varying means and covariances, varying means and common covariances, and common means and common covariances. These models are nested in descending order as listed above and change the manner in which the scoring criteria are computed. Thus, there are 3 sets of equations used to compute AIC and ICOMPIFIM in MSCA, depending upon the means and covariances of the data. A test of homogeneity determines the appropriate model under which to run the MSCA and is achieved by interpreting the scoring criteria for the model with all of the variables considered separately. The model with the minimum criteria score is chosen as that model under which to run the overall MSCA. AIC and ICOMPIFIM are computed as follows for model 1, varying means and varying covariances:

$$AIC(M_1) = -2LogL(\hat{\underset{\sim}{\Theta}}) + 2[kp + \frac{kp(p+1)}{2}],$$

where

$$-2LogL(\hat{\underset{\sim}{\Theta}}) = np\log(2\pi) + \sum_{g=1}^{k}\{n_g[-p\log(n_g) + \sum_{i=1}^{p}\log(\lambda_{gi})]\} + np,$$

k = the number of clusters of samples compared, p = the number of variables, n_g = the sample size of each group g = 1, 2, ...k, ...,K, $\lambda_1 \geq \lambda_2 \geq \ldots \lambda_p > 0$ is the ordered positive eigenvalues of: the among groups SSP matrix, the within groups SSP matrix, and the total SSP matrix, and $kp + \frac{kp(p+1)}{2}$ is the number of parameter estimates.

$$ICOMPIFIM(M_1) = -2LogL(\hat{\underset{\sim}{\Theta}}) + 2C_1(\hat{F}^{-1}),$$

where

$$C_1(\hat{F}^{-1}) = \tfrac{1}{2}\Big[(kp + \frac{kp(p+1)}{2})$$

$$*\log\Big(\frac{\sum_{g=1}^{k}[n(\frac{tr\hat{\Sigma}}{n_g}) + \tfrac{1}{2}tr(\hat{\Sigma}^2) + \tfrac{1}{2}(tr\hat{\Sigma})^2 + \sum_{i=1}^{p}(diag\hat{\Sigma})^2]}{kp + \frac{kp(p+1)}{2}}\Big)\Big]$$

$$-\tfrac{1}{2}\Big[(p+2)\sum_{g=1}^{k}(\log|\hat{\Sigma}|) - p\sum_{g=1}^{k}(\log n_g)\Big] - \tfrac{1}{2}kp\log(2n),$$

$\hat{\Sigma}$ is the biased maximum likelihood estimator estimate of the covariance matrix and the lack of fit is the same as that of AIC(M_1).

For model 2, varying means and common covariances, AIC and ICOMPIFIM are computed as follows:

$$AIC(M_2) = -2LogL(\hat{\underset{\sim}{\Theta}}) + 2[kp + \frac{p(p+1)}{2}],$$

where

$$-2LogL(\hat{\underset{\sim}{\Theta}}) = np\log(2\pi) + n[-p\log(n) + \sum_{i=1}^{p}\log(\lambda_i)] + np,$$

$kp + \frac{p(p+1)}{2}$ is the number of paramter estimates, and the other variables are the same as those used in AIC(M_1) and ICOMPIFIM(M_1).

$$ICOMPIFIM(M_2) = -2LogL(\hat{\underset{\sim}{\Theta}}) + 2C_1(\hat{F}^{-1}),$$

where

$$C_1(\hat{F}^{-1}) = \tfrac{1}{2}\Big[(kp + \frac{p(p+1)}{2})$$

$$*\log\left(\frac{\sum_{g=1}^{k}(\frac{n}{n_g})tr\hat{\Sigma}+\frac{1}{2}tr(\hat{\Sigma}^2)+\frac{1}{2}(tr\hat{\Sigma})^2+\sum_{i=1}^{p}(diag\hat{\Sigma})^2]}{kp+\frac{p(p+1)}{2}}\right)]$$

$$-\tfrac{1}{2}\left[k(p+2)\log\left|\hat{\Sigma}\right|-p\sum_{g=1}^{k}(\log n_g)\right]-\tfrac{1}{2}kp\log(2n)$$

the lack of fit is the same as that of AIC(M_2), and the other variables are as in the previous equations.

For model 3, common means and common covariances, AIC and ICOMPIFIM are computed as follows:

$$AIC(M_3)=-2LogL(\hat{\underset{\sim}{\Theta}})+2[\frac{p+p(p+1)}{2}],$$

where

$$-2LogL(\hat{\underset{\sim}{\Theta}})=np\log(2\pi)+n[-p\log(n)+\sum_{i=1}^{p}\log(\lambda_i)]+np,$$

$\frac{p+p(p+1)}{2}$ is the number of parameter estimates and the other variables are as in the above equations.

$$ICOMPIFIM(M_3)=-2LogL(\hat{\underset{\sim}{\Theta}})+2C_1(\hat{F}^{-1})$$

where

$$C_1(\hat{F}^{-1})=\tfrac{1}{2}\left[(p+\frac{p(p+1)}{2})\right.$$

$$*\log\left(\frac{tr\hat{\Sigma}+\frac{1}{2}tr(\hat{\Sigma}^2)+\frac{1}{2}(tr\hat{\Sigma})^2+\sum_{i=1}^{p}(diag\hat{\Sigma})^2]}{p+\frac{p(p+1)}{2}}\right)]$$

$$-\tfrac{1}{2}[(p+2)\log\left|\hat{\Sigma}\right|-p\sum_{g=1}^{k}(\log n_g)]-\tfrac{1}{2}kp\log(2n),$$

and the lack of fit is as in the above equations.

The modules took the data that I had grouped into the subspecies and ecoregion province congregations and compared all possible subsets of the groupings based on the minimum AIC and ICOMPIFIM scores. Thus, there were 15 clustering alternatives for the subspecies analysis and 52 for the ecoregion analysis. Then, as with the multiple regression analyses above, I chose the optimum clustering (under the appropriate model; M_1, M_2 or M_3) based on the minimum AIC and ICOMP scores. Based on these groupings, I determined which populations were morphometrically similar.

Habitat Quality

I undertook a literature search on the regional habitat quality of the areas supporting the various black bear populations to determine if black bear weights, morphometrics, and fat levels correlated with habitat quality. Because it was beyond the scope of this project to study every possible way of estimating habitat quality, my literature search focused on: net primary productivity, basic soil characteristics, agricultural practices, and latitude. Fat level estimation and weight/body length ratios of black bears were also examined as a means of indexing habitat quality. The other methods of estimating and indexing black bear habitat quality (as described earlier) were not investigated.

I followed Rosenzweig (1968b) and used climatological data published by Thornthwaite Associates (1964) to determine actual evapotranspiration levels which estimated the net primary productivity (NPP) of the various study areas (Kennedy and Lindsay 1984). I recorded soil types, with their respective attributes, for each site and ranked them by their fertility ratings (Brady 1990). In conjunction with these parameters, I examined agricultural practices. The amount of corn (bushels), wheat (bushels), and sugarcane (tons) crops harvested for each of the counties which encompassed the study sites was recorded. Harvest levels were recorded from the 1992 Census of Agriculture Geographic Area Series (U. S. Bureau of the Census 1993). I then converted the harvests into gigacalories to adjust for the differing nutritional levels of each crop. Thus, I ended up with a total energy value of crops (corn + wheat + sugarcane) for each study area. The latitude of each area was also recorded using the U. S. Geological Survey's National Atlas of the United States of America (1970).

The mean fat levels and weight/body length ratios of bears were calculated for all of the study areas. Fat levels were estimated using 2 equations designed for black bears. Cattet (1990) devised the first equation while studying black bears in Canada:

$$Y = e^{-8.42} X_1^{2.11} X_2^{0.14} X_3^{0.58}$$

This equation predicts nonfat body weight based on the total body length (X_1), age (X_2) and foreleg girth (X_3) of sampled black bears. Cattet's equation appeared reliable as it accounted for 98.5% of the variation in black bear nonfat body weight. Scott (1991) derived the second equation from black bears in northwestern Arkansas:

$$Y = -95.0 + 1.9X_4 + 0.55X_5 + 3.81X_6$$

This equation predicted nonfat body weight from the foreleg girth (X_4), neck girth (X_5), and head width (X_6) of black bears and accounted for 89% of the variation in their nonfat body weight. I set negative percent fat estimates equal to 0.

I incorporated the habitat variables (NPP, soil fertility, total crop kilocalories, and latitude) and the weight and morphometric variables into a multivariate analyses to determine if weights and morphometrics correlate with habitat quality. To calculate the correlation among the variables, I employed a canonical correlation analysis in SAS (proc CANCORR). I also used canonical correlation analysis to calculate the correlations among the physiological variables (Cattet's mean fat levels, Scott's mean fat levels, and weight/body length ratios) and the habitat variables. I considered any correlations at or below the $\alpha = 0.10$ level to be significant.

CHAPTER IV

RESULTS

Yearly Variation

The multi-sample cluster analyses by year (1992 vs. 1993) for Great Smoky Mountains National Park and Neuse-Pamlico Peninsula yielded similar results. For the Great Smoky Mountains National Park data, AIC and ICOMPIFIM yielded minimum scores under homogeneity models M_1 (varying μ and Σ) and M_2 (varying μ and common Σ), respectively (Table 1.5). These values also represented the minimum criteria scores for the multi-sample clustering (Appendix F). Thus, even though AIC and ICOMPIFIM had minimum scores under different models, they both agreed that, based on their weights and morphometrics, bears clustered separately between 1992 and 1993. The results for the Neuse-Pamlico Peninsula bears were similar for ICOMPIFIM, but not for AIC. For the test of homogeneity, there was no clear minimum AIC score (all scores were less then e apart), which demonstrated this criterion's inability to discriminate between the 2 years. ICOMPIFIM, however, had a clear minimum, which occurred at M_2 (Table 1.5). Under this homogeneity, the minimum ICOMPIFIM score for the cluster analysis occurred when the years were separated. Thus, as with the Great Smoky Mountains National Park data, this analysis indicated that the bears in the Neuse-Pamlico Peninsula were morphometrically dissimilar between the years (Appendix F).

Table 1.5. Homogeneity models for the multi-sample cluster analyses on inter-year variation of black bear weights and morphometrics at Great Smoky Mountains National Park and Neuse-Pamlico Peninsula, 1992-1993.

Model	Homogeneity	AIC	ICOMPIFIM
Great Smoky Mountains NP			
M_1	varying μ and varying Σ	1,801.2†	2,128.2
M_2	varying μ and common Σ	1,843.3	1,834.0†
M_3	common μ and common Σ	1,833.9	1,961.9
Neuse-Pamlico Peninsula			
M_1	varying μ and varying Σ	1,657.5†[a]	1,949.0
M_2	varying μ and common Σ	1,657.4†[a]	1,654.4†
M_3	common μ and common Σ	1,655.0†	1,775.9

†Denotes minimum score for criterion.
[a]These values were not the absolute minimums for their level, but were so close as to be statistically identical to the absolute minimum.

Multi-sample Cluster Analysis

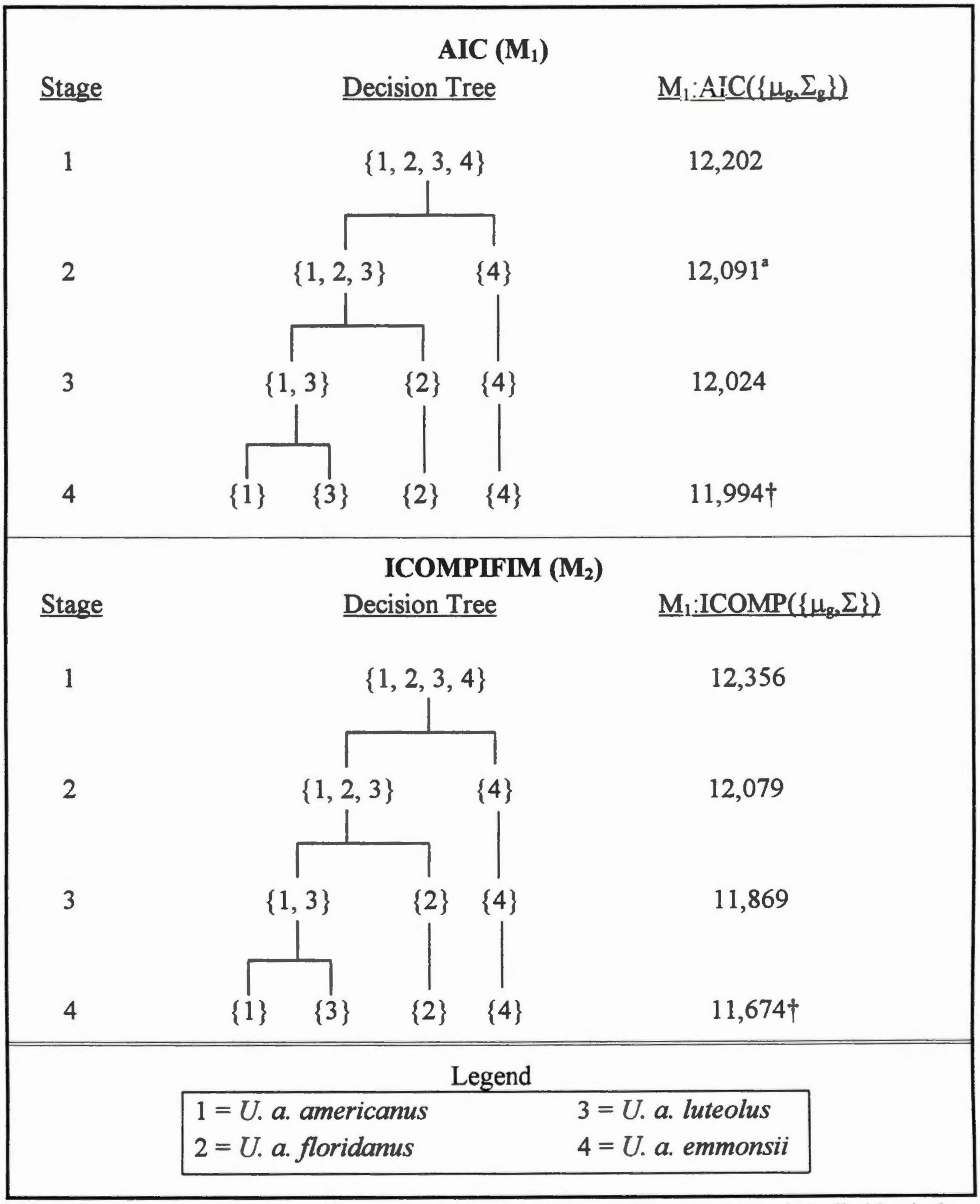
The AIC and ICOMPIFIM criteria of the multi-sample cluster analysis on black bear populations categorized by subspecies yielded complimentary results. AIC and ICOMPIFIM had minimum scores under homogeneity models M_1 (varying μ and Σ) and M_2 (varying μ and common Σ), respectively (Table 1.6). Therefore, I ran the analysis under both of the models and interpreted each criterion under its chosen homogeneity. The minimum AIC score (under M_1) and ICOMPIFIM score (under M_2) both occurred when the subspecies grouped separately (Figure 1.4). Consequently, the multi-sample cluster analysis on the black bear subspecies indicated that there were morphometric differences among all 4 of the subspecies. These differences were pronounced for several of the parameters (Table 1.7). For a full synopsis of the subspecies multi-sample cluster analyses under both models, see Appendix G.

The AIC and ICOMPIFIM criteria of the multi-sample cluster analysis on black bear populations categorized by ecoregion provinces also yielded complimentary results. The test of homogeneity on the ecoregion provinces yielded 2 different models under which to analyze the data (Table 1.6). Again, because the two criteria chose different models, I ran the analysis under both of the homogeneity models; M_1 (varying μ and Σ) and M_2 (varying μ and common Σ). I then interpreted each criteria under its chosen model. As with the subspecies analysis, the minimum AIC score (under M_1) and ICOMPIFIM score (under M_2) both occurred when the ecoregion provinces grouped separately (Figure 1.5). Consequently, the multi-sample cluster analysis on the physiographic regions indicated that there were morphometric differences among all 5 of

Table 1.6. Homogeneity models for the multi-sample cluster analyses on 4 subspecies and 5 ecoregion provinces of black bears based on weights and morphometrics, 1992-1994.

Model	Homogeneity	AIC	ICOMPIFIM
Subspecies			
M_1	varying μ and varying Σ	11,548†	13,335
M_2	varying μ and common Σ	12,094	11,677†
M_3	common μ and common Σ	12,202	12,277
Ecoregion Province			
M_1	varying μ and varying Σ	11,884†	12,842
M_2	varying μ and common Σ	11,974	11,384†
M_3	common μ and common Σ	12,202	12,267

†Denotes minimum score for criterion.

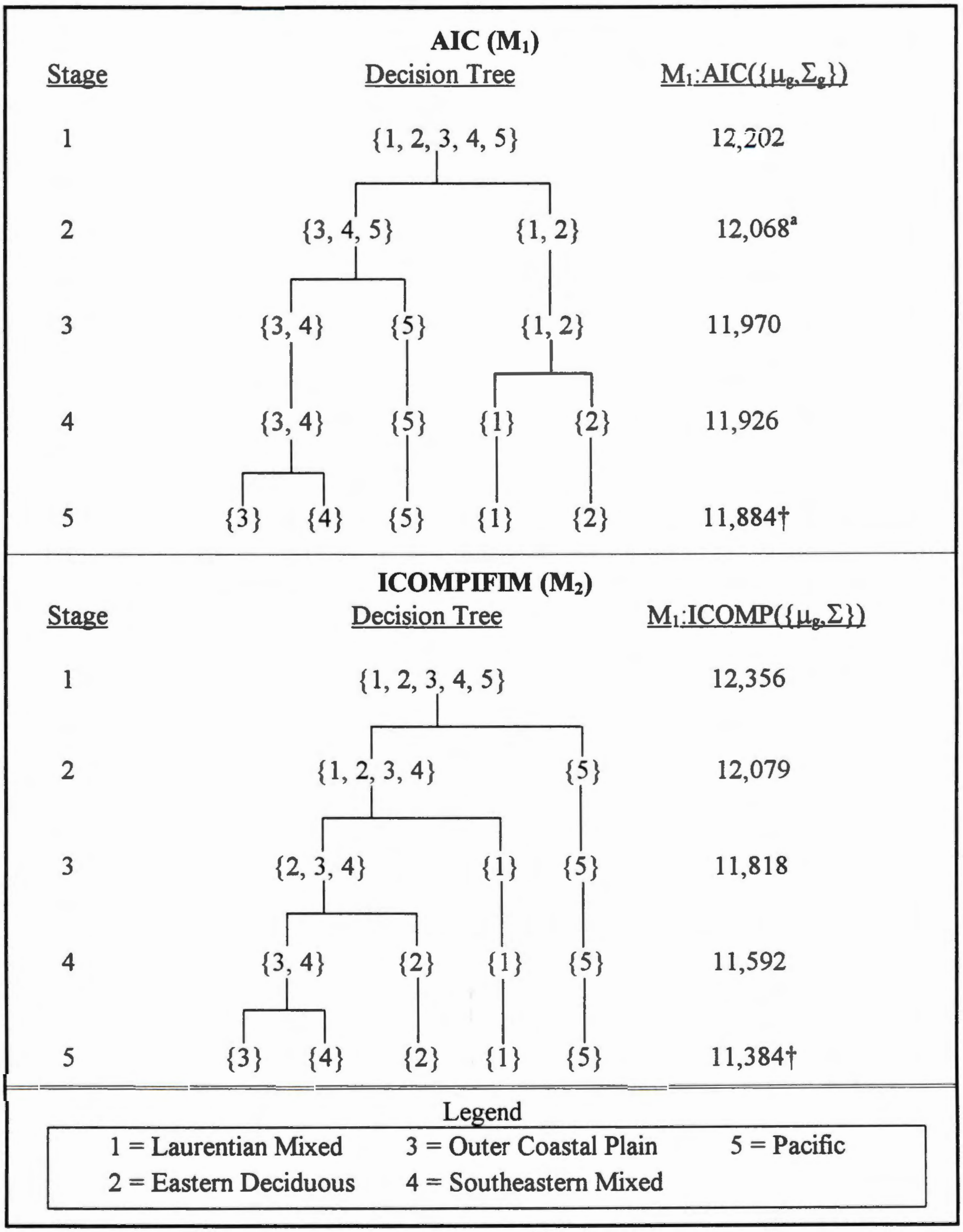


[a]This value was not the absolute minimum for its stage, but was so close as to be statistically identical to the absolute minimum.

