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I am submitting herewith a thesis written by Jeffrey James Tasca entitled "The Use Of White-tailed Deer As Biological Monitors of Heavy Metals." 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 Life Sciences.

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THE USE OF WHITE-TAILED DEER AS
BIOLOGICAL MONITORS OF HEAVY METALS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Jeffrey James Tasca

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ABSTRACT

The object of this study was to provide information on background levels of three heavy metals (cadmium, lead, and mercury) in white-tailed deer (Odocoileus virginianus). These metals occur naturally and are also associated with industrial, mining, and urban activity.

Male and female white-tailed deer of four herds native to Tennessee were used. Three of these herds were from East Tennessee, Cades Cove Great Smoky Mountain National Park, Chuck Swan Wildlife Management Area, and the Energy Research and Development Administration's Oak Ridge Reservation. The other was located in West Tennessee, The Hobart Ames Plantation. One hundred animals were randomly sampled from each location. Trace metal analyses were performed by atomic absorption spectrophotometry using hair samples obtained from several locations on the animal's body. Several variables, age, geographic location, sex, weight, and their interactions were included in the analyses.

Of the four populations of white-tailed deer studied, trace metal analyses indicated levels of metals reflected a natural background exposure. This information is useful in determining the significance of heavy metal residues detected in hair samples of animals inhabiting polluted areas and in assessing the potential for subsequent human health effects.

TABLE OF CONTENTS

CHAPTER	PAGE
I. THE STUDY	1
II. DESCRIPTION OF STUDY AREAS	5
Hobart Ames Plantation	5
Cades Cove Great Smoky Mountain National Park	7
Chuck Swan Wildlife Management Area.....	10
Energy Research and Development Administration's Oak Ridge Reservation...	13
III. METHODS AND MATERIALS	17
Sample Collection	17
Sample Preparation	21
Sample Analysis	22
Materials	24
Statistical Analysis of Data	25
IV. RESULTS	27
General Information	27
Multifactorial Analysis	30
Hobart Ames Plantation	35
Cades Cove GSMNP	35
Chuck Swan WMA	36
ERDA Oak Ridge Reservation	37
V. DISCUSSION	39
Assumptions and Limitations	44
VI. SUMMARY, CONCLUSIONS, AND IMPLICATIONS	60
Summary	60
Conclusions	61
Implications	64
LITERATURE CITED	66
APPENDICES	77
Appendix A. Chapter II Results	78
Appendix B. Chapter III Results	83
Appendix C. Chapter IV Results	91
Appendix D. Ames Plantation	108
Appendix E. Cades Cove	119
Appendix F. Chuck Swan	133
Appendix G. Oak Ridge	149
VITA	165

LIST OF TABLES

TABLE	PAGE
4.1. Comparison Of The Levels Of Cadmium, Lead, And Mercury From Hair Of White-tailed Deer From Four Locations In Tennessee.....	28
5.1. The Relative Levels Of Cadmium, Lead, And Mercury, Found In The Hair Of Several Species.....	40
C 4.1. Cadmium, Lead, And Mercury Levels In The Hair Of White-tailed Deer From Four Areas Of Tennessee....	92
C 4.2. Multifactorial Analysis Of Variance Of White-tailed Deer From Tennessee, Based On Cadmium Level Present And Its Relation To Geographic Location, Age, Sex, Origin/Age, Origin/Sex, And Age/Sex Interactions..	93
C 4.3. Multifactorial Analysis Of Variance Of White-tailed Deer From Tennessee, Based On Lead Level Present And Its Relation To Geographic Location, Age, Sex, Origin/Age, Origin/Sex, And Age/Sex Interactions..	94
C 4.4. Multifactorial Analysis Of Variance Of White-tailed Deer From Tennessee, Based On Logarithm Of Lead Present And Its Relation To Geographic Location, Age, Sex, Origin/Age, Origin/Sex, And Age/Sex Interactions.....	95
C 4.5. Multifactorial Analysis Of Variance Of White-tailed Deer From Oak Ridge, Tennessee, Based On Mercury Level Present And Its Relation To Geographic Location, Age, Sex, Origin/Age, Origin/Sex, And Age/Sex Interactions.....	96
C 4.6. Levels Of Cadmium, Lead, And Mercury Found In White-tailed Deer From The Hobart Ames Plantation, West Tennessee, 1986.....	97
C 4.7. Levels Of Cadmium, Lead, And Mercury Found In White-tailed Deer From Cades Cove, GSMNP Tennessee, 1980-1982.....	98
C 4.8. Levels Of Cadmium, Lead, And Mercury Found In White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.....	99

LIST OF TABLES

TABLE	PAGE
C 4.9. Levels Of Cadmium, Lead, And Mercury Found In White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee,.1986.....	100
C 4.10. Mean White-tailed Deer Weights By Age For Three Areas Of East Tennessee.....	101
D 4.1. Number Of White-tailed Deer By Sex Sampled From The Hobart Ames Plantation, Tennessee.....	109
E 4.1. Comparison Of The Total Number Of Males Versus Females Per Age Group, Cades Cove, GSMNP, Tennessee.....	120
E 4.2. Mean Levels Of Cadmium, Lead, And Mercury Evaluated In The Study Based On Sex And Age, Cades Cove, GSMNP, Tennessee, 1980-1982.....	121
F 4.1. Comparison Of The Total Number Of Males Versus Females Per Age Group, Chuck Swan WMA, Tennessee.....	134
F 4.2. Mean Levels Of Cadmium, Lead, And Mercury Evaluated In The Study Based On Sex And Age, Chuck Swan WMA, Tennessee, 1986.....	135
G 4.1. Comparison Of The Total Number Of Males Versus Females Per Age Group, The ERDA Oak Ridge Reservation, Tennessee.....	150
G 4.2. Mean Levels Of Cadmium, Lead, And Mercury Evaluated In The Study Based On Sex And Age, The ERDA Oak Ridge Reservation, Tennessee, 1986.....	151

LIST OF FIGURES

FIGURE	PAGE
2.1. Location Of Study Area Number One, The Hobart Ames Plantation, Fayette And Hardeman Counties, West Tennessee.....	6
2.2. Location Of Study Area Number Two, Cades Cove, Within The Northwest Portion Of Great Smoky Mountains National Park, Tennessee.....	8
2.3. Location Of Study Area Number Three, Chuck Swan Wildlife Management Area, Union And Campbell Counties, Tennessee.....	11
2.4. Location Of Study Area Number Four, The Energy Research And Development Administration's Oak Ridge Reservation, Anderson And Roane Counties, Tennessee.....	14
3.1. Location Of Areas In Tennessee From Which Animals Were Sampled For The Heavy Metal Study, 1986.....	18
4.1. Comparison Of The Concentration Of Heavy Metals Found In White-tailed Deer From Four Study Locations In Tennessee. Cadmium And Lead Levels Are In PPM, While Mercury Levels Are In PPB.....	29
4.2. Distribution Of Lead Levels For All White-tailed Deer Analyzed In Tennessee, 1986.....	31
4.3. Distribution Of The Logarithm Of Lead Levels For All White-tailed Deer Analyzed In Tennessee, 1986.....	32
4.4. Normal Dispersion Of Mercury Levels Found In White-tailed Deer Sampled From The ERDA Oak Ridge Reservation, Tennessee, 1986.....	33
5.1. Comparison Of Cadmium Levels In PPM, Demonstrating The Difference Between Males And Females For All Locations Included In The Study (Ames Plantation AP, Cades Cove CC, Chuck Swan CS, Oak Ridge OR).....	41
5.2. Comparison Of Lead Levels In PPM, Demonstrating The Similarities Between Males And Females For All Locations Included In The Study (Ames Plantation AP, Cades Cove CC, Chuck Swan CS, Oak Ridge OR).....	42

LIST OF FIGURES

FIGURE	PAGE
5.3. Comparison Of Mercury Levels In PPB, Demonstrating The Similarities Between Males And Females For All Locations Included In The Study (Ames Plantation AP, Cades Cove CC, Chuck Swan CS, Oak Ridge OR).....	43
A 2.1. Combination Data Sheet And Locational Map Of The Hobart Ames Plantation Supplied To Hunters For The 1986 Hunting Season.....	79
A 2.2. Locational Map, Cades Cove, Great Smoky Mountains National Park, Tennessee, Illustrating Area Identification Numbers.....	80
A 2.3. Locational Map, Chuck Swan Wildlife Management Area, Tennessee, Illustrating Area Identification Numbers, Roads And Buildings.....	82
B 3.1. Standard Six Point Calibration Curve Used For The Determination Of Cadmium In Unknown Hair Samples. Dotted Lines Represent The Areas Of 95 % Confidence And 95 % Prediction Limits.....	85
B 3.2. Standard Six Point Calibration Curve Used For The Determination Of Lead In Unknown Hair Samples. Dotted Lines Represent The Areas Of 95 % Confidence And 95 % Prediction Limits.....	87
B 3.3. Diagram Of Mercury Determination Vessel And Associated Cold Vapor Atomic Absorption Spectrophotometric Hardware.....	89
B 3.4. Standard Six Point Calibration Curve Used For The Determination Of Mercury In Unknown Hair Samples. Dotted Lines Represent The Areas Of 95 % Confidence And 95 % Prediction Limits.....	90
D 4.1. The Distribution Of Cadmium Levels For White-tailed Deer From The Hobart Ames Plantation, Tennessee, 1986.....	111
D 4.2. The Distribution Of Lead Levels For White-tailed Deer Form The Hobart Ames Plantation, Tennessee, 1986.....	113

LIST OF FIGURES

FIGURE	PAGE
D 4.3. The Distribution Of Mercury Levels For White-tailed Deer From The Hobart Ames Plantation, Tennessee, 1986.....	115
E 4.1. The Distribution Of Cadmium Levels For White-tailed Deer From Cades Cove, GSMNP, Tennessee, 1980-1982.....	123
E 4.2. The Distribution Of Lead Levels For White-tailed Deer From Cades Cove, GSMNP, Tennessee, 1980-1982.....	125
E 4.3. The Distribution Of Mercury Levels For White-tailed Deer From Cades Cove, GSMNP, Tennessee, 1980-1982.....	127
E 4.4. The Weight Of White-tailed Deer From Cades Cove, GSMNP, Tennessee, 1980-1982.....	129
F 4.1. The Distribution Of Cadmium Levels For White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.....	137
F 4.2. The Distribution Of Lead Levels For White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.....	139
F 4.3. The Distribution Of Mercury Levels For White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.....	141
F 4.4. The Age Of White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.....	143
F 4.5. The Weight Of White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.....	145
G 4.1. The Distribution Of Cadmium Levels For White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee, 1986.....	153
G 4.2. The Distribution Of Lead Levels For White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee, 1986.....	155

LIST OF FIGURES

FIGURE	PAGE
G 4.3. The Distribution Of Mercury Levels For White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee, 1986.....	157
G 4.4. The Age Of White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee, 1986.....	159
G 4.5. The Weight Of White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee, 1986.....	161

LIST OF PLATES

PLATE	PAGE
1.0. Locational Map Of The ERDA Oak Ridge Reservation, Tennessee, Illustrating Area Identification Numbers, Areas Open To Hunters, Roads, And Buildings For The 1986 Hunting Season.....	In Pocket

CHAPTER I

THE STUDY

White-tailed deer (Odocoileus virginianus) are widely extolled as the premier big game mammal in most parts of North and Central America because of their keen senses and intelligence (Halls, 1984). Throughout their extensive range, deer are at home in many northern temperate to tropical environments (near tree-line southern Canada, 60° north latitude, to subequatorial South America, 15° latitude), where ground cover, low trees and shrubs are features of the landscape. When given protection from overkill, white-tailed deer flourish in the presence of people and their land-use practices. Habitat manipulations resulting from human encroachment have allowed the species to expand its range throughout North America. Cutting and clearing that sets back plant succession in forest areas, produces edge and brushy growth which in turn greatly increase the carrying capacity of the land for white-tailed deer (Baker, 1984).

It is for this reason, despite man's continual efforts to "tame" the North American landscape, and despite vigorous pursuit of white-tailed deer, deer have persisted and even thrived throughout a vast range in close proximity to people, making their use as biological monitors of "man's" environment evident.

The use of biological monitors can yield useful information concerning many human health issues. In so far as man's health is concerned, the study of metals are emerging as one of the more important issues in modern times. There is no area of cellular biology that is not involved with metals. All genetic, congenital, growth, maintenance, mental, emotional, and aging processes of life are influenced by them (Olwin, 1977).

The analysis of hair for trace metal content has continuously attracted interest as a means of monitoring excessive or inadequate ingestion of various elements. Hair analysis was first used in forensic medicine and was then adopted by toxicologists as a screening tool for detecting heavy metal poisoning. It has been demonstrated within the last decade that hair can be an important indicator of the body's burden of heavy metals (Laker, 1982, Wibowo, et al., 1980, Corridan, 1974, Hammer, 1972).

The most unique property of hair is that it can provide a history of the mineral status of an individual (Hilerbrand and White, 1974). Elements incorporated into hair are no longer in dynamic equilibrium with the rest of the body. Therefore, the concentration of an element a given distance from the epidermis should reflect the elemental concentration of an individual at a particular and specific point in time (Renshaw et al., 1973, 1972, Hambidge et al., 1972, Kopito et al., 1967, Forslev, 1966).

In addition to providing a continuous record of nutritional status and exposure to heavy metal pollutants, hair accumulates trace metals at concentrations that are generally at least ten times higher than those present in blood, serum or urine (Maugh, 1978, Hammer et al., 1971).

During summer, adult white-tailed deer have a thin coat of reddish-brown hair about 1 to 3.5 mm deep on the animals trunk (Jacobsen, 1973). This coat is shed during August and September (Sauer, 1984). Both fawns and adults replace summer hair with brownish-gray winter hair that is from 5 to 27 mm deep. Hair depth is a major determinant of the thermoregulatory qualities of an animal's coat, and the deeper winter hair helps trap more insulating air than does the summer coat (Jacobsen, 1973). The winter coat is composed of long guard hairs and short underfur that insulates the deer. Winter hair is shed in April, May and June, and is replaced by the reddish-brown summer coat (Sauer, 1984). The growth of two coats of hair each year costs deer energy and protein as part of a cost of living. It is during this growth phase that heavy metals are incorporated into the structure of the hair strand, making their measurement possible.

Based on formulas derived by Moen and Severinghaus (1981) for calculating hair weight, a fawn weighing 36 kg produces a winter coat weighing 802 g, and an adult buck weighing 64 kg produces a winter coat weighing 1,274 g.

At birth, white-tailed deer fawns weigh 1.8 to 3.6 kg. Adult females weigh approximately 45 kg, and adult males approximately 68 kg, but actual weights vary according to subspecies, region, habitat-type and quality, age of the animal, and season of the year. Weights over 180 kg are exceptional. Females attain maximum weight in about four years and males reach peak weight in five to six years (Sauer, 1984).

The objective of this study was to provide information on background levels of three heavy metals, cadmium, lead, and mercury in white-tailed deer. These metals occur naturally and also are associated with industrial, mining and urban activity. There is currently a scarcity of information on background concentrations of heavy metals. Information on background levels would be useful in determining the significance of heavy metal residues detected in hair samples of animals inhabiting polluted areas and in assessing the potential implications for human health.

Hence, we proposed to determine the residue levels of cadmium, lead and mercury in hair samples collected from four distinct geographic locations of Tennessee that may have varied levels of natural occurrence or contamination.

CHAPTER II

DESCRIPTION OF STUDY AREAS

The Hobart Ames Plantation

LOCATION

The Ames Plantation is located in west Tennessee, in Fayette and Hardeman Counties, about 97 km east of Memphis and 16 km north of the Tennessee - Mississippi border (Figure 2.1). The plantation consists of approximately 7489.8 ha of land with overall dimensions of 16 km east to west and 13 km north to south (Ewing, 1956).

This region is composed of rolling plains sloping gradually from 61 to 76 m in the west, to 183 m above sea level in the hills overlooking the Tennessee River. The mean elevation above sea level is 140 m (Dickson, 1965).

PLANTATION UNITS

Several departments from the Institute of Agriculture, University of Tennessee conduct research and educational activities at Ames Plantation. These research efforts are designed to seek solutions to current problems encountered by area producers and to increase the efficiency of agricultural production in western Tennessee.

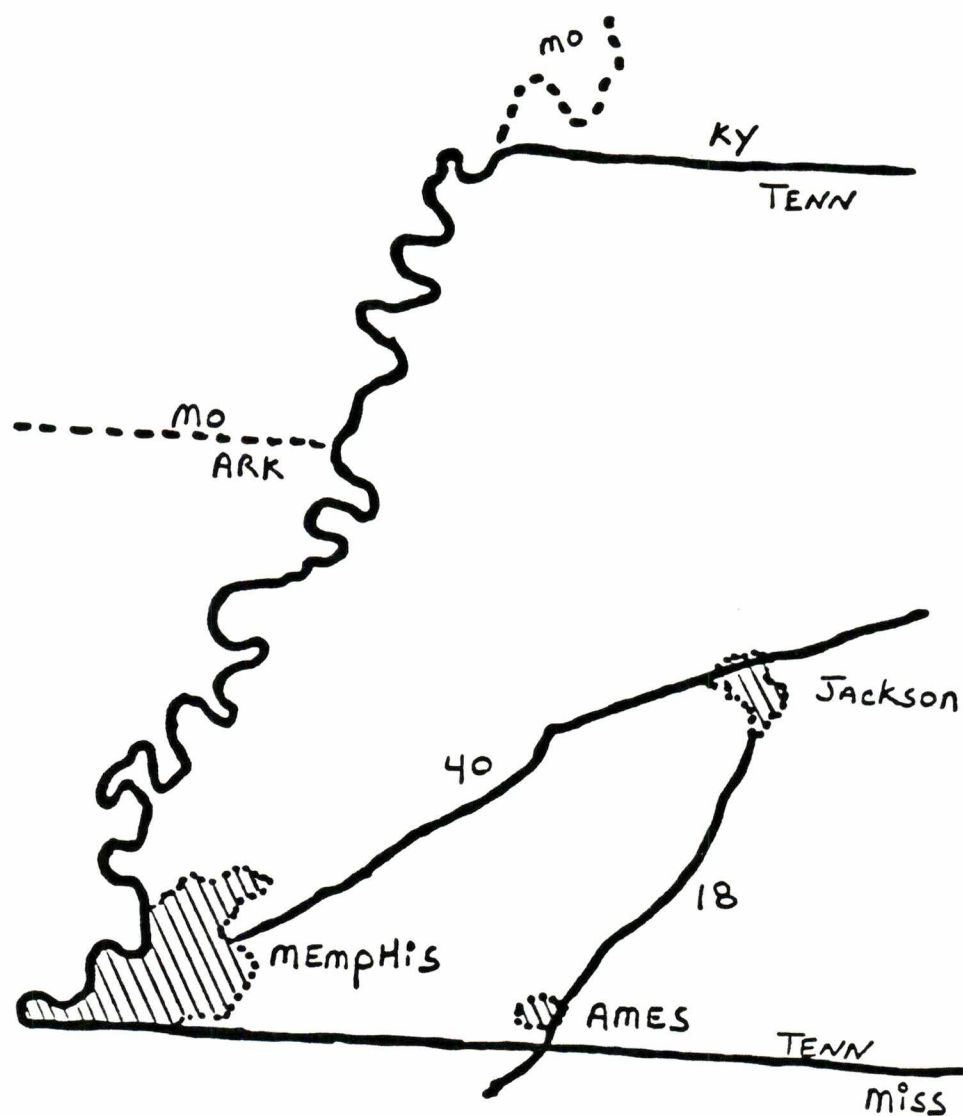


Fig. 2.1. Location Of Study Area Number One, The Hobart Ames Plantation, Fayette And Hardeman Counties, West Tennessee.

GEOLOGY AND SOILS

The major soils of Ames Plantation consist of Memphis silt loam, eroded undulating phase, Memphis silty clay loam, severely eroded rolling phase, Loring silt loam, eroded undulating phase, Loring silty clay loam, severely eroded rolling phase, gullied land, hilly erosion stabilized, and gullied land, rolling erosion active (Carr, 1959). Other soils in smaller amounts consist of Tigrett, Briensburg, Dyer, Loring silt loam, undulating phase, Henry silt loam, Lexington silty clay loam, severely eroded rolling phase, Calloway silt loam, eroded undulating phase, and gullied land rolling, erosion stabilized (Carr, 1959).

Surface drainage is variable between good and rapid according to soil type. Drainage is through several relatively small rivers flowing directly into the Mississippi river.

Cades Cove, Great Smoky Mountains National Park

LOCATION

Cades Cove is located approximately 96 km southeast of Knoxville, Tennessee. The Cove itself lies in the northwest corner of the Great Smoky Mountains National Park (GSMNP). The area is comprised of a 977.2 ha valley in Blount County, Tennessee (Figure 2.2).

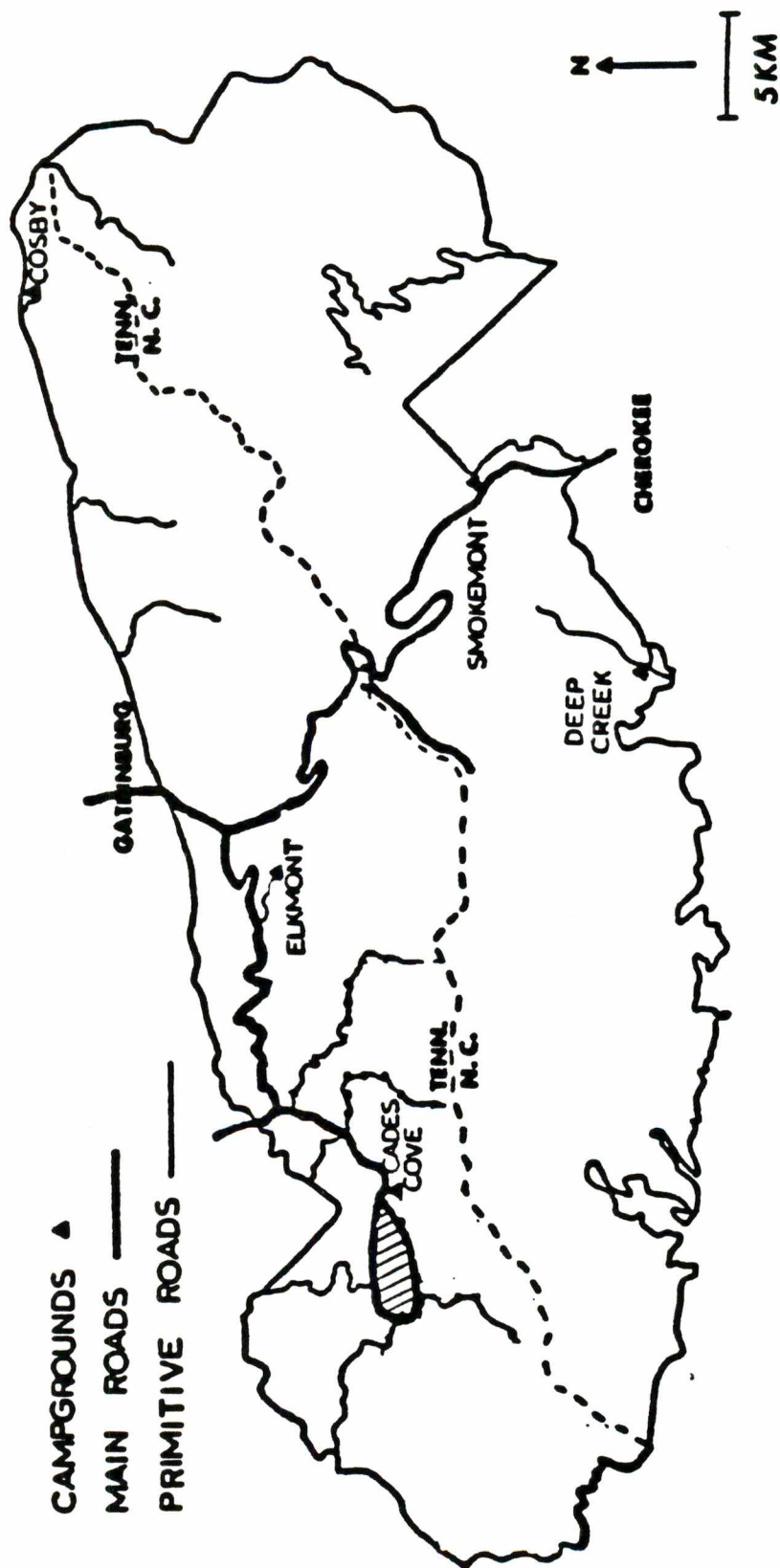


Fig. 2.2. Location of Study Area Number Two, Cades Cove, Within The Northwest Portion of Great Smoky Mountains National Park, Tennessee.

The Cove is predominately fields, 747.6 ha, with the rest consisting of small wooded areas, 229.6 ha. Cades Cove is frequently described as a pastoral valley with gently rolling slopes isolated by high mountains. Elevation varies from 445 m to 600 m. The mean elevation above sea level is 522 m (National Park Service, 1969).

PARK UNITS

Grazing and haying operations are conducted by special use permit, and are used to maintain open fields and vistas. Currently a private herd of 400 to 500 head of cattle are maintained within the Cove. With the exception of logging prior to the establishment of the park in 1938, industrial sites have not been established on park grounds and agricultural techniques predate the use of modern chemicals.

GEOLOGY AND SOILS

Most of the park is underlain by rock of the Ocoee series which dates to the late Precambrian era and is made up predominately of quartz, feldspar and slate, with schist and limestone (King et al., 1969, King and Stupka, 1950). The predominate soil classification is the Ramsey soil type, which displays moderate natural fertility, low water storage capacity and medium to high acidity (United States Forest Service, 1970). Some unique geological formations such as caves, outcrops, sinkholes, and sag ponds are found within the Cove.

Most of the Cove consists of alluvial deposits from Abrams Creek and its tributaries. Abrams Creek enters Cades Cove as a fast flowing mountain stream but its flow rate decreases as it winds throughout the flat areas of the Cove. Portions of Abrams Creek dry up occasionally during the year. There also are several small swampy areas along the Creek and its tributaries (Kinningham, 1980).