Figure 1.4 Optimal hierarchical structures of multi-sample clustering of 4 subspecies of black bears based on morphometric data according to the minimum AIC and ICOMPIFIM procedures in each stage; † denotes the optimal clustering.

Table 1.7. Mean values of weights (kg) and morphometrics (cm) for the optimal hierarchical structure for 4 black bear subspecies as developed by information complexity based on the inverse-Fisher information matrix (ICOMPIFIM): Model 2 - varying means and common covariances.

Parameter	Mean value under hierarchical structure			
	{U. a. americanus, U. a. floridanus, U. a. luteolus, U. a. emmonsii}			
CG	90.44			
FLG	33.37			
HW	18.43			
NG	58.00			
TBL	161.77			
WT	88.51			
ZC	54.63			
	{U. a. americanus, U. a. floridanus, U. a. luteolus}			*{U. a. emmonsii}*
CG	90.46			89.99
FLG	33.39			32.66
HW	18.54			15.14
NG	58.21			51.23
TBL	162.48			139.47
WT	87.98			105.30
ZC	54.89			46.50
	{U. a. americanus, U. a. luteolus}		*{U. a. floridanus}*	*{U. a. emmonsii}*
CG	91.05		74.92	89.99
FLG	33.53		29.10	32.66
HW	18.63		15.84	15.14
NG	58.59		46.97	51.23
TBL	162.87		154.40	139.47
WT	88.23		76.35	105.30
ZC	54.91		50.96	46.50
	{U. a. americanus}	*{U. a. luteolus}*	*{U. a. floridanus}*	*{U. a. emmonsii}*
CG	90.54	91.48	74.92	89.99
FLG	33.55	33.26	29.10	32.66
HW	18.65	18.43	15.84	15.14
NG	58.41	58.54	46.97	51.23
TBL	163.32	160.59	154.40	139.47
WT	86.15	94.50	76.35	105.30
ZC	55.08	54.61	50.96	46.50



[a]This value was not the absolute minimum for its stage, but was so close as to be statistically identical to the absolute minimum.

Figure 1.5 Optimal hierarchical structures of multi-sample clustering of 5 ecoregion provinces of black bears based on morphometric data according to the minimum AIC and ICOMP procedures in each stage; † denotes the optimal clustering.

the ecoregion provinces. These differences, as they were for the subspecies, were pronounced for many of the parameters (Table 1.8). For a full synopsis of the ecoregion province multi-sample cluster analyses under both models, see Appendix H.

Habitat Quality

The 2 equations that I used to predict the percent body fat of black bears yielded contradictory results. Both equations predicted that many bears had negative percent body fat; Cattet's (1990) and Scott's (1991) equations gave negative percent body fat estimates for individuals in 15 of the 18 and 10 of the 18 populations, respectively. The negative estimates averaged -18.2% (range -0.2 to -44.3%) and -30.3% (range -0.7 to -131.5%) for Cattet's and Scott's equations, respectively. Additionally, Scott's equation yielded mean estimates of percent fat by population that were significantly larger than Cattet's ($P = 0.0163$), (Table 1.9). Cattet's equation had smaller sample sizes than Scott's in some cases because of the difficulty in obtaining accurate age estimates of black bears. Consequently, I was unable to estimate the percent body fat for those bears with unknown ages.

The canonical correlation analysis between the weights and morphometrics and habitat parameters (Appendix I) yielded non-significant results. The weight and morphometric variables exhibited many high correlations among themselves, whereas the habitat variables did not; only Latitude and actual transpiration (AE) were highly correlated (Appendix J). Total body length and AE were the only variables highly correlated between the habitat and weight and morphometric parameters

Table 1.8. Mean values of weights (kg) and morphometrics (cm) for the optimal hierarchical structure for 5 black bear ecoregion forest provinces as developed by information complexity based on the inverse-Fisher information matrix (ICOMPIFIM); Model 2 - varying means and common covariances.

Parameter	Mean value under hierarchical structure	
	{Laurentian Mixed, Eastern Deciduous, Outer Coastal Plain, Southeastern Mixed, Pacific}	
CG	90.44	
FLG	33.37	
HW	18.43	
NG	58.00	
TBL	161.77	
WT	88.51	
ZC	54.63	
	{Laurentian Mixed, Eastern Deciduous, Outer Coastal Plain, Southeastern Mixed}	{Pacific}
CG	90.46	89.99
FLG	33.39	32.66
HW	18.54	15.14
NG	58.21	51.23
TBL	162.48	139.47
WT	87.98	105.30
ZC	54.89	46.50

Table 1.8. Continued.

Parameter	Mean value under hierarchical structure				
	{Eastern Deciduous, Outer Coastal Plain, Southeastern Mixed}			{Laurentian Mixed}	{Pacific}
CG	91.03			79.99	89.99
FLG	33.37			33.85	32.66
HW	18.38			21.47	15.14
NG	58.61			51.03	51.23
TBL	163.33			146.83	139.47
WT	89.45			60.89	105.30
ZC	55.18			49.46	46.50
	{Outer Coastal Plain, Southeastern Mixed}		{Eastern Deciduous}	{Laurentian Mixed}	{Pacific}
CG	88.47		86.98	79.99	89.99
FLG	31.99		31.18	33.85	32.66
HW	18.17		18.12	21.47	15.14
NG	55.98		54.55	51.03	51.23
TBL	160.16		160.19	146.83	139.47
WT	84.67		77.51	60.89	105.30
ZC	54.33		54.32	49.46	46.50
	{Outer Coastal Plain}	{Southeastern Mixed}	{Eastern Deciduous}	{Laurentian Mixed}	{Pacific}
CG	90.22	94.91	86.98	79.99	89.99
FLG	32.95	35.45	31.18	33.85	32.66
HW	18.23	18.70	18.12	21.47	15.14
NG	57.67	62.59	54.55	51.03	51.23
TBL	160.12	168.15	160.19	146.83	139.47
WT	93.13	96.70	77.51	60.89	105.30
ZC	54.33	56.47	54.32	49.46	46.50

Table 1.9. Mean estimated percent fat of black bear populations in the Southeast and selected other areas, 1992-1994.

	Scott[a]				Cattet[b]				
Population	N	% Fat	S.D.	COV[c]	N	% Fat	S.D.	CV[c]	Diff[d]
Alaska	8	47.7	8.3	17.4	8	45.6	5.5	12.1	2.1
Alligator River NWR, NC	24	29.1	15.0	51.6	24	16.5	13.9	84.2	12.6
Atchafalaya Basin, LA	24	22.9	10.5	45.9	24	9.5	11.4	120.0	13.4
Camp Lejeune, NC	8	8.1	9.5	117.3	8	7.4	8.5	114.9	0.7
Great Dismal Swamp NWR, VA/NC	10	18.3	8.9	48.6	10	5.1	7.2	141.2	13.2
Great Smoky Mt. NP, TN	42	17.2	13.2	76.7	42	3.4	6.6	191.1	13.8
Horry County, SC	4	30.7	6.0	19.5	4	15.1	2.9	19.2	15.6
Mobile River, AL	9	25.5	7.5	29.4	8	17.6	12.7	72.2	7.9
Neuse-Pamlico Penninsula, NC	39	14.3	10.1	70.6	39	12.2	10.4	85.3	2.1
New York	13	3.2	11.7	365.6	4	9.8	12.3	125.5	-6.6
Ocmulgee River, GA	10	13.3	15.5	116.5	10	4.3	11.8	274.4	9.0
Okefenokee NWR, GA	5	35.0	8.7	24.9	5	13.8	15.0	108.7	21.2
Ozark/Ouachita NF, AR	11	26.7	11.6	43.5	11	20.7	12.9	62.3	6.0
Shenandaoh NP, VA	4	35.6	14.8	41.6	4	18.7	7.1	38.0	16.9
Sumpter NF, SC	16	16.1	12.3	76.4	16	16.1	11.0	68.3	0.0
Tensas River NWR, LA	9	25.4	18.8	74.0	5	5.0	6.2	124.0	20.4
West Virginia	5	21.5	14.2	66.1	5	14.6	11.8	80.8	6.9
White River NWR, AR	19	21.3	14.8	69.5	6	21.9	15.8	72.2	-0.6

[a]% fat estimated from equation derived by Scott (1991).
[b]% fat estimated from equation derived by Cattet (1990).
[c]CV = coefficient of variation (%).
[d]The means were significantly different ($p = 0.0163$).

(Appendix J). However, although there was high correlation between the first 2 canonical variables derived from the habitat and morphometrics, none of the 4 were significant (P = 0.4514, 0.9699, 0.9985, 0.9617 for the first, second, third, and fourth canonical variables, respectively). Thus, the correlations between the habitat and weight and morphometric variables were not significant at the $\alpha = 0.10$ level.

The canonical correlation analysis between the physiological and habitat parameters also yielded non-significant results. For the physiological parameters, the two estimates of percent fat were highly correlated with one another as were Cattet's percent fat and the weight:total body length parameter (Appendix J). Latitude and AE exhibited a negative correlation and were the only parameters highly correlated between the physiological and habitat parameters (Appendix J). Of the 3 canonical variables computed from the habitat and physiological variables, none were significantly correlated at the α = 0.10 level (P = 0.1444, 0.5823, and 0.9439 respectively).

CHAPTER V

DISCUSSION

The multi-sample cluster analysis on the 4 subspecies of black bears represented in this study revealed that they were morphometrically distinct from one another. AIC and ICOMPIFIM were minimized under different homogeneity models: the minimum AIC score occurred under M_1 (varying means and varying covariances), whereas the minimum ICOMPIFIM score occurred under M_2 (varying means and common covariances). Even though they gave identical results in this analysis, over-all I favored the ICOMP criterion because it was developed for multicollinear data, such as the weights and morphometrics that I collected on black bears (Bozdogan 1990*b*). Also, I speculated that black bear populations across the Southeast exhibited the same levels of variance around their weights and morphometrics even if their means varied. Either way, both AIC and ICOMPIFIM had minimum values at the same optimal clustering of subspecies under the models that they indicated best represented the homogeneity of the data (Fig. 1.4). These minimums occurred when the 4 subspecies clustered separately. Therefore, I concluded that, based on their weights and morphometrics, the 4 subspecies of black bears were dissimilar.

By examining the hierarchical structure of the clusterings (which were identical for both AIC and ICOMPIFIM), the pattern of subspecies divergence can be discerned (Fig. 1.6). All 4 of the subspecies were clustered together at stage 1. At stage 2, the 3 eastern

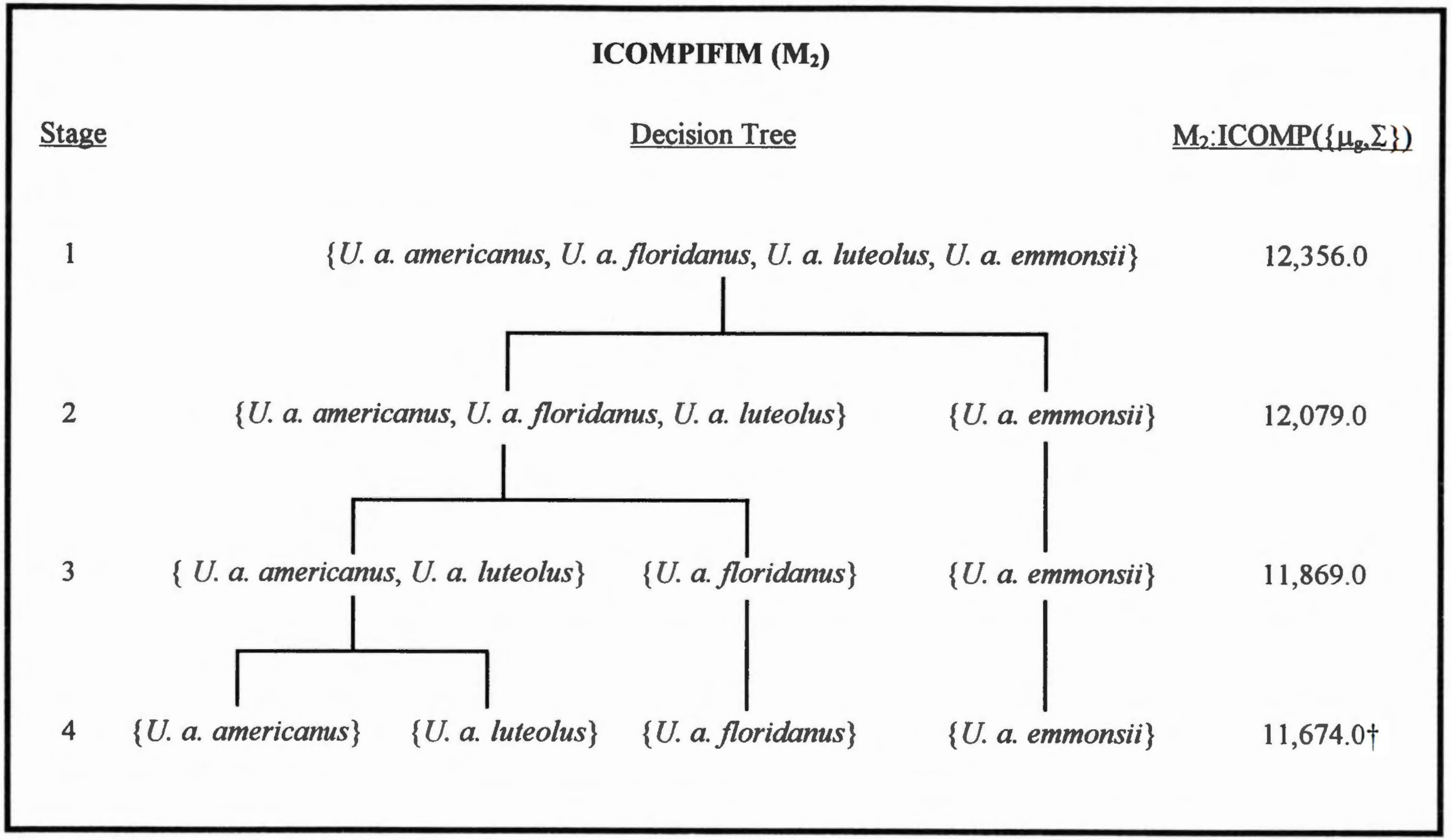


Figure 1.6 Optimal hierarchical structures of multi-sample clustering of 4 subspecies of black bears based on morphometric data according to the minimum ICOMPIFIM (M_2: varying means and common covariances) procedure in each stage; † denotes the optimal clustering.

subspecies clustered together and the Alaskan subspecies split off by itself. Stage 3 had *U. a. floridanus* split off from *U. a. luteolus* and *U. a. americanus*, and stage 4, the optimal grouping, showed all of the subspecies clustered separately. This pattern of clustering differed from those discussed by Kennedy (1989) and Miller (1995), who found that *U. a. floridanus* and *U. a. luteolus* were more similar to each other than they were to *U. a. americanus* based on skull morphology and multilocus DNA fingerprinting techniques, respectively.

The differences in the means of the weights and morphometrics at each stage of the multi-sample clustering demonstrated that the clusterings were morphometrically significant (Table 1.7). At stage 2, the Alaskan black bears differed markedly in chest girth, head width, neck girth, total body length, weight, and zygomatic circumference from the eastern black bears. When *U. a. floridanus* split off at stage 3, the 3 clusterings of black bears differed significantly in neck girth, total body length, weight, and zygomatic circumference; there were also differences between 2 of the 3 clusterings in chest girth and foreleg girth. At the final stage, weight was the one parameter that varied markedly across all 4 subspecies, whereas the other 6 parameters varied only across 2 or 3 of the subspecies. The above differences seemed to be biologically significant as they were many times larger than the inter-researcher differences found in black bear weights and morphometrics in Part II of this thesis.

The multi-sample cluster analysis of the 5 ecoregion provinces yielded similar results as that for the subspecies. AIC and ICOMPIFIM again had minimums under different homogeneity models; the minimum AIC score occurred at M_1 (varying means and varying covariances), whereas the minimum ICOMPIFIM occurred at M_2 (varying means and common covariances). As with the previous analysis, I used the MSCA under both homogeneity models, favoring the clusterings chosen by the minimum ICOMPIFIM analysis because of its superior ability with multicollinear data (Bozdogan 1990*b*). Both the minimum AIC and ICOMPIFIM scores occurred at the same clustering: all of the ecoregion provinces separate (Fig. 1.5). Therefore the MSCA showed that there were significant differences among the weights and morphometrics of black bears in the ecoregion provinces

The hierarchical structure of the MSCA under the 2 scoring criteria depicted different decompositions of the clusterings (Fig. 1.7). Again, because ICOMPIFIM was developed for multidimensional data, I favored the ICOMPIFIM decomposition under M_2. Under this model, at stage 2, the bears from Alaska (Pacific Forest Province) split off from the eastern bears. Next, at stage 3, the northeastern bears (Laurentian Mixed Forest Province) grouped separately from the southeastern bears. At stage 4, the coastal bears remained clustered whereas the highland bears (Eastern Deciduous Forest Province) split off. At stage 5 (the optimal clustering) all of the ecoregion provinces cluster by themselves.