Chuck Swan Wildlife Management Area

LOCATION

Chuck Swan Wildlife Management Area (WMA) is located approximately 56 km northwest of Knoxville and 80 km northeast of The ERDA Oak Ridge Reservation, between the Clinch and Powell Rivers in the upper portion of Norris Lake (Figure 2.3). The area is comprised of 10,049 ha of land in Union and Campbell Counties Tennessee (Safley, 1974, Lewis and Safley, 1966).

The Management Area is located in the same physiographic region as The ERDA Oak Ridge Reservation. Therefore, they share the same characteristically well rounded hills with narrow steep sided Y-shaped valleys. Elevation varies from 310.9 m to 512 m. The mean elevation above sea level is 375 m (Lewis and Safley, 1966).

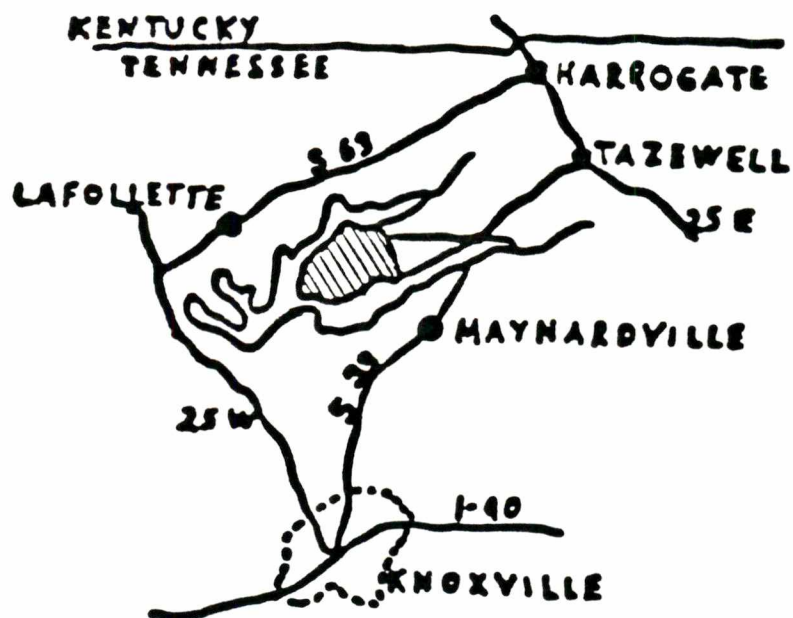


Fig. 2.3. Location Of Study Area Number Three, Chuck Swan Wildlife Management Area, Union And Campbell Counties, Tennessee.

MANAGEMENT AREA UNITS

On premise sites include: the area manager's residence, one bunk house, one storage shed, one checking station, and twelve docks and boathouses on Norris lake. Chuck Swan WMA is made up largely of a peninsula extending into Norris reservoir. There are no large scale manufacturing plants or industries on or near the management area that could be possible sources of heavy metals.

GEOLOGY AND SOILS

The Wildlife Management Area lies within the dolomite hill area of the Norris Reservoir Watershed. Sandy and cherty dolomite and dolomite limestone of the Knox formation underlie the hills similar to the GSMNP. Many lime sinks are found throughout the area (USDA, 1953).

The flood plains and terraces of the Clinch and Powell rivers have been flooded by Norris Reservoir. Surface drainage is rapid and internal drainage is variable between good and rapid according to the soil type. The soils are generally low in fertility, low in organic matter and strongly acidic (USDA, 1953).

**The Energy Research And Development
Administration's Oak Ridge, Tennessee Reservation**

LOCATION

The ERDA Oak Ridge Reservation lies 32 km northwest of Knoxville. The Reservation is located within the city of Oak Ridge, Tennessee, in Anderson and Roane Counties (Figure 2.4). The Reservation consists of 14,762 ha of the original 23,828 ha purchased in 1942 to serve as an Atomic Science Developmental Center (Strock, 1970, Curlin, 1965). The Reservation is bounded on the east, south and west by the Tennessee Valley Authority's Melton Hill and Watts Bar Reservoirs of the Clinch River and on the north by the City of Oak Ridge (Curlin, 1965).

The Reservation is located in the Ridge and Valley physiographic province of the Great Valley of East Tennessee. It is characterized by a series of alternating ridges and valleys oriented in a southwest - northeast direction, parallel to the Cumberland escarpment (USDA, 1942). Elevation ranges from 225.6 m to 414.5 m above mean sea level with a maximum relief of 188.9 m (Curlin, 1965). The valleys are deep V-shaped and have steep walls (USDA, 1942).

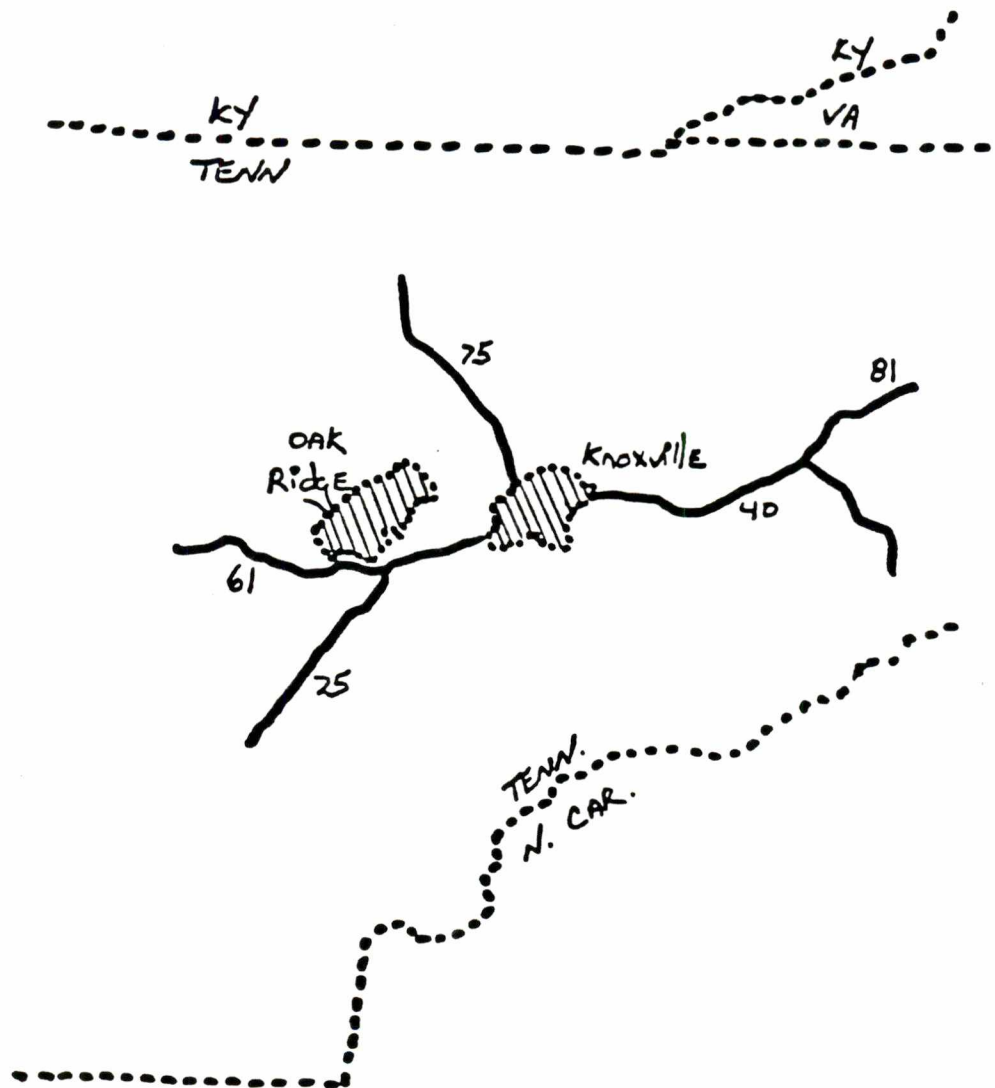


Fig. 2.4. Location Of Study Area Number Four, The Energy Research And Development Administration's Oak Ridge Reservation, Anderson And Roane Counties, Tennessee.

Drainage is well developed within the Reservation. A trellis pattern exists with creeks and small streams flowing parallel to the ridges except where they cut sharply to the left or right across the ridges through narrow gaps. Drainage is primarily to the southwest where the creeks and streams empty into the Clinch River (USDA, 1942).

RESERVATION UNITS

Five separate production and/or research facilities are located within the Reservation. Three of these, the Oak Ridge National Laboratory (ORNL X-10), the Y-12 Nuclear Arms Plant and the Oak Ridge Gaseous Diffusion Plant (K-25) are operated by the Union Carbide Nuclear Company. The Cooperative Animal Research Laboratory (CARL) is operated by the University of Tennessee and a small area is occupied by the Experimental Gas Cooled Reactor (EGCR) site (Curlin, 1965) (Plate 1.0).

Buffer zones are reserved around each plant for special use and future plant expansion. A total of 4,014 ha are located in the buffer zones of X-10, Y-12, and K-25. Of this total, 2,583 ha are forested, most of which are located in the X-10 Buffer zone. CARL contains 432 ha of which 123 ha are forest (Curlin, 1965). The remainder of the Reservation's 10,317 ha are devoted to ecological research and commercial timber management, 9,207 ha of which are forest (Strock, 1970).

Because the Reservation was formed from a large number of small private tracts of land, there is no written history of the land before 1942 (Strock, 1970, Curlin, 1965). Industry in the area prior to 1942 was unlikely and would predate the widespread use of agricultural chemicals.

GEOLOGY AND SOILS

The Reservation lies in the northern part of the zone of Red and Yellow Podzolic soils (USDA, 1938). Except for the alluvial and colluvial materials, the parent materials are the residues of decomposition and leaching of consolidated sedimentary rocks, limestone, dolomites, shales and sandstones. Sedimentary rocks had been formed during the Paleozoic era (USDA, 1942).

The well developed soils on gentle slopes of the limestone valleys are medium to strongly acidic, containing moderate amounts of organic matter. These soils are intermediate in fertility. Moisture holding capacity of the limestone soils is good. Soils on the steep slopes are stony and cherty, low in organic matter (USDA, 1942).

In general fertility is poor and these soils are excessively permeable with low water holding capacity. Sandstone and shale soils are generally shallow, excessively drained and strongly acidic with low fertility (Curlin, 1965).

CHAPTER III

METHODS AND MATERIALS

Sample Collection

The initial phase of this study utilized hair samples collected from white-tailed deer immobilized for other wildlife studies. In all, 301 samples were collected, of which 103 usable samples were obtained; these first samples originated from Cades Cove, GSMNP. Hair samples from Cades Cove GSMNP were collected from January 1980, through December 1982.

Phase two of the project involved the collection of samples from three other populations; Ames Plantation, Chuck Swan WMA and The ERDA Oak Ridge Reservation (Figure 3.1). During Fall/Winter of 1986-1987, 295 additional usable samples were collected (100 from Ames Plantation, 95 from Chuck Swan WMA, and 100 from The ERDA Oak Ridge Reservation) as a result of hunter kills. In all 398 deer were sampled based on the availability of sample in milligrams.

Trace metal analyses were performed by atomic absorption spectrophotometry using hair samples randomly clipped from several locations on the body, (ventral, dorsal and tail). Stainless steel scissors free of contamination were used to remove hair from the skins of animals at Ames Plantation, Chuck Swan WMA, and The ERDA Oak Ridge Reservation.

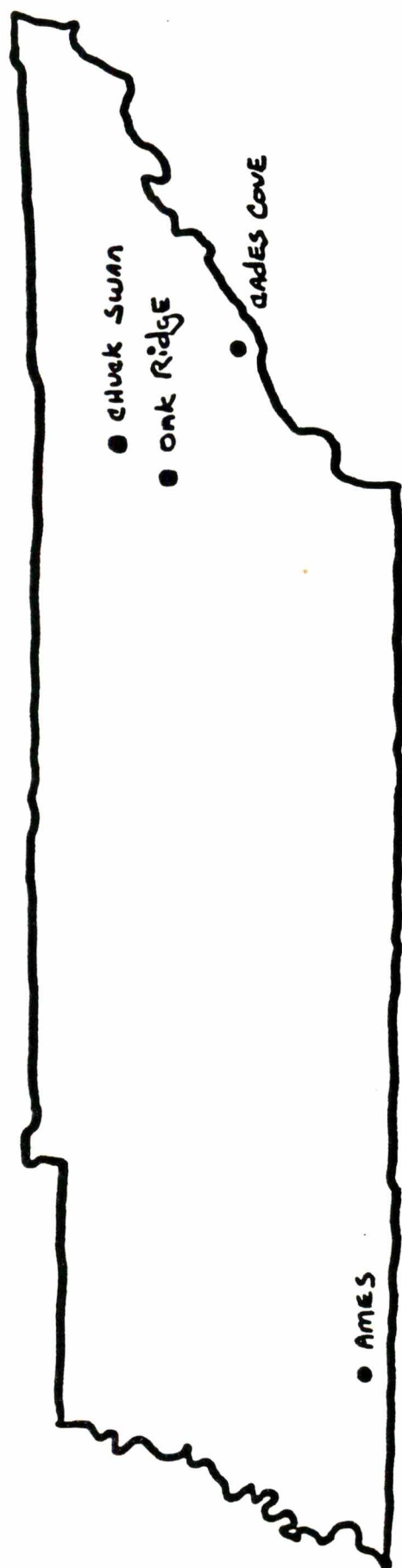


Fig. 3.1. Location Of Areas In Tennessee From Which Animals Were Sampled For The Heavy Metal Study, 1986.

Scissors and knives were used at Cades Cove GSMNP. Samples were placed in Whirl-Pak containers (Nasco, USA), and stored in cardboard boxes at room temperature until time of analysis.

HOBART AMES PLANTATION

Hair and tissue samples from Ames Plantation were collected in conjunction with monthly controlled hunts. Each hunter was supplied with Whirl-paks and a map of the plantation. Hunters were requested to mark with an "X", the location where animals were killed and to record other pertinent information in ink upon the data sheet and Whirl-paks provided (Appendix B). Data on age and weight were not available for animals from Ames Plantation. A grid composed of two by two centimeter squares was superimposed over the original maps and coordinates taken to tabulate sites of kills. Each area on the grid was equal to approximately 188 ha in size. Thirty-five squares, 6,586 ha were open to hunters with permits.

CADES COVE GSMNP

Cades Cove GSMNP, is unique among the areas used in this study; since it is a national park no hunting is allowed. Deer sampled were chemically immobilized by Tennessee Wildlife Resource Agency (TWRA) and park personnel as well as personnel from the University of Tennessee.

Data on the location of darting and other pertinent information for each animal were compiled in the field (Appendix B). Measurements of age and weight were subjective. Estimated field weights were later recalculated by substituting chest circumference measurements into the following equation:

$$\text{WEIGHT} = (\text{CHEST CIRCUMFERENCE} \times 5.6037) - 94.0982$$

CHUCK SWAN WMA

Chuck Swan WMA is divided into eighteen compartments, each one varying in size, the largest being area number ten, 791 ha, and the smallest area number three, 419 ha (Appendix B). The mean compartment size is 593.7 ha. All compartments were open to hunters drawing permits for any of the managed hunts. Each hunter killing a deer was required to stop at the checking station to confirm the location from which the animal was taken. Information pertaining to individual animals was recorded by TWRA personnel and stored in a computer database. Information collected included age, sex, weight, and geographic location of kill.

ERDA OAK RIDGE RESERVATION

Prior to the 1986 hunting season, hunters were supplied with a grid map of the reservation (Plate 1.0). Each square comprised an area of approximately 256 ha.

There were 190 location squares totaling 49,230 ha, of this 59 squares, 15,287 ha were open to hunters drawing permits. Area numbers G-7, H-6,7,8,9,10, I-7,8,9, and J-7, were open to Fall archery hunts only. All other non-restricted area numbers were open for gun hunts held later in the season (Plate 1.0). Area squares did not represent any one particular type of habitat. Each hunter making a kill was required to pinpoint the exact location from which the animal was taken on an area map at the checking station. Information on age, sex, weight, and location was logged directly into a computer database at the checking facility by Oak Ridge and TWRA personnel.

Sample Preparation

All clippings from a single sample [animal] were placed into a Buchner funnel with a Scientific Products grade 615 filter paper. Individual strands were cut to approximately 1 cm in length. Each sample was then carefully mixed to ensure complete randomization of the hair. Samples were then washed using a modified procedure of Magos (1971); double distilled water, five portions of 10 mls, rinsed with ethyl alcohol, 10 mls (200 proof) and pesticide grade acetone, 10 mls. Excess liquid was removed by vacuum filtration. All samples were transferred to new Whirl-Pak containers and oven dried at 50° C for a minimum of five days.

Sample Analysis

Determination of cadmium and lead concentrations were completed according to the methods outlined in Allied Analytical Systems Flameless Operations Manual, Volume 2 (Sotera et al., 1982). The equipment used was a Video 12 AA/AE spectrophotometer and recorder equipped with a model 755 Furnace Atomizer, Fastac II control unit and autosampler, Instrumentation Laboratory (Waltham, Ma).

Samples of 0.0100 +/- 0.0005 grams were weighed using a Sartorius Research model R160p electronic semimicro balance and placed into 12 x 75 mm Rohren tubes (Sarstedt, West Germany). Nitric acid, 1.0 ml AR Select and double distilled water, 1.0 ml were added. The tubes were then capped and digested in a Buchler Thermo Lift water bath at 75° C for approximately fifty minutes, vortexing twice at twenty-five minute intervals to aid digestion. Samples were then analyzed directly by graphite furnace atomic absorption. The instrumental parameters used for these two determinations can be found in Appendix B. Analytical standards were prepared monthly in the following concentrations; 0.000, 0.100, 0.200, 0.300, 0.400, and 0.500 ppm and used to calibrate the instrument between sets of twenty-five samples. In addition, a blank was analyzed after every fourth sample to rule out possible cross contamination. Each sample was analyzed four times.

The mean, standard deviation and relative standard deviation were calculated. Standard calibration curves were constructed and sample concentrations in ppm determined (Appendix B). All results used in the comparison study were based upon the mean.

Determination of mercury concentrations were completed according to a modified E.P.A. Method # 245.1 Manual Cold Vapor technique, using a Spectro Products HG-3 mercury analyzer (North Haven, Conn.) and a Fisher Recordall series 5000 strip chart recorder.

The instrumental parameters used for this determination can be found in Appendix B. Following the wash and dry procedure noted above, 0.1000 ± 0.0010 gram samples were weighed and placed into 30 ml Hypo-Vials Pierce (Rockford, Il), double distilled water, 15.0 mls, sulfuric acid, 1.5 mls (conc.), nitric acid, 0.75 mls (conc.) and potassium permanganate, 4.5 mls were added. After the purple color from the addition of potassium permanganate had persisted for a minimum of 15 minutes, 2.5 mls of potassium persulfate were added. Samples were then capped and digested in a water bath at 95° C for approximately two hours. When the vials had returned to room temperature, sodium chloride-hydroxylamine sulfate solution, 1.8 mls, was added. Decolorization must occur at this step, otherwise, additional sodium chloride-hydroxylamine sulfate solution was added until decolorization occurred.

Samples were then placed into an air tight test chamber (Appendix B) with an argon atmosphere. Stannous sulfate was added 30 seconds prior to analysis, readings were taken directly. Analytical standards (0.0, 2.0, 4.0, 6.0, 8.0 and 10.0 ppb) were prepared daily prior to analysis and digested along with the samples. A minimum of two calibration curves were determined before sample analysis began. A blank was used between sample runs to ensure that the base line returned to zero. Standard calibration curves were constructed and sample concentrations in ppb determined (Appendix B).

Materials

Acetone # 010 (0.28% water) high purity solvent was purchased from American Burdick and Jackson (Muskegon, MI). Argon # un 1006 (95% pure) speciality gas was purchased from MG Industries (Valley Forge, Pa). Certified Atomic Absorption standards, cadmium # SO-C-118, cadmium metal in dilute nitric acid (1,000 ppm +/- 1%), lead # SO-L-21, lead nitrate in dilute nitric acid (1,000 ppm +/- 1%), and mercury SO-M-1114, mercuric chloride in distilled water (1,000 ppm +/- 1%) were purchased from Fisher Scientific Co. (Fairlawn, NJ).

Ethyl alcohol U.S.P. dehydrated 200 proof punctilious was purchased from both Aaper Alcohol and Chemical Co. (Shelbyville, Ky) and U.S. Industrial Chemical Co. (Newark, NJ). Hydroxylamine sulfate salt # H-0127 (97% pure) was purchased from Sigma Chemical Corporation (St. Louis, Mo). Magnesium perchlorate anhydrous reagent grade # M-54 and potassium permanganate crystals certified A.C.S. # P-279 were purchased from Fisher Scientific Co. (Fairlawn, NJ). Potassium persulfate Baker Instra-Analyzed # 3239-1 (99.2% pure) was purchased from J.T. Baker Chemical Co. (Phillipsburg, NJ). Stannous sulfate AR # 8505 (52.63% SnSO_4), sulfuric acid AR Select # 5557 and nitric acid AR Select # 6623 were purchased from Mallinckrodt Chemical Co. (Paris, Ky).

Statistical Analysis Of Data

Descriptive statistics for all white-tailed deer used in the study were compiled. Analyses included: mean, median, mode, geometric mean, variance, standard deviation, standard error, range, skewness, and kurtosis, based on a sample size of 398 animals for each of the metals of interest.

In the next phase of the analysis independent variables such as age, geographic location, sex, and weight were evaluated by multifactorial ANOVA. The model used was represented by the equation:

$$L_{IJKLM} = M + O_I + S_J + A_K + W_L + (OSAW)_{IJKL} + E_M$$

Where "L" represents the level of the metal of interest, "M" the overall mean, "O" the effect of origin, "S" the effect of sex, "A" the effect of age, "W" the effect attributed to weight, "OSAW" the combined interaction factor of all the variables, and "E" the explained effect of error on the model.

A comparison study among locations was also constructed. Bonferroni comparisons with individual confidence levels of 0.99 and overall confidence level equal to 0.94 were employed to show significant differences between mercury levels at different locations. In addition, trends were sighted for varying metal levels within a location based on area, including regression correlations between pairs of metals.

CHAPTER IV

RESULTS

General Information

Sample size at The Hobart Ames Plantation was 100 animals, 49 males, 33 females, and 18 were not identified. For deer from Cades Cove GSMNP ($n = 103$), 17 were males and 86 females. Ninety-five deer were sampled at Chuck Swan WMA, 39 males and 56 females. Sample size at The ERDA Oak Ridge Reservation ($n = 100$) was composed of 48 males and 52 females. In total 398 hair samples of white-tailed deer were analyzed; 227 females, 153 males, and 18 unidentified.

The mean levels reported ($n = 398$) were cadmium 0.44 ppm ($r = 0.00$ to 9.67 ppm), lead 2.49 ppm ($r = 0.00$ to 87.63 ppm), and mercury 2.13 ppb ($r = 0.00$ to 63.00 ppb) (Appendix C).

CADMIUM

Cadmium levels in white-tailed deer varied between eastern and western locations; cadmium levels at Ames Plantation ($\bar{x} = 0.17$ ppm) were significantly lower (P value 0.0502) than either Cades Cove GSMNP ($\bar{x} = 0.61$ ppm), Chuck Swan WMA ($\bar{x} = 0.47$ ppm), or The ERDA Oak Ridge Reservation ($\bar{x} = 0.47$ ppm) (Table 4.1). No significant differences were found among the other study locations (Figure 4.1.).

Table 4.1. Comparison Of The Levels Of Cadmium, Lead, And Mercury From Hair Of White-tailed Deer From Four Locations In Tennessee.

	MEAN	STANDARD DEVIATION	MEDIAN
CADMIUM (ppm)			
AMES PLANTATION	0.171	+/- 0.28	0.07
CADES COVE	0.616	+/- 1.16	0.23
CHUCK SWAN	0.471	+/- 1.20	0.19
OAK RIDGE	0.472	+/- 1.00	0.22
LEAD (ppm)			
AMES PLANTATION	1.071	+/- 1.93	0.54
CADES COVE	2.179	+/- 5.58	1.30
CHUCK SWAN	2.458	+/- 3.40	1.69
OAK RIDGE	4.251	+/- 10.3	1.33
MERCURY (ppb)			
AMES PLANTATION	0.208	+/- 0.81	0.00
CADES COVE	1.209	+/- 6.59	0.00
CHUCK SWAN	1.711	+/- 4.52	0.00
OAK RIDGE	5.415	+/- 4.88	5.53

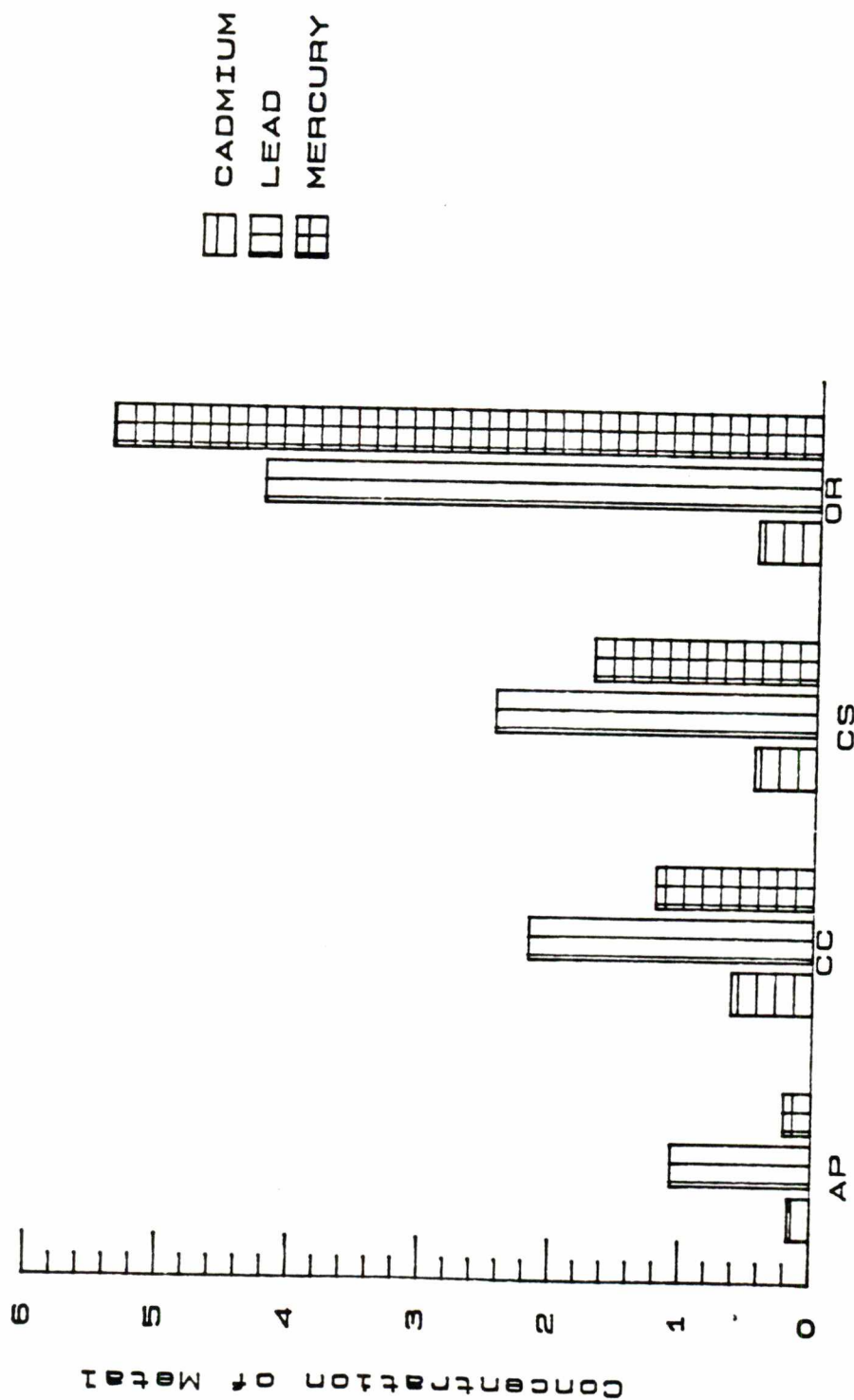


Fig. 4.1. Comparison Of The Concentration Of Heavy Metals Found In White-tailed Deer From Four Study Locations In Tennessee. Cadmium And Lead Levels Are In PPM, While Mercury Levels Are In PPB.

LEAD

Analysis of variance indicate that level of lead in the hair of white-tailed deer seemed to differ by location (P value 0.0009) (Table 4.1, Figure 4.1.). However, the distribution of the levels were skewed (Figure 4.2.). The logarithm of lead values were then examined to see if their distributions were more symmetric (Figure 4.3.). Logarithmic analysis indicated levels of lead did not differ by location (P value of 0.0784).

MERCURY

Levels of mercury in white-tailed deer varied by location (Table 4.1.). Levels in deer from The ERDA Oak Ridge Reservation were more randomly dispersed based upon the median and mode than other study locations (Figure 4.4.). Bonferroni analyses based upon the mean demonstrated a significant difference between The ERDA Oak Ridge Reservation and all other locations in the study. In addition, a difference between Ames Plantation and Chuck Swan WMA was also demonstrated (Appendix C).

Multifactorial Analysis

CADMIUM

Levels of cadmium were examined for the effects of age, geographic location, sex, plus possible interactions.

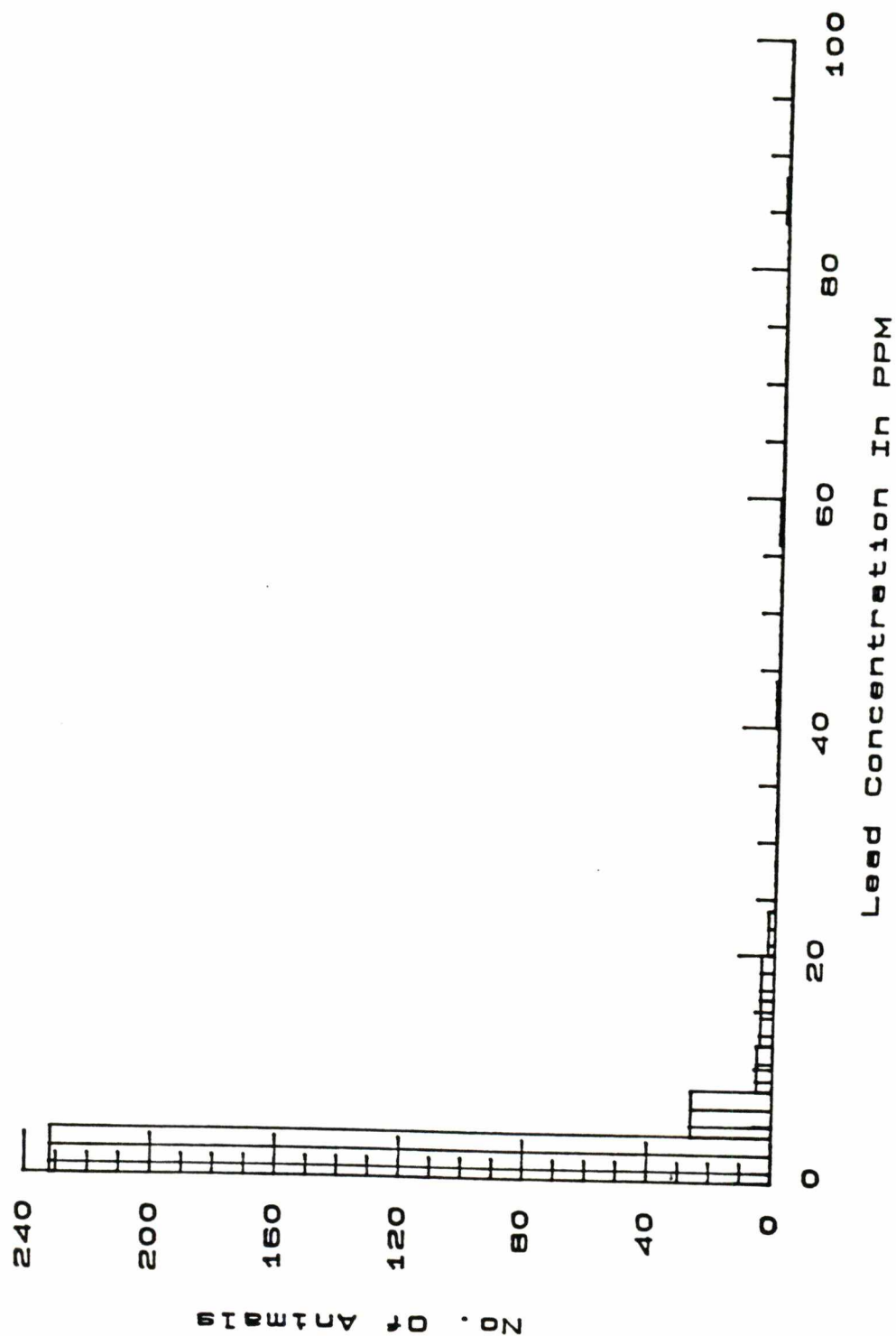


Fig. 4.2. Distribution Of Lead Levels For All White-tailed Deer Analyzed In Tennessee, 1986.

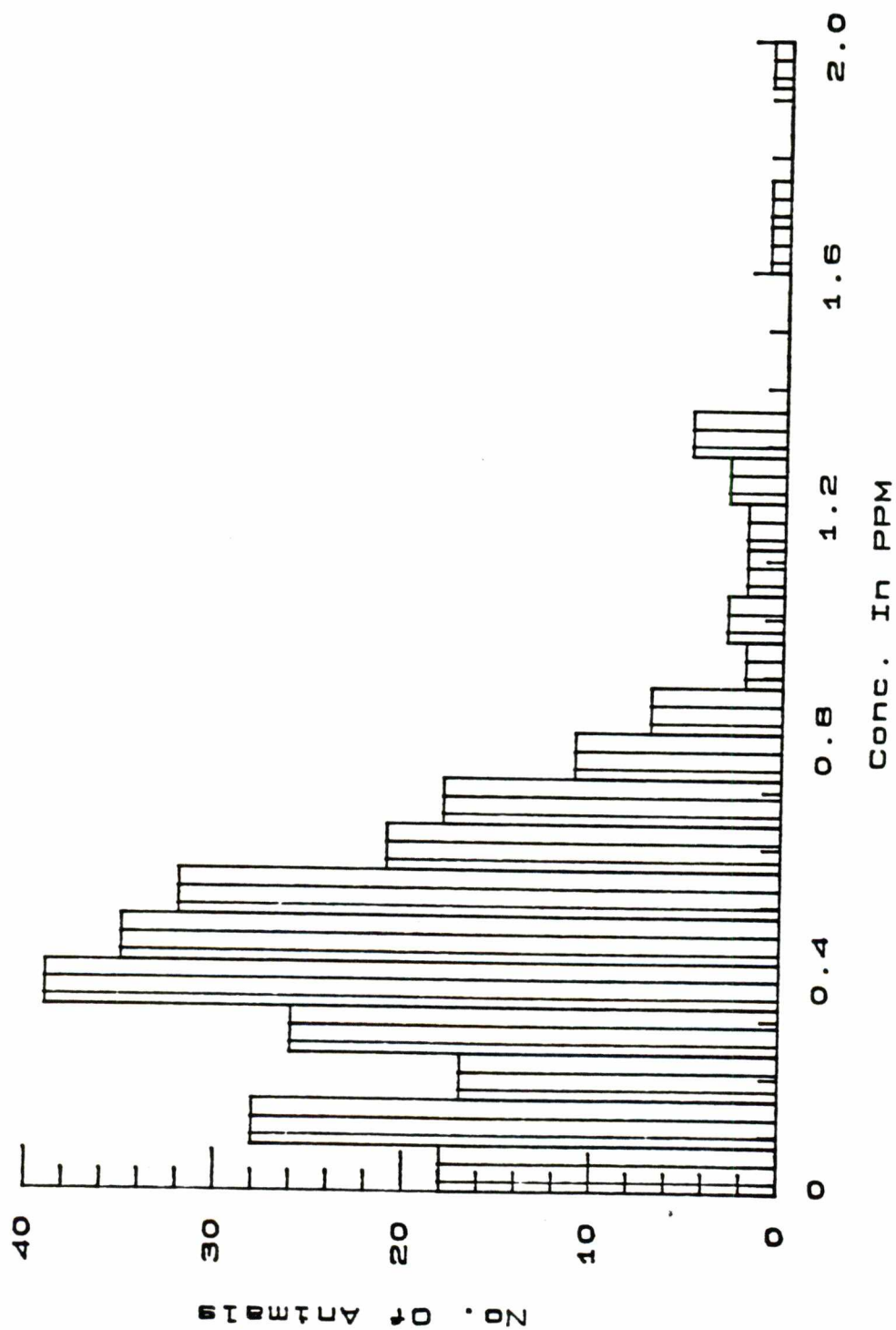


Fig. 4.3. Distribution Of The Logarithm Of Lead Levels For All White-tailed Deer Analyzed In Tennessee, 1986.

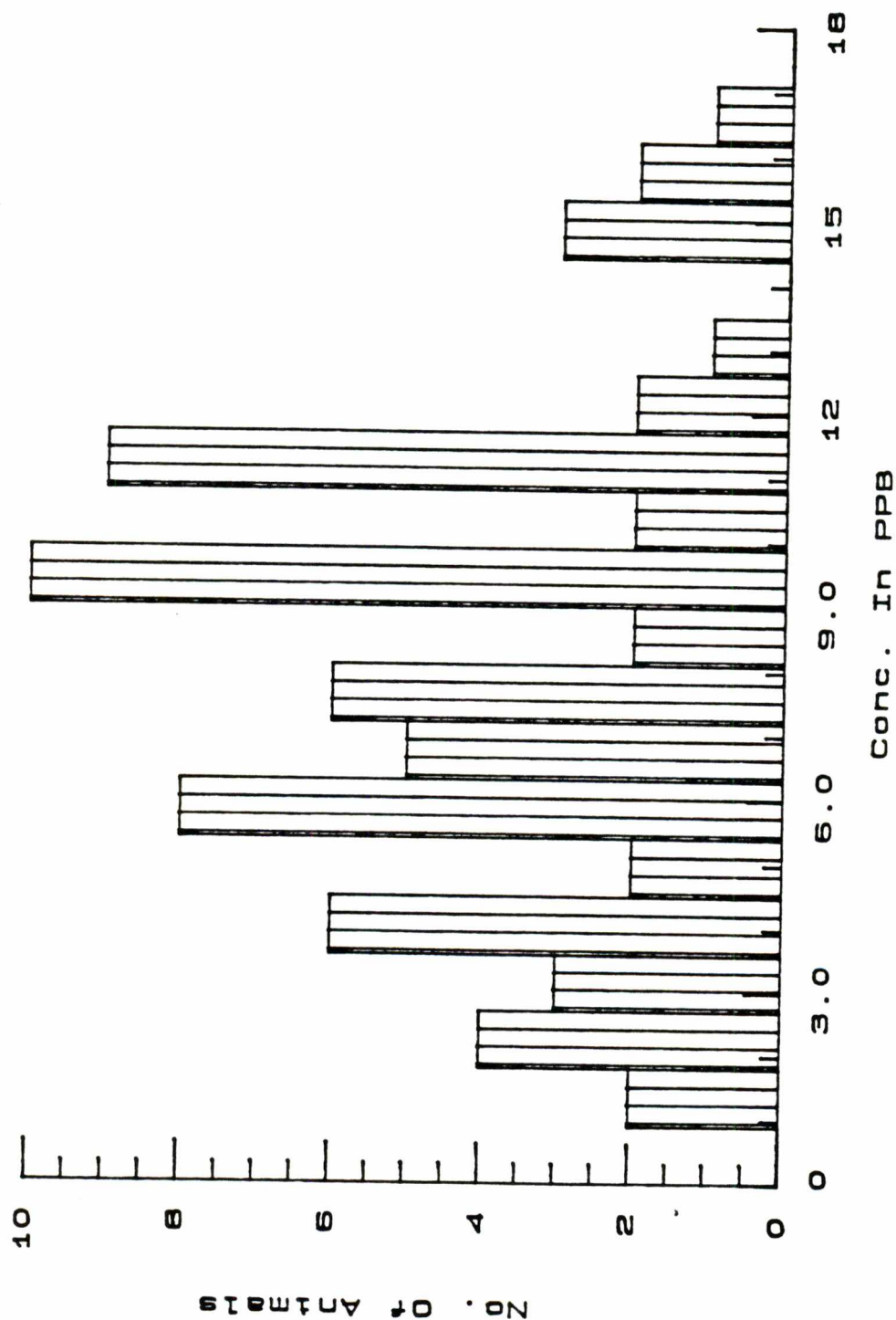


Fig. 4.4. Normal Dispersion Of Mercury Levels Found In White-tailed Deer Sampled From The ERDA Oak Ridge Reservation, Tennessee, 1986.

Analysis of an interaction involving weight was dropped from the model due to confounding between age and weight. No additional affect on cadmium levels could be attributed to the variables included in the model (Appendix C).

LEAD

Levels of lead initially seemed to indicate that there were differences by origin (P value 0.0009), age (P value 0.0001), and with an interaction between age and sex (P value 0.0300) (Appendix C).

However, as noted previously, levels of lead appeared to be skewed with a few very large values: to correct for this logarithm of lead levels were examined for symmetry (Figure 4.3.). Logarithmic analysis of lead data showed no significant effect could be attributed to the independent variables (Appendix C).

MERCURY

Because of the preponderance of values below the lowest detectable limit (0.2 ppb) for three of the study areas, mercury levels for Ames Plantation, Cades Cove GSMNP, and Chuck Swan WMA were not fitted into the general model. An ANOVA was only run on animals from The ERDA Oak Ridge Reservation. Analysis indicated that neither age, sex, nor their interaction seemed to have had any independent effect on the levels of mercury retained (Appendix C).

THE HOBART AMES PLANTATION

Mean levels for deer from The Ames Plantation were, 0.17 ppm cadmium ($r = 0.00$ to 1.69 ppm), 1.07 ppm lead ($r = 0.00$ to 9.58 ppm), and 0.21 ppb mercury ($r = 0.00$ to 5.48 ppb) (Appendix D).

Of the four locations sampled Ames Plantation was the only area in which males and females were equal in the concentration of the three metals. The levels of cadmium detected in hair were, males 0.16 ppm, females 0.18 ppm; 0.77 ppm lead and 0.25 ppb mercury for both males and females (Appendix C).

Histograms of cadmium, lead, and mercury distributions were skewed right and leptokurtic, suggesting that they did not represent normal distributions (Appendix D). No significance could be attributed to the regression correlation of the level of one metal versus another. Frequency tabulations, histograms and regression correlations of each metal level can be found in Appendix D.

CADES COVE GREAT SMOKY MOUNTAINS NATIONAL PARK

The mean levels of metals for white-tailed deer from Cades Cove GSMNP were, cadmium 0.62 ppm ($r = 0.00$ to 6.90 ppm), lead 2.18 ppm ($r = 0.00$ to 56.1 ppm) and mercury 1.21 ppb ($r = 0.00$ to 63.0 ppb) (Appendix E).

No significant differences were noted between the sexes. Males retained the following levels, 0.31 ppm cadmium, 1.75 ppm lead, and 0.39 ppb mercury. While females had concentrations of 0.59 ppm cadmium, 2.27 ppm lead, and 0.63 ppb mercury (Appendix C). Frequency distributions of the levels of metals were skewed right and leptokurtic, similar to the results from The Hobart Ames Plantation.

Mean live animal weight for deer from Cades Cove GSMNP was estimated to be 42.3 kg. Because of the variety of people aging deer from Cades Cove, class distinction was only made between animals younger and older than 1.5 years of age. The mean age therefore was not determined. Distribution of weight for the deer approached a normal bell shaped curve. No trends could be inferred from the analysis of metal levels based on either age or sex. In addition the regression correlation of one metal on another did not prove to be significant. Frequency tabulations, histograms, and regression correlations of the metal levels can be found in Appendix E.

CHUCK SWAN WILDLIFE MANAGEMENT AREA

The mean metal levels found in deer were, cadmium 0.47 ppm ($r = 0.00$ to 9.67 ppm), lead 2.46 ppm ($r = 0.00$ to 20.2 ppm), mercury 1.71 ppb ($r = 0.00$ to 22.0 ppb) (Appendix F).

Again no significant differences were noted between the sexes. Males retained the following levels, 0.33 ppm cadmium, 1.91 ppm lead, and 1.61 ppb mercury. Females had concentrations of 0.60 ppm cadmium, 2.78 ppm lead, and 1.77 ppb mercury (Appendix C). Frequency distributions of the metal levels fit the established trend, all curves being skewed right and leptokurtic.

The mean age for white-tailed deer at Chuck Swan WMA was 2.5 years, males 2.0 and females 2.7. Deer at Chuck Swan WMA were slightly smaller than either Cades Cove GSMNP or The ERDA Oak Ridge Reservation; the mean weight was 27.3 kg. No trends could be detected for age, location, sex, or weight versus metal concentration. No significance was attributed to the regression correlation of the level of one metal versus another. Frequency histograms, tabulations, and regression correlations for this information can be found in Appendix F.

THE ENERGY RESEARCH AND DEVELOPMENT

ADMINISTRATION'S OAK RIDGE, TENNESSEE RESERVATION

Mean metal levels were, cadmium 0.47 ($r = 0.00$ to 7.99 ppm), lead 4.25 ppm ($r = 0.00$ to 87.6 ppm), mercury 5.41 ppb ($r = 0.00$ to 17.0 ppb) (Appendix G). No significant differences were noted between the sexes. Levels for males were 0.33 ppm cadmium, 5.15 ppm lead, and 5.16 ppb mercury.

Females had concentrations of 0.60 ppm cadmium, 3.42 ppm lead, and 5.65 ppb mercury (Appendix C). Frequency distribution histograms of cadmium and lead were skewed right and leptokurtic, while the mercury distribution was determined to be normally skewed and platykurtic.

Information was most abundant on white-tailed deer from this location. The mean age was 2.2 years, 2.1 for males and 2.3 for females. Animals were approximately the same size as Cades Cove GSMNP deer weighing 40 kg. The frequency distribution of weight appeared bell shaped and normal while age was skewed left. No correlation was established between the effects of one metal level upon another. Frequency tables, histograms, and regression correlations are in Appendix G.

CHAPTER V

DISCUSSION

While little published data are available for metal levels in hair of white-tailed deer, a comparison can be drawn from recorded levels in other animals and humans (Table 5.1.). Mean levels of metals determined in the study fell well within an expected range. Levels of mercury in deer sampled from Tennessee were lower than white-tailed deer from either Georgia or Ohio (Table 5.1.). In addition, cadmium and lead levels were lower than values reported by researchers in several other species (Table 5.1.).

Marginal significance was noted for interactions of the independent variables involving sex. Visual inspection of cadmium levels demonstrated a trend for all eastern locations, females on the average being twice as high as males (Figure 5.1.). While the levels were not significant at a 95% level, P values suggest that further investigation of interactions involving cadmium and sex with a larger sample population ($n > 400$) might be worthwhile. No similar differences were noted between males and females for either lead or mercury (Figure 5.2. and 5.3.).

Table 5.1. The Relative Levels Of Cadmium, Lead, And Mercury, Found In The Hair Of Several Species.

Species	#	Location	Levels	Reference
Human	281	New York	0.88 ppm Cd	Creason et al., 1975
Children	284		13.47 ppm Pb	
age 0-15	280		0.672 ppm Hg	
Human	201	New York	0.76 ppm Cd	
Adults	207		12.21 ppm Pb	
> 16	203		0.774 ppm Hg	
Moose	98	Alaska	1.51 ppm Cd	Franzmann et al., 1976
	100		6.99 ppm Pb	
	40		0.25 ppm Hg	
Otters	25	Britain	1.12 ppm Cd	Mason, et al., 1986
	25		13.05 ppm Pb	
	25		18.75 ppm Hg	
Bovine	8	SE Missouri	0.06 ppm Cd	Dorn et al., 1974
	8		2.19 ppm Pb	
White-tail Deer	31	Georgia	0.2 ppm Hg	Cumbie & Jenkin 1974
White-tail Deer	38	Ohio	0.01 ppm Hg	Lynch, 1973
Black Bear	4	Idaho	0.18 ppm Hg	Benson et al., 1974
Raccoons	23	N. Florida	7.5 ppm Hg	Bigler et al., 1975
	11	S. Florida	4.4 ppm Hg	
	76	Georgia	6.12 ppm Hg	
	5	S. Carolina	9.86 ppm Hg	
Elk	4	Idaho	0.2 ppm Hg	Huckabee et al., 1973
Mice	14	Utah	10.8 ppm Hg	Burton et al., 1977
Rats	10	U. of Minnisota	0.21 ppm Cd	Combs et al., 1983

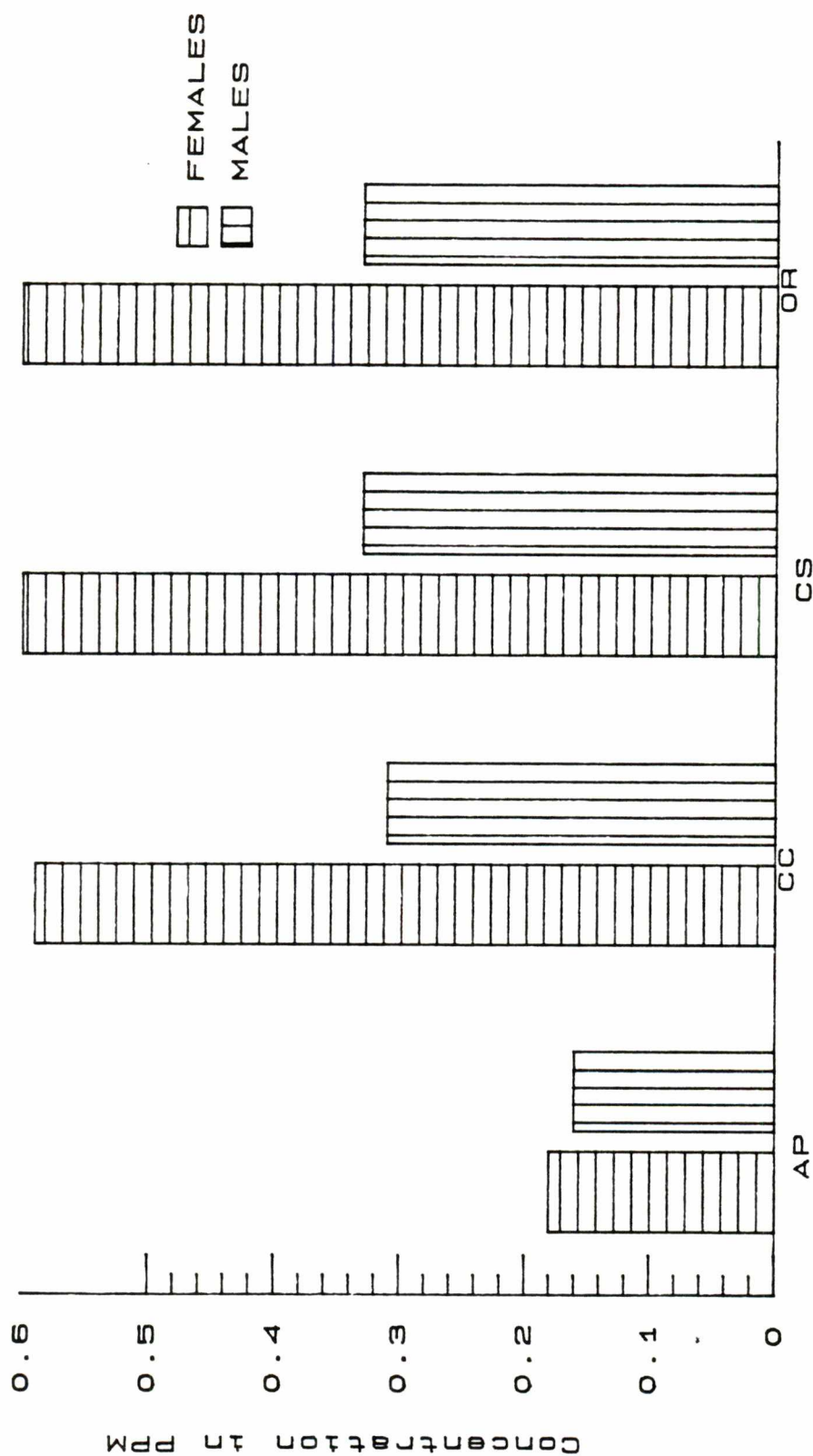


Fig. 5.1. Comparison Of Cadmium Levels In PPM, Demonstrating The Difference Between Males And Females For All Locations Included In The Study (Ames Plantation AP, Cades Cove CC, Chuck Swan CS, Oak Ridge OR).