As with the subspecies analysis, the mean weights and morphometrics at each stage of the multi-sample cluster analysis varied significantly among the clusterings (Table 1.8). The second stage was identical to that for the subspecies because the Alaska bears were the same for both. For the next steps, however, chest girth, total body length, and weight seemed to be the parameters that exhibited the largest differences among all of the

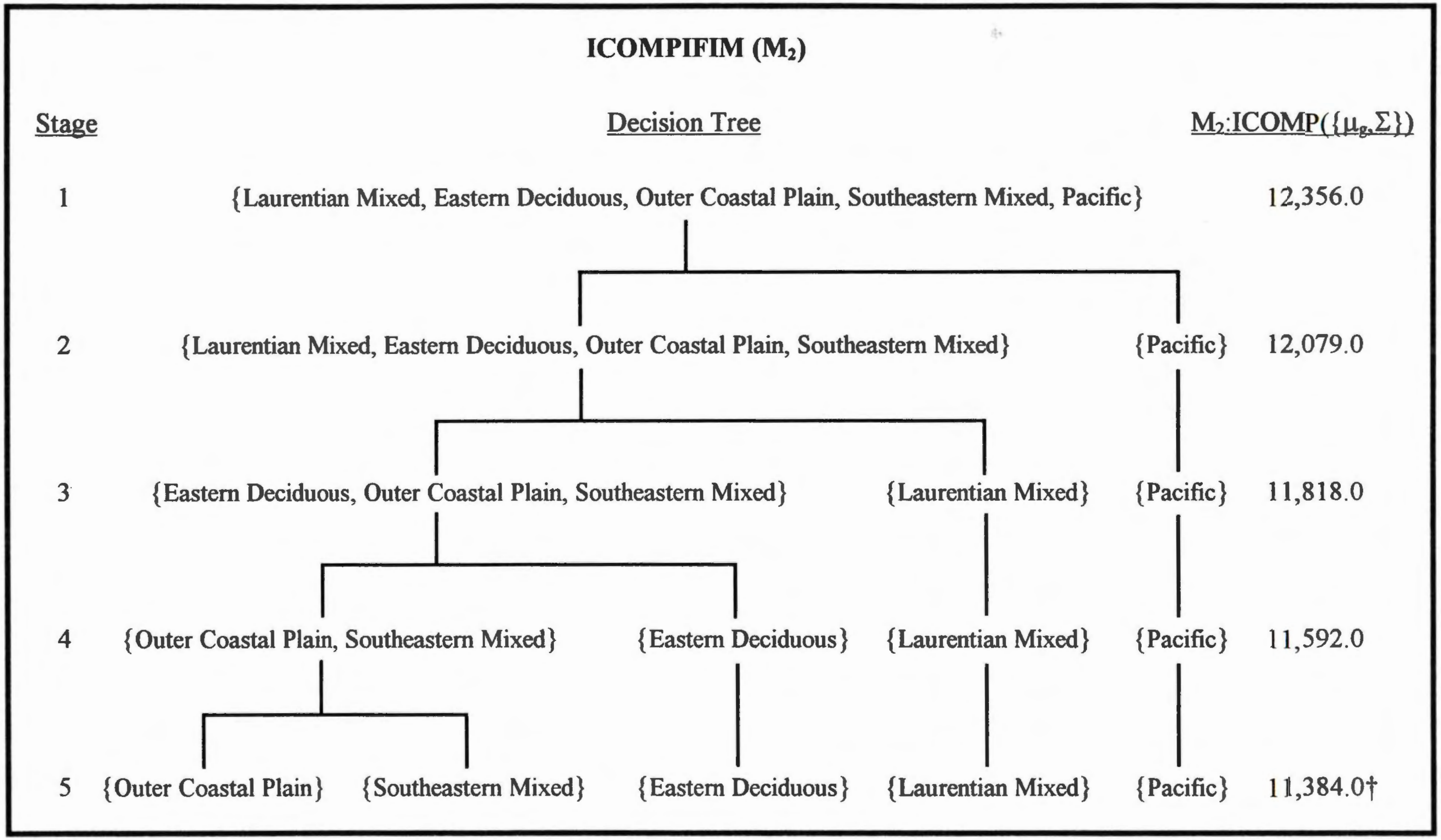


Figure 1.7 Optimal hierarchical structures of multi-sample clustering of 5 ecoregion forest provinces of black bears based on morphometric data according to the minimum ICOMPIFIM (M_2: varying means and common covariances) procedure in each stage; † denotes the optimal clustering.

ecoregion clusterings. The other morphometrics varied between and among some of the clusterings at each stage, but not across all of them. These differences, as were the ones for the subspecies, seemed biologically significant as they were several times larger than the researcher induced errors found (see Part II).

The subspecies MSCA showed that *U. a. floridanus*, *U. a. luteolus*, and *U. a. americanus* were morphometrically distinct from one another. However, because the bears in the Laurentian Mixed Forest Province clustered separately from the bears in the Eastern Deciduous Forest Province and because both of these provinces were encompassed by the range of the *U. a. americanus* subspecies, there was also evidence that bears currently listed as *U. a. americanus* may differ morphometrically among themselves. The hierarchical structure of the ecoregion province analysis also showed that black bears in the Southeast were more similar to one another than they were to black bears in the Northeast and Alaska (Figure 1.7). It appeared that this trend continued northward, with black bears being more morphometrically dissimilar from those in the Southeast as they proceed northward (Figure 1.7). These differences, however, were not supported by the subspecies MSCA hierarchical structure, and therefore may reflect the fact that Bailey's (1980) ecoregion delineations follow natural divisions in soil, topography, climate, and habitat, which grow more pronounced as one moves northward.

The 3 subspecies of black bears in the Southeast were named based on skull morphology, consequently, weight and morphometric data cannot be used to directly accept or reject the subspecies delineation; they can only lend or draw away support for the demarcations. Even so, the results of this study generally followed those of previous investigations into the taxonomy of black bears in the Southeast. Kennedy (1989) showed that, based on skull morphology, *U. a. luteolus* was distinct from *U. a. americanus*, and that *U. a. luteolus* and *U. a. floridanus* were similar. More recently, Kennedy (pers. commun.) found that even though they were similar, *U. a. luteolus* and *U. a. floridanus* could be distinguished using skull morphology. Also, Miller (1995) reported that estimated genetic similarities were higher between *U. a. luteolus* and *U. a. floridanus* than among *U. a. americanus* populations. The present analysis showed that weight and morphometric data, as clustered by the 2 MSCA analyses, also appear to support the traditional subspecies demarcations of black bears in the Southeast. However, the subspecies MSCA did not coincide with ecoregion province MSCA, which depicted black bears in the deep southeastern states being more similar that those in the eastern central and northeastern states. Also, there may be weight and morphometric differences among black bears in the more widespread *U. a. americanus* subspecies.

The difficulties in interpreting the results of this study were not unexpected. Black bears are large, secretive, omnivores that inhabit diverse habitats across the Southeast and North America. They seem to be morphometrically plastic (black bears clustered separately by year in Great Smoky Mountains National Park and in the Neuse-Pamlico Peninsula) and are capable of dispersing great distances, which allows for gene flow across population boundaries arbitrarily imposed by humans. Thus, without predetermined, stringent guidelines defining what constitutes a distinct subspecies, it is difficult to partition existing populations into traditional subspecies demarcations. This study, along with the taxonomic investigations of Kennedy (1989), Miller (1995), and Pelton (1989) portrayed the difficulties in delineating the taxonomy of black bears in the Southeast.

Because the black bear populations clustered by ecoregion provinces, there was evidence that the weights and morphometrics of black bears may be correlated with habitat variables. However, canonical correlations failed to support this hypothesis. These findings augment earlier studies investigating the relationship between weights, morphometrics and habitat quality. Five of the 6 earlier studies discriminated habitat quality on a finer scale than was possible in this investigation. Dozier's (1950) study of muskrats was performed within one wildlife refuge, McLean's (1990) investigation of black bears analyzed bears from Great Smoky Mountains National Park and an adjacent national forest, Schacher and Pelton's (1976) investigation of muskrats addressed a localized East Tennessee riverine system, Rayor's (1985) study of prairie dogs was restricted to south central Colorado, and Roger's (1976) black bear study used captive bears. Pelton's (1970) study of Georgia cottontail rabbit weights and morphometrics was the only one done on a similarly large geographic scale as the present study, but even his work was done in 1 state. Because all of these studies found correlations between habitat quality and the size and weight of animals, but the present study did not, it seems that the habitat variables measured in this study were too broad in scope and did not capture the variety of environments used by black bears. Thus, regional measures of habitat quality seem to be poor predictors of black bear weights and morphometrics.

The results of the habitat correlations and the MSCA's, however, must be interpreted within the limits of the weight and morphometric data used in this study.

Gathering the data and preparing them for analyses introduced unknown levels of variation and uncertainty into the data set. Because the data were gathered from multiple localities by numerous people, there may have been significant researcher-induced variation within the data (see Part II). The estimation of missing data values also may have added to the variation within the data. The high r^2 values of the multiple regression equations (Table 7), coupled with the relatively few missing data points (< 5%); however, illustrated the success of the missing data estimation technique. Another possible source of uncertainty in the data was the use of sexual dimorphism correction factors (zwitters). Under ideal circumstances, the sexes should be analyzed separately; however, due to the small sample sizes of 14 of the populations, I was forced to combine males and females. Given this constraint, the modified zwitters were the best way to reduce the differences in male and female weights and morphometrics.

The inter-year variation shown for the Great Smoky Mountains National Park and Neuse-Pamlico Peninsula bears (Appendix F) depicted another source of uncertainty in the data set. Inter-year differences in weights and morphometrics were not unexpected for the Great Smoky Mountains National Park bears but were surprising for the Neuse-Pamlico Peninsula bears. Black bears in Great Smoky Mountains National Park experience wide fluctuations in both hard and soft mast abundance which affect their weights and morphometrics. Thus, if the 2 years that were sampled varied in mast production, the bears may exhibit different weights and morphometrics. Consequently, the severe mast failure in Great Smoky Mountains National Park, 1992 (Great Smoky Mountains NP Mast Survey, unpubl. data, 1992) may have caused the differences in weights and weights and morphometrics depicted by the MSCA. Black bears in Neuse-Pamlico Peninsula, however, do not experience such wide fluctuations in available food. Their diet consists of natural foods available throughout the year and is highly supplemented with stable agricultural crops. Thus, I did not expect the inter-year differences in the weights and morphometrics of bears from Neuse-Pamlico Peninsula found in the MSCA.

The inter-year differences in weights and morphometrics found in this investigation add to earlier studies of animals which were geographically close to one another. Dozier (1950), McLean (1990), Pelton (1970), Rayor (1985), Rogers (1976), and Schacher and Pelton (1796) all found that animals ingesting foods high in nutrition were larger and heavier than animals ingesting foods low in nutrition. The present study extends these findings to include temporal variation in the weights and morphometrics of animals, namely black bears. Alternatively, these findings may simply show that black bears come in a variety of shapes and sizes that are difficult to compare. Either way, such inter-year variation may make it difficult to detect weight and morphometric differences between populations when analyses include data from multiple years.

The difficulties in collecting, transforming, and ultimately analyzing the weights and morphometrics made it necessary to accept certain degrees of uncertainty. Even so, given: (1) the use of summer weights and morphometrics from adult bears only, (2) the success of the estimation and zwitter procedures, (3) the coherent results of the MSCA's, (4) the large differences in the weights and morphometrics of various clusterings of black bears, and (5) the consistency of the results with other studies, there was strong evidence that the unknown levels of variation in the data were not restrictive to the analyses. Thus, when used in conjunction with other methods of comparing individuals, variations in weights and morphometrics can help to distinguish the relationships among black bear subspecies.

Management and Research Implications

Even though the ESA calls for the protection of populations as well as species and subspecies, it is important to understand the genetic, morphologic, and behavior characteristics of species at risk of becoming extinct. Management decisions may depend upon the understanding of the underlying relationships among populations of endangered species and, more importantly, the political will to protect species may depend upon the taxonomic uniqueness of a species. Both of these considerations apply to black bear populations in the Southeast. This study found that black bear weights and morphometrics varied by subspecies and ecoregion province. Thus, there was evidence supporting the current classification of black bears in the Southeast, but there was also evidence that this classification may not portray all of the differences among black bears in the eastern United States. Using skull morphology, Kennedy (1989 and pers. commun.) also found that *U. a. floridanus* and *U. a. luteolus* were distinct subspecies. Miller (1995), however, reported that *U. a. luteolus* and *U. a. floridanus* were more genetically similar to one another than they were to *U. a. americanus*. The combined results of these studies demonstrate that even though *U. a. luteolus* and *U. a. floridanus* are similar to one another, they are valid subspecies that differ from the more widespread *U. a. americanus*. Thus, they represent unique forms of the American black bear that should be conserved.

However, until wildlife professionals, taxonomists, and politicians develop and agree upon criteria that explicitly define subspecies and how best to manage them, it is unlikely that a unifying classification of black bears in the Southeast can be attained.

This study also showed that using multiple regressions of weight and morphometric data can be an effective method of estimating missing data points. Further, the modified sexual dimorphism correction factors seemed to work adequately at equalizing male and female weights and morphometrics. However, the 2 fat estimation equations did not seem to work well for black bears across the Southeast and selected other areas.

While performing this investigation, I discovered areas that could be studied in more detail and methods that could improve upon future research. The inter-year differences in black bear weights and morphometrics found in this study could be better addressed using long-term data such as that maintained by Pelton for the Great Smoky Mountains National Park (1968-1995). By looking at weight and morphometric changes over time and correlating them to habitat quality indices such as hard mast, researchers could gain a better understanding of how black bears respond to habitat quality. Based on the present study, it seems that black bear weights and morphometrics may correspond to some environmental factors that have not yet been identified. Therefore, future researchers could also focus on different regional habitat indices than those measured in this study or they could investigate more detailed sub-regional estimates of habitat quality.

For studies that are performed in the future, care should be taken to collect large, robust samples of data, which should be gathered from key areas that best represent the regions under study. Stringent data collection protocols should be developed to reduce the inadvertent accumulation of researcher-induced variation into data. Also, methods need to be developed that will enable researchers to analyze species and subspecies from the subpopulation level up, instead of arbitrarily combining them into existing subspecies or other classifications. Bozdogan's (1986) MSCA does this well, but is constrained by the number of comparisons involved when sample numbers grow large. A modified MSCA (binary decomposition) developed by Bozdogan (1986) uses a "Splitting Algorithm" to reduce the number of comparisons for large numbers of groups and may prove useful for regional studies with many groups of individuals. By use of innovative approaches such as this, future research may be better able to distinguish meaningful taxonomic demarcations among black bears and other species with disputed classifications.

PART II

RESEARCHER VARIATION IN COLLECTION OF MORPHOMETRICS ON BLACK BEARS

CHAPTER I

INTRODUCTION

Researchers take weights and morphometrics on vertebrates for many reasons. Naturalists use morphometrics to describe animals, and scientists often utilize body measurements as taxonomic criteria. Moreover, the sexes of sexually dimorphic species may often be distinguished with morphometric data. Researchers also use morphometrics to predict the age, weight, or condition of individual animals. Such predictions are especially useful for large mammals such as bears that are difficult to age or weigh. A variety of studies have attempted to develop easier ways to obtain reliable weights of bears without the use of scales (Cherry and Pelton 1976, Payne 1976, LeCount 1977, Nagy et. al. 1984, Swenson et al. 1987, Cattet 1988). Others have investigated the correlation between morphometrics and fat levels as an index to body condition (Cattet 1990, Scott 1991). Such equations, however, often have been based on measurements taken by a number of people.

Payne (1976) reported a correlation between live weight and chest girth of Newfoundland black bears that allowed for easy estimation of weight in the field. His study, however, employed more than 15 people to measure bears. Cherry and Pelton (1976) also developed a predictive equation for weight based on chest girth, but, as with Payne's study, their equation was derived from measurements collected by multiple researchers. Glenn (1980) investigated the morphometric characteristics of brown bears in coastal Alaska and found correlations between chest girth, zygomatic width, and weight. However, he also found that body measurements were inconsistent based on measurements taken on 13 female brown bears, each sampled multiple times. Also, Swenson et al. (1987) found that the predicted weights from different models varied widely. They attributed these inter-population differences to changes in the elevational zones where the bears were found, and they cautioned researchers against applying any 1 model over large geographic areas or elevational zones.

CHAPTER II

METHODS

Variation in morphometric data collected by a number of researchers may account for some of the inter-population differences in the weights and morphometrics of animals. Such variation also may affect the statistical power to predict weights and other parameters. To assess this variation, I compared data collected by different researchers on 8 morphometric parameters (Table 2.1) of black bears in Great Smoky Mountains National Park (GSMNP). These data were collected independently from the original weight and morphometric data used in Part I, and no missing data estimation or zwitter procedures were used on them.

Three teams of 2 researchers trapped bears during a 3-month period from June to August 1994. Traplines were divided equally between the northwest and southwest quadrants of the park which enabled us to collect morphometrics on bears from the Tennessee and North Carolina sides of the park, respectively. A total of 70 black bears were captured and measured by the 3 trapping teams, with individual researchers measuring an average of 21.2 bears (range = 10 - 29). Both researchers in each team collected 8 morphometrics on every bear that was captured (Table 2.1); each measurement was taken once in inches and again in centimeters. Our basis for the use of different scales was to negate any residual bias from the previous measurement. Morphometrics were taken holding the tape firmly to the hide and were recorded to the nearest 1/8 inch or 1/2

Table 2.1 Description of measurements taken for morphometric study of adult black bears in Great Smoky Mountains National Park, 1994.

Morphometric	Code	Description
Chest Girth	CG	-the circumference of the chest (directly behind the front legs) on the exhale
Ear Length	EL	-from the base of the ear to the tip of the ear
Forearm Girth	FG	-the circumference of the thickest part of the forearm
Head Contour	HC	-from one zygomatic arch to the other along the top of the head
Head Length	HL	-from the tip of the nose to the peak of the sagittal crest
Height at Shoulder	HAS	-from the tip of the longest digit of the front paw, up the leg, to the top of the scapula
Neck Girth	NG	-the circumference of the neck
Total Body Length	TBL	-from the tip of the nose, along the backbone, to the tip of the most distal tail vertebra

cm. The duplication of measurements resulted in 4 samples for each morphometric and allowed us to assess both the variation within a single researcher's measurements (intra-researcher variation) and the variation between measurements of different researchers (inter-researcher variation). I converted all data to centimeters, tabulated them, and summarized the intra- and inter-researcher variation associated with each morphometric. Differences between measurements were expressed in absolute terms. The inter-researcher differences had half as many observations as the intra-researcher differences because I had to pair measurements to compute them. Moreover, due to field conditions, we were unable to collect all 4 sets of measurements on every bear, which left unequal sample sizes between the morphometrics. Two outliers that were obviously wrong measurements were deleted from the data set.

I then documented the effect of the researcher induced variation on the precision of 4 predictive equations; 3 equations estimated total weight (Cherry and Pelton 1976, Cattet 1990, Eason and van Manen, unpubl. data), and 1 estimated nonfat body weight (Cattet 1990). Each equation was run 4 times using the 4 sets of measurements that I obtained from the field (2 sets from each researcher). I then determined the absolute intra- and inter-researcher differences among the 4 runs of each equation. Intra-researcher differences were calculated by averaging the differences between the runs based on the same researcher's 2 sets of measurements for the same bears. Inter-researcher differences were calculated by averaging the differences between runs based on different reseachers' sets of measurements for the same bears. The objective of this investigation was to study the influence of intra- and inter-researcher variation on the precision (not the accuracy) of the equations, therefore, I did not directly incorporate the estimated or actual weights of the bears into the analyses.

CHAPTER III

RESULTS

Of the 8 measurements taken, total body length, height at shoulder, and chest girth displayed the largest absolute intra-researcher differences, whereas ear length displayed the smallest (Table 2.2). The same pattern was evident for the inter-researcher measurements, except that height at shoulder displayed a larger absolute difference than chest girth. (Table 2.2). Based on their coefficients of variation (CV), however, the morphometrics showed a different pattern. Ear length, chest girth, and forearm girth had the largest CV's for inter-researcher differences, whereas total body length and head length had the smallest (Table 2.2). For intra-researcher differences, total body length, head contour, and head length had the largest CV's, whereas ear length had the smallest (Table 2.2). The intra-researcher simulations differed from one another by 0.8 - 1.5 units, which represented 1.5 - 2.6% of the average of the predicted parameters (Table 2.3). The inter-researcher simulations differed from one another by 1.8 - 3.8 units, which represented 3.4 - 8.1% of the average of the predicted parameters (Table 2.3).