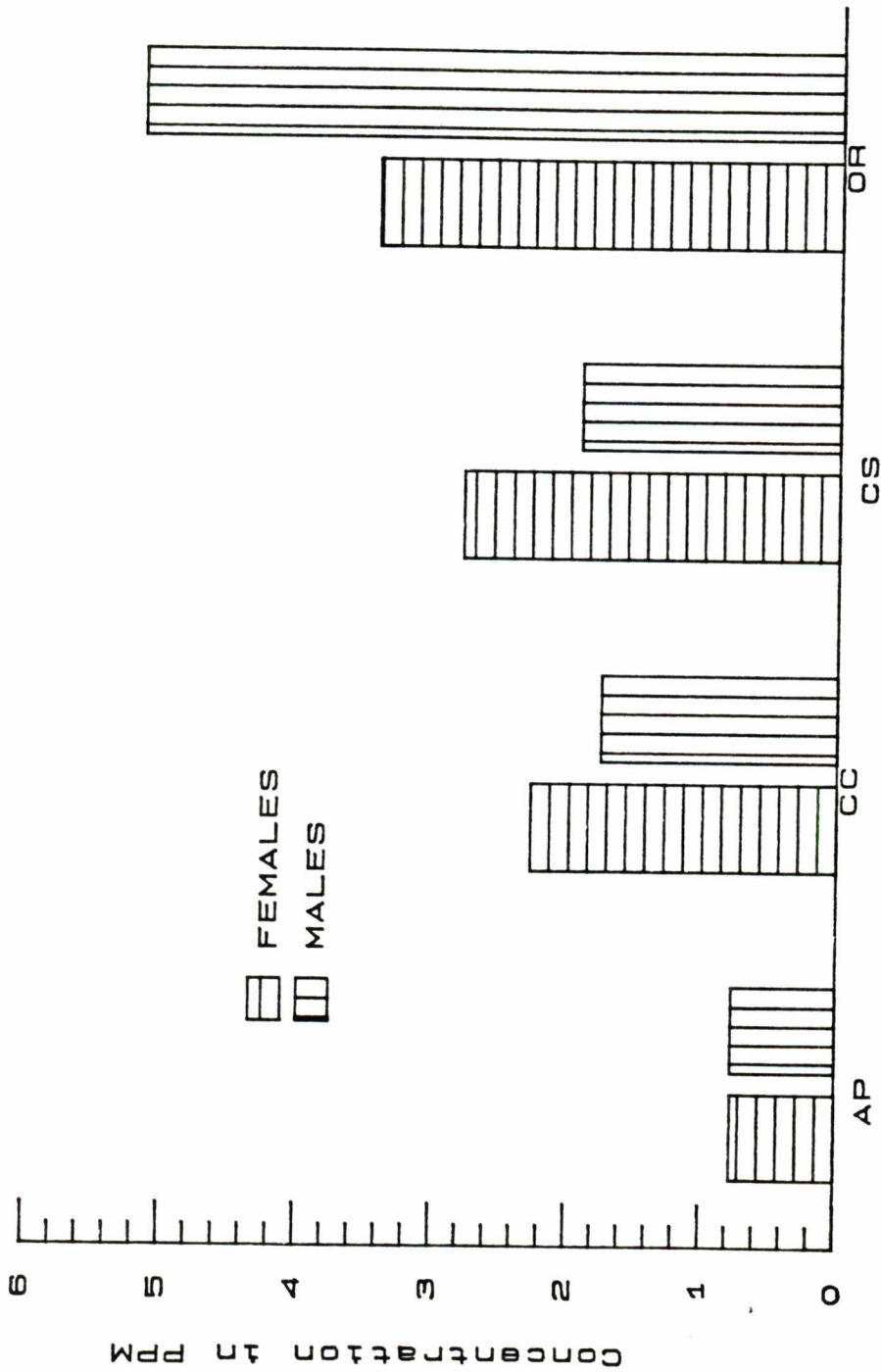


Fig. 5.2. Comparison Of Lead Levels In PPM, Demonstrating The Similarities Between Males And Females For All Locations Included In The Study (Ames Plantation AP, Cades Cove CC, Chuck Swan CS, Oak Ridge OR).

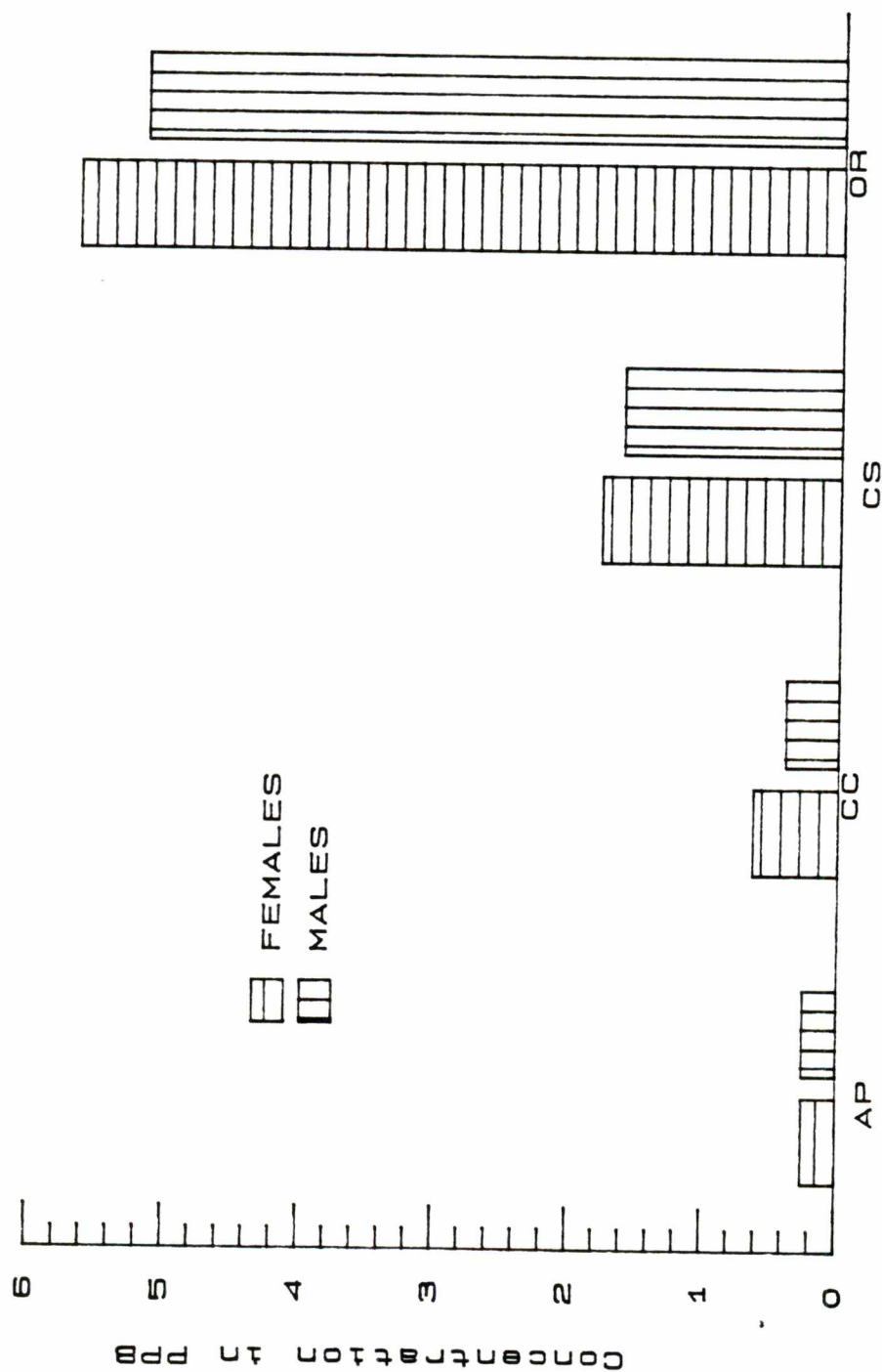


Fig. 5.3. Comparison Of Mercury Levels In PPB, Demonstrating The Similarities Between Males And Females For All Locations Included In The Study (Ames Plantation AP, Cades Cove CC, Chuck Swan CS, Oak Ridge OR).

Assumptions And Limitations

Despite its drawbacks, hair analysis is one of the best screening tests for heavy metal contamination, especially lead (Fletcher, 1982, Chattopadhyay et al., 1977). The United States Environmental Protection Agency in a 1980 report on biological monitoring of toxic trace metals, concluded that "human hair can be used effectively for biological monitoring of the highest priority toxic trace metals, lead, cadmium, mercury, and arsenic." (Jenkins, 1980).

Many relevant specimens are not available from living patients: for example, lead is stored in the bones, cadmium in the liver and kidneys, and mercury in the central nervous system. Information about the body's accumulation of these elements cannot be obtained easily; in general, a sample must be chosen on the basis of availability rather than straight forwardness of analysis and interpretation (Laker, 1982). Samples from living patients usually include blood, hair, nails, teeth, and urine. Three of these are not practical for general use, although each may be of value under certain circumstances.

Nails

At the present time there is little information about the normal range of elements present, or contamination from external contact.

Teeth

Are rarely used because they are not readily available. One notable exception are milk teeth in children (Needleman et al., 1979).

Urine

Gives only information on what the body has lost not on what it has retained.

Therefore only blood and hair are available to give representative pictures of the body's elemental status in living patients. Before discussing the relative merits of each it should be stated that these two analyses are not different ways of assessing the same thing as seen with other specimens, but a single manner in which body trace element status is reflected over different scales of time. Trace element levels in blood are transient, related to the exposure of elements in the previous hours or days, while hair fixes trace elements, providing a lasting record of levels over the previous few months (Laker, 1982).

Traditionally blood has been relied on for assessing the levels of essential and nonessential elements within the body but blood has been demonstrated to have several shortcomings. As opposed to hair, blood lead concentrations due to inhaled lead peak after four to five hours, and after about twenty-four hours for ingested lead. After reaching maximal values blood lead concentrations decline exponentially while hair levels remain constant (Chamberlain et al., 1978).

In addition, Petering et al. (1973) concluded that "blood is not a suitable material to analyze for cadmium either, since the metal remains in the blood only very briefly and, in consequence, the levels are always extremely low." Blood also has been found to be a less reliable index of mercury exposure than hair (Clemente, 1978).

Blood can be used only for immediate measurement of exposure to lead, cadmium, and mercury, since it gives no indication of the cumulative levels of these elements. In this study cumulative intakes were of interest as opposed to information on the amount of an element available for immediate use by the body.

Because it was the purpose of this study to assess low level chronic exposures of several nonessential elements (cadmium, lead, and mercury), hair was chosen as the medium of choice. Defense of hair being the preferred sample of analysis can be found in the following advantages.

1. Hair provides a better assessment of normal trace element concentrations because short-term variations are averaged out.
2. Hair offers a good way of discerning long-term variations in trace element concentrations.
3. Hair, unlike blood is an inert and chemically homogeneous substance.
4. The concentration of most trace elements are relatively high in hair as compared to the rest of the body, especially blood.

5. Hair provides a record of past as well as present trace element levels.
6. Specimens can be collected more quickly and easily than specimens of blood, urine, or any other tissue.
7. Hair is readily available and easily obtained without special equipment or trained personnel.
8. No special storage conditions are required.
9. Analysis is rapid, relatively inexpensive and can be performed at anytime after the sample is collected.

Advantages that made hair an attractive alternative to blood for trace element analysis in this study have been presented but a number of criticisms do exist which require consideration:

First there is the possibility of sample variation across the scalp or epidermis (Laker, 1982). It cannot be denied that variations undoubtedly exist but are in general small compared to the variation among individuals (Hambidge et al., 1972, Coleman et al., 1966). Part of this difference has been reported to be due to different lengths of hair being taken from different areas of the head in the case of humans or the body in animals (Coleman et al., 1966). Sample variation across the epidermis for individual analysis can be easily prevented by taking hair from the same part of the head or body. In humans the nape of the neck is the most common location sampled.

If the goal of a study is to assess community exposure, variation across the epidermis would be of little consequence since small variations would undoubtedly be averaged out with sufficient sample size (Creason et al., 1975).

Since it was the object of this study to assess background levels at several locations and not individuals for their relative metal levels, hair was randomly taken from several different locations on the body.

Second, and possibly the most widely disputed criticism of hair analysis is the choice of washing procedures and their relative effectiveness (Laker, 1982, Alvarez, 1978, Maugh, 1978, Clarke and Wilson, 1974, Hilderbrand and White, 1974, Petering et al., 1973). A multitude of procedures have been presented in the literature. These include simple rinses with double distilled water (Rabinowitz et al., 1976) to complicated procedures involving detergents, organic solvents, and or chelating agents (Clarke and Wilson, 1974, Hammer, 1972, Strain, 1972, Petering et al., 1971, Kopito et al., 1969).

Because so many washes are available, comparisons between washing agents is difficult at best. It is the recommendation of the International Atomic Energy Agency, that acetone be used; this suggestion has been met with some opposition because various other washing agents remove more trace elements than acetone (Salmela et al., 1981).

Various experiments (Sheard et al., 1980, Mckenzie, 1974) have drawn no conclusions as to which may provide the best wash. Experimentation has demonstrated that the effects of organic solvents and detergents appeared to be roughly the same (Sheard et al., 1980, Hambidge et al., 1972). Furthermore, it is impossible to tell whether or not any of the more strenuous washes are extracting elements incorporated into the hair strand during growth as well as external contaminates.

It would seem that the washing procedure does not create a major stumbling block in the actual analysis of samples if a common procedure is implemented for all samples. Although, without the standardization of washing procedures a small degree of error may be interjected when comparing results from independent lab analyses. For the purpose of this study a modified Mago's procedure was used. This wash procedure removed a suitable amount of external contamination, while not disrupting endogenously bound metals.

Third, the possible influences of hair treatments should be taken into consideration. Several factors have been addressed in the literature:

A. Diet

Aiery, 1983, Fletcher, 1982, Kelvay, 1970,
Kopito et al., 1967, Strain, 1966.

- B. Age**
Kello and Kostial, 1978, Gross et al., 1976,
Creason et al., 1975, Reeves et al., 1975,
Petering et al., 1973.
- C. Sex**
Shirmomura et al., 1980, Creason et al.,
1975, Reeves et al., 1975, Hilderbrand and
White, 1974, Kelvay, 1973, Petering et al., 1973.
- D. Hair Color**
Fletcher, 1982, Laker, 1982, Chattopadhyay
et al., 1977.
- E. Sebaceous Gland Secretions**
Fletcher, 1982, Hinnners et al., 1974.
- F. Eccrine Sweat**
Fletcher, 1982, Hinnners et al., 1974,
Hambridge et al., 1972, Petering et al.,
1971, Kelvay, 1970.
- G. Epidermal Desquamation**
Fletcher, 1982.
- H. Substances in the Environment**
Brown et al., 1980, Valkovic et al., 1975
Schroeder, 1967.
- I. Accessibility to the Environment**
Clarke and Wilson, 1974, Hilderbrand and White,
1974, Wilson et al., 1974, El-Dakhakhany
and El-Sadik, 1972, Hammer et al., 1971,
Petering et al., 1971, Kelvay, 1970.
- J. Geographic Location and Soil**
Limic and Valkovic, 1986, Pratt and Sikorski,
1982, Barltrop et al., 1974, Roberts et al.,
1974.

Most of these factors can be eliminated by careful collection and handling of samples. In addition since most if not all of the studies cited used human hair some of these factors may not apply in the same manner. The following arguments are made.

DIET

White-tailed deer are herbivores as opposed to humans who are omnivores. Which is an important factor if biomagnification of trace metals in the food chain is taken into consideration. In turn man could be exposed to higher levels of metals than deer.

Almost one hundred percent of the diet of a deer comes from their immediate environment whereas human foodstuffs in some cases are imported worldwide. Besides these obvious differences, human foodstuffs may be processed in some manner or totally artificial. It is unclear at this time whether the addition of chemicals to the diet may have a synergistic effect upon the uptake of certain metals (Ladinskaya et al., 1973). Because of these differences, metal levels in the hair strands of humans may not truly reflect the status of their environment but to some extent nutritional levels.

AGE

Some investigators have reported a correlation between metal concentrations and age (Okamoto et al., 1985, Petering et al., 1973, Weiss et al., 1972). Several arguments can be made against the importance of this variable in deer.

First, an age-metal concentration relationships have not been universally established in people nor animals (Gross et al., 1976, Lockeretz, 1973, Weiss et al., 1972, Schroeder and Nason, 1969).

Second, in most papers that demonstrate a sex linked relationship, metal levels tend to increase until midlife, age 45 to 50, and then decrease throughout the next three decades (Creason et al., 1975, Kelvay, 1973, Petering et al., 1973). Pointing out that one or more confounding factors may be at work. For instance, job related exposures, lifestyle, or physical activity, might actually be associated factors. Since physical activity and "occupation" does not change dramatically in deer with age, white-tailed deer would not seem to be subject to these confounding factors.

The last argument that can be made is that the lifespans of deer and humans are dissimilar. The average lifespan of humans is 71 years for males and 78 years for females in this country. In deer, the male's lifespan is 6 years with females living slightly longer (Hayne, 1984, Eberhardt, 1969). White-tailed deer seldom live beyond 20 years of age. This makes the lifespan of humans five to ten times that of deer. When deer are compared to normal children under the age of six, lead levels appear similar.

SEX

This variable has also not been universally established in humans (Okamoto et al., 1985, Rockway et al., 1984, Fujita and Takabatake, 1977, Galster, 1976, Creason et al., 1975, Kelvay, 1973, Petering et al., 1973) and data developed in early studies (late 1960's to early 1970's) would seem to indicate that a sex linked difference was more a function of the greater number of males in the industrial work force than females. Once again this does not seem to be readily applicable to deer since both males and females share the same standing in the community.

A subvariable of sex deserves mention here. Pregnancy and lactation has been shown to effect metal levels in human females (Huel et al., 1984, Rockway et al., 1984, Huel et al., 1981, Fujita & Takabatake, 1977, Galster, 1976, Baumslag et al., 1974, Kelvay, 1973, Mansour et al., 1973). Maternal influence on the levels of metals in fawns could not be evaluated in this study as no information was taken on the reproductive status of the does.

HAIR COLOR

Metal levels in certain individuals have been shown to vary according to hair color. For example, Fletcher (1982) states that "specimens should be separated according to color prior to analysis, as magnesium content varies in hair of different colors."

Several authors also have noted relationships between certain metals and hair color (Okamoto, et al., 1985, Chattopadhyay et al., 1977, Clarke and Wilson, 1974, Hammer et al., 1971, Schroeder and Nason, 1969). Animal to animal variations in white-tailed deer does not seem as extreme as variations in humans. However, a difference in weight was noted for hair strands of varying color and texture. A homogeneous mixture of both white and brown hair was analyzed for each sample in this study.

SUBSTANCES IN THE ENVIRONMENT

Examples of some environmental substances affecting hair are aerosols, cosmetics and detergents. Bleaching and dyeing of hair has been demonstrated to leach out trace metals (Laker, 1982). Other investigators have reported similar results with people using hair sprays, shampoos, permanent formulations, and chemical relaxants (Okamoto et al., 1985, Fletcher, 1982, Laker, 1982, Adeva, 1978, Valkovic et al., 1975, Hilderbrand and White, 1974, Hinners et al., 1974, Wilson et al., 1974, Kelvay, 1970). Accounts must be taken, therefore, when necessary, of the use of hair treatments to avoid spurious results in humans.

This is not to say that all hair preparations remove metals, some in fact have been noted to add irreversibly bound exogenous elements (Valkovic et al., 1975, Wilson et al., 1974, Kelvay, 1970).

It has been suggested that compounds of zinc, selenium, and sometimes tellurium, which are added to certain shampoos may be absorbed into the hair (Laker, 1982, Wibowo et al., 1980). In conjunction with this, factors such as the hardness of the water in one's home or the material used in piping may add metals innocuously into hair.

Besides personal hygiene products, certain medications have been proven to alter metal binding in hair proteins. Fletcher (1982) denotes an influence of oral contraceptives on some hair mineral levels.

Because white-tailed deer are not subject to the same standards of cosmetic vanity as humans, these factors would not seem to have had an influence on the concentrations of lead, cadmium, and mercury reported.

ACCESSIBILITY TO THE ENVIRONMENT

This is perhaps the most valid criticism of the use of hair. That of the samples routinely used in trace metal analyses hair is the most readily accessible to external influences. Some investigators have reported sample contamination due to increased exogenous binding of metals from airborne sources (Limic and Valkovic, 1986, Roberts et al., 1974).

Hair is inherently an oily tissue with dusts adhering to it. Since it is being constantly exposed to exogenous contaminants, any microanalysis for metal content must take into account the possibility that what is measured may not all be metals deposited internally in hair tissue during the growth process within the follicle (Chattopadhyay et al., 1977).

One proposed way of eliminating error due to aerial contamination of hair is to use pubic or axillary hair. Hair from either of these locations would be less strenuously exposed to treatments inflicted by the environment (Hilderbrand and White, 1974).

It is questionable whether selecting pubic or axillary samples in white-tailed deer would eliminate spurious results since most accounts in the literature are due to contamination from industrial releases or job related exposures. Some hair samples used in this study did include pubic and axillary hair strands.

GEOGRAPHIC LOCATION AND SOIL

Cadmium

The geochemistry of cadmium is not completely known, but an outline can be given of some of its essential features (Goldschmidt, 1954).

Eight stable isotopes of cadmium exist in nature, with an estimated abundance of 0.2 g/ton for the earth's crust. Cadmium is mainly distributed in the earth as a guest ion or atom and is fairly accessible as a by-product (Goldschmidt, 1954). Cadmium is produced practically as a by-product of zinc smelting (Day, 1964). The ratio of cadmium to zinc is rather uniform, on the average about 1:500 by weight. Giving an average amount of cadmium in magmatic rocks of 18 ppm, if the average accepted amount of zinc is 80 ppm (Goldschmidt, 1954). Cadmium also may be found in association with calcium and sulphur (Day, 1964, Goldschmidt, 1954).

Lead

There are four natural stable isotopes of lead. At 15 g/ton, lead is a relatively common element in the earth's crust. Lead may well be siderophile but in the accessible crust it is more particularly associated with sulphide bodies. The occurrence and distribution of lead in magmatic rocks is well known. The average concentration being 14 to 20 ppm, and 5 to 10 ppm in limestones. In addition it is important to note that lead is intimately associated with the radioactive decay processes (Day, 1964).

Mercury

Seven stable isotopes of mercury exist in nature. Not much geochemical data are available and there is no certain information as to isotopic variations under natural conditions (Goldschmidt, 1954).

Mercury is relatively abundant for a heavy metal but it must nevertheless be considered among the scarcer of the elements. The estimated value for the earth's crust is about 0.5 g/ton, which is about the same as that of silver (Day, 1964). Concentrations of mercury in nature are extremely few but may be very rich (Day, 1964). As with cadmium and lead, mercury is usually fixed by combination with sulphur (Day, 1964, Goldschmidt, 1954).

Finally, it is argued that since no correlations have been established between concentrations of trace elements in blood and hair, there must be little meaning in the hair concentrations. As already explained earlier, this is a false argument because the timescales reflected by blood and hair are different. Even if the concentrations of the metal in blood are currently at or near normal, prior recent exposure can be documented by determining the concentration of the suspected metal in hair at various distances from the scalp (Hilderbrand and White, 1974).

As mentioned earlier the concentrations of minerals found in hair do not reflect the body's status of minerals at the time the sample is collected, but at some time prior. Therefore, it would be surprising if there were a clear correlation between the concentrations in blood and hair.

CHAPTER VI

SUMMARY, CONCLUSIONS, IMPLICATIONS

Summary

Three hundred and ninety-eight animals were surveyed for their relative levels of three metals with the inclusion of several variables, age, sex, weight, location, and their interactions.

Cadmium values were examined for an age, sex, location, or interaction effects; of these factors, location was the only significant feature at a 95% level (P value of 0.0502).

The preliminary ANOVA table of lead levels seemed to indicate that values differed by age, location, origin age and age sex interactions. However, upon examining frequency distributions of the values, histograms were skewed right and leptokurtic, with some locations and ages having a few very large values. Lead levels were then converted to their logarithms by substituting the values into the following equation, $\log (x + 1)$. This conversion produced a more symmetric distribution of values. The ANOVA table of log lead levels indicated that these values did not differ by age or by location (P value 0.0943 and 0.0784 respectively).

Mercury levels for Ames Plantation, Cades Cove, and Chuck Swan, as determined by the descriptive statistics were zero (median and mode equal to zero). Values for Oak Ridge were more widely dispersed as evidenced by the frequency histogram. An individual ANOVA table of mercury levels for Oak Ridge indicated that neither sex, age, or sex age interaction affected mercury levels. Bonferroni comparisons were done with individual confidence levels of 0.99 and an overall level of 0.94. These calculations showed a significant difference between Oak Ridge and all other locations, in addition a difference was noticed between Ames Plantation and Chuck Swan WMA based upon the mean.