Table 2.2. Average absolute inter- and intra-researcher differences (in cm) of black bear morphometrics in Great Smoky Mountains National Park, 1994: differences based on measurements collected by 6 researchers (in descending order of inter-reseacher coefficient of variation).

Measurement[a]	Difference[b]	N	Mean	Std. Dev.	Min.	Max.	CV(%)[c]
EL	Inter	70	0.49	0.61	0.00	3.43	124
	Intra	127	0.29	0.29	0.01	1.15	100
CG	Inter	68	2.47	2.39	0.00	9.88	97
	Intra	125	0.92	1.10	0.00	8.67	120
FG	Inter	70	1.02	0.85	0.00	3.54	83
	Intra	127	0.52	0.57	0.00	3.54	110
NG	Inter	68	1.45	1.16	0.00	4.66	80
	Intra	126	0.74	0.78	0.02	5.16	105
HAS	Inter	61	2.42	1.83	0.05	7.11	76
	Intra	127	1.05	1.10	0.01	5.26	105
HC	Inter	70	1.98	1.48	0.00	6.31	75
	Intra	127	0.63	0.79	0.00	4.98	125
TBL	Inter	70	2.92	2.07	0.05	8.78	71
	Intra	127	1.75	2.33	0.00	13.21	133
HL	Inter	70	1.40	1.00	0.00	4.16	71
	Intra	127	0.49	0.59	0.00	4.30	120

[a]see Table 2.1 for variable codes.
[b]Intra = the absolute value of the first measurement minus the second measurement; Inter = the absolute value of the average of the second researchers 2 measurements subtracted from the average of the first researchers 2 measurements.
[c]CV = Coefficient of variation

Table 2.3 Influence of inter- and intra-researcher variation on the precision of predicted weight and nonfat body weight (kg) of black bears in Great Smoky Mountains National Park, 1994.

				Absolute Difference Among 4 Runs of Each Equation				
Equation[a]	Variation[b]	N	Mean	SD	Min.	Max.	CV(%)[c]	%[d]
Weight:								
Cattet	Inter	52[e]	3.52	2.74	0.17	12.75	78	6.29
	Intra	52[e]	1.48	2.59	0.08	17.71	175	2.31
Cherry	Inter	60	3.76	3.41	0.00	16.16	91	8.07
	Intra	60	1.39	2.37	0.04	17.21	120	2.61
Eason & van Manen	Inter	60	1.77	2.59	0.07	19.02	146	3.42
	Intra	60	0.77	0.66	0.01	4.17	86	1.53
Nonfat Body Weight:								
Cattet	Inter	52[e]	2.57	2.04	0.18	9.23	79	4.45
	Intra	52[e]	1.44	1.67	0.10	7.87	116	2.37

[a]Weight: Cattet = predicted weight based on equation derived by Cattet for black bears (Cattet 1988); Cherry = predicted weight based on equation derived by Cherry and Pelton for black bears (Cherry and Pelton 1976); Eason & van Manen = predicted weight based on equation derived by Eason and van Manen for black bears (Eason and van Manen, unpubl. data). Nonfat Body Weight: Cattet = predicted nonfat body weight from an equation derived by Cattet for black bears (Cattet 1988).
[b]Intra = simulated weights based on the variation due to the average intra-researcher difference in morphometrics in GSMNP based on the measurements of 6 researchers; Inter = simulated weights based on the variation due to the average inter-researcher difference in morphometrics in GSMNP based on the measurements of 6 researchers.
[c]CV = Coefficient of variation
[d]% = absolute difference as a percent of the average of the predicted weights.
[e]Sample sizes for Cattet's equation included only those bears with known ages.

CHAPTER IV

DISCUSSION

At first glance, my results generally agreed with those of Glenn (1980) who found that neck girth, chest girth, body length, and height at shoulder were the least reliable measurements on brown bears. For black bears in GSMNP, I found that total body length, height at shoulder and chest girth measurements contained the most intra- and inter-researcher variation. All 3 of these morphometrics were affected by the position of the bear when it was measured. Moreover, it was difficult to determine the exact beginning and ending point of height at shoulder measurements, and chest girth measurements were complicated by whether they were taken on the exhale or inhale. Thus, the above pattern of variation was expected because of the difficulty associated with taking these long measurements.

When the size of the measurement was factored out (by using the coefficient of variation), however, a different pattern of reliability becomes evident. For inter-researcher differences, ear length had the largest CV, whereas total body length and head length had the smallest. However, for intra-researcher differences, total body length had the largest CV, whereas ear length had the smallest. The difference in CV's between the intra- and inter-researcher differences may be attributed to the fact that some morphometrics are poorly defined. For example, total body length is easy to demarcate, whereas, ear length is more subjective. Thus, morphometrics that are poorly defined may contain more variation than those that are less clearly defined. It was interesting, however, that the CV's for the intra-researcher differences were all larger than the inter-researcher difference CV's. This difference appeared to be attributable to the few large differences (both intra- and inter-researcher) present in the data, which inflated the amount of variation in the measurements. The mean inter-researcher differences, however, were all larger than the mean intra-researcher differences and were not as greatly affected by the few large differences present in the morphometrics.

I found that the inter-researcher variation was approximately twice that of the intra-researcher variation for all of the measurements examined (Table 2). Because most morphometric studies employ multiple researchers, I suggest that inter-researcher differences cause more variation in predictive equations than intra-researcher differences. Similarly, I suggest that the inter-researcher difference CV's better represent the reliability of the morphometrics taken than the intra-researcher difference CV's. Thus, ear length, chest girth, and forearm girth were the least reliable measures, whereas head length and total body length were the most reliable measures.

The simulations demonstrated the effect that researcher-induced variation can have on predictive equations. All 4 of the models I tested produced varying results based on the 4 sets of morphometrics collected on each bear. The models least affected were those incorporating multiple morphometrics to predict either weight or nonfat body weight of black bears. In these models, the variation in measurements may cancel each other out and yield a more precise estimate. Even so, the variation demonstrated in this study was larger than most of the inter-population differences shown by Swenson et al. (1987).

Also, such levels of researcher-induced variation may limit the predictive power of equations based on morphometrics. Thus, models based on morphometrics may be more precise (and accurate) if measurements can be taken more consistently.

Management Implications

Factors that may have influenced the accuracy of the morphometrics in my study, besides the number of researchers, included: indistinct and subjective criteria for obtaining morphometrics, short tape measures, differences in measuring techniques, and unnoticed slipping of the tape while taking measurements. Morphometrics could be taken more precisely in several ways. First, as documented by this study, the number of researchers collecting morphometric data should be small: 1 person being the ideal number. Next, measurements should be standardized and clearly defined. Also, field researchers should be trained together before they begin field work and outfitted with the proper equipment.

Researchers need to be aware of the variation introduced into morphometric data simply by taking the measurements. Once this source of variation is acknowledged, steps can be taken to minimize its magnitude. By implementing the above suggestions, researchers can minimize the variance associated with taking measurements on large animals and improve the predictive power of morphometric models.

SUMMARY

SUMMARY

1. Regional variation in the weights and body sizes (morphometrics) of mammals has been documented, however, the occurrence of such variation has not been systematically investigated in black bears. If black bear weights and morphometrics vary regionally, they may conform to subspecies or habitat quality differences. The objectives of the research in Part I were to determine if black bears in the Southeast and selected other areas exhibit weight and morphometric variation, and, if so, to determine if these parameters correspond to subspecies demarcations or regional habitat quality indices.

2. I collected summer weights and morphometrics on 260 adult (≥ 4 yrs.) black bears from 20 locations across the Southeast and selected other areas from 1992 to 1994. Due to their close proximity and small sample sizes, however, I pooled the bears from Mobile River, AL and DeSoto National Forest, MS, and from Ozark Mountains, AR and Ouachita Mountains, AR, respectively. Thus, I had weight and morphometric data from 18 populations of black bears.

3. The data sets had 87 missing data values. These missing data points were estimating using multiple regressions of each morphometric parameter against all of the other parameters. The multiple regressions were derived from the Great Smoky Mountains data set because it had the largest sample size. The equations were individualized for each population by calculating coefficients based on the data gathered from each location. The equations accounted for 79.9% to 99.9% of the variation in the parameters.

4. Black bears exhibit sexual dimorphism, with males achieving sizes more than twice those of females. Consequently, males and females should be analyzed separately, however, because 14 of the 18 populations had sample sizes of 10 or fewer bears, the sexes were combined for this study. A sexual dimorphism correction factor procedure, modified from Schnell et.al. (1985), was used to minimize the size and weight differences between the male and female bears. This procedure brought the means closer together and reduced the coefficient of variation (CV) around the weights and morphometrics of 15 of the 18 populations. The deficiency of the procedure on 3 of the populations was attributed to either their geographic distance from the Southeast or to their small sample sizes.

5. The multi-sample cluster analyses (MSCA) of Great Smoky Mountain National Park and Neuse-Pamlico Peninsula data sets revealed that, based on their weights and morphometrics, bears from different years clustered separately. The inter-year differences in Great Smoky Mountain National Park bears corresponded to a mast failure in the Park. The inter-year differences in the Neuse-Pamlico Peninsula, however, did not correspond to any apparent food shortages. Thus, it seems that black bear weights and morphometrics may respond to yearly fluctuations in food supply or that bears may come in a variety of shapes and sizes that are difficult to compare.

6. The MSCA of all 18 populations by subspecies revealed that black bear weights and morphometrics varied across subspecies demarcations. AIC and ICOMPIFIM, under their respective homogeneity models, showed that the subspecies were morphometricaly separated. The 2 criteria also portrayed the same, logical decomposition of the data.

Under both of these models, black bears in Alaska (*U. a. emmonsii*) first separated from black bears in the Southeast. Then, bears from the *U. a. floridanus* subspecies separated from *U. a. americanus* and *U. a. luteolus*. Finally, under the optimal model *U. a. americanus* and *U. a. luteolus* separated, leaving all of the subspecies separated from one another.

7. The MSCA of all 18 populations by ecoregion province had similar results as that for the subspecies. AIC and ICOMPIFIM again showed that the black bears in the ecoregion provinces were morphometricaly separated and the best model portrayed a logical decomposition of the data. Under this model, black bears in Alaska (Pacific Forest Province) again first separated from black bears in the Southeast. Bears from the Northeast (Laurentian Mixed Forest Province) then separated from bears in the Southeast, followed by bears in the Eastern Deciduous Forest Province. Finally, under the optimal model, the 2 ecoregion provinces of the Southeast (Outer Coastal Plain Forest Province and Southeastern Mixed Forest Province) separated, leaving all of the provinces separated from one another.

8. Because the ranges of the subspecies and the ecoregion provinces overlapped, and because the analyses showed that black bears grouped under each of these categories clustered separately, the MSCA's yielded conflicting results. These results supported the current subspecies delineations of black bears in the Southeast, however, they also indicated that these groupings may not account for all of the differences in black bear weights and morphometrics in the region. The MSCA's showed that black bears in the deep Southeast may be more morphometrically similar to one another than to black bears

in the North, and that there may be morphometric differences among black bears in *the U. a. americanus* subspecies.

9. Because the regional habitat quality indices examined in this study were not correlated with black bear weights, morphometrics or fat levels, they do not seem to represent the habitat needs of black bears. Bear weights and morphometrics may correspond to habitat quality measures not examined in this study or to sub-regional habitat differences.

10. The 2 fat estimation equations used in this study predicted significantly different % fat estimates for the same bears ($P = 0.0163$), with Scott's equation yielding higher estimates than Cattet's. Both equations also predicted that many bears had negative % fat, which is impossible. These results, suggest that these equations do not perform adequately for black bears in the Southeast and selected other areas.

11. The results of this study indicate that future research may be directed in several areas. To be definitive, studies of regional differences in mammals must collect large numbers of samples from locations that represent the entire range of the species, subspecies, or population under investigation. Inter-year differences in black bear weights and morphometrics could be better understood using long-term data such as that maintained by Pelton for Great Smoky Mountains National Park. Future research could also focus on other measures of regional habitat quality that better represent black bear needs or it could investigate sub-regional indices of black bear habitat quality.

12. Morphometric data are usually collected by multiple researchers, and the variation introduced into the data by these people may account for some of the inter-

population differences in black bear weights and morphometrics. Additionally, researchers have used morphometric data to predict the age, weight, and condition of mammals but have not investigated the influence of multiple researcher data collection on these models. The objectives of the research in Part II were to document the level of variation associated with multiple researchers collecting data and to determine the effect of this variation on weight and body fat estimation equations.

13. I analyzed morphometric data collected by 3 teams of 2 researchers which trapped and measured 70 black bears in Great Smoky Mountains National Park during the Summer, 1992. Both researchers in each team collected 8 measurements on every bear caught, with individual researchers measuring an average of 21.2 bears (range = 10 - 29). Each measurement was taken twice by each researcher.

14. Over-all inter-researcher variation (average = 1.77 cm) was more than twice as great as intra-researcher variation (average = 0.80 cm). However, ear length, chest girth, and forearm girth had the largest inter-researcher CV's, whereas total body length, head contour, and head length had the largest intra-researcher CV's.

15. Intra-researcher variation caused the predictive equations to differ by an average of 2.21%, whereas inter-researcher variation caused them to differ by an average of 5.56%. These differences were larger than those found by Swenson et.al (1987) in their study of inter-population variability in bear weights and may account for the differences found in their study.

16. Researchers can reduce the variability introduced into morphometric data by reducing the number of data gatherers (preferably to 1), standardizing data collection

procedures, clearly defining measurements, and training field personnel together. By use of these suggestions, researchers can collect more robust data that may improve the predictive power of equations based on morphometrics.

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APPENDICES

Appendix A. Summary of best subsets of information theory criteria for multiple regression analyses of weights and morphometrics of black bears.

Table A.1. Summary of best subsets of: information complexity based on the inverse Fisher information matrix (ICOMPIFIM), information complexity (ICOMP), and Akaike's information criterion (AIC) for multiple regression on chest girth of black bears in Great Smoky Mountains NP, 1992-1993.

Morphometric Variables[a]							$2k^b$	-2LogL	$2^*C_1(F^{-1})$	2^*C_1CB	ICOMPIFIM	ICOMP	AIC
WT	TBL	FLG	NG	HW	ZC	INT.	14	293.3	44.3	44.2	337.6	337.5	307.3
WT	TBL	FLG	NG	HW		INT.	12	293.4	-----	-----	-----	-----	305.4
WT	TBL	FLG	NG	HW	ZC		--	296.2	30.1	13.8	326.3	**310.0†**	-----
WT	TBL		NG	HW		INT.	10	294.5	-----	-----	-----	-----	**304.5†**
WT	**TBL**	**FLG**	**NG**	**HW‡**			--	297.1	27.5	13.4	**324.6†**	310.5	-----
WT	TBL	FLG	NG				8	300.2	25.8	12.8	326.0	313.0	308.2
WT	TBL		NG				6	308.1	-----	9.7	-----	317.8	314.1
	TBL	FLG	NG				--	310.4	19.0	-----	329.4	-----	-----
		FLG	NG				4	315.7	13.0	5.4	328.7	321.1	319.7
WT							2	513.9	15.3	0.0	529.2	513.9	515.9
	TBL						2	389.4	13.3	0.0	402.7	389.4	391.4
		FLG					2	346.7	9.4	0.0	356.1	346.7	348.7
			NG				2	339.2	10.2	0.0	349.4	339.2	341.2
				HW			2	444.2	9.8	0.0	454.0	444.2	446.2
					ZC		2	380.9	11.0	0.0	391.9	380.9	382.9
						INT.	2	472.1	4.8	0.0	476.9	472.1	474.1

[a]See Table 1.2 for variable codes.
[b]k = the number of estimated parameters including the intercept.
† denotes global minimum for each criterion.
‡ denotes model chosen as best-fitting model.

Table A.2. Summary of best subsets of: information complexity based on the inverse Fisher information matrix (ICOMPIFIM), information complexity (ICOMP), and Akaike's information criterion (AIC) for multiple regression on foreleg girth of black bears in Great Smoky Mountains NP, 1992-1993.

Morphometric Variables[a]	2k[b]	-2LogL	$2{*}C_1(F^{-1})$	$2{*}C_1CB$	ICOMPIFIM	ICOMP	AIC
WT TBL NG CG HW ZC INT.	14	198.5	46.1	45.0	244.6	243.5	212.5
WT TBL NG CG HW INT.	12	198.9	-----	-----	-----	-----	210.9
WT TBL NG CG HW ZC	--	207.9	22.9	12.7	230.8	220.6	-----
WT TBL NG HW INT.	10	200.0	-----	-----	-----	-----	**210.0†**
TBL NG CG HW ZC‡	--	207.9	17.7	8.6	225.6	**216.5†**	-----
WT CG HW INT.	8	202.1	-----	-----	-----	-----	210.1
TBL NG CG ZC	--	210.3	-----	8.0	-----	218.3	-----
NG CG HW INT.	--	207.3	17.6	-----	224.9	-----	-----
WT HW INT.	6	207.1	-----	16.6	-----	-----	213.1
TBL CG ZC	--	214.3	-----	6.6	-----	220.9	-----
NG CG INT.	--	209.2	14.4	-----	**223.6†**	-----	-----
CG INT.	4	217.6	10.9	10.6	228.5	228.2	221.6
CG ZC	--	218.3	-----	5.1	-----	223.4	-----
WT	2	413.9	13.6	0.0	427.5	413.9	415.9
TBL	2	267.5	11.2	0.0	278.7	267.5	269.5
FLG	2	256.6	8.7	0.0	265.3	256.6	258.6
NG	2	236.5	9.4	0.0	245.9	236.5	238.5
HW	2	326.4	7.7	0.0	334.1	326.4	328.4
ZC	2	256.0	8.8	0.0	364.8	256.0	258.0
INT.	2	346.2	2.6	0.0	348.8	346.2	348.2

[a]See Table 1.2 for variable codes.
[b]k = the number of estimated parameters including the intercept.
† denotes global minimum for each criterion.
‡ denotes model chosen as best-fitting model.

Table A.3. Summary of best subsets of: information complexity based on the inverse Fisher information matrix (ICOMPIFIM), information complexity (ICOMP), and Akaike's information criterion (AIC) for multiple regression on head width of black bears in Great Smoky Mountains NP, 1992-1993.

Morphometric Variables[a]							$2k^b$	-2LogL	$2{*}C_1(F^{-1})$	$2{*}C_1CB$	ICOMPIFIM	ICOMP	AIC
WT	TBL	FLG	NG	CG	ZC	INT.	14	232.0	45.4	44.7	277.4	276.7	246.0
WT		FLG	NG	CG	ZC	INT.	12	233.6	-----	-----	-----	-----	**245.6†**
WT	TBL	FLG	NG	CG	ZC		--	239.2	25.5	13.8	264.7	**253.0†**	-----
WT		FLG	NG	CG		INT.	10	236.1	-----	-----	-----	-----	246.1
WT	TBL	FLG	NG	CG			--	241.3	-----	11.5	-----	252.8	-----
WT	TBL	FLG	NG	CG			--	240.2	23.8	-----	264.0	-----	-----
WT		FLG		CG		INT.	8	240.0	-----	-----	-----	-----	248.0
WT		FLG	NG	CG			--	243.7	19.9	11.3	263.6	255.0	-----
WT		**FLG**	**NG‡**				6	244.6	17.5	9.9	**262.1†**	254.5	250.6
WT			NG				4	249.5	-----	-----	-----	-----	253.5
WT				CG			--	249.7	-----	2.8	-----	252.5	-----
		FLG				INT.	--	253.2	9.1	-----	262.2	-----	-----
WT							2	294.3	1.7	0.0	296.0	294.3	296.3
	TBL						2	363.1	12.7	0.0	375.8	363.1	365.1
		FLG					2	268.3	11.2	0.0	279.5	268.3	270.3
			NG				2	254.7	7.7	0.0	262.4	254.7	256.7
				HW			2	266.3	8.9	0.0	275.2	266.3	268.3
					ZC		2	262.3	9.8	0.0	272.1	262.3	264.3
						INT.	2	256.6	8.8	0.0	265.4	256.6	258.6

[a]See Table 1.2 for variable codes.
[b]k = the number of estimated parameters including the intercept.
† denotes global minimum for each criterion.
‡ denotes model chosen as best-fitting model.

Table A.4. Summary of best subsets of: information complexity based on the inverse Fisher information matrix (ICOMPIFIM), information complexity (ICOMP), and Akaike's information criterion (AIC) for multiple regression on neck girth of black bears in Great Smoky Mountains NP, 1992-1993.

Morphometric Variables[a]							2k[b]	-2LogL	$2*C_1(F^{-1})$	$2*C_1CB$	ICOMPIFIM	ICOMP	AIC
WT	TBL	FLG	CG	HW	ZC	INT.	14	265.2	45.2	44.9	310.4	310.1	279.2
WT		FLG	CG	HW	ZC	INT.	12	303.2	-----	-----	-----	-----	277.3
WT	TBL	FLG	CG	HW	ZC		--	266.1	27.6	14.0	293.7	280.1	-----
WT		**FLG**	**CG**	**HW**	**ZC‡**		10	266.4	23.4	11.8	289.4	**278.2†**	276.4
WT			CG	HW		INT.	8	267.6	-----	-----	-----	-----	**275.6†**
WT		FLG	CG	HW			--	268.0	21.1	11.2	**289.1†**	279.2	-----
WT		FLG	CG				6	270.4	19.6	10.8	290.0	281.2	276.4
WT			CG				4	279.2	-----	2.8	-----	282.0	283.2
		FLG	CG				--	281.1	12.4	-----	293.5	-----	-----
WT							2	426.5	4.0	0.0	430.5	426.5	428.5
	TBL						2	454.4	14.3	0.0	468.7	454.4	456.4
		FLG					2	356.8	12.8	0.0	369.6	356.8	358.8
			NG				2	312.2	8.7	0.0	320.9	312.2	314.2
				HW			2	284.5	10.2	0.0	294.7	284.5	286.5
					ZC		2	393.6	8.9	0.0	402.5	393.6	395.6
						INT.	2	341.7	10.3	0.0	352.0	341.7	343.7

[a]See Table 1.2 for variable codes.
[b]k = the number of estimated parameters including the intercept.
† denotes global minimum for each criterion.
‡ denotes model chosen as best-fitting model.

Table A.5. Summary of best subsets of: information complexity based on the inverse Fisher information matrix (ICOMPIFIM), information complexity (ICOMP), and Akaike's information criterion (AIC) for multiple regression on total body length of black bears in Great Smoky Mountains NP, 1992-1993.

Morphometric Variables[a]	2k[b]	-2LogL	$2*C_1(F^{-1})$	$2*C_1CB$	ICOMPIFIM	ICOMP	AIC
WT FLG NG CG HW ZC INT.	14	412.8	43.6	42.0	456.4	454.8	426.8
WT FLG CG HW ZC INT.	12	412.9	-----	-----	-----	-----	424.9
WT FLG NG CG HW ZC	--	416.1	-----	12.1	-----	428.2	-----
FLG NG CG HW ZC INT.	--	413.5	31.5	-----	445.0	-----	-----
FLG CG HW ZC INT.	10	413.5	26.8	-----	440.3	-----	423.5
WT FLG CG HW ZC	--	416.5	-----	11.8	-----	428.3	-----
FLG CG ZC INT.	8	414.4	-----	-----	-----	-----	422.4
WT CG HW ZC	--	421.4	-----	10.3	-----	431.7	-----
FLG CG HW INT.	--	414.9	21.5	-----	436.4	-----	-----
CG ZC INT.	6	414.9	-----	-----	-----	-----	420.9
FLG CG INT.	--	415.4	17.1	14.0	432.5	429.4	-----
CG INT.‡	4	416.6	12.9	10.6	**429.5†**	**427.2†**	**420.6†**
WT	2	508.4	5.4	0.0	513.8	508.4	510.4
TBL	2	612.4	17.1	0.0	629.5	612.4	614.4
FLG	2	452.4	11.2	0.0	463.6	452.4	454.4
NG	2	486.2	12.8	0.0	499.0	486.2	488.2
HW	2	464.0	13.3	0.0	477.3	464.0	466.0
ZC	2	524.9	11.2	0.0	536.1	524.9	526.9
INT.	2	452.3	12.3	0.0	464.6	452.3	454.3

[a]See Table 1.2 for variable codes.
[b]k = the number of estimated parameters including the intercept.
† denotes global minimum for each criterion.
‡ denotes model chosen as best-fitting model.

Table A.6. Summary of best subsets of: information complexity based on the inverse Fisher information matrix (ICOMPIFIM), information complexity (ICOMP), and Akaike's information criterion (AIC) for multiple regression on zygomatic circumference of black bears in Great Smoky Mountains NP, 1992-1993.

Morphometric Variables[a]							$2k^b$	-2LogL	$2*C_1(F^{-1})$	$2*C_1CB$	ICOMPIFIM	ICOMP	AIC
WT	TBL	FLG	NG	CG	HW	INT.	14	290.5	43.8	43.7	334.3	334.2	304.5
WT	TBL	FLG	NG		HW	INT.	12	290.6	-----	-----	-----	-----	302.6
WT	TBL	FLG	NG	CG	HW		--	297.4	-----	13.9	-----	311.3	-----
	TBL	FLG	NG	CG	HW	INT.	--	292.6	29.8	-----	322.4	-----	-----
WT	TBL		NG		HW	INT.	10	291.2	-----	-----	-----	-----	301.2
	TBL	FLG	NG	CG	HW		--	298.7	-----	9.7	-----	308.4	-----
		FLG	NG	CG	HW	INT.	--	293.9	21.2	-----	315.1	-----	-----
WT	TBL				HW	INT.	8	292.0	-----	-----	-----	-----	**300.0†**
	TBL	**FLG**	**NG**		**HW‡**		--	299.0	-----	8.9	-----	**307.9†**	-----
		FLG	NG	CG		INT.	--	295.5	17.4	-----	312.9	-----	-----
WT					HW	INT.	6	295.9	-----	-----	-----	-----	301.9
	TBL	FLG			HW		--	300.4	-----	7.5	-----	307.9	-----
		FLG		CG		INT.	--	296.9	14.1	-----	**311.0†**	-----	-----
				CG		INT.	4	301.7	10.7	-----	312.4	-----	305.7
	TBL	FLG					--	303.5	-----	6.9	-----	310.4	-----
WT							2	396.4	3.4	0.0	399.8	396.4	398.4
	TBL						2	482.4	14.8	0.0	497.2	482.4	484.4
		FLG					2	328.0	12.3	0.0	340.3	328.0	330.0
			NG				2	316.5	8.8	0.0	325.3	316.5	318.5
				HW			2	346.7	10.3	0.0	357.0	346.7	348.7
					ZC		2	331.2	11.0	0.0	342.2	331.2	333.2
						INT.	2	388.9	8.8	0.0	397.7	388.9	390.9

[a]See Table 1.2 for variable codes.
[b]k = the number of estimated parameters including the intercept.
† denotes global minimum for each criterion.
‡ denotes model chosen as best-fitting model.

Appendix B. Summary statistics for multiple regressions of black bears with missing data points.

Table B.1. Statistics for multiple regression equations on populations of black bears with missing data, Southeast and selected other areas, 1992-1994.

Parameter	n	Equation[a]	r^2	# Estimated
<u>Chest Girth</u>				
Atchafalaya River Basin	39	0.0435WT + 0.1158TBL + 0.4855FLG + 0.4385NG + 1.1894HW	0.997	1
Great Smoky Mtns. NP	56	0.0634WT + 0.1654TBL + 0.6121FLG + 0.4353NG + 0.3733HW	0.998	1
<u>Foreleg Girth</u>				
Atchafalaya River Basin	38	0.0128TBL - 0.1399NG + 0.2010CG + 0.7376HW + 0.1278ZC	0.994	1
New York	10	0.3411TBL - 0.5303NG - 0.5698CG + 1.3063HW + 0.5828ZC	0.997	2
White River NWR	35	0.1496TBL + 0.3544NG - 0.0070CG + 0.1368HW - 0.2317ZC	0.995	3
<u>Head Width</u>				
Great Smoky Mtns. NP	61	-0.0161WT - 0.0824FLG + 0.4410NG	0.872	2
Neuse-Pamlico Peninsula	49	-0.0113WT + 0.3796FLG + 0.1138NG	0.990	14
New York	13	0.0056WT + 0.5853FLG + 0.0162NG	0.984	1
Ocmulgee River	9	-0.0239WT + 0.1738FLG + 0.2673NG	0.999	1
Tensas River	19	-0.0275WT + 0.3275FLG + 0.2619NG	0.917	1
<u>Neck Girth</u>				
Alligator River NWR	9	0.0821WT - 0.0781FLG + 0.3167CG - 0.2456HW + 0.5694ZC	0.997	1
<u>Total Body Length</u>				
Great Smoky Mtns. NP	64	1.2423CG + 53.9251	0.797	1
Tensas River	21	1.2428CG + 48.5817	0.879	1

Table B.1. Statistics for multiple regression equations on populations of black bears with missing data, Southeast and selected other areas, 1992-1994.

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Atchafalaya River Basin	39	0.0435WT + 0.1158TBL + 0.4855FLG + 0.4385NG + 1.1894HW	0.997	1
Great Smoky Mtns. NP	56	0.0634WT + 0.1654TBL + 0.6121FLG + 0.4353NG + 0.3733HW	0.998	1
Foreleg Girth				
Atchafalaya River Basin	38	0.0128TBL - 0.1399NG + 0.2010CG + 0.7376HW + 0.1278ZC	0.994	1
New York	10	0.3411TBL - 0.5303NG - 0.5698CG + 1.3063HW + 0.5828ZC	0.997	2
White River NWR	35	0.1496TBL + 0.3544NG - 0.0070CG + 0.1368HW - 0.2317ZC	0.995	3
Head Width				
Great Smoky Mtns. NP	61	-0.0161WT - 0.0824FLG + 0.4410NG	0.872	2
Neuse-Pamlico Peninsula	49	-0.0113WT + 0.3796FLG + 0.1138NG	0.990	14
New York	13	0.0056WT + 0.5853FLG + 0.0162NG	0.984	1
Ocmulgee River	9	-0.0239WT + 0.1738FLG + 0.2673NG	0.999	1
Tensas River	19	-0.0275WT + 0.3275FLG + 0.2619NG	0.917	1
Neck Girth				
Alligator River NWR	9	0.0821WT - 0.0781FLG + 0.3167CG - 0.2456HW + 0.5694ZC	0.997	1
Total Body Length				
Great Smoky Mtns. NP	64	1.2423CG + 53.9251	0.797	1
Tensas River	21	1.2428CG + 48.5817	0.879	1

Appendix C. Sample calculation of sexual dimorphism correction factors used on weights and morphometrics of black bears.

Table C.1 Sample calculation of zwitter correction factor used on weights and morphometrics of black bears in the Southeast and selected other areas, 1992-1994: steps in the calculation are shown as superscripts.

Variable: Weight

Population[1]	Mean Male[2]	Mean Female[2]	Difference[3]	% Difference[4]	N Male	N Female	Weighting Factor[5]	Weighted Difference[6]
White River NWR	321.90	132.40	189.50	143.13	9	10	0.9972	142.7304
Great Smoky Mtns. NP	184.20	103.00	81.20	78.83	20	22	0.9977	78.6562
Neuse-Pamlico Penn.	298.10	152.80	145.30	95.09	21	18	0.9941	94.5290
Atchafalaya River	248.00	148.40	99.60	67.12	8	16	0.8889	59.6586
Ocmulgee	261.20	132.00	129.20	97.88	5	5	1.0000	97.8788
Sumpter NF	272.00	141.40	130.60	92.36	9	7	0.9844	90.9189
							5.8623[7]	96.2713[8]
							Female Zwitter[9]	48.1%
							Male Zwitter[10]	24.5%

Steps:

1. Only populations with at least 5 males and 5 females were used to calculate the zwitters.
2. The mean male and female weights of each population were calculated.
3. The mean female weights were subtracted from the mean male weights for each population.
4. The difference was computed as a % of the mean female weight for each population.
5. A weighting factor for each population was derived as the harmonic mean of the number of males and females.
6. The weighted difference for each population was computed as the product of the % difference and the weighting factor.
7. The total weighting factor was computed as the sum of the weighting factors.
8. The overall weighted difference was computed as the sum of the weighted differences divided by the total weighting factor.
9. The female zwitter was calculated as 1/2 the overall weighted difference ÷ 100.
10. The male zwitter was calculated as 1/2 the overall weighted difference ÷ the sum of 100 + the overall weighted difference.

Appendix D. Summary of the sexual dimorphism correction factor values.

Table D.1. Summary of the parameters used in calculating the sexual dimorphism correction factors (zwitters) for male and female black bears, southeastern United States and selected other areas, 1992-1994.

	Parameter Means[a]			Correction Factor[f] (%)	
Variable[b]	Difference[c] (Male - Female)	% Difference[d]	Weighted % Difference[e]	Male	Female
CG	26.3	32.8	32.9	12.4	16.5
FLG	8.9	29.7	29.9	11.2	14.5
HW	3.9	23.2	23.2	9.4	11.6
NG	18.5	36.3	36.4	13.3	18.2
TBL	27.7	18.5	18.6	7.8	9.3
WT	129.2	95.7	96.3	24.5	48.1
ZC	9.8	19.3	19.4	8.1	9.7

[a]Parameter means based only on those populations with at least 5 males and 5 females.

[b]See Table 2 for variable codes.

[c]Differences in cm and lb. for the morphometric variables and weight, respectively.

[d]Differences computed as % of female variables.

[e]% Differences weighted by the harmonic mean of number of males and females for each population (see Appendix A).

[f]The Correction Factors were derived by dividing the Weighted % Differences by 2 and determining what % of an average female and male (for each parameter) these quotients were (see Appendix A).

Appendix E. Summary statistics of adult black bear weights and morphometrics by location.

Table E.1. Mean chest girth (cm) of adult black bears sampled for morphometric study, 1992-1994.

Population	Sex	n	Measured Mean	Measured S.D.	Measured CV (%)	Zwitterized Mean	Zwitterized S.D.	Zwitterized CV (%)
Alaska	F	3	94.4	13.7	14.5	110.0	16.0	14.5
	M	5	89.0	8.4	9.4	78.0	7.4	9.5
	F+M	8	91.1	10.1	11.1	90.0	19.4	21.6
Alligator River NWR	F	4	79.0	5.7	7.2	92.0	6.7	7.3
	M	20	109.5	13.9	12.7	95.9	12.1	12.6
	F+M	24	104.4	17.2	16.5	95.2	11.4	12.0
Atchafalaya River Basin	F	16	80.7	7.9	9.8	94.0	9.2	9.8
	M	8	100.0	10.7	10.7	87.6	9.4	10.7
	F+M	24	87.1	12.8	14.7	91.8	9.6	10.5
Camp Lejeune	F	5	83.3	5.4	6.5	97.0	6.3	6.5
	M	3	100.7	11.5	11.4	88.2	10.1	11.5
	F+M	8	89.8	11.6	12.9	93.7	8.5	9.1
Great Dismal Swamp NWR	F	3	76.3	3.4	4.5	88.9	4.0	4.5
	M	7	96.1	9.7	10.1	84.2	8.5	10.1
	F+M	10	90.2	12.5	13.9	85.6	7.5	8.8
Great Smoky Mt. NP	F	22	73.3	7.4	10.1	85.4	8.6	10.1
	M	20	92.5	12.0	13.0	81.0	10.5	13.0
	F+M	42	82.4	13.8	16.7	83.3	9.7	11.6
Horry County	F	2	77.4	1.2	1.6	90.1	1.4	1.6
	M	2	88.6	6.7	7.6	77.6	5.9	7.6
	F+M	4	83.0	7.6	9.2	83.8	8.0	9.5
Mobile River / DeSoto NF	F	3	73.1	3.5	4.8	85.2	4.1	4.8
	M	6	94.2	13.7	14.5	82.5	12.0	14.5
	F+M	9	87.2	15.2	17.4	83.4	9.8	11.8
Neuse-Pamlico Penninsula	F	18	84.6	6.9	8.2	98.5	8.1	8.2
	M	21	112.3	9.5	8.5	98.4	8.3	8.4
	F+M	39	99.5	16.3	16.4	98.4	8.1	8.2
New York	F	3	77.2	3.9	5.1	89.9	4.5	5.0
	M	10	87.9	15.6	17.7	77.0	13.7	17.8
	F+M	13	85.4	14.4	16.9	80.0	13.3	16.6
Ocmulgee River	F	5	79.6	4.7	5.9	92.7	5.5	5.9
	M	5	111.3	15.3	13.7	97.5	13.4	13.7
	F+M	10	95.4	19.8	20.8	95.1	10.0	10.5
Okefenokee NWR	F	2	74.4	0.2	0.3	86.6	0.2	0.2
	M	3	76.6	10.6	13.8	67.1	9.3	13.9
	F+M	5	75.7	7.6	10.0	74.9	12.5	16.7
Ozark/Ouachita NF	F	3	78.2	4.0	5.1	91.1	4.6	5.0
	M	8	101.1	10.1	10.0	88.5	8.8	9.9
	F+M	11	94.8	13.7	14.5	89.2	7.8	8.7
Shenandaoh NP	F	3	72.8	9.9	13.6	84.9	11.6	13.7
	M	1	83.5	—	—	73.1	—	—
	F+M	4	75.5	9.7	12.8	81.9	11.1	13.6
Sumpter NF	F	7	81.6	12.5	15.3	95.0	14.6	15.4
	M	9	108.8	20.4	18.8	95.3	17.8	18.7
	F+M	16	96.9	21.9	22.6	95.2	16.0	16.8
Tensas River NWR	F	7	75.0	9.6	12.8	87.3	11.2	12.8
	M	2	112.5	13.4	11.9	98.5	11.7	11.9
	F+M	9	83.3	19.1	22.9	89.9	11.6	12.9
West Virginia	F	1	75.4	—	—	87.8	—	—
	M	4	104.4	3.7	3.5	91.4	3.3	3.6
	F+M	5	98.6	13.4	13.6	90.7	3.3	3.6
White River NWR	F	10	79.9	8.5	10.6	93.1	9.9	10.6
	M	9	112.3	14.4	12.8	98.4	12.6	12.8
	F+M	19	95.3	20.1	21.1	95.6	11.3	11.8

Table E.2. Mean foreleg girth (cm) of adult black bears sampled for morphometric study, 1992-1994.