Conclusion

Of the four populations of white-tailed deer studied cadmium, lead, and mercury levels as determined seemed to indicate that these animals were not exposed to possible sources of external contamination. With the exception of mercury in the white-tailed deer of Oak Ridge, the concentrations of each metal seemed to represent the relative natural [background] exposure, that an animal living within each of these microenvironments would be subjected to normally.

The following explanation is given for the variation between cadmium results in eastern and western locations. Since none of the four study locations contained industrial sources and each lies outside the reach of aerial borne cadmium contamination, the most probable source is the soil. As was discussed earlier cadmium is found in association with several other minerals, one of the most prevalent being zinc (Day, 1964, Goldschmidt, 1954). Geologic maps of the State of Tennessee (Dept. of Education, Div. of Geology, 1922) demonstrating the location of zinc mines, prospects, and their relation to geologic formations revealed that the three eastern locations, Cades Cove, Chuck Swan, and Oak Ridge, are underlain with formations of the lower Ordovician and uppermost Cambrian. The predominate make up of which is Knox dolomite, limestones, and shales containing moderate amounts of zinc ore. Ames Plantation in the western part of the state is underlain by Carboniferous and Devonian formations composed of several types of silt and clay loam, that contain no zinc ores. Thus the difference in cadmium levels noted may reflect the distribution of zinc deposits.

In addition to cadmium results lead levels also seemed to differ between eastern and western locations, again geological formations within the areas can be used to explain part of the difference.

Two lead ores , galena and cerussite are found in East Tennessee. The composition of galena is 86.6% lead, 13.4% sulphur; 83.5% lead oxide, 16.5% carbon dioxide, or 77.3% metallic lead for cerussite. Galena occurs in more or less abundance in several localities in East Tennessee and is practically always associated with zinc minerals. There were several old mines in Bradley, Fleknor, Jefferson and Union Counties that principally mined galena (Secrist, 1924). Little or no lead ore is found in the formations of southwest Tennessee.

Deer at the Oak Ridge reservation were slightly higher in lead content than animals from either of the other two eastern locations. This difference might be attributable to additional sources of lead such as stable end products of radioactive families, ^{206}Pb , ^{207}Pb , and ^{208}Pb . Also Oak Ridge is a more industrialized area as compared to either Cades Cove or Chuck Swan, supporting a larger volume of vehicular traffic which again may account for the higher levels measured.

Mercury levels for Ames Plantation, Cades Cove, and Chuck Swan had a median value of zero. None of these three areas had possible sources of mercury, either in the form of natural deposits or industrial waste. Oak Ridge animals proved to have had a significant level of mercury in comparison. A detectable amount of mercury residue is present in the sedimentary soil layer at Oak Ridge.

No significance was attributable to the regression correlation of metal levels in individual animals. Neither was there a significant difference between animals of different ages or sex. This might have been caused by the low levels of each metal in individual animals. Further it may be probable that animals of a higher metal burden would demonstrate age and sex related differences in retention described by other researchers.

Implications

Hair has been increasingly considered a valuable tissue for monitoring ingestion of toxic heavy metals (Chattopadhyay et al., 1977, Corridan, 1974). In the past, hair has been used to estimate body burden of mercury in poisoning cases in Japan (Tsubaki, 1971), Iraq (Al-shahristani and Al-Haddad, 1973, Clarkson, 1973), and the United States (Jervis and Tiefenbach, 1971, Jervis et al., 1970). In addition, hair has also been used as a criteria to distinguish children with increased body burdens of lead (Pueschel, 1974, Kopito et al., 1969 and 1967).

In most of these circumstances persistent and cumulative metals such as lead, cadmium, and mercury were ingested in either single massive or irregular doses.

In such cases blood levels of these metals inaccurately reflect total body burden. This would seem to leave hair as a viable alternative for monitoring living subjects.

It has been demonstrated in this paper that hair samples of white-tailed deer are relatively easy to collect, inexpensively analyzed, and are not subject to the same pitfalls that have been associated with human samples.

From the work undertaken in this project it is evident that using hair from animals such as white-tailed deer, is a viable means of readily assessing the influence of environmental lead, cadmium, and mercury on community body burdens. Since initial background concentrations were established additional samplings could be used to monitor potential contamination from emissions and distributions of future pollutants.

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A P P E N D I C E S

A P P E N D I X A

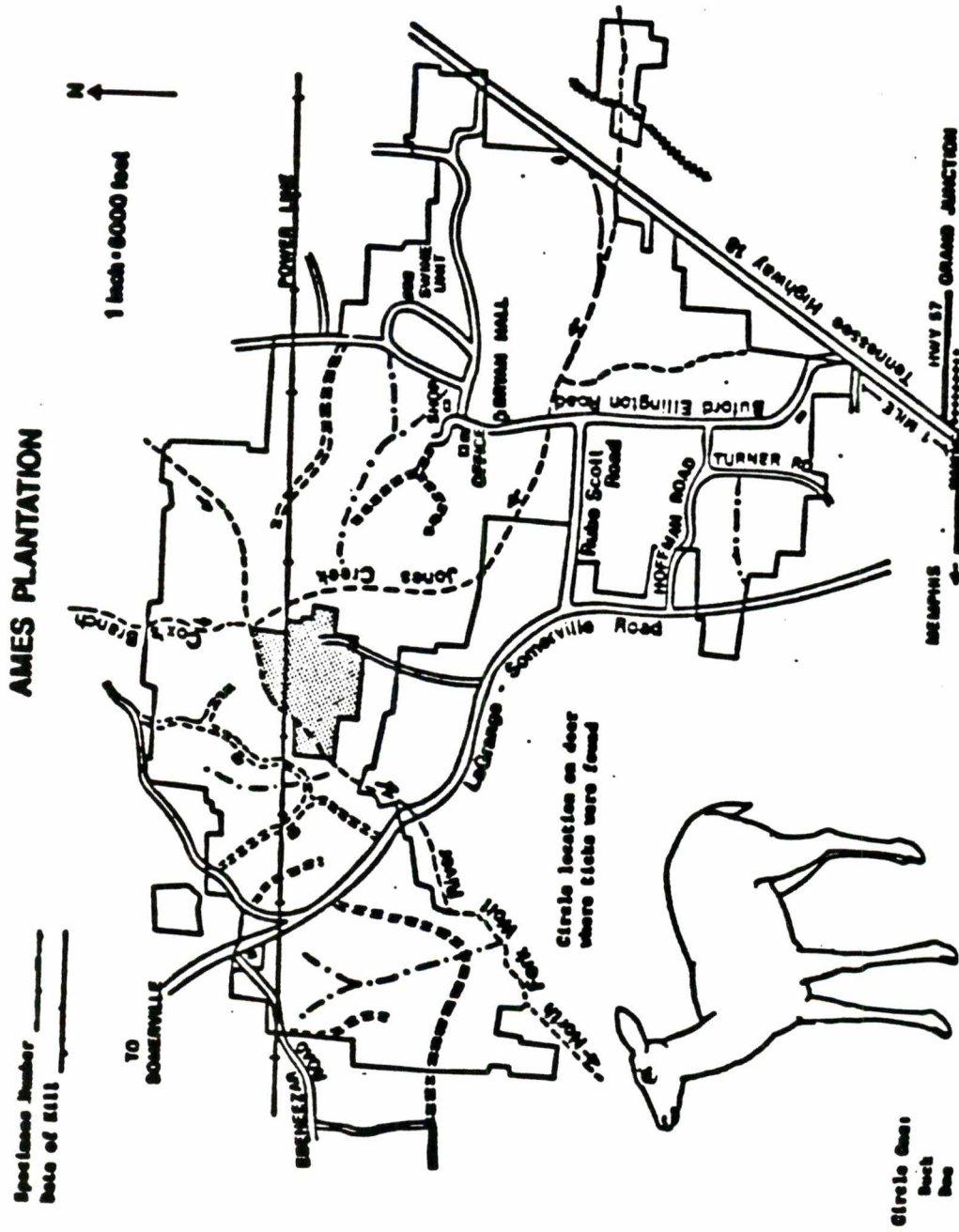


Fig. A 2.1. Combination Data Sheet And Locational Map Of The Hobart Ames Plantation supplied To Hunters For The 1986 Hunting Season.

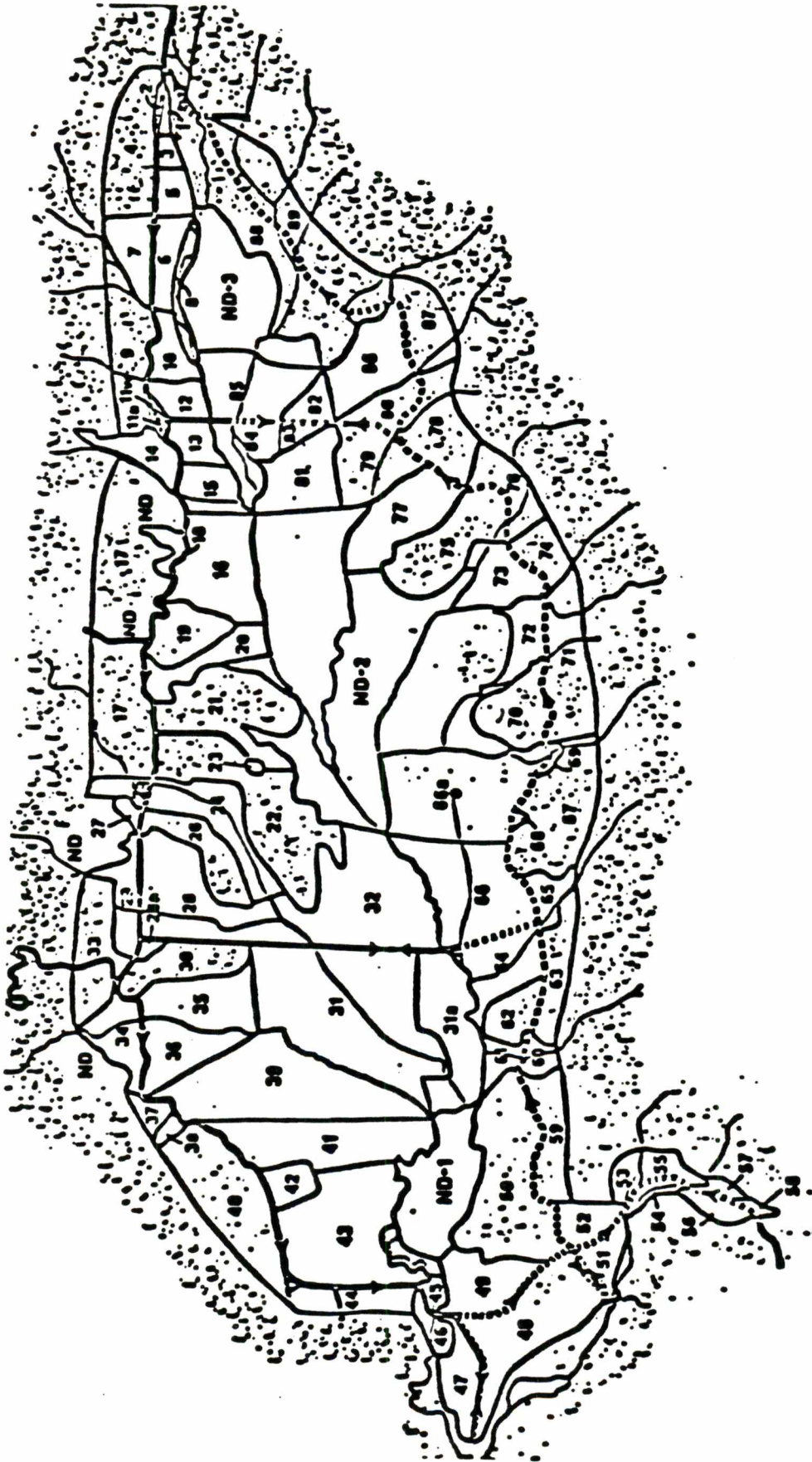


Fig. A 2.2. Locational Map, Cades Cove, Great Smoky Mountains National Park, Tennessee, Illustrating Area Identification Numbers.

UPLANDS FIELD RESEARCH LABORATORY
WHITE-TAILED DEER PROJECT
GSMNP

DATE: _____ SEX: _____ RECORDERS: _____

DEER #: _____ AGE: _____ LOCATION: _____

RECAPTURE _____ WEIGHT: _____

RADIOCOLLAR: FREQUENCY _____ COLOR _____ NUMBER _____

CONDITION:

REPRODUCTIVE CONDITION: LACTATING yes/no PREGNANT yes/no

GENERAL CONDITION: ECTOPARASITES _____
COMMENTS _____

SAMPLES & PARAMETERS:

BLOOD	RESPIRATION _____	ECTOPARASITES _____
RED TOPS _____	PULSE _____	HAIR _____
PURPLE TOPS _____	RECTAL T _____	OTHER _____

MEDICAL INTERVENTION:

DRUG	DOSE	COMMENTS
_____	_____	_____
_____	_____	_____
_____	_____	_____

OUTCOME

IMPROVED _____ RECOVERED _____ DIED, NECROPSY _____ DIED, NO _____

IMMOBILIZATION DRUG:	DOSE	TIME INJECTED	TIME ATAXIC	TIME DOWN	COMMENTS
_____	_____	_____	_____	_____	_____

XYLAZINE _____
ATROPINE _____
SUCCINYL CHOLINE _____

REVERSAL DRUG:	DOSE	TIME INJECTED	TIME STANDING	TIME RECOVERED	COMMENT
_____	_____	_____	_____	_____	_____

YOHIMBINE _____
4-AMINOPYRIDINE _____

COMMENTS: _____

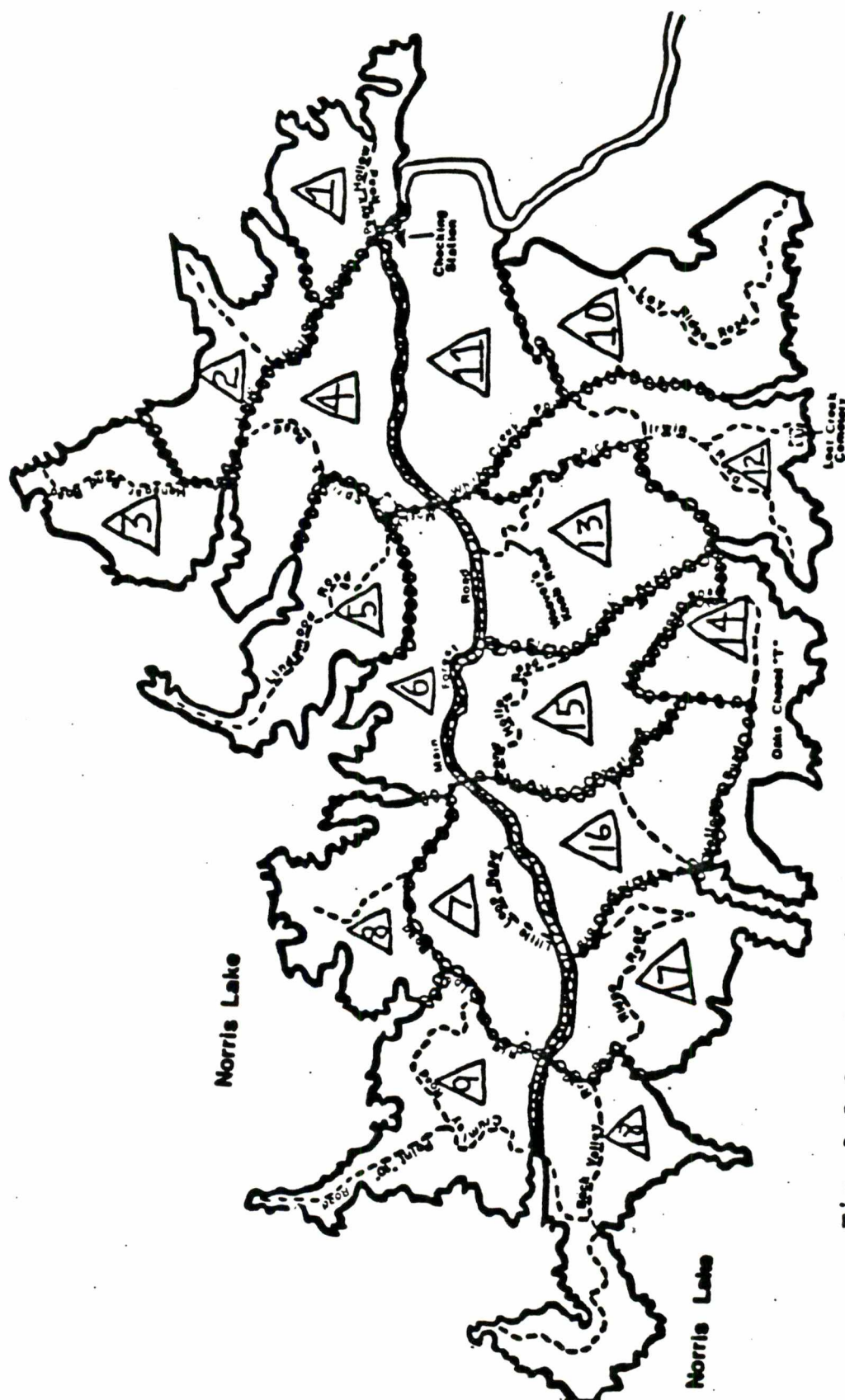


Fig. A 2.3. Locational Map, Chuck Swan Wildlife Management Area, Tennessee, Illustrating Area Identification Numbers, Roads And Buildings

A P P E N D I X B

Instrumental Parameters For The Determination
of Cadmium in White-tailed Deer Hair.

LIGHT SOURCE : Hollow Cathode Lamp, Visimax II # 62933
LAMP CURRENT : 3 milliamps
WAVELENGTH : 228.8 nm
SLIT WIDTH : 320
ANALYSIS MODE : Double beam, D2 background correction
READOUT MODE : Peak Height
INTERGRATION TIME : Six seconds
DELAY TIME : Seven seconds
PURGE GAS : Argon
AUTO CLEAN : Yes
OPERATION MODE : Non-pressurized

ATOMIZATION	DRY				PYROLYSIS	
INDICATED TEMPERATURE :	130	225	250	275	1400	1500
TIME SETTING (SECONDS) :	0	10	30	30	10	0
FURNACE GEOMETRY :	Uncoated round graphite					

Source: Allied Analytical Systems, Atomic Absorption
Methods Manual, volume # 2, Flameless Operations,
May, 1981.

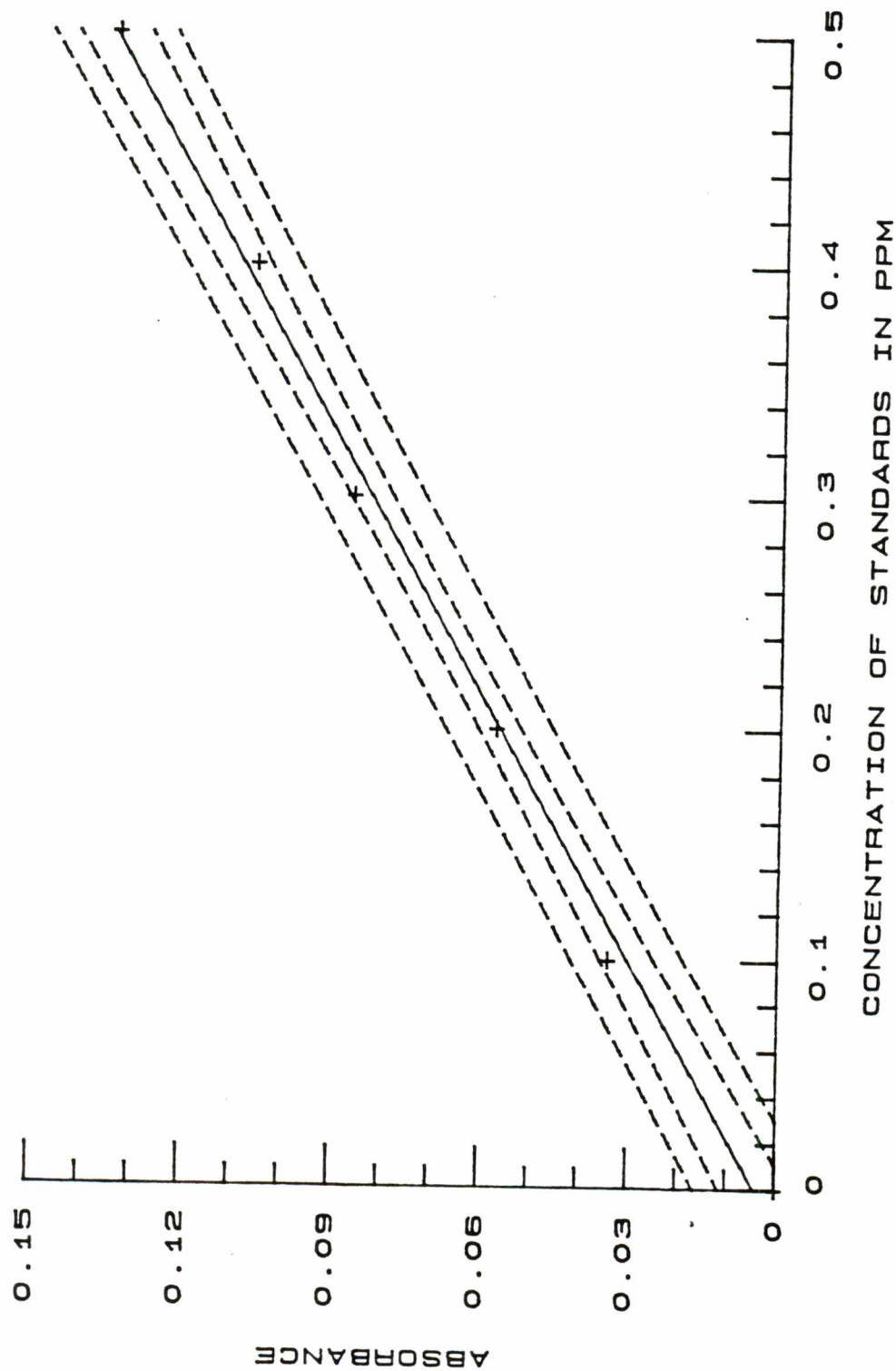


Fig. B 3.1. Standard Six Point Calibration Curve Used For The Determination Of Cadmium In Unknown Hair Samples. Dotted Lines Represent The Areas Of 95 % Confidence And 95 % Prediction Limits.

Instrumental Parameters For The Determination
of Lead in White-tailed Deer Hair.

LIGHT SOURCE : Hollow Cathode Lamp, Visimax II # 62927
 LAMP CURRENT : 5 milliamps
 WAVELENGTH : 283.3 nm
 SLIT WIDTH : 320
 ANALYSIS MODE : Double beam, D2 background correction
 READOUT MODE : Peak height
 INTERGRATION TIME : Six seconds
 DELAY TIME : Seven seconds
 PURGE GAS : Argon
 AUTO CLEAN : Yes
 OPERATION MODE : Non-pressurized

	DRY				PYROLYSIS	
ATOMIZATION						
INDICATED TEMPERATURE :	120	130	500	600	2000	2000
TIME SETTING (SECONDS) :	0	15	15	15	5	5
FURNACE GEOMETRY :	Uncoated round graphite					

Source: Allied Analytical Systems, Atomic Absorption
 Methods Manual, volume # 2, Flameless Operations,
 May, 1981.

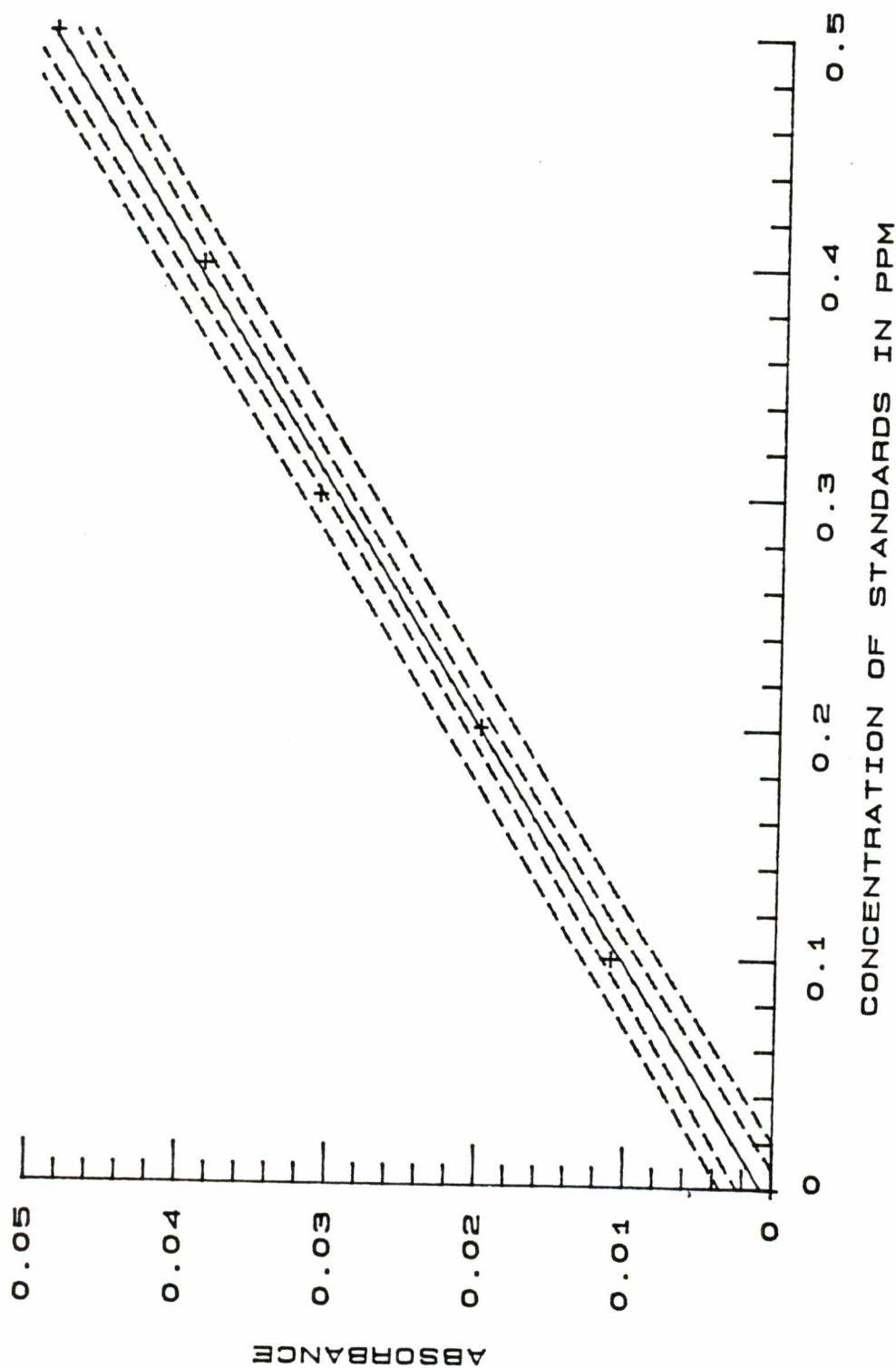


Fig. B 3.2. Standard Six Point Calibration Curve Used For The Determination Of Lead In Unknown Hair Samples. Dotted Lines Represent The Areas Of 95 % Confidence And 95 % Prediction Limits.