Population	Sex	n	Measured Mean	Measured S.D.	Measured CV (%)	Zwitterized Mean	Zwitterized S.D.	Zwitterized CV (%)
Alaska	F	3	33.3	4.1	12.3	38.3	4.7	12.3
	M	5	33.1	4.3	13.0	29.3	3.8	13.0
	F+M	8	33.2	3.9	11.7	32.7	6.0	18.3
Alligator River NWR	F	4	28.5	4.5	15.8	32.7	5.2	15.9
	M	20	37.4	5.1	13.6	33.1	4.5	13.6
	F+M	24	35.9	6.0	16.7	33.0	4.5	13.6
Atchafalaya River Basin	F	16	29.6	2.5	8.4	34.0	2.9	8.5
	M	8	36.5	5.1	14.0	32.3	4.5	13.9
	F+M	24	31.9	4.8	15.0	33.4	3.5	10.5
Camp Lejeune	F	5	31.1	3.5	11.2	35.7	4.1	11.5
	M	3	34.4	3.4	9.9	30.5	3.0	9.8
	F+M	8	32.4	3.7	11.4	33.8	4.4	13.0
Great Dismal Swamp NWR	F	3	30.0	2.3	7.7	34.4	2.6	7.6
	M	7	37.3	4.4	11.8	33.0	3.9	11.8
	F+M	10	35.1	5.2	14.8	33.5	3.5	10.4
Great Smoky Mt. NP	F	22	27.5	3.6	13.1	31.5	4.2	13.3
	M	20	34.7	4.1	11.8	30.7	3.6	11.7
	F+M	42	30.9	5.3	17.2	31.2	3.9	12.5
Horry County	F	2	30.7	0.9	2.9	35.2	1.1	3.1
	M	2	36.2	0.8	2.2	32.0	0.8	2.5
	F+M	4	33.4	3.3	9.9	33.6	2.0	6.0
Mobile River / DeSoto NF	F	3	28.7	1.1	3.8	33.0	1.2	3.6
	M	6	36.0	3.7	10.3	31.9	3.2	10.0
	F+M	9	33.6	4.7	14.0	32.3	2.7	8.4
Neuse-Pamlico Penninsula	F	18	32.2	2.5	7.8	37.0	2.9	7.8
	M	21	43.0	3.3	7.7	38.1	2.9	7.6
	F+M	39	38.0	6.2	16.3	37.6	2.9	7.7
New York	F	3	31.8	1.7	5.3	36.6	1.9	5.2
	M	10	37.3	6.7	18.0	33.0	6.0	18.2
	F+M	13	36.1	6.4	17.7	33.9	5.5	16.2
Ocmulgee River	F	5	31.7	1.9	6.0	36.4	2.2	6.0
	M	5	42.6	4.6	10.8	37.7	4.1	10.9
	F+M	10	37.1	6.6	17.8	37.0	3.2	8.6
Okefenokee NWR	F	2	29.4	1.2	4.1	33.7	1.4	4.2
	M	3	29.4	3.4	11.6	26.0	3.0	11.5
	F+M	5	29.4	2.5	8.5	29.1	4.8	16.5
Ozark/Ouachita NF	F	3	27.0	1.0	3.7	31.0	1.1	3.5
	M	8	34.3	4.5	13.1	30.3	4.0	13.2
	F+M	11	32.3	5.1	15.8	30.5	3.4	11.1
Shenandaoh NP	F	3	24.8	3.3	13.3	28.5	3.7	13.0
	M	1	25.0	—	—	22.1	—	—
	F+M	4	24.9	2.7	10.8	26.9	4.4	16.4
Sumpter NF	F	7	28.5	3.7	13.0	32.8	4.2	12.8
	M	9	35.0	4.9	14.0	31.0	4.3	13.9
	F+M	16	32.1	5.4	16.8	31.7	4.2	13.2
Tensas River NWR	F	7	27.3	3.1	11.4	31.4	3.6	11.5
	M	2	41.0	1.3	3.2	36.2	1.2	3.3
	F+M	9	30.3	6.6	21.8	32.5	3.8	11.7
West Virginia	F	1	29.1	—	—	33.4	—	—
	M	4	39.2	8.2	20.9	34.7	7.2	20.7
	F+M	5	37.2	8.4	22.6	34.4	6.3	18.3
White River NWR	F	10	28.7	2.2	7.7	32.9	2.6	7.9
	M	9	39.6	5.7	14.4	35.0	5.0	14.3
	F+M	19	33.8	6.9	20.4	33.9	4.0	11.8

Table E.3. Mean head width (cm) of adult black bears sampled for morphometric study, 1992-1994.

Population	Sex	n	Measured Mean	Measured S.D.	Measured CV (%)	Zwitterized Mean	Zwitterized S.D.	Zwitterized CV (%)
Alaska	F	3	14.7	1.6	10.9	16.4	1.8	11.0
	M	5	15.8	2.3	14.6	14.4	2.1	14.6
	F+M	8	15.4	2.0	13.0	15.1	2.1	13.9
Alligator River NWR	F	4	16.5	0.6	3.6	18.4	0.6	3.3
	M	20	20.0	1.8	9.0	18.1	1.6	8.8
	F+M	24	19.4	2.1	10.8	18.2	1.5	8.2
Atchafalaya River Basin	F	16	16.3	1.5	9.2	18.1	1.6	8.8
	M	8	20.0	1.2	6.0	18.1	1.1	6.1
	F+M	24	17.5	2.3	13.1	18.1	1.5	8.3
Camp Lejeune	F	5	19.8	3.6	18.2	22.1	4.1	18.6
	M	3	21.7	2.5	11.5	19.6	2.3	11.7
	F+M	8	20.5	3.2	15.6	21.2	3.5	16.5
Great Dismal Swamp NWR	F	3	14.0	0.4	2.9	15.6	0.4	2.6
	M	7	18.0	2.5	13.9	16.3	2.2	13.5
	F+M	10	16.8	2.8	16.7	16.1	1.9	11.8
Great Smoky Mt. NP	F	22	15.5	3.1	20.0	17.3	3.5	20.2
	M	20	18.0	2.9	16.1	16.3	2.7	16.6
	F+M	42	16.7	3.3	19.8	16.8	3.1	18.5
Horry County	F	2	16.8	0.4	2.4	18.7	0.4	2.1
	M	2	18.9	0.8	4.2	17.1	0.8	4.7
	F+M	4	17.8	1.4	7.9	17.9	1.0	5.6
Mobile River / DeSoto NF	F	3	16.7	0.7	4.2	18.6	0.8	4.3
	M	6	18.9	1.8	9.5	17.1	1.7	9.9
	F+M	9	18.1	1.9	10.5	17.6	1.6	9.1
Neuse-Pamlico Penninsula	F	18	17.4	2.2	12.6	19.4	2.4	12.4
	M	21	21.5	1.9	8.8	19.5	1.7	8.7
	F+M	39	19.6	2.9	14.8	19.5	2.0	10.3
New York	F	3	21.2	2.0	9.4	23.6	2.3	9.7
	M	10	23.0	5.3	23.0	20.8	4.8	23.1
	F+M	13	22.6	4.7	20.8	21.5	3.5	16.3
Ocmulgee River	F	5	16.2	0.8	4.9	18.1	0.9	5.0
	M	5	19.5	2.9	14.9	17.7	2.6	14.7
	F+M	10	17.9	2.6	14.5	17.9	1.9	10.6
Okefenokee NWR	F	2	16.0	0.7	4.4	17.9	0.8	4.5
	M	3	16.0	1.3	8.1	14.5	1.2	8.3
	F+M	5	16.0	1.0	6.3	15.8	2.1	13.3
Ozark/Ouachita NF	F	3	17.5	3.8	21.7	19.6	4.3	21.9
	M	8	20.2	2.6	12.9	18.3	2.3	12.6
	F+M	11	19.5	3.0	15.4	18.7	2.8	15.0
Shenandaoh NP	F	3	16.7	2.5	15.0	18.6	2.8	15.1
	M	1	18.0	—	—	16.3	—	—
	F+M	4	17.0	2.2	12.9	18.0	2.6	14.4
Sumpter NF	F	7	18.1	2.0	11.0	20.2	2.2	10.9
	M	9	23.7	3.4	14.3	21.5	3.0	14.0
	F+M	16	21.3	4.0	18.8	20.9	2.7	12.9
Tensas River NWR	F	7	16.4	3.3	20.1	18.4	3.7	20.1
	M	2	22.2	3.7	16.7	20.1	3.4	16.9
	F+M	9	17.7	4.0	22.6	18.7	3.5	18.7
West Virginia	F	1	14.9	—	—	16.6	—	—
	M	4	21.3	2.6	12.2	19.3	2.4	12.4
	F+M	5	20.0	3.6	18.0	18.8	2.4	12.8
White River NWR	F	10	16.9	1.9	11.2	18.9	2.1	11.1
	M	9	21.2	4.0	18.9	19.2	3.6	18.8
	F+M	19	19.0	3.7	19.5	19.0	2.8	14.7

Table E.4. Mean neck girth (cm) of adult black bears sampled for morphometric study, 1992-1994.

			Measured			Zwitterized		
Population	Sex	n	Mean	S.D.	CV (%)	Mean	S.D.	CV (%)
Alaska	F	3	55.6	5.7	10.3	65.7	6.8	10.4
	M	5	49.1	6.2	12.6	42.6	5.4	12.7
	F+M	8	51.5	6.6	12.8	51.2	13.2	25.8
Alligator River NWR	F	4	47.8	6.6	13.8	56.4	7.7	13.7
	M	20	70.3	15.3	21.8	60.9	13.2	21.7
	F+M	24	66.5	16.5	24.8	60.2	12.5	20.8
Atchafalaya River Basin	F	16	49.9	5.4	10.8	59.0	6.4	10.8
	M	8	65.7	11.0	16.7	56.9	9.6	16.9
	F+M	24	55.2	10.7	19.4	58.3	7.5	12.9
Camp Lejeune	F	5	51.3	4.0	7.8	60.7	4.7	7.7
	M	3	68.9	4.7	6.8	59.8	4.0	6.7
	F+M	8	57.9	9.9	17.1	60.3	4.2	7.0
Great Dismal Swamp NWR	F	3	47.4	1.2	2.5	56.0	1.4	2.5
	M	7	65.5	8.6	13.1	56.8	7.5	13.2
	F+M	10	60.1	11.2	18.6	56.6	6.1	10.8
Great Smoky Mt. NP	F	22	44.7	4.5	10.1	52.9	5.4	10.2
	M	20	58.3	9.1	15.6	50.5	7.9	15.6
	F+M	42	51.2	9.8	19.1	51.8	6.7	12.9
Horry County	F	2	48.0	2.3	4.8	56.7	2.8	4.9
	M	2	59.2	5.4	9.1	51.3	4.7	9.2
	F+M	4	53.6	7.3	13.6	54.0	4.4	8.1
Mobile River / DeSoto NF	F	3	46.7	2.4	5.1	55.2	2.8	5.1
	M	6	62.4	8.3	13.3	54.1	7.2	13.3
	F+M	9	57.2	10.3	18.0	54.5	5.9	10.8
Neuse-Pamlico Penninsula	F	18	55.6	4.3	7.7	65.7	5.1	7.8
	M	21	78.8	6.9	8.8	68.4	5.9	8.6
	F+M	39	68.1	13.1	19.2	67.1	5.6	8.3
New York	F	3	47.0	5.7	12.1	55.5	6.8	12.3
	M	10	57.3	10.8	18.8	49.7	9.4	18.9
	F+M	13	54.9	10.7	19.5	51.0	9.0	17.6
Ocmulgee River	F	5	52.1	3.8	7.3	61.6	4.5	7.3
	M	5	71.7	11.0	15.3	62.2	9.5	15.3
	F+M	10	61.9	12.9	20.8	61.9	7.0	11.3
Okefenokee NWR	F	2	46.8	1.1	2.4	55.3	1.3	2.4
	M	3	47.8	6.0	12.6	41.4	5.2	12.6
	F+M	5	47.4	4.3	9.1	47.0	8.4	17.9
Ozark/Ouachita NF	F	3	50.3	2.1	4.2	59.4	2.4	4.0
	M	8	63.4	11.0	17.4	54.9	9.6	17.5
	F+M	11	59.8	11.1	18.6	56.2	8.4	14.9
Shenandaoh NP	F	3	50.5	7.5	14.9	59.7	8.8	14.7
	M	1	58.0	—	—	50.3	—	—
	F+M	4	52.4	7.2	13.7	57.3	8.6	15.0
Sumpter NF	F	7	51.4	8.3	16.1	60.8	9.8	16.1
	M	9	66.8	13.1	19.6	57.9	11.3	19.5
	F+M	16	60.1	13.5	22.5	59.2	10.4	17.6
Tensas River NWR	F	7	46.9	4.9	10.4	55.5	5.8	10.5
	M	2	71.4	3.3	4.6	61.9	2.8	4.5
	F+M	9	52.4	11.7	22.3	56.9	5.9	10.4
West Virginia	F	1	44.8	—	—	53.0	—	—
	M	4	67.7	5.2	7.7	58.7	4.5	7.7
	F+M	5	63.1	11.2	17.7	57.5	4.7	8.2
White River NWR	F	10	50.3	5.0	9.9	59.4	5.9	9.9
	M	9	73.7	7.8	10.6	63.9	6.8	10.6
	F+M	19	61.3	13.6	22.2	61.5	6.6	10.7

Table E.5. Mean total body length (cm) of adult black bears sampled for morphometric study, 1992-1994.

Population	Sex	n	Measured Mean	Measured S.D.	Measured CV (%)	Zwitterized Mean	Zwitterized S.D.	Zwitterized CV (%)
Alaska	F	3	140.1	10.6	7.6	153.2	11.5	7.5
	M	5	142.4	7.7	5.4	131.3	7.1	5.4
	F+M	8	141.5	8.2	5.8	139.5	14.0	10.0
Alligator River NWR	F	4	154.3	6.2	4.0	168.6	6.8	4.0
	M	20	184.6	10.8	5.9	170.2	10.0	5.9
	F+M	24	179.5	15.3	8.5	169.9	9.4	5.5
Atchafalaya River Basin	F	16	153.3	10.7	7.0	167.6	11.7	7.0
	M	8	175.2	4.2	2.4	161.5	3.9	2.4
	F+M	24	160.6	13.8	8.6	165.6	10.1	6.1
Camp Lejeune	F	5	153.0	5.5	3.6	167.2	6.0	3.6
	M	3	175.2	13.3	7.6	161.5	12.3	7.6
	F+M	8	161.3	14.1	8.7	165.1	8.5	5.2
Great Dismal Swamp NWR	F	3	155.3	4.5	2.9	169.8	4.9	2.9
	M	7	171.3	9.6	5.6	157.9	8.8	5.6
	F+M	10	166.5	11.2	6.7	161.5	9.5	5.9
Great Smoky Mt. NP	F	22	147.5	6.6	4.5	161.3	7.2	4.5
	M	20	168.4	13.3	7.9	155.3	12.3	7.9
	F+M	42	157.5	14.7	9.3	158.4	10.3	6.5
Horry County	F	2	153.3	3.9	2.5	167.5	4.3	2.6
	M	2	178.0	11.3	6.4	164.1	10.4	6.3
	F+M	4	165.6	15.9	9.6	165.8	6.8	4.1
Mobile River / DeSoto NF	F	3	141.3	8.1	5.7	154.5	8.8	5.7
	M	6	171.3	12.5	7.3	157.9	11.6	7.4
	F+M	9	161.3	18.4	11.4	156.8	10.3	6.6
Neuse-Pamlico Penninsula	F	18	154.1	5.6	3.6	168.5	6.1	3.6
	M	21	183.9	7.9	4.3	169.5	7.3	4.3
	F+M	39	170.2	16.5	9.7	169.0	6.7	4.0
New York	F	3	136.4	11.0	8.1	149.1	12.0	8.1
	M	10	158.5	20.3	12.8	146.1	18.8	12.9
	F+M	13	153.4	20.6	13.4	146.8	17.0	11.6
Ocmulgee River	F	5	151.6	3.4	2.2	166.0	3.7	2.2
	M	5	189.6	14.7	7.8	174.8	13.6	7.8
	F+M	10	170.8	22.3	13.1	170.4	10.5	6.2
Okefenokee NWR	F	2	154.5	9.2	6.0	168.9	10.0	5.9
	M	3	157.0	13.4	8.5	144.8	12.4	8.6
	F+M	5	156.0	10.6	6.8	154.4	16.6	10.8
Ozark/Ouachita NF	F	3	153.1	3.1	2.0	167.3	3.4	2.0
	M	8	171.0	13.1	7.7	157.7	12.1	7.7
	F+M	11	166.1	13.9	8.4	160.3	11.2	7.0
Shenandaoh NP	F	3	148.0	8.8	6.0	161.8	9.6	5.9
	M	1	158.0	---	---	145.7	---	---
	F+M	4	150.5	8.7	5.8	157.7	11.2	7.1
Sumpter NF	F	7	150.2	11.9	7.9	164.2	13.0	7.9
	M	9	177.9	15.5	8.7	164.1	14.3	8.7
	F+M	16	165.8	19.6	11.8	164.1	13.3	8.1
Tensas River NWR	F	7	143.9	15.7	10.9	157.3	17.2	10.9
	M	2	189.3	1.8	1.0	174.5	1.6	0.9
	F+M	9	154.0	24.2	15.7	161.1	16.7	10.4
West Virginia	F	1	151.4	---	---	165.5	---	---
	M	4	177.9	3.6	2.0	164.0	3.3	2.0
	F+M	5	172.6	12.3	7.1	164.3	2.9	1.8
White River NWR	F	10	141.9	6.8	4.8	155.1	7.4	4.8
	M	9	170.0	13.4	7.9	156.7	12.4	7.9
	F+M	19	155.2	17.6	11.3	155.8	9.8	6.3

Table E.6. Mean weight (kg) of adult black bears sampled for morphometric study, 1992-1994.