Instrumental Parameters For The Determination
of Mercury in White-tailed Deer Hair.

LIGHT SOURCE : Hollow Cathode Lamp, **Fisher** # F-121

LAMP CURRENT : 3-10 milliamps

WAVELENGTH : 251 nm

SLIT WIDTH : Fixed

ANALYSIS MODE : Double beam, Iron reference lamp

READOUT MODE : Peak height

INTERGRATION TIME : Continuous

DELAY TIME : None

PURGE GAS : Argon, 200 ml/min.

AUTO CLEAN : No

OPERATION MODE : Non-pressurized

DRY PYROLYSIS ATOMIZATION

INDICATED TEMPERATURE : Ambient room temperature

TIME SETTING (SECONDS) : Continuous

FURNACE GEOMETRY : Cold Vapor Technique

Source: Fisher Mercury Analyzer, Instrument Manual,
Fisher Scientific Company, Pittsburg,
Pennsylvania.

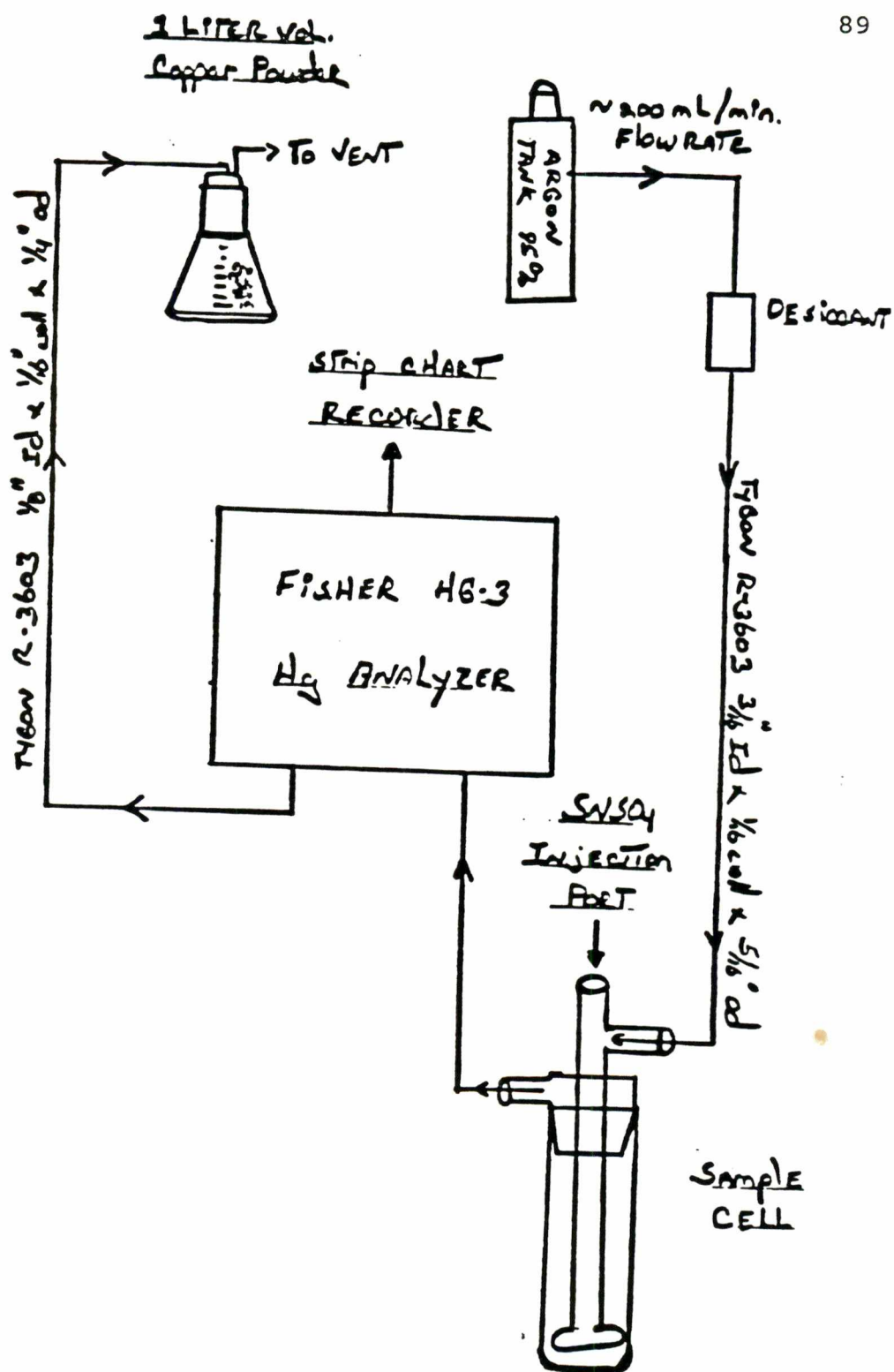


Fig. B 3.3. Diagram Of Mercury Determination Vessel And Associated Cold Vapor Atomic Absorption Spectrophotometric Hardware.

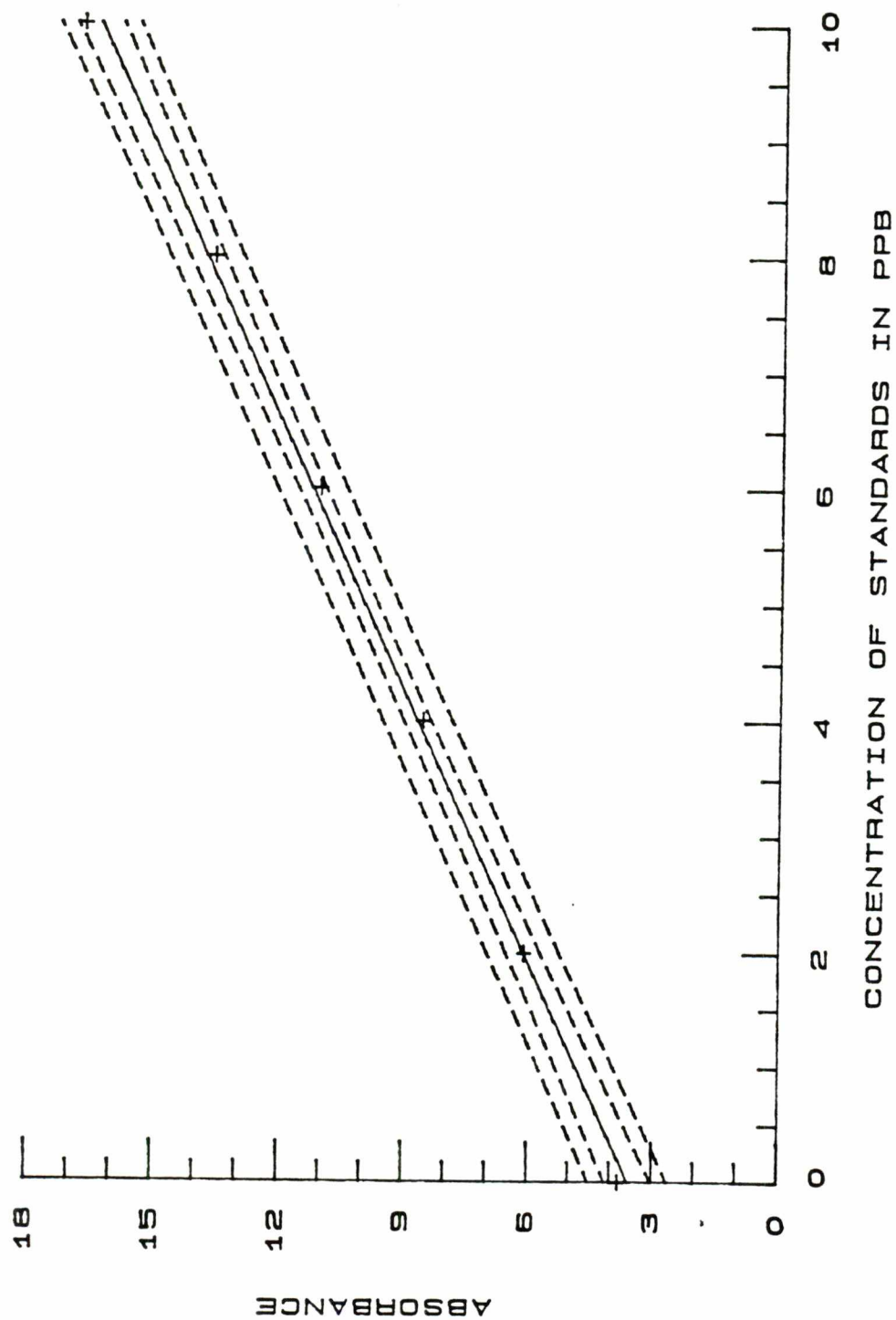


Fig. B 3.4. Standard Six Point Calibration Curve Used For The Determination Of Mercury In Unknown Hair Samples. Dotted Lines Represent The Areas Of 95 % Confidence And 95 % Prediction Limits.

A P P E N D I X C

Table C 4.1. Cadmium, Lead, And Mercury Levels In The Hair Of White-tailed Deer From Four Areas In Tennessee.

	METAL		
	CADMIUM	LEAD	MERCURY
	(ppm)	(ppm)	(ppb)
Sample Size	398	398	398
Mean	0.44	2.49	2.13
Median	0.16	1.10	0.00
Mode	0.00	0.00	0.00
Geometric Mean	0.00	0.00	0.00
Variance	0.10	3.93	2.60
Standard Deviation	1.00	6.27	5.10
Standard Error	0.05	0.31	0.25
Minimum	0.00	0.00	0.00
Maximum	9.67	87.63	63.00
Skewness	5.42	8.91	5.36
Kurtosis	35.23	102.15	51.60

Table C 4.2. Multifactorial Analysis Of Variance Of White-tailed Deer From Tennessee, Based On Cadmium Level Present And Its Relation To Geographic Location , Age, Sex, Origin/Age, Origin/Sex, And Age/Sex Interactions.

DEPENDENT VARIABLE: CADMIUM					
SOURCE	DF	S.S.	M.S.	F VALUE	PR > F
MODEL	21	30.219	1.439	1.25	0.2063
ERROR	272	312.101	1.147		
CORRECTED TOTAL	293	342.321			

SOURCE	DF	TYPE III SS	F VALUE	PR > F
ORIGIN	2	6.94030048	3.02	0.0502
AGE	4	3.87120873	0.84	0.4986
SEX	1	0.02965108	0.03	0.8724
ORIGIN - AGE	8	15.5151197	1.69	0.1007
ORIGIN - SEX	2	6.10856445	2.66	0.0716
AGE - SEX	4	9.99645099	2.18	0.0717

Table C 4.3. Multifactorial Analysis Of Variance Of White-tailed Deer From Tennessee, Based On Lead Level Present And Its Relation To Geographic Location , Age, Sex, Origin/Age, Origin/Sex, And Age/Sex Interactions.

DEPENDENT VARIABLE: LEAD

SOURCE	DF	S.S.	M.S.	F VALUE	PR > F
MODEL	21	3227.47	153.689	3.56	0.0001
ERROR	272	11738.7	43.1572		
CORRECTED TOTAL	293	14966.2			

SOURCE	DF	TYPE III SS	F VALUE	PR > F
ORIGIN	2	619.1624878	7.17	0.0009
AGE	4	1026.162997	5.94	0.0001
SEX	1	39.05417391	0.90	0.3423
ORIGIN - AGE	8	982.5851964	2.85	0.0047
ORIGIN - SEX	2	67.94548157	0.79	0.4562
AGE - SEX	4	469.8349405	2.72	0.0300

Table C 4.4. Multifactorial Analysis Of Variance Of White-tailed Deer From Tennessee, Based On Logarithm Of Lead Present And Its Relation To Geographic Location, Age, Sex, Origin/Age, Origin/Sex, And Age/Sex Interactions.

DEPENDENT VARIABLE: LOG LEAD					
SOURCE	DF	S.S	M.S.	F VALUE	PR > F
MODEL	21	2.7537	0.13113	1.30	0.1761
ERROR	272	27.507	0.10112		
CORRECTED TOTAL	293	30.260			

SOURCE	DF	TYPE III SS	F VALUE	PR > F
SEX	1	0.00053261	0.01	0.9422
AGE	4	0.81046838	2.00	0.0943
ORIGIN	2	0.51975017	2.57	0.0784
SEX - AGE	4	0.63615269	1.57	0.1818
SEX - ORIGIN	2	0.01730482	0.09	0.9180
AGE - ORIGIN	8	0.71474076	0.88	0.5308

Table C 4.5. Multifactorial Analysis Of Variance Of White-tailed Deer From Oak Ridge, Tennessee, Based On The Level Of Mercury Present And Its Relation To Geographic Location, Age, Sex, Origin/Age, Origin/Sex, And Age/Sex Interactions.

DEPENDENT VARIABLE: MERCURY					
SOURCE	DF	S.S.	M.S.	F VALUE	PR > F
MODEL	9	46.636	5.18184	0.20	0.9934
ERROR	90	2308.3	25.6480		
CORRECTED TOTAL	99	2354.9			

SOURCE	DF	TYPE III SS	F VALUE	PR > F
SEX	1	15.51113904	0.60	0.4388
AGE	4	27.93792970	0.27	0.8951
SEX - AGE	4	17.74705672	0.17	0.9517

Table C 4.6. Levels Of Cadmium, Lead And Mercury Found In White-tailed Deer From The Hobart Ames Plantation, West Tennessee, 1986.

	METALS		
	CADMIUM	LEAD	MERCURY
	(ppm)	(ppm)	(ppb)
Sample size	100	100	100
Mean	0.17	1.07	0.21
Median	0.07	0.53	0.00
Mode	0.00	0.00	0.00
Geometric Mean	0.00	0.00	0.00
Variance	0.008	0.37	0.06
Standard Deviation	0.28	1.92	0.81
Standard Error	0.02	0.19	0.08
Minimum	0.00	0.00	0.00
Maximum	1.69	9.58	5.48
Skewness	3.12	3.28	4.51
Kurtosis	11.4	10.8	22.2

Table C 4.7. Levels Of Cadmium, Lead And Mercury Found In White-tailed Deer From Cades Cove GSMNP, Tennessee, 1980-1982.

	METALS		
	CADMIUM	LEAD	MERCURY
	(ppm)	(ppm)	(ppb)
Sample size	103	103	103
Mean	0.64	2.21	1.21
Median	0.26	1.30	0.00
Mode	0.00	1.10	0.00
Geometric Mean	0.00	0.00	0.00
Variance	1.48	31.2	43.5
Standard Deviation	1.22	5.58	6.59
Standard Error	0.12	0.55	0.65
Minimum	0.00	0.00	0.00
Maximum	6.90	56.1	63.0
Skewness	3.37	9.01	8.46
Kurtosis	11.5	87.1	77.6

Table C 4.8. Levels Of Cadmium, Lead And Mercury Found In White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.

	METALS		
	CADMIUM	LEAD	MERCURY
	(ppm)	(ppm)	(ppb)
Sample size	95	95	95
Mean	0.47	2.46	1.71
Median	0.18	1.69	0.00
Mode	0.00	0.00	0.00
Geometric Mean	0.00	0.00	0.00
Variance	1.39	11.6	20.4
Standard Deviation	1.18	3.40	4.51
Standard Error	0.12	0.35	0.46
Minimum	0.00	0.00	0.00
Maximum	9.67	20.2	22.0
Skewness	5.95	3.54	2.60
Kurtosis	41.9	15.1	6.07

Table C 4.9. Levels Of Cadmium, Lead And Mercury Found In White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee, 1986.

	METALS		
	CADMIUM	LEAD	MERCURY
	(ppm)	(ppm)	(ppb)
Sample size	100	100	100
Mean	0.47	4.25	5.41
Median	0.22	1.33	5.53
Mode	0.10	0.00	0.00
Geometric Mean	0.00	0.00	0.00
Variance	0.10	10.6	2.38
Standard Deviation	1.00	10.3	4.88
Standard Error	0.10	1.03	0.48
Minimum	0.00	0.00	0.00
Maximum	7.99	87.6	17.0
Skewness	5.68	6.12	0.42
Kurtosis	37.2	45.4	-0.88

Table C 4.10. Mean White-tailed Deer Weights By Age
For Three Areas Of East Tennessee.

AGE	CADES COVE	CHUCK SWAN	OAK RIDGE	
MALES	-----	42.6	55.9	
FEMALES	65.0	36.0	52.8	0.5
AVERAGE	65.0	38.4	53.9	
MALES	71.3	64.7	90.9	
FEMALES	75.2	57.1	81.5	1.5
AVERAGE	74.1	61.6	87.7	
MALES	105.2	74.0	110.2	
FEMALES	89.1	68.4	87.8	2.5
AVERAGE	92.3	71.2	97.7	
MALES	119.0	87.2	127.3	
FEMALES	92.9	66.8	96.3	3.5
AVERAGE	94.6	71.9	105.6	
MALES	146.5	111.0	138.0	
FEMALES	90.8	63.7	92.0	4.5
AVERAGE	103.2	79.5	122.7	
MALES	155.0	----	111.0	
FEMALES	104.2	86.2	91.5	5.5
AVERAGE	121.2	86.2	98.0	
MALES	----	82.0	----	
FEMALES	91.7	61.7	----	6.5
AVERAGE	91.7	66.7	----	

Note: The average weight for an animal in the study was 80.3 pounds (36.5 kilograms). These numbers do not include animals from Ames Plantation since weights were not available for this group.

Average Age In Years Of The White-tailed
Deer In Study, Eastern Tennessee.

Cades Cove

Age in Years

males 1.5 (+) *
females 1.5 (+) *

average 1.5 (+) *

Chuck Swan

males 1.96
females 2.64

average 2.38

Oak Ridge

males 2.08
females 2.25

average 2.16

Note: The average age of study animals was 2.55 years,
2.38 for males and 2.67 for females. These numbers
do not include animals from Ames Plantation since
ages were not available for this group.

* See note page 120.

Bonferroni Analyses Demonstrating The Significant
Differences Between The Four Areas of Study

	<u>$\bar{X}$</u>	<u>S</u>	<u>N</u>
Ames Plantation	0.2082	0.8073	100
Cades Cove	1.2235	6.6930	103
Chuck Swan	1.6225	4.4570	95
Oak Ridge	5.4154	4.8772	100

Ames Plantation vs Cades Cove

$$(1.2235 - 0.2082) \pm 2.576 \sqrt{\frac{(0.8073)^2}{100} + \frac{(6.6930)^2}{100}}$$

$$1.0153 \pm 1.7366 = (-0.7213, 2.7519)$$

Ames Plantation vs Chuck Swan

$$(1.6225 - 0.2082) \pm 2.576 \sqrt{\frac{(0.8073)^2}{100} + \frac{(4.4570)^2}{100}}$$

$$1.4143 \pm 1.2023 = (0.2120, 2.6166)$$

Cades Cove vs Chuck Swan

$$(1.6225 - 1.2235) \pm 2.576 \sqrt{\frac{(6.6930)^2}{100} + \frac{(4.4570)^2}{100}}$$

$$0.3990 \pm 2.0714 = (-1.6724, 2.4704)$$

Bonferroni Analyses Demonstrating The Significant Differences Between The Four Areas of Study (cont.)

Oak Ridge vs Ames Plantation

$$(5.4154 - 0.2082) \pm 2.576 \sqrt{\frac{(0.8073)^2}{100} + \frac{(4.8772)^2}{100}}$$

$$5.2072 \pm 1.2735 = (3.9337, 6.4807)$$

Oak Ridge vs Cades Cove

$$(5.4154 - 1.2235) \pm 2.576 \sqrt{\frac{(6.6930)^2}{100} + \frac{(4.8772)^2}{100}}$$

$$4.1919 \pm 2.1333 = (2.0586, 6.3252)$$

Oak Ridge vs Chuck Swan

$$(5.4154 - 1.6225) \pm 2.576 \sqrt{\frac{(4.4570)^2}{100} + \frac{(4.8772)^2}{100}}$$

$$3.7929 \pm 1.1571 = (2.6358, 4.9500)$$

**The Regression Analysis Of Lead Levels On Cadmium
Levels For All Animals In The Study.**

Dependent variable: Lead

Independent variable: Cadmium

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.244646	0.343689	7.11823	5.14877E-12
Slope	0.117316	0.31353	0.374178	0.708472

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	R-Ratio	Prob. Level
Model	.0552125	1	.0552125	.1400093	.70847
Error	156.16204	396	.39435		
Total (Corr.)	156.21725	397			

Correlation Coefficient = 0.0187998
 Std. Error of Est. = 0.627972
 R-squared = .04 percent

**The Regression Analysis Of Lead Levels On Mercury
Levels For All Animals In the Study.**

Dependent variable: Lead

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.237538	0.0340968	6.96656	1.35927E-11
Slope	0.057501	0.0617357	0.931406	0.352211

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	.3414771	1	.3414771	.8675172	.35221
Error	155.87578	396	.39363		
Total (Corr.)	156.21725	397			

Correlation Coefficient = 0.0467537
 Stnd. Error of Est. = 0.627396
 R-squared = .22 percent

**The Regression Analysis Of Cadmium Levels On
Mercury Levels For All Animals In The Study.**

Dependent variable: Cadmium

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.0476267	5.44972E-3	8.73929	2.35367E-14
Slope	-0.0169467	9.86725E-3	-1.71747	0.0866753

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F-Ratio	Prob. Level
Model	.0296607	1	.029667	2.9497005	.08668
Error	3.98198	396	.01006		
Total (Corr.)	4.01164	397			

Correlation Coefficient = -0.0859864
 Stnd. Error of Est. = 0.100277
 R-squared = .74

A P P E N D I X D

Table D 4.1. Number Of White-Tailed Deer By Sex Sampled
From Ames Plantation, Tennessee.

S E X	MALES	49
	FEMALES	33
	UNKNOWN	18
	TOTAL	100

**Frequency Tabulation Of The Distribution Of Cadmium Values In
PPM For White-Tailed Deer From Ames Plantation, Tennessee.**

	Lower Class Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		0.000		28	.2800	28	.280
1	0.000	0.100	0.0500	30	.3000	58	.580
2	0.100	0.200	0.1500	20	.2000	78	.780
3	0.200	0.300	0.2500	6	.0600	84	.840
4	0.300	0.400	0.3500	2	.0200	86	.860
5	0.400	0.500	0.4500	6	.0600	92	.920
6	0.500	0.600	0.5500	1	.0100	93	.930
7	0.600	0.700	0.6500	2	.0200	95	.950
8	0.700	0.800	0.7500	1	.0100	96	.960
9	0.800	0.900	0.8500	1	.0100	97	.970
10	0.900	1.000	0.9500	0	.0000	97	.970
11	1.000	1.100	1.0500	0	.0000	97	.970
12	1.100	1.200	1.1500	0	.0000	97	.970
13	1.200	1.300	1.2500	2	.0200	99	.990
14	1.300	1.400	1.3500	0	.0000	99	.990
15	1.400	1.500	1.4500	0	.0000	99	.990
16	1.500	1.600	1.5500	0	.0000	99	.990
17	1.600	1.700	1.6500	1	.0100	100	1.000
18	1.700	1.800	1.7500	0	.0000	100	1.000
19	1.800	1.900	1.8500	0	.0000	100	1.000
20	1.900	2.000	1.9500	0	.0000	100	1.000
above	2.000			0	.0000	100	1.000

Mean = 0.170

Standard Deviation = 0.285

Median = 0.07

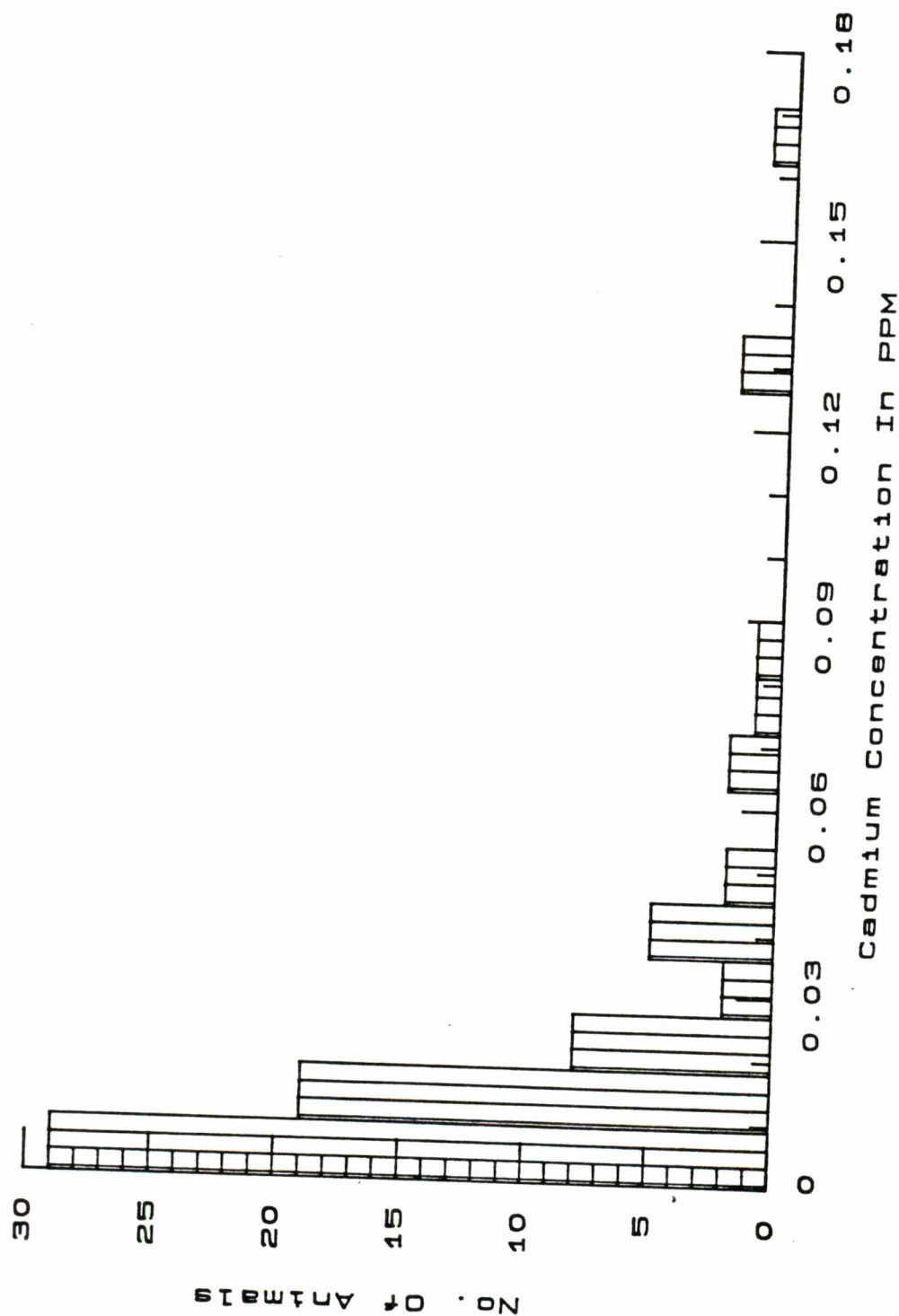


Fig. D 4.1. The Distribution Of Cadmium Levels For White-tailed Deer From The Hobart Ames Plantation, Tennessee, 1986.