Population	Sex	n	Measured			Zwitterized		
			Mean	S.D.	CV (%)	Mean	S.D.	CV (%)
Alaska	F	3	97.5	25.8	26.5	144.4	38.1	26.4
	M	5	108.4	19.1	17.6	81.8	14.4	17.6
	F+M	8	104.3	20.7	19.9	105.3	39.8	37.8
Alligator River NWR	F	4	57.0	7.5	13.2	84.5	11.1	13.1
	M	20	139.5	46.9	33.6	105.3	35.4	33.6
	F+M	24	125.8	53.0	42.1	101.9	33.4	32.8
Atchafalaya River Basin	F	16	67.3	18.4	27.3	99.7	27.3	27.4
	M	8	112.5	22.8	20.3	84.9	17.2	20.3
	F+M	24	82.4	29.2	35.4	94.8	25.0	26.4
Camp Lejeune	F	5	64.5	5.0	7.8	95.5	7.5	7.9
	M	3	102.9	20.1	19.5	77.7	15.2	19.6
	F+M	8	78.9	22.9	29.0	88.8	13.5	45.2
Great Dismal Swamp NWR	F	3	55.9	3.5	6.3	82.8	5.1	6.2
	M	7	94.4	18.9	20.0	71.3	14.3	20.1
	F+M	10	82.9	24.2	29.2	74.7	13.2	17.7
Great Smoky Mt. NP	F	22	46.7	9.4	20.1	69.2	14.0	20.2
	M	20	83.5	27.7	33.2	63.1	20.9	33.1
	F+M	42	64.3	27.3	42.5	66.3	17.7	26.7
Horry County	F	2	77.1	3.2	4.2	114.2	4.7	4.1
	M	2	115.0	27.9	24.3	86.8	21.1	24.3
	F+M	4	96.0	27.2	28.3	100.5	20.1	20.0
Mobile River / DeSoto NF	F	3	63.5	6.0	9.5	94.0	8.9	9.47
	M	6	111.9	34.7	31.0	84.5	26.2	31.0
	F+M	9	95.8	36.7	38.3	87.7	21.7	24.7
Neuse-Pamlico Penninsula	F	18	69.3	10.3	14.9	102.7	15.3	14.9
	M	21	135.2	21.5	15.9	102.1	16.2	15.9
	F+M	39	104.8	37.4	35.7	102.3	15.6	15.3
New York	F	3	47.5	6.2	13.1	70.3	9.2	13.1
	M	10	76.9	37.5	48.8	58.1	28.3	48.7
	F+M	13	70.1	35.0	49.9	60.9	25.4	41.7
Ocmulgee River	F	5	59.9	4.7	7.9	88.7	7.0	7.9
	M	5	118.5	8.0	6.8	89.4	6.1	6.8
	F+M	10	89.2	31.5	35.3	89.0	6.2	7.0
Okefenokee NWR	F	2	65.8	6.4	9.7	97.4	9.5	9.8
	M	3	82.5	34.9	42.3	62.3	26.3	42.2
	F+M	5	75.8	26.5	35.0	76.3	27.2	35.7
Ozark/Ouachita NF	F	3	59.0	4.0	6.8	87.3	5.9	6.8
	M	8	115.6	30.8	26.6	87.3	23.3	26.7
	F+M	11	100.2	37.0	36.9	87.3	19.6	22.5
Shenandaoh NP	F	3	66.2	16.4	24.8	98.1	24.2	24.7
	M	1	79.4	—	—	59.9	—	—
	F+M	4	69.5	14.9	21.4	88.5	27.5	31.1
Sumpter NF	F	7	64.1	15.5	24.2	95.0	22.9	24.1
	M	9	123.4	43.7	35.4	93.1	33.0	35.5
	F+M	16	97.4	45.1	46.3	93.9	28.2	30.0
Tensas River NWR	F	7	57.8	12.8	22.2	85.6	18.9	22.1
	M	2	146.3	33.7	23.0	110.4	25.4	23.0
	F+M	9	77.5	42.3	54.6	91.1	21.6	23.7
West Virginia	F	1	54.4	—	—	80.6	—	—
	M	4	120.2	8.5	7.1	90.7	6.4	7.1
	F+M	5	107.0	30.3	28.3	88.7	7.2	8.1
White River NWR	F	10	60.0	10.2	17.0	88.9	15.1	17.00
	M	9	146.0	35.1	24.0	110.2	26.5	24.1
	F+M	19	100.8	50.4	50.0	99.0	23.3	23.5

Table E.7. Mean zygomatic circumference (cm) of adult black bears sampled for morphometric study, 1992-1994.

			Measured			Zwitterized		
Population	Sex	n	Mean	S.D.	CV (%)	Mean	S.D.	CV (%)
Alaska	F	3	46.0	4.0	8.7	50.4	4.4	8.7
	M	5	48.0	7.9	16.5	44.1	7.2	16.3
	F+M	8	47.2	6.4	13.6	46.5	6.8	14.6
Alligator River NWR	F	4	51.5	4.4	8.5	56.5	4.8	8.5
	M	20	64.1	5.9	9.2	58.9	5.4	9.2
	F+M	24	62.0	7.3	11.8	58.5	5.3	9.1
Atchafalaya River Basin	F	16	50.3	4.8	9.5	55.2	5.2	9.4
	M	8	57.6	5.8	10.1	52.9	5.4	10.2
	F+M	24	52.7	6.1	11.6	54.4	5.3	9.7
Camp Lejeune	F	5	51.9	3.9	7.5	57.0	4.2	7.4
	M	3	61.5	0.5	0.8	56.5	0.5	0.9
	F+M	8	55.5	5.8	10.5	56.8	3.2	5.6
Great Dismal Swamp NWR	F	3	50.4	2.1	4.2	55.3	2.2	4.0
	M	7	60.7	5.8	9.6	55.8	5.3	9.5
	F+M	10	57.6	6.9	12.0	55.6	4.5	8.1
Great Smoky Mt. NP	F	22	49.1	3.4	6.9	53.8	3.8	7.1
	M	20	58.3	7.1	12.2	53.6	6.5	12.1
	F+M	42	53.4	7.2	13.5	53.7	5.2	9.7
Horry County	F	2	51.5	0.6	1.2	56.4	0.7	1.2
	M	2	60.0	2.0	3.3	55.1	1.9	3.4
	F+M	4	55.7	5.1	9.2	55.8	1.4	2.5
Mobile River / DeSoto NF	F	3	50.6	2.8	5.5	55.5	3.0	5.4
	M	6	61.8	4.4	7.1	56.8	4.1	7.2
	F+M	9	58.0	6.7	11.6	56.3	3.3	5.9
Neuse-Pamlico Penninsula	F	18	48.8	3.2	6.6	53.6	3.5	6.5
	M	21	61.2	5.4	8.8	56.2	5.0	8.9
	F+M	39	55.5	7.7	13.9	55.0	4.5	8.2
New York	F	3	44.4	1.8	4.1	48.7	2.0	4.1
	M	10	54.1	12.9	23.8	49.7	11.8	23.7
	F+M	13	51.9	12.0	23.1	49.5	10.3	20.8
Ocmulgee River	F	5	52.3	2.1	4.0	57.4	2.3	4.0
	M	5	64.5	8.0	12.4	59.2	7.4	12.5
	F+M	10	58.4	8.5	14.6	58.3	5.2	8.9
Okefenokee NWR	F	2	51.2	1.0	2.0	56.2	1.1	2.0
	M	3	51.7	3.5	6.8	47.5	3.3	6.9
	F+M	5	51.5	2.6	5.0	51.0	5.3	10.4
Ozark/Ouachita NF	F	3	50.6	3.7	7.3	55.5	4.0	7.2
	M	8	62.0	8.3	13.4	56.9	7.7	13.5
	F+M	11	58.9	8.9	15.1	56.6	6.7	11.8
Shenandaoh NP	F	3	46.7	6.3	13.5	51.2	6.9	13.5
	M	1	49.0	—	—	45.0	—	—
	F+M	4	47.3	5.3	11.2	49.7	6.5	13.1
Sumpter NF	F	7	51.6	1.9	3.7	56.6	2.1	3.7
	M	9	60.7	3.6	5.9	55.8	3.3	5.9
	F+M	16	56.7	5.5	9.7	56.2	2.8	5.0
Tensas River NWR	F	7	42.6	6.3	14.8	46.8	6.9	14.7
	M	2	53.4	0.1	0.2	49.0	0.1	0.2
	F+M	9	45.0	7.2	16.0	47.3	6.0	12.7
West Virginia	F	1	42.5	—	—	46.6	—	—
	M	4	58.8	5.9	10.0	54.1	5.4	10.0
	F+M	5	55.6	8.9	16.0	52.6	5.7	10.8
White River NWR	F	10	53.0	4.7	8.9	58.2	5.1	8.8
	M	9	61.7	13.4	21.7	56.7	12.3	21.7
	F+M	19	57.1	10.5	18.4	57.5	9.0	15.7

Appendix F. Summary of multi-sample cluster analysis of inter-year variability in black bear weights and morphometrics.

Table F.1 Multi-sample cluster analysis of Great Smoky Mountains National Park and Neuse-Pamlico Peninsula adult black bears by year: 1992 versus 1993.

Clustering	k[a]	m[b]	-2LogL	$2*C_1(F^{-1})$	ICOMPIFIM	AIC
Great Smoky Mountains NP						
M_1: varying means and varying covariances						
{1 2}	1	70	1.9765e+003	212.5970		1.8339e+003
{1} {2}‡	2	140	1.6613e+003	466.9051		1.8013e+003†
M_2: varying means and common covariances						
{1 2}	1	70	1.7639e+003	212.5970	1.9765e+003	
{1} {2}‡	2	84	1.7593e+003	74.6590	1.8340e+003†	
Neuse-Pamlico Peninsula						
M_1: varying means and varying covariances						
{1 2}	1	70	1.5849e+003	205.4671		1.6549e+003†[c]
{1} {2}	2	140	1.5174e+003	431.5614		1.6574e+003
M_2: varying means and common covariances						
{1 2}	1	70	1.5849e+003	205.4670	1.7904e+003	1.6549e+003†[c]
{1} {2}‡	2	84	1.5733e+003	81.0634	1.6544e+003†	1.6574e+003
M_3: common means and common covariances						
{1 2}	1	70	1.5849e+003	205.4670		1.6549e+003†[c]
{1} {2}	2	70	1.5849e+003	190.8694		1.6549e+003†[c]

[a]k = the number of clusters.
[b]m = the number of estimated parameters.
[c] these models were indistinguishable based on AIC scores (they were less than e apart).
† denotes the global minimum.
‡ denotes model chosen as optimal model.

Appendix G. Summary of multi-sample cluster analysis by subspecies.

Table G.1. Summary of best subsets of information complexity based on the inverse Fisher information matrix (ICOMPIFIM) and Akaike's information criterion (AIC) for multi-sample cluster analysis on subspecies: Model 1 - varying means and varying covariances

Clustering	k[a]	m[b]	$2*C_1(F^{-1})$	-2LogL	ICOMPIFIM	AIC
{1 2 3 4}	1	70	112.1479	1.2132e+04	1.2356e+04††	1.2202e+04
{1 2 3} {4}	2	140	301.9601	1.1951e+04	1.2554e+04	1.2091e+04†[c]
{1 2 4} {3}	2	140	215.7622	1.2049e+04	1.2480e+04	1.2189e+04
{1 3 4} {2}	2	140	259.5341	1.1997e+04	1.2516e+04	1.2137e+04
{2 3 4} {1}	2	140	222.5071	1.1976e+04	1.2421e+04†	1.2116e+04
{1 2} {3 4}	2	140	219.2552	1.1989e+04	1.2427e+04	1.2129e+04
{1 3} {2 4}	2	140	255.9355	1.1948e+04	1.2459e+04	1.2088e+04†
{1 4} {2 3}	2	140	219.7986	1.2039e+04	1.2479e+04	1.2179e+04
{1 2} {3} {4}	3	210	413.6027	1.1851e+04	1.2678e+04	1.2061e+04
{1 3} {2} {4}	3	210	458.1036	1.1814e+04	1.2730e+04	1.2024e+04†
{1 4} {2} {3}	3	210	362.8811	1.1914e+04	1.2640e+04	1.2124e+04
{2 3} {1} {4}	3	210	416.8234	1.1839e+04	1.2673e+04	1.2049e+04
{2 4} {1} {3}	3	210	362.0801	1.1848e+04	1.2572e+04†	1.2058e+04
{3 4} {1} {2}	3	210	366.8512	1.1852e+04	1.2585e+04	1.2062e+04
{1} {2} {3} {4}	4	280	567.1121	1.1714e+04	1.2848e+04	1.1994e+04††

[a]k = the number of clusters.

[b]m = the number of estimated parameters.

[c]This value was not the absolute minimum for its level, but was so close as to be statistically identical to the absolute minimum.

† denotes the minimum for each level of k.

†† denotes the global minimum.

Table G.2. Summary of best subsets of information complexity based on the inverse Fisher information matrix (ICOMPIFIM) and Akaike's information criterion (AIC) for multi-sample cluster analysis on subspecies: Model 2 - varying means and common covariances

Clustering	k[a]	m[b]	$2*C_1(F^{-1})$	-2LogL	ICOMPIFIM	AIC
{1 2 3 4}	1	70	112.1479	1.2132e+04	1.2356e+04	1.2202e+04
{1 2 3} {4}	2	84	23.0206	1.2033e+04	1.2079e+04†	1.2117e+04†
{1 2 4} {3}	2	84	25.5978	1.2120e+04	1.2171e+04	1.2204e+04
{1 3 4} {2}	2	84	22.9445	1.2101e+04	1.2146e+04	1.2185e+04
{2 3 4} {1}	2	84	27.8779	1.2077e+04	1.2133e+04	1.2161e+04
{1 2} {3 4}	2	84	26.6066	1.2087e+04	1.2140e+04	1.2171e+04
{1 3} {2 4}	2	84	25.9964	1.2054e+04	1.2106e+04	1.2138e+04
{1 4} {2 3}	2	84	26.7609	1.2113e+04	1.2167e+04	1.2197e+04
{1 2} {3} {4}	3	98	-62.0386	1.2011e+04	1.1886e+04	1.2109e+04
{1 3} {2} {4}	3	98	-64.3701	1.1997e+04	1.1869e+04†	1.2095e+04†
{1 4} {2} {3}	3	98	-63.5216	1.2088e+04	1.1961e+04	1.2186e+04
{2 3} {1} {4}	3	98	-60.3731	1.1998e+04	1.1877e+04	1.2096e+04
{2 4} {1} {3}	3	98	-59.3801	1.2032e+04	1.1914e+04	1.2130e+04
{3 4} {1} {2}	3	98	-61.8406	1.2051e+04	1.1927e+04	1.2149e+04
{1} {2} {3} {4}	4	112	-148.8547	1.1972e+04	1.1674e+04††	1.2084e+04††

[a]k = the number of clusters.
[b]m = the number of estimated parameters.
† denotes the minimum for each level of k.
†† denotes the global minimum.

Appendix H. Summary of multi-sample cluster analysis by ecoregion province.

Table H.1. Summary of best subsets of information complexity based on the inverse Fisher information matrix (ICOMPIFIM) and Akaike's information criterion (AIC) for multi-sample cluster analysis on ecoregion provinces: Model 1 - varying means and varying covariances

Clustering	k[a]	m[b]	$2*C_1(F^{-1})$	-2LogL	ICOMPIFIM	AIC
{1 2 3 4 5}	1	70	112.1479	1.2132e+04	1.2356e+04††	1.2202e+04
{2 3 4 5} {1}	2	140	229.9090	1.1972e+04	1.2432e+04	1.2112e+04
{1 3 4 5} {2}	2	140	221.5680	1.1982e+04	1.2425e+04	1.2122e+04
{1 2 4 5} {3}	2	140	219.7986	1.2039e+04	1.2479e+04	1.2179e+04
{1 2 3 5} {4}	2	140	220.9581	1.1953e+04	1.2395e+04	1.2093e+04
{1 2 3 4} {5}	2	140	301.9601	1.1951e+04	1.2554e+04	1.2091e+04
{3 4 5} {1 2}	2	140	217.7441	1.1928e+04	1.2363e+04†	1.2068e+04†[c]
{2 4 5} {1 3}	2	140	223.2971	1.2002e+04	1.2449e+04	1.2142e+04
{2 3 5} {1 4}	2	140	222.5268	1.1995e+04	1.2440e+04	1.2135e+04
{2 3 4} {1 5}	2	140	253.0750	1.1927e+04	1.2433e+04	1.2067e+04†
{1 4 5} {2 3}	2	140	221.6582	1.2013e+04	1.2456e+04	1.2153e+04
{1 3 5} {2 4}	2	140	226.6060	1.1941e+04	1.2394e+04	1.2081e+04
{1 3 4} {2 5}	2	140	222.9796	1.2003e+04	1.2449e+04	1.2143e+04
{1 2 5} {3 4}	2	140	220.1238	1.1962e+04	1.2402e+04	1.2102e+04
{1 2 3} {4 5}	2	140	218.5008	1.1977e+04	1.2414e+04	1.2117e+04
{1 2 4} {3 5}	2	140	222.5071	1.1976e+04	1.2421e+04	1.2116e+04
{3 4 5} {1} {2}	3	210	337.3395	1.1815e+04	1.2489e+04	1.2025e+04
{2 4 5} {1} {3}	3	210	337.4788	1.1880e+04	1.2555e+04	1.2090e+04
{2 3 5} {1} {4}	3	210	338.5195	1.1820e+04	1.2497e+04	1.2030e+04
{2 3 4} {1} {5}	3	210	426.9414	1.1791e+04	1.2645e+04	1.2001e+04
{1 4 5} {2} {3}	3	210	329.4471	1.1892e+04	1.2551e+04	1.2102e+04
{1 3 5} {2} {4}	3	210	335.0390	1.1800e+04	1.2470e+04	1.2010e+04
{1 3 4} {2} {5}	3	210	419.9847	1.1814e+04	1.2654e+04	1.2024e+04
{1 2 5} {3} {4}	3	210	327.3215	1.1849e+04	1.2504e+04	1.2059e+04
{1 2 4} {3} {5}	3	210	416.8234	1.1839e+04	1.2673e+04	1.2049e+04
{1 2 3} {4} {5}	3	210	418.6321	1.1783e+04	1.2620e+04	1.1993e+04
{2 3} {4 5} {1}	3	210	336.2073	1.1849e+04	1.2521e+04	1.2059e+04
{2 4} {3 5} {1}	3	210	340.8356	1.1813e+04	1.2494e+04	1.2023e+04
{2 5} {3 4} {1}	3	210	339.6235	1.1836e+04	1.2515e+04	1.2046e+04
{1 3} {4 5} {2}	3	210	330.3371	1.1850e+04	1.2511e+04	1.2060e+04
{1 4} {3 5} {2}	3	210	332.1074	1.1847e+04	1.2511e+04	1.2057e+04
{1 5} {3 4} {2}	3	210	370.2483	1.1783e+04	1.2523e+04	1.1993e+04
{1 2} {4 5} {3}	3	210	323.5172	1.1841e+04	1.2488e+04	1.2051e+04
{1 4} {2 5} {3}	3	210	331.0407	1.1899e+04	1.2561e+04	1.2109e+04
{1 5} {2 4} {3}	3	210	367.8811	1.1812e+04	1.2548e+04	1.2022e+04
{1 2} {3 5} {4}	3	210	327.9202	1.1784e+04	1.2440e+04†	1.1994e+04
{1 3} {2 5} {4}	3	210	333.3672	1.1846e+04	1.2513e+04	1.2056e+04
{1 5} {2 3} {4}	3	210	369.1306	1.1791e+04	1.2530e+04	1.2001e+04
{1 2} {3 4} {5}	3	210	417.9339	1.1760e+04	1.2595e+04	1.1970e+04†
{1 3} {2 4} {5}	3	210	418.0874	1.1798e+04	1.2634e+04	1.2008e+04
{1 4} {2 3} {5}	3	210	417.5740	1.1831e+04	1.2666e+04	1.2041e+04

Table H.1. Continued

Clustering	k	m	ComplIfim	Lackoffit	ICOMPIFIM	AIC
{4 5} {1} {2} {3}	4	280	443.1136	1.1728e+04	1.2614e+04	1.2008e+04
{3 5} {1} {2} {4}	4	280	447.5201	1.1671e+04	1.2566e+04†	1.1951e+04
{3 4} {1} {2} {5}	4	280	542.2308	1.1646e+04	1.2731e+04	1.1926e+04†
{2 5} {1} {3} {4}	4	280	446.7055	1.1724e+04	1.2617e+04	1.2004e+04
{2 4} {1} {3} {5}	4	280	540.1203	1.1676e+04	1.2756e+04	1.1956e+04
{2 3} {1} {4} {5}	4	280	541.2018	1.1655e+04	1.2738e+04	1.1935e+04
{1 5} {2} {3} {4}	4	280	482.5984	1.1670e+04	1.2636e+04	1.1950e+04
{1 4} {2} {3} {5}	4	280	532.2713	1.1710e+04	1.2774e+04	1.1990e+04
{1 3} {2} {4} {5}	4	280	534.2682	1.1657e+04	1.2725e+04	1.1937e+04
{1 2} {3} {4} {5}	4	280	530.9310	1.1647e+04	1.2709e+04	1.1927e+04
{1} {2} {3} {4} {5}	5	350	653.7992	1.1534e+04	1.2842e+04	1.1884e+04††

[a]k = the number of clusters.
[b]m = the number of estimated parameters.
[c]This value was not the absolute minimum for its level, but was so close as to be statistically identical to the absolute minimum.
† denotes the minimum for each level of k.
†† denotes the global minimum.