Frequency Tabulation Of The Distribution Of Lead Values In
PPM For White-Tailed Deer From Ames Plantation, Tennessee.

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		0.000		20	.2000	20	.200
1	0.000	0.500	0.250	30	.3000	50	.500
2	0.500	1.000	0.750	27	.2700	77	.770
3	1.000	1.500	1.250	9	.0900	86	.860
4	1.500	2.000	1.750	3	.0300	89	.890
5	2.000	2.500	2.250	2	.0200	91	.910
6	2.500	3.000	2.750	1	.0100	92	.920
7	3.000	3.500	3.250	0	.0000	92	.920
8	3.500	4.000	3.750	2	.0200	94	.940
9	4.000	4.500	4.250	0	.0000	94	.940
10	4.500	5.000	4.750	0	.0000	94	.940
11	5.000	5.500	5.250	0	.0000	94	.940
12	5.500	6.000	5.750	0	.0000	94	.940
13	6.000	6.500	6.250	2	.0200	96	.960
14	6.500	7.000	6.750	1	.0100	97	.970
15	7.000	7.500	7.250	0	.0000	97	.970
16	7.500	8.000	7.750	0	.0000	97	.970
17	8.000	8.500	8.250	0	.0000	97	.970
18	8.500	9.000	8.750	0	.0000	97	.970
19	9.000	9.500	9.250	2	.0200	99	.990
20	9.500	10.000	9.750	1	.0100	100	1.000
above 10.000				0	.0000	100	1.000

Mean = 1.070

Standard Deviation = 1.926

Median = 0.535

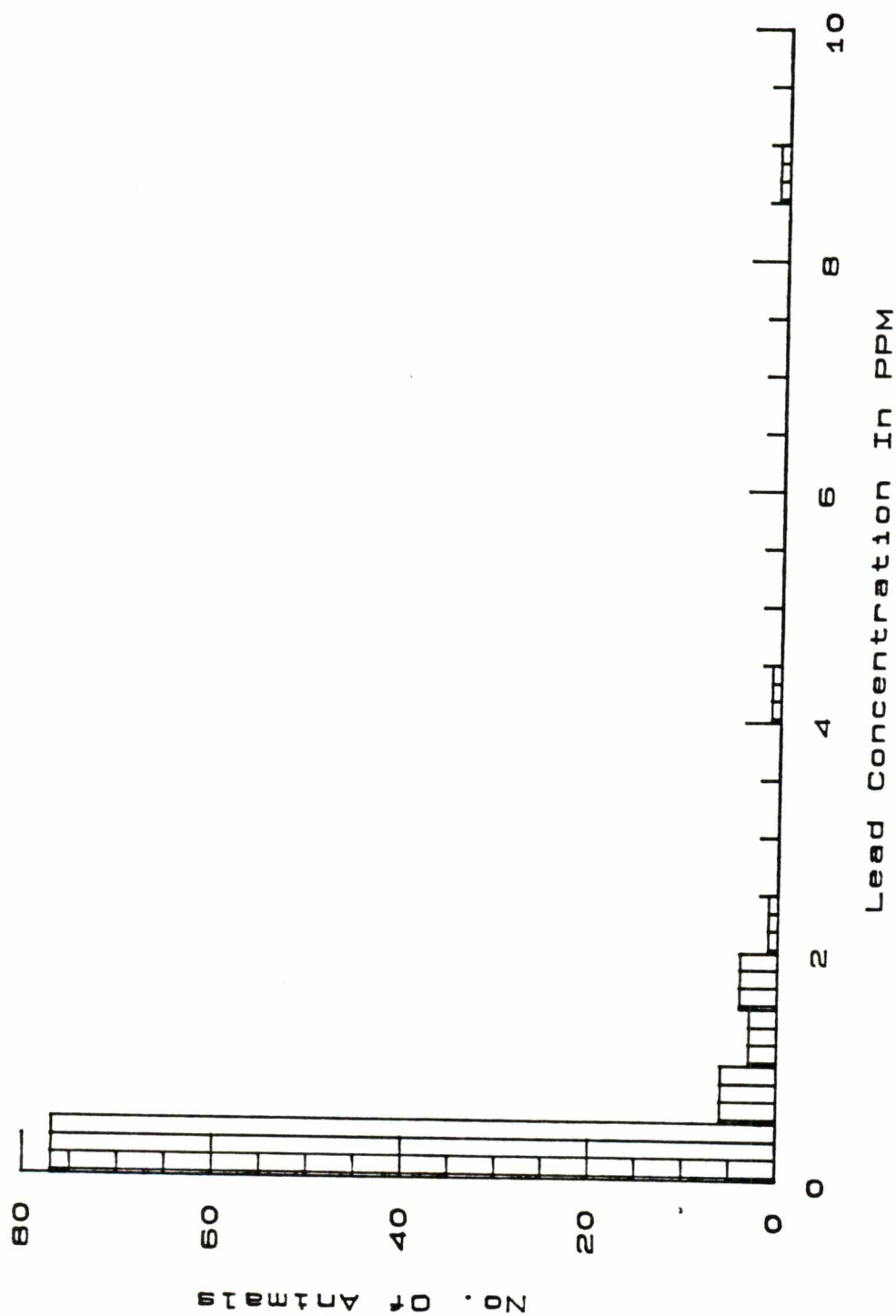


Fig. D 4.2. The Distribution Of Lead Levels For White-tailed Deer From The Hobart Ames Plantation, Tennessee, 1986.

**Frequency Tabulation Of The Distribution Of Mercury Values
In PPB For White-Tailed Deer From Ames Plantation, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below	0.000			92	.9200	92	.920
1	0.000	0.300	0.150	0	.0000	92	.920
2	0.300	0.600	0.450	0	.0000	92	.920
3	0.600	0.900	0.750	0	.0000	92	.920
4	0.900	1.200	1.050	2	.0200	94	.940
5	1.200	1.500	1.350	0	.0000	94	.940
6	1.500	1.800	1.650	0	.0000	94	.940
7	1.800	2.100	1.950	1	.0100	95	.950
8	2.100	2.400	2.250	1	.0100	96	.960
9	2.400	2.700	2.550	1	.0100	97	.970
10	2.700	3.000	2.850	0	.0000	97	.970
11	3.000	3.300	3.150	2	.0200	99	.990
12	3.300	3.600	3.450	0	.0000	99	.990
13	3.600	3.900	3.750	0	.0000	99	.990
14	3.900	4.200	4.050	0	.0000	99	.990
15	4.200	4.500	4.350	0	.0000	99	.990
16	4.500	4.800	4.650	0	.0000	99	.990
17	4.800	5.100	4.950	0	.0000	99	.990
18	5.100	5.400	5.250	0	.0000	99	.990
19	5.400	5.700	5.550	1	.0100	100	1.000
20	5.700	6.000	5.850	0	.0000	100	1.000
above	6.000			0	.0000	100	1.000

Mean = 0.208

Standard Deviation = 0.807

Median = 0.00

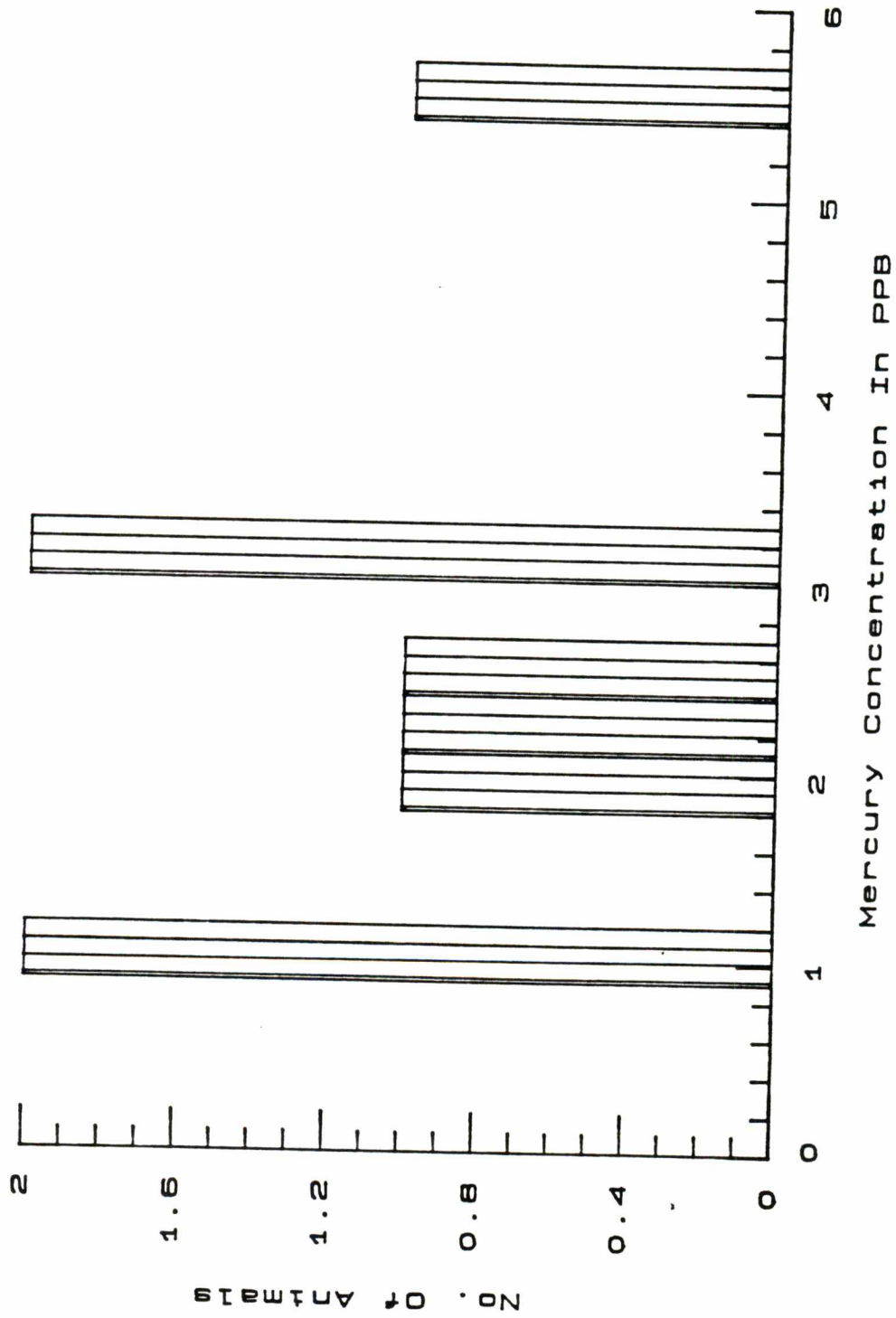


Fig. D 4.3. The Distribution Of Mercury Levels For White-tailed Deer From The Hobart Ames Plantation, Tennessee, 1986.

**The Regression Analysis Of Lead Levels On Cadmium Levels
For Animals From The Hobart Ames Plantation, Tennessee.**

Dependent variable: Lead

Independent variable: Cadmium

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.122642	0.022376	5.48098	3.28704E-7
Slope	-0.912207	0.675392	-1.35063	0.179923

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	.0671170	1	.0671170	1.8242106	.17992
Error	3.605650	98	.036792		
Total (Corr.)	3.672767	99			

Correlation Coefficient = -0.135182
 Std. Error of Est. = 0.191813
 R-squared = 1.83 percent

**The Regression Analysis Of Lead Levels On Mercury Levels
For Animals From The Hobart Ames Plantation, Tennessee.**

Dependent variable: Lead

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.100352	0.0198145	5.0646	1.92327E-6
Slope	0.323135	0.238784	1.35325	0.179089

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	.0673724	1	.0673724	1.8312830	.17909
Error	3.605395	98	.036790		
Total (Corr.)	3.672767	99			

Correlation Coefficient = 0.135439
 Stnd. Error of Est. = 0.191807
 R-squared = 1.83 percent

**The Regression Analysis Of Cadmium Levels On Mercury Levels
For Animals From The Hobart Ames Plantation, Tennessee.**

Dependent variable: Cadmium

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.0166657	2.95941E-3	5.63142	1.70793E-7
Slope	0.0189406	0.0356638	0.531088	0.596559

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	.0002315	1	.0002315	.2820544	.59656
Error	.080426	98	.000821		
Total (Corr.)	.080658	99			

Correlation Coefficient = 0.0535709
 Stnd. Error of Est. = 0.0286474
 R-squared = .29 percent

A P P E N D I X E

Table E 4.1. Comparison Of The Total Number Of Males Versus Females Per Age Group, Cades Cove, GSMNP, Tennessee.

AGE		Equal To Or Less Than 1.5	More Than 1.5
S E X	MALE	4	11
	FEMALE	15	71
	TOTAL	19	82

NOTE: Because of the variety of people aging deer from Cades Cove, GSMNP, Tennessee, class distinction was only made between animals younger and older than 1.5 years of age.

Table E 4.2. Mean Levels Of Cadmium, Lead, And Mercury Evaluated In The Study Based On Sex And Age, Cades Cove, GSMNP, Tennessee, 1980-1982.

		CADMIUM		LEAD	MERCURY
SEX	MALE	0.31		1.75	0.39
	FEMALE	0.59		2.27	0.63
AGE	Equal To Or Less Than 1.5			More Than 1.5	
		Males	Females	Males	Females
CADMIUM		1.82	0.48	0.75	0.53
LEAD		0.56	1.41	2.08	2.46
MERCURY		0.00	0.10	0.49	3.23

NOTE: Cadmium and Lead Results are Expressed in PPM, Figures for the Mercury Results are in PPB. Because of the variety of people aging deer from Cades Cove, GSMNP, Tennessee, class distinction was only made between animals younger and older than 1.5 years of age.

**Frequency Tabulation Of The Distribution Of Cadmium Values In
PPM For White-Tailed Deer From Cades Cove, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below	0.000			7	.06796	7	.0680
1	0.000	0.381	0.190	56	.54369	63	.6117
2	0.381	0.762	0.571	21	.20388	84	.8155
3	0.762	1.143	0.952	8	.07767	92	.8932
4	1.143	1.524	1.333	2	.01942	94	.9126
5	1.524	1.905	1.714	1	.00971	95	.9223
6	1.905	2.206	2.095	0	.00000	95	.9223
7	2.286	2.667	2.476	2	.01942	97	.9417
8	2.667	3.048	2.857	1	.00971	98	.9515
9	3.048	3.429	3.238	0	.00000	98	.9515
10	3.429	3.810	3.619	1	.00971	99	.9612
11	3.810	4.190	4.000	0	.00000	99	.9612
12	4.190	4.571	4.381	0	.00000	99	.9612
13	4.571	4.952	4.762	0	.00000	99	.9612
14	4.952	5.333	5.143	3	.02913	102	.9903
15	5.333	5.714	5.524	0	.00000	102	.9903
16	5.714	6.095	5.905	0	.00000	102	.9903
17	6.095	6.476	6.286	0	.00000	102	.9903
18	6.476	6.857	6.667	0	.00000	102	.9903
19	6.857	7.238	7.048	1	.00971	103	1.0000
20	7.238	7.619	7.429	0	.00000	103	1.0000
21	7.619	8.000	7.810	0	.00000	103	1.0000
above	8.000			0	.00000	103	1.0000

Mean = 0.616

Standard Deviation = 1.157

Median = 0.23

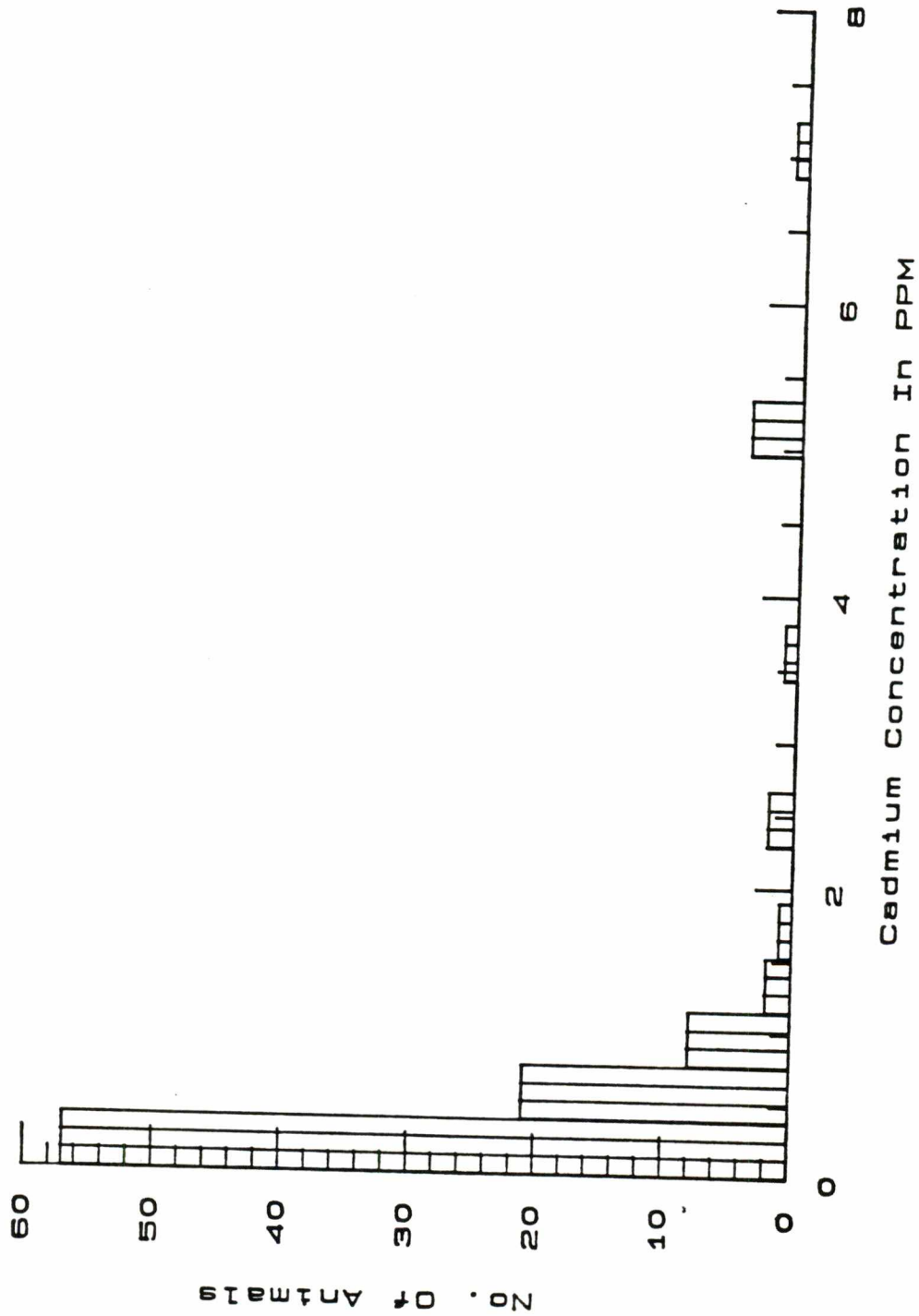


Fig. E 4.1. The Distribution Of Cadmium Levels For White-tailed Deer From Cades Cove GSMNP, Tennessee, 1980-1982.

**Frequency Tabulation Of The Distribution Of Lead Values In
PPM For White-Tailed Deer From Cades Cove, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		0.000		4	.03883	4	.0388
1	0.000	0.500	0.250	15	.14563	19	.1845
2	0.500	1.000	0.750	19	.18447	38	.3689
3	1.000	1.500	1.250	19	.18447	57	.5534
4	1.500	2.000	1.750	16	.15534	73	.7087
5	2.000	2.500	2.250	11	.10680	84	.8155
6	2.500	3.000	2.750	8	.07767	92	.8932
7	3.000	3.500	3.250	1	.00971	93	.9029
8	3.500	4.000	3.750	2	.01942	95	.9223
9	4.000	4.500	4.250	3	.02913	98	.9515
10	4.500	5.000	4.750	2	.01942	100	.9709
11	5.000	5.500	5.250	0	.00000	100	.9709
12	5.500	6.000	5.750	1	.00971	101	.9806
13	6.000	6.500	6.250	0	.00000	101	.9806
14	6.500	7.000	6.750	0	.00000	101	.9806
15	7.000	7.500	7.250	0	.00000	101	.9806
16	7.500	8.000	7.750	0	.00000	101	.9806
17	8.000	8.500	8.250	0	.00000	101	.9806
18	8.500	9.000	8.750	0	.00000	101	.9806
19	9.000	9.500	9.250	0	.00000	101	.9806
20	9.500	10.000	9.750	0	.00000	101	.9806
above	10.000			2	.01942	103	1.0000

Mean = 2.179

Standard Deviation = 5.579

Median = 1.30

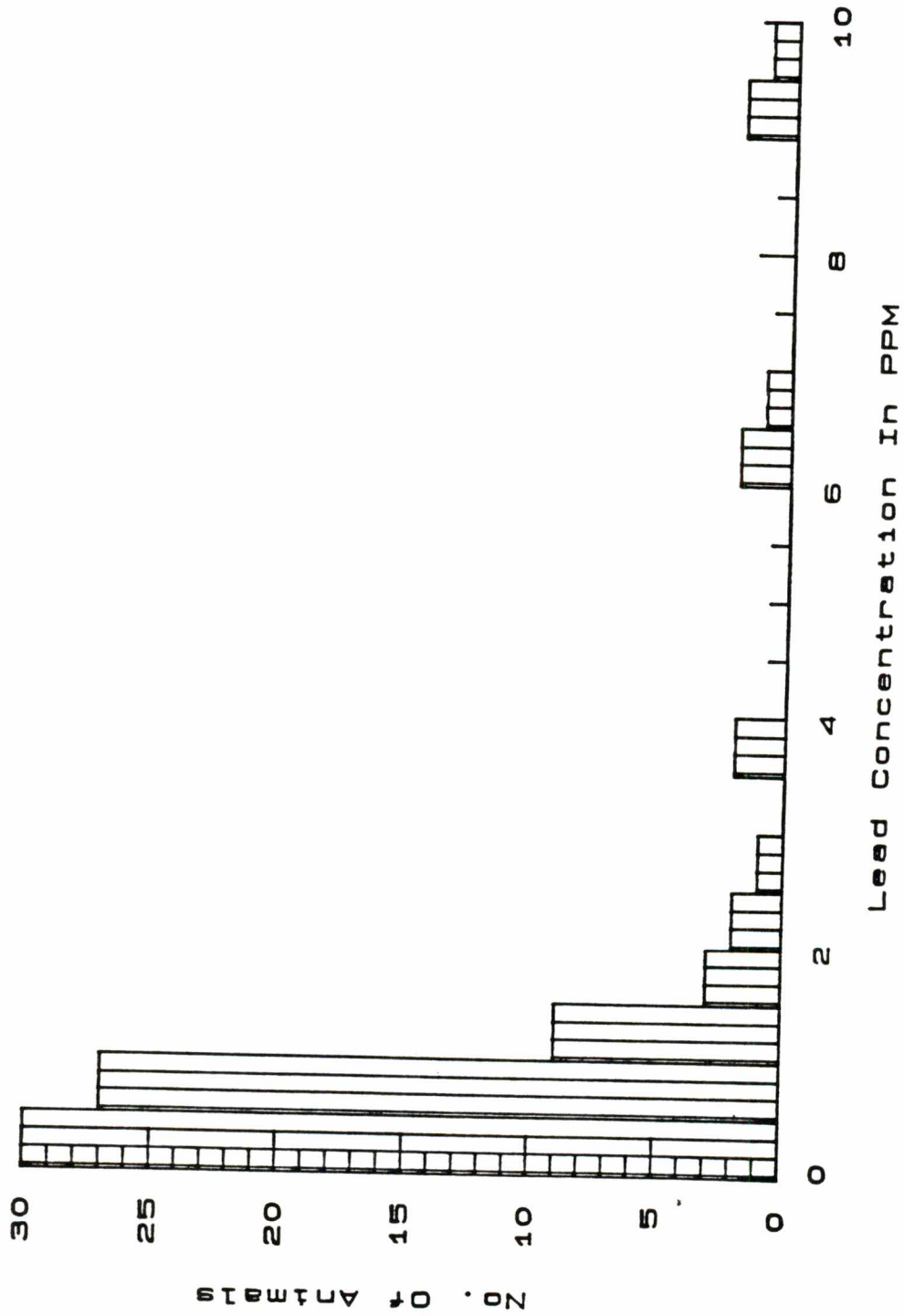


Fig. E 4.2. The Distribution Of Lead Levels For White-tailed Deer From Cades Cove GSMNP, Tennessee, 1980-1982.