Table H.2. Summary of best subsets of information complexity based on the inverse Fisher information matrix (ICOMPIFIM) and Akaike's information criterion (AIC) for multi-sample cluster analysis on ecoregion provinces: Model 2 - varying means and common covariances.

Clustering	k[a]	m[b]	$2*C_1(F^{-1})$	-2LogL	ICOMPIFIM	AIC
{1 2 3 4 5}	1	70	112.1479	1.2132e+04	1.2356e+04	1.2202e+04
{2 3 4 5} {1}	2	84	22.0967	1.2048e+04	1.2092e+04	1.2132e+04
{1 3 4 5} {2}	2	84	25.4703	1.2079e+04	1.2130e+04	1.2163e+04
{1 2 4 5} {3}	2	84	26.7609	1.2113e+04	1.2167e+04	1.2197e+04
{1 2 3 5} {4}	2	84	27.0561	1.2061e+04	1.2115e+04	1.2145e+04
{1 2 3 4} {5}	2	84	23.0206	1.2033e+04	1.2079e+04†	1.2117e+04†
{3 4 5} {1 2}	2	84	23.3106	1.2062e+04	1.2108e+04	1.2146e+04
{2 4 5} {1 3}	2	84	27.8110	1.2105e+04	1.2160e+04	1.2189e+04
{2 3 5} {1 4}	2	84	28.4837	1.2078e+04	1.2135e+04	1.2162e+04
{2 3 4} {1 5}	2	84	25.7991	1.2036e+04	1.2088e+04	1.2120e+04
{1 4 5} {2 3}	2	84	27.6687	1.2092e+04	1.2147e+04	1.2176e+04
{1 3 5} {2 4}	2	84	29.1463	1.2070e+04	1.2128e+04	1.2154e+04
{1 3 4} {2 5}	2	84	26.2346	1.2091e+04	1.2144e+04	1.2175e+04
{1 2 5} {3 4}	2	84	24.4699	1.2074e+04	1.2123e+04	1.2158e+04
{1 2 3} {4 5}	2	84	25.8746	1.2077e+04	1.2129e+04	1.2161e+04
{1 2 4} {3 5}	2	84	27.8779	1.2077e+04	1.2133e+04	1.2161e+04
{3 4 5} {1} {2}	3	98	-65.1114	1.1989e+04	1.1859e+04	1.2087e+04
{2 4 5} {1} {3}	3	98	-62.4143	1.2029e+04	1.1904e+04	1.2127e+04
{2 3 5} {1} {4}	3	98	-61.3873	1.1982e+04	1.1860e+04	1.2080e+04
{2 3 4} {1} {5}	3	98	-64.8451	1.1948e+04	1.1818e+04†	1.2046e+04†
{1 4 5} {2} {3}	3	98	-59.8369	1.2058e+04	1.1938e+04	1.2156e+04
{1 3 5} {2} {4}	3	98	-57.9169	1.2008e+04	1.1892e+04	1.2106e+04
{1 3 4} {2} {5}	3	98	-62.2026	1.1984e+04	1.1859e+04	1.2082e+04
{1 2 5} {3} {4}	3	98	-60.5990	1.2035e+04	1.1914e+04	1.2133e+04
{1 2 4} {3} {5}	3	98	-60.3731	1.1998e+04	1.1877e+04	1.2096e+04
{1 2 3} {4} {5}	3	98	-60.9802	1.1966e+04	1.1844e+04	1.2064e+04
{2 3} {4 5} {1}	3	98	-62.8562	1.1999e+04	1.1873e+04	1.2097e+04
{2 4} {3 5} {1}	3	98	-60.5686	1.1991e+04	1.1870e+04	1.2089e+04
{2 5} {3 4} {1}	3	98	-64.1604	1.2001e+04	1.1873e+04	1.2099e+04
{1 3} {4 5} {2}	3	98	-60.1177	1.2042e+04	1.1922e+04	1.2140e+04
{1 4} {3 5} {2}	3	98	-58.0048	1.2024e+04	1.1908e+04	1.2122e+04
{1 5} {3 4} {2}	3	98	-60.7826	1.1985e+04	1.1863e+04	1.2083e+04
{1 2} {4 5} {3}	3	98	-62.4818	1.2038e+04	1.1913e+04	1.2136e+04
{1 4} {2 5} {3}	3	98	-58.6199	1.2059e+04	1.1941e+04	1.2157e+04
{1 5} {2 4} {3}	3	98	-57.6900	1.2005e+04	1.1890e+04	1.2103e+04
{1 2} {3 5} {4}	3	98	-60.3967	1.2001e+04	1.1881e+04	1.2099e+04
{1 3} {2 5} {4}	3	98	-58.5577	1.2039e+04	1.1922e+04	1.2137e+04
{1 5} {2 3} {4}	3	98	-57.7894	1.1977e+04	1.1861e+04	1.2075e+04
{1 2} {3 4} {5}	3	98	-64.5080	1.1967e+04	1.1838e+04	1.2065e+04
{1 3} {2 4} {5}	3	98	-58.8982	1.1987e+04	1.1870e+04	1.2085e+04
{1 4} {2 3} {5}	3	98	-59.3756	1.1984e+04	1.1866e+04	1.2082e+04

Table H.2. Continued

Clustering	k	m	Complfim	Lackoffit	ICOMPIFIM	AIC
{4 5} {1} {2} {3}	4	112	-149.9000	1.1965e+04	1.1665e+04	1.2077e+04
{3 5} {1} {2} {4}	4	112	-147.1399	1.1928e+04	1.1634e+04	1.2040e+04
{3 4} {1} {2} {5}	4	112	-150.6421	1.1893e+04	1.1592e+04†	1.2005e+04
{2 5} {1} {3} {4}	4	112	-148.0122	1.1962e+04	1.1666e+04	1.2074e+04
{2 4} {1} {3} {5}	4	112	-146.8380	1.1912e+04	1.1618e+04	1.2024e+04
{2 3} {1} {4} {5}	4	112	-147.2366	1.1888e+04	1.1594e+04	1.2000e+04†
{1 5} {2} {3} {4}	4	112	-143.9331	1.1942e+04	1.1655e+04	1.2054e+04
{1 4} {2} {3} {5}	4	112	-144.9365	1.1945e+04	1.1655e+04	1.2057e+04
{1 3} {2} {4} {5}	4	112	-144.7479	1.1926e+04	1.1636e+04	1.2038e+04
{1 2} {3} {4} {5}	4	112	-147.4779	1.1922e+04	1.1627e+04	1.2034e+04
{1} {2} {3} {4} {5}	5	126	-232.1415	1.1848e+04	1.1384e+04††	1.1974e+04††

[a]k = the number of clusters.
[b]m = the number of estimated parameters.
† denotes the minimum for each level of k.
†† denotes the global minimum.

Appendix I. Summary of habitat quality and physiological variables used in the canonical correlation anlayses.

Table I.1. Crop harvests[a] and available digestible energy (Gcal) of crops by county for study areas in morphometric study of black bears in the Southeast and selected other areas, 1992-1994.

Study Area		Corn (bushels)	Wheat (bushels)	Sugarcane (tons)	Crop DE[b] (Gcal)
Alaska (AK):					
Juneau		0	0	0	
	total	0	0	0	0
Alligator River (NC):					
Dare		0	46268	0	
Hyde		4445412	992495	0	
	total	4445412	1038763	0	494705.8
Atchafalaya (LA):					
Iberia		8180	23103	1588255	
Pointe Coupee		4946504	711643	364191	
St. Mary		0	0	1127707	
	total	4954684	734746	3080153	8027286
Camp Lejeune (NC):					
Onslow		1488831	74510	0	
	total	1488831	74510	0	140386.3
Great Dismal Swamp (VA/NC):					
Suffolk		0	0	0	
Chesapeake		0	0	0	
Camden		1816596	459504	0	
Gates		1822291	48150	0	
Pasquotank		2944451	756596	0	
	total	6583338	1264250	0	707261.9
GSMNP (TN):					
Blount		421581	76611	0	
Sevier		43662	6317	0	
	total	465243	82928	0	49388.31
Horry (SC):					
Horry		1857664	262476	0	
	total	1857664	262476	0	190849.9
Mobile River (AL) / DeSoto NF (MS):					
Mobile		600786	113131	0	
Jackson		45408	0	0	
	total	646194	113131	0	68407.56
Neuse-Pamlico Penn. (NC):					
Beaufort		5006916	1801380	0	
Craven		1581188	139667	0	
Pamlico		1533982	426024	0	
	total	8122086	2367071	0	947278
New York (NY):					
Essex		34874	3010	0	
	total	34874	3010	0	3405.401

Table I.1. Continued.

Study Area		Corn (bushels)	Wheat (bushels)	Sugarcane (tons)	Crop DE (Gcal)
Ocmulgee (GA):					
Bleckley		417472	258891	0	
Houston		254395	431444	0	
Twiggs		67470	51440	0	
	total	739337	741775	0	134930.1
Okefenokee (GA):					
Charlton		25110	0	0	
Clinch		55250	0	0	
Ware		393823	2098	0	
	total	474183	2098	0	42710.33
Ozark/Ouachita (AR):					
Johnson		0	36949	0	
Madison		0	6865	0	
Polk		0	0	0	
Pope		0	124779	0	
Pulaski		53240	456290	0	
van Buren		4010	0	0	
Yell		127732	117080	0	
	total	184982	741963	0	85242.96
Shenandoah (VA):					
Madison		701324	12150	0	
Page		357768	27964	0	
Rappahannock		54184	6033	0	
Warren		12492	2274	0	
	total	1125768	48421	0	105419.2
Sumpter (SC):					
Oconee		35343	55564	0	
Pickens		31590	6140	0	
	total	66933	61704	0	11711.09
Tensas (LA):					
Madison		5217078	345496	0	
	total	5217078	345496	0	499743.9
West Virginia (WV):					
Greenbrier		54296	0	0	
Hardy		597973	19950	0	
Kanawha		1793	0	0	
Pocahontas		79614	0	0	
Randolf		121275	0	0	
	total	854951	19950	0	78502.68
White River (AR):					
Arkansas		850387	3255356	0	
Desha		133280	635265	0	
Monroe		20027	911258	0	
	total	1003694	4801879	0	534332.2

[a]Crop harvests from U. S. Bureau of the Census (1993).
[b]DE = digestible enery; total energy availabe from all crops combined.

Table I.2. Soil types[a], fertility scores[b], and latitudes[c] of study areas for morphometric study of black bears in the Southeast and selected other areas, 1992-1994.

Study Area	Soil Type	Fertility Score	Latitude (°)
Alaska	Spodosols; Orthods	1.00	58.00
Alligator River NWR, NC	Ultisols; Aquults	1.33	35.67
Atchafalaya River, LA	Inceptisols; Aquepts	2.00	30.25
Camp Lejeune Marine Base, NC	Ultisols; Aquults	1.33	34.67
Great Dismal Swamp NWR, VA/NC	Ultisols; Aquults	1.33	36.5
Great Smoky Mountains NP, TN	Inceptisols; Ochrepts	1.67	35.58
Horry County, SC	Ultisols; Aquults	1.33	34.00
Mobile River/DeSoto NF, AL/MS	Inceptisols; Aquepts	2.00	30.78
Neuse-Pamlico Penninsula, NC	Ultisols; Aquults	1.33	35.50
New York	Inceptisols; Ochrepts	1.67	44.00
Ocmulgee River, GA	Ultisols; Udults	1.00	32.58
Okefenokee NWR, GA	Spodosols; Aquods	1.00	30.83
Ozark/Ouachita Mountains, AR	Ultisols; Udults	1.00	35.00
Shenandoah NP, VA	Ultisols; Udults	1.00	38.50
Sumpter NF, SC	Ultisols; Udults	1.00	34.83
Tensas River, LA	Inceptisols; Aquepts	2.00	32.50
West Virginia	Inceptisols; Ochrepts	1.67	38.50
White River NWR, AR	Inceptisols; Aquepts	2.00	34.25

[a]Soil types from Brady (1990).
[b]Fertility scores based on ratings from Table 3.5 in Brady (1990): Low = 1.00, Low-Moderate = 1.33, Moderate-Low = 1.67, and Moderate = 2.00.
[c]Latitudes determined from USGS (1970).

Table I.3. Actual Evapotranspiration (AE)[a] levels of study areas for morphometric study of black bears in the Southeast and selected other areas, 1992-1994.

Study Area	Location[b]	AE
Alaska	Juneau	496
Alligator River NWR, NC	Belhaven	892
Atchafalaya River, LA	New Iberia	1069
Camp Lejeune Marine Base, NC	Wilmington	905
Great Dismal Swamp NWR, VA/NC	Norfolk	840
Great Smoky Mountains NP, TN	Knoxville	859
Horry County, SC	Florence	941
Mobile River/DeSoto NF, AL/MS	Mobile	1039
Neuse-Pamlico Penninsula, NC	Belhaven	892
New York	Lake Placid	522
Ocmulgee River, GA	Macon	892
Okefenokee NWR, GA	Brunswick	1056
Ozark/Ouachita Mountains, AR	Ozark	851
Shenandoah NP, VA	Winchester	717
Sumpter NF, SC	Greenville	833
Tensas River, LA	Winnsboro	966
West Virginia	Marlinton	614
White River NWR, AR	Helena	859

[a]From Thornthwaite Associates (1964).
[b]AE levels taken from location nearest the study areas with AE data available (from Thornthwaite 1964).

Table I.4. Fat levels[a] and weight:total body length ratios of populations for morphometric study of black bears in the Southeast and selected other areas, 1992-1994.

Population	Percent Fat Scott	Cattet	WT/TBL
Alaska	47.7	45.6	0.733
Alligator River NWR, NC	29.1	16.5	0.683
Atchafalaya Basin, LA	22.9	9.5	0.505
Camp Lejeune, NC	8.1	7.4	0.483
Great Dismal Swamp NWR, VA/NC	18.3	5.1	0.492
Great Smoky Mt. NP, TN	17.2	3.4	0.398
Horry County, SC	30.7	15.1	0.573
Mobile River, AL	25.5	17.6	0.581
Neuse-Pamlico Penninsula, NC	14.3	12.2	0.602
New York	3.2	9.8	0.440
Ocmulgee River, GA	13.3	4.3	0.511
Okefenokee NWR, GA	35.0	13.8	0.481
Ozark/Ouachita NF, AR	26.7	20.7	0.592
Shenandaoh NP, VA	35.6	18.7	0.459
Sumpter NF, SC	16.1	16.1	0.570
Tensas River NWR, LA	25.4	5.0	0.482
West Virginia	21.5	14.6	0.612
White River NWR, AR	21.3	21.9	0.627

[a]fat levels computed from equations derived by Scott (1991) and Cattet (1990), respectively.

Appendix J. Summary of correlations among and between the weight and morphometric, physiologic, and habitat parameters.

Table J.1. Correlations among the habitat and morphometric parameters used in the canonical correlation analyses of black bears in the Southeast and selected other areas, 1992-1994[a].

Variable[b,c]	CG	FLG	HW	NG	TBL	WT	ZC	CROP	AE	LAT	SOIL
CG	1.0000										
FLG	0.6200	1.0000									
HW	0.3663	0.2715	1.0000								
NG	0.8667	0.5690	0.4489	1.0000							
TBL	0.5049	0.3714	0.2807	0.6863	1.0000						
WT	0.6596	0.2521	-0.0424	0.5328	0.2726	1.0000					
ZC	0.4586	0.3570	0.2341	0.5415	0.6832	0.1891	1.0000				
CROP	0.1841	0.1253	-0.0296	0.1710	0.2238	0.1682	0.0642	1.0000			
AE	0.0277	-0.0225	-0.1045	0.1664	0.5554	0.1245	0.4680	0.3711	1.0000		
LAT	-0.0302	-0.0075	-0.1874	-0.2807	-0.7017	0.0843	-0.5631	-0.2652	-0.8708	1.0000	
SOIL	0.0375	-0.0032	0.1674	0.0589	-0.0032	-0.0954	-0.0200	0.3929	0.2338	-0.2914	1.0000

[a]Note: the canonical correlation analysis showed that none of the correlations between the habitat and weight and morphometric parameters were significant at the $\alpha = 0.10$ level.

[b] See Table 2 for weight and morphometric codes.

[c]For the habitat parameters: CROP = total Gcal / study area from crops, AE = actual evapotranspiration, LAT = latitude, and Soil = fertility score of soils.

Table J.2. Correlations among the habitat and physiological parameters used in the canonical correlation analyses of black bears in the Southeast and selected other areas, 1992-1994[a].

Variable[b,c]	CPFAT	SPFAT	WTTBL	CROP	AE	LAT	SOIL
CPFAT	1.0000						
SPFAT	0.7068	1.0000					
WTTBL	0.7556	0.4763	1.0000				
CROP	-0.1564	-0.0223	-0.0897	1.0000			
AE	-0.4609	-0.0280	-0.2167	0.3711	1.0000		
LAT	0.6980	0.3294	0.3933	-0.2652	-0.8708	1.0000	
SOIL	-0.2816	-0.2635	-0.1349	0.3929	0.2338	-0.2914	1.0000

[a]Note: the canonical correlation analysis showed that none of the correlations between the habitat and physiological parameters were significant at the $\alpha = 0.10$ level.

[b] For physiological parameters: CPFAT = Cattet's (1990) estimated percent fat, SPFAT = Scott's (1991) estimated percent fat, and WTTBL = the weight to total body length ratio.

[c]For the habitat parameters: CROP = total Gcal / study area from crops, AE = actual evapotranspiration, LAT = latitude, and Soil = fertility score of soils.

VITA

Thomas Hunter Eason was born on April 11, 1970 in Arlington, Virginia. He graduated from James Madison High School in Vienna, Virginia in 1988. He then attended Virginia Polytechnic Institute and State University (VA Tech), where he received a Bachelor of Science degree in Forestry and Wildlife in May, 1992. Thomas enrolled in the Department of Forestry, Wildlife, and Fisheries at the University of Tennessee, Knoxville (UTK) and began his Master's research on black bears during the summer of 1992. He received the Master's of Science degree in Wildlife and Fisheries Science at UTK in December, 1995. Thomas is married to Danielle Marie Unger and resides in Knoxville, Tennessee.