**Frequency Tabulation Of The Distribution Of Mercury Values In
PPB For White-Tailed Deer From Cades Cove, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below	0.00			85	.82524	85	.825
1	0.00	1.00	0.500	5	.04854	90	.874
2	1.00	2.00	1.500	4	.03883	94	.913
3	2.00	3.00	2.500	3	.02913	97	.942
4	3.00	4.00	3.500	2	.01942	99	.961
5	4.00	5.00	4.500	1	.00971	100	.971
6	5.00	6.00	5.500	0	.00000	100	.971
7	6.00	7.00	6.500	0	.00000	100	.971
8	7.00	8.00	7.500	0	.00000	100	.971
9	8.00	9.00	8.500	0	.00000	100	.971
10	9.00	10.00	9.500	0	.00000	100	.971
11	10.00	11.00	10.500	0	.00000	100	.971
12	11.00	12.00	11.500	0	.00000	100	.971
13	12.00	13.00	12.500	0	.00000	100	.971
14	13.00	14.00	13.500	0	.00000	100	.971
15	14.00	15.00	14.500	0	.00000	100	.971
16	15.00	16.00	15.500	1	.00971	101	.981
17	16.00	17.00	16.500	1	.00971	102	.990
18	17.00	18.00	17.500	0	.00000	102	.990
19	18.00	19.00	18.500	0	.00000	102	.990
20	19.00	20.00	19.500	0	.00000	102	.990
above	20.00			1	.00971	103	1.000

Mean = 1.208

Standard Deviation = 6.596

Median = 0.00

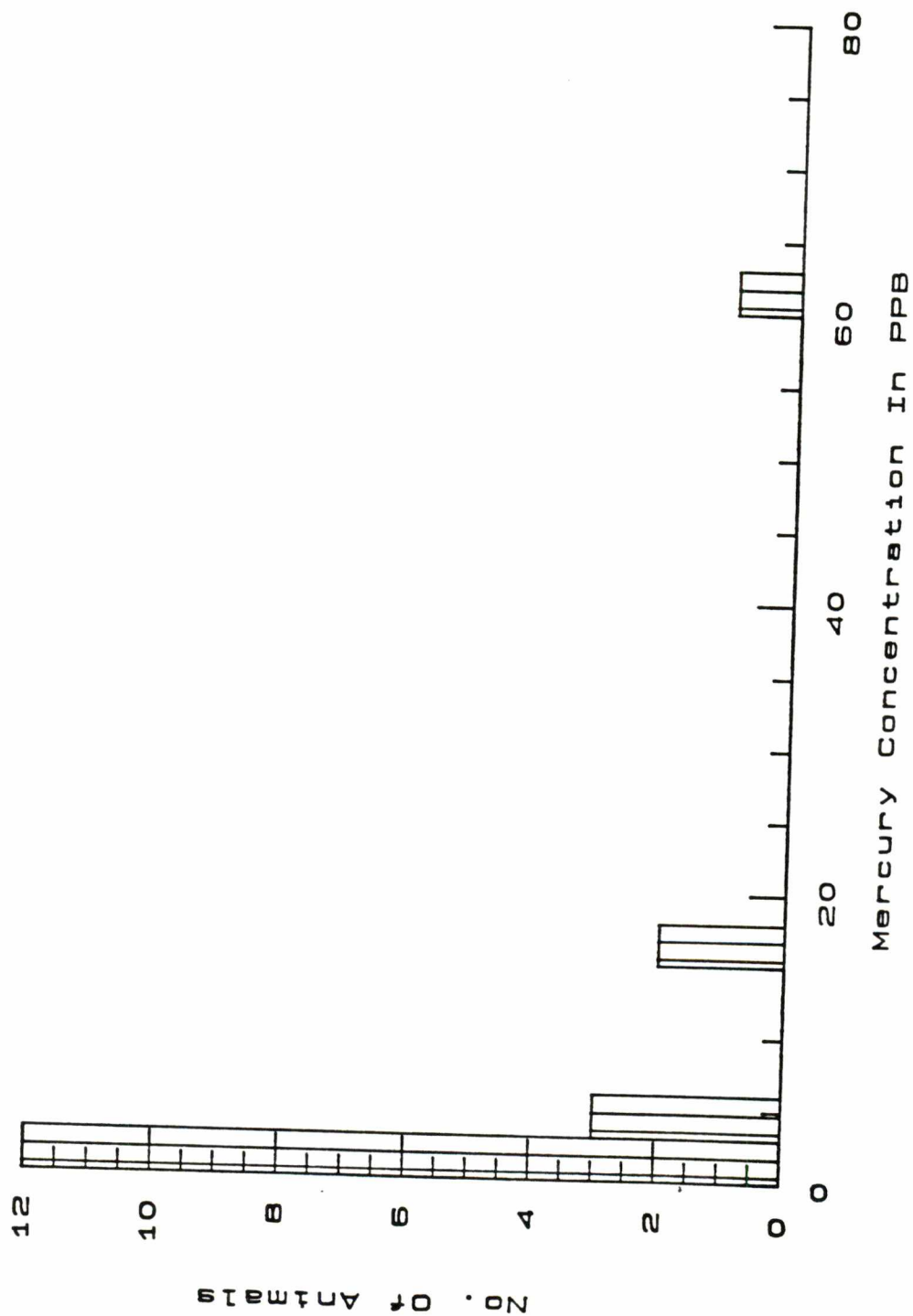


Fig. E 4.3. The Distribution Of Mercury Levels For White-tailed Deer From Cades Cove GSMNP, Tennessee, 1980-1982

Frequency Tabulation Of The Weight Of Animals At Cades Cove,
G.S.M.N.P., Tennessee.

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		25.00		0	.00000	0	.00000
1	25.00	50.00	37.50	1	.00990	1	.00990
2	50.00	75.00	62.50	14	.13861	15	.14851
3	75.00	100.00	87.50	62	.61386	77	.76238
4	100.00	125.00	112.50	17	.16832	94	.93069
5	125.00	150.00	137.50	5	.04950	99	.98020
6	150.00	175.00	162.50	2	.01980	101	1.00000
above	175.00			0	.00000	101	1.00000

Mean = 93.3

Standard Deviation = 20.3

Median = 90.0

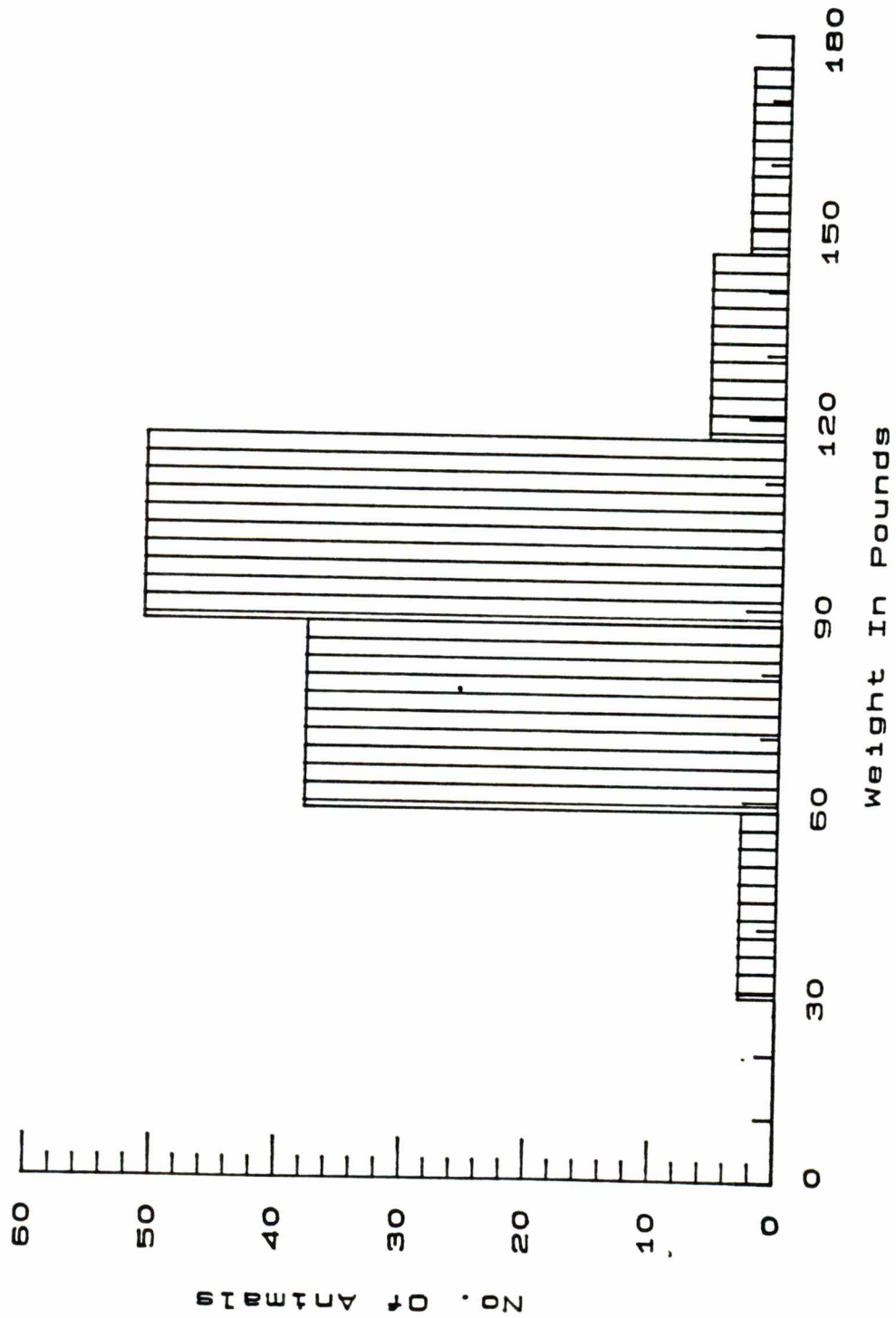


Fig. E 4.4. The Weight Of White-tailed Deer From Cades Cove GSMNP, Tennessee, 1980-1982.

**The Regression Analysis of Lead Levels On Cadmium Levels
For Animals From Cades Cove, GSMNP, Tennessee.**

Dependent variable: Lead

Independent variable: Cadmium

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	2.44378	0.624162	3.91529	1.64197E-4
Slope	-0.35881	0.455414	-0.787875	0.432615

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	19.437291	1	19.437291	.620747	.43261
Error	3162.5856	101	31.3127		
Total (Corr.)	3182.0229	102			

Correlation Coefficient = -0.0781567
 Stnd. Error of Est. = 5.59578
 R-squared = .61 percent

**The Regression Analysis Of Lead Levels On Mercury Levels
For Animals From Cades Cove, GSMNP, Tennessee.**

Dependent variable: Lead

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	2.20923	0.562353	3.92854	1.56549E-4
Slope	3.37036E-3	0.084248	0.0400052	0.968168

Analysis of Variance

Source	Sum of Square	Df	Mean Square	F-Ratio	Prob. Level
Model	.0504207	1	.0504207	.0016004	.96817
Error	3181.9725	101	31.5047		
Total (Corr.)	3182.0229	102			

Correlation Coefficient = 3.98064E-3
 Std. Error of Est. = 5.6129
 R-squared = .00 percent

**The Regression Analysis Of Cadmium Levels On Mercury
Levels For Animals From Cades, Cove, GSMNP, Tennessee.**

Dependent variable: Cadmium

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.658597	0.122167	5.39094	4.88088E-7
Slope	-0.0134576	0.0183023	-0.735293	0.463865

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	.8038748	1	.8038748	.5406559	.46387
Error	150.17197	101	1.48685		
Total (Corr.)	150.97585	102			

Correlation Coefficient = -0.0729693
 Stnd. Error of Est. = 1.21937
 R-squared = .53 percent

A P P E N D I X F

Table F 4.1. Comparison Of The Total Number Of Males
Versus Females Per Age Group, Chuck Swan,
WMA, Tennessee.

	AGE	0.5	1.5	2.5	3.5	4.5	5.5	6.5
S E X	MALE	10	12	5	5	2	0	1
	FEMALE	17	8	5	15	4	4	3
	TOTAL	27	20	10	20	6	4	4

Table F 4.2. Mean Levels Of Cadmium, Lead, And Mercury Evaluated In The Study Based On Sex And Age, Chuck Swan, WMA, Tennessee, 1986.

		CADMIUM				LEAD		MERCURY	
SEX	MALE	0.33				1.91		1.61	
	FEMALE	0.60				2.78		1.77	
AGE		0.5	1.5	2.5	3.5	4.5	5.5	6.5	
CADMIUM		0.20	0.58	0.13	0.30	0.17	-----	0.20	
		0.56	0.21	2.20	0.59	0.12	0.16	0.03	
LEAD		2.17	2.04	1.23	1.72	2.27	-----	1.31	
		2.32	1.39	6.35	3.27	2.32	2.51	1.80	
MERCURY		0.99	1.55	0.00	5.60	0.00	-----	0.00	
		0.01	1.23	5.80	0.93	2.50	2.20	7.33	

NOTE: Cadmium and Lead Results are Expressed in PPM,
Figures for the Mercury Results are in PPB.

**Frequency Tabulation Of The Distribution Of Cadmium Values In
PPM For White-Tailed Deer From Chuck Swan, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		0.000		38	.4176	38	.418
1	0.000	0.500	0.250	28	.3077	66	.725
2	0.500	1.000	0.750	17	.1868	83	.912
3	1.000	1.500	1.250	4	.0440	87	.956
4	1.500	2.000	1.750	0	.0000	87	.956
5	2.000	2.500	2.250	1	.0110	88	.967
6	2.500	3.000	2.750	0	.0000	88	.967
7	3.000	3.500	3.250	0	.0000	88	.967
8	3.500	4.000	3.750	1	.0110	89	.978
9	4.000	4.500	4.250	0	.0000	89	.978
10	4.500	5.000	4.750	1	.0110	90	.989
11	5.000	5.500	5.250	0	.0000	90	.989
12	5.500	6.000	5.750	0	.0000	90	.989
13	6.000	6.500	6.250	0	.0000	90	.989
14	6.500	7.000	6.750	0	.0000	90	.989
15	7.000	7.500	7.250	0	.0000	90	.989
16	7.500	8.000	7.750	0	.0000	90	.989
17	8.000	8.500	8.250	0	.0000	90	.989
18	8.500	9.000	8.750	0	.0000	90	.989
19	9.000	9.500	9.250	0	.0000	90	.989
20	9.500	10.000	9.750	1	.0110	91	1.000
above	10.000			0	.0000	91	1.000

Mean = 0.487

Standard Deviation = 1.20

Median = 0.19

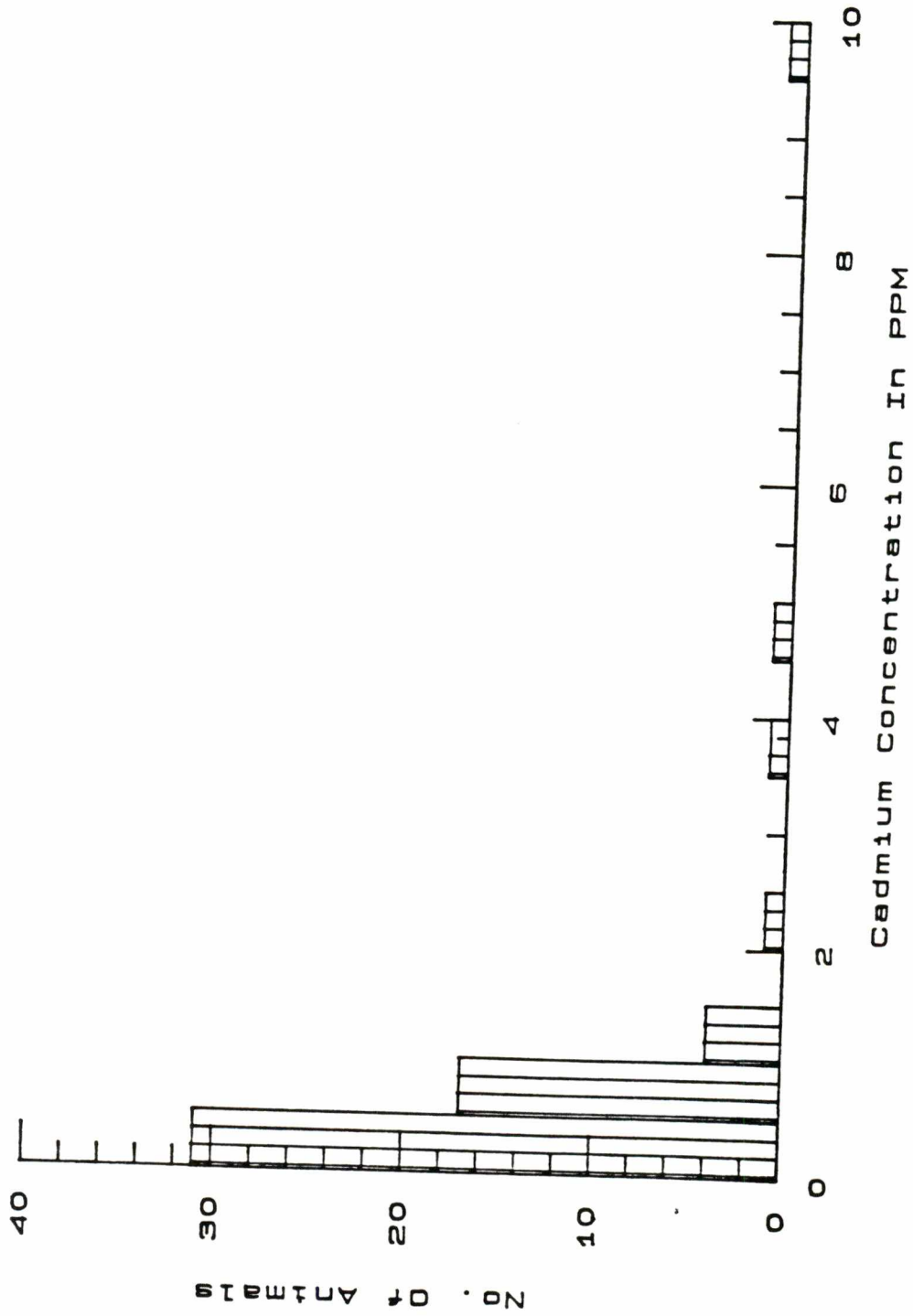


Fig. F 4.1.1. The Distribution Of Cadmium Levels For White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.

**Frequency Tabulation Of The Distribution Of Lead Values In
PPM For White-Tailed Deer From Chuck Swan, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		0.00		11	.1158	11	.116
1	0.00	1.20	0.600	18	.1895	29	.305
2	1.20	2.40	1.800	40	.4211	69	.726
3	2.40	3.60	3.000	10	.1053	79	.832
4	3.60	4.80	4.200	5	.0526	84	.884
5	4.80	6.00	5.400	4	.0421	88	.926
6	6.00	7.20	6.600	3	.0316	91	.958
7	7.20	8.40	7.800	1	.0105	92	.968
8	8.40	9.60	9.000	0	.0000	92	.968
9	9.60	10.80	10.200	0	.0000	92	.968
10	10.80	12.00	11.400	0	.0000	92	.968
11	12.00	13.20	12.600	0	.0000	92	.968
12	13.20	14.40	13.800	0	.0000	92	.968
13	14.40	15.60	15.000	1	.0105	93	.979
14	15.60	16.80	16.200	0	.0000	93	.979
15	16.80	18.00	17.400	0	.0000	93	.979
16	18.00	19.20	18.600	0	.0000	93	.979
17	19.20	20.40	19.800	2	.0211	95	1.000
18	20.40	21.60	21.000	0	.0000	95	1.000
19	21.60	22.80	22.200	0	.0000	95	1.000
20	22.80	24.00	23.400	0	.0000	95	1.000
above	24.00			0	.0000	95	1.000

Mean = 2.45

Standard Deviation = 3.40

Median = 1.69

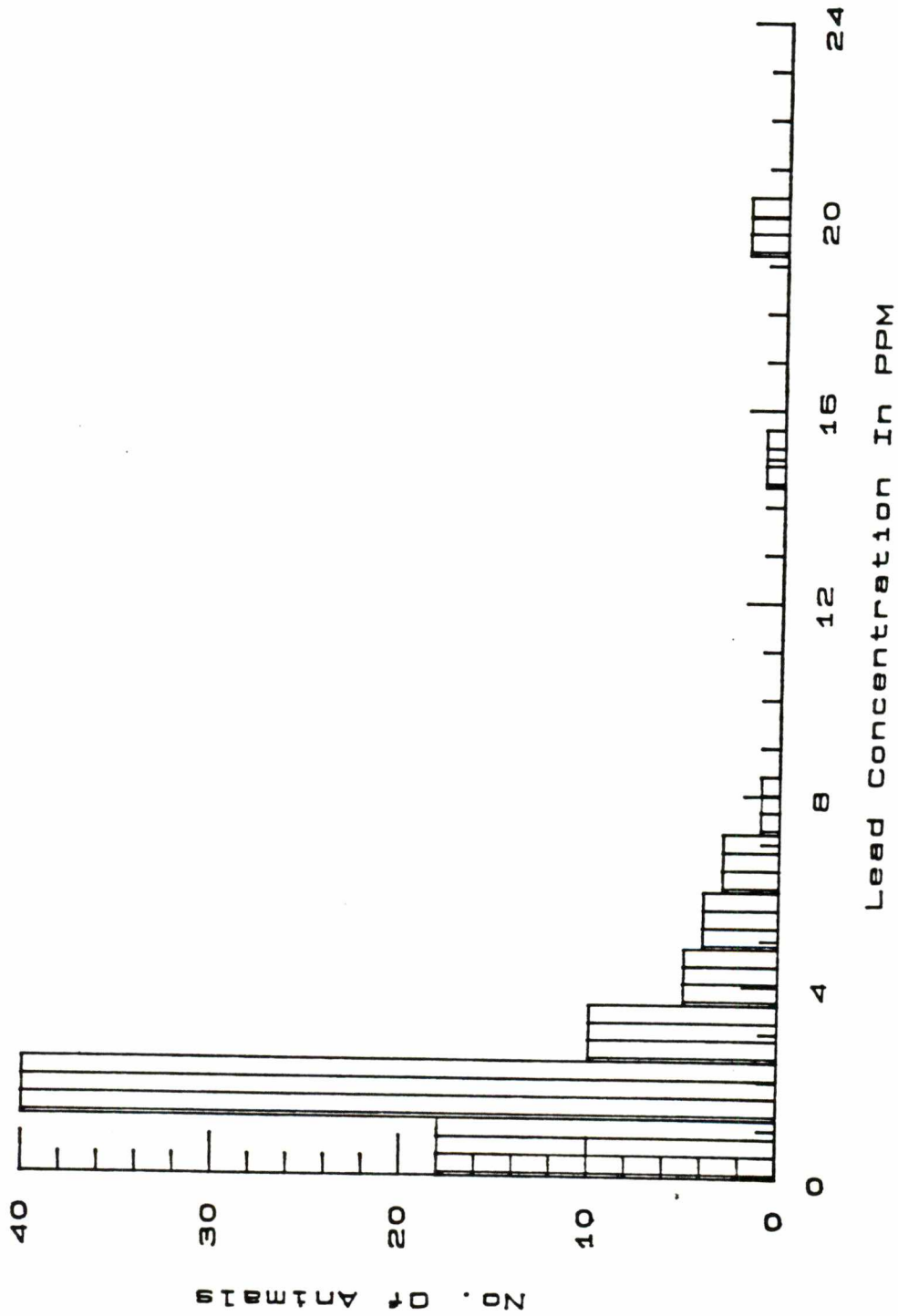


Fig. F 4.2. The Distribution Of Lead Levels For White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.

**Frequency Tabulation Of Distribution Of Mercury Values In
PPB For White-Tailed Deer From Chuck Swan, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below	0.00			81	.526	81	.853
1	0.00	1.20	0.600	1	.0105	82	.863
2	1.20	2.40	1.800	0	.0000	82	.863
3	2.40	3.60	3.000	0	.0000	82	.863
4	3.60	4.80	4.200	0	.0000	82	.863
5	4.80	6.00	5.400	0	.0000	82	.863
6	6.00	7.20	6.600	0	.0000	82	.863
7	7.20	8.40	7.800	0	.0000	82	.863
8	8.40	9.60	9.000	2	.0211	84	.884
9	9.60	10.80	10.200	4	.0421	88	.926
10	10.80	12.00	11.400	2	.0211	90	.947
11	12.00	13.20	12.600	1	.0105	91	.958
12	13.20	14.40	13.800	1	.0105	92	.968
13	14.40	15.60	15.000	0	.0000	92	.968
14	15.60	16.80	16.200	2	.0211	94	.989
15	16.80	18.00	17.400	0	.0000	94	.989
16	18.00	19.20	18.600	0	.0000	94	.989
17	19.20	20.40	19.800	0	.0000	94	.989
18	20.40	21.60	21.000	0	.0000	94	.989
19	21.60	22.80	22.200	1	.0105	95	1.000
20	22.80	24.00	23.400	0	.0000	95	1.000
above	24.00			0	.0000	95	1.000

Mean = 1.71

Standard Deviation = 4.51

Median = 0.00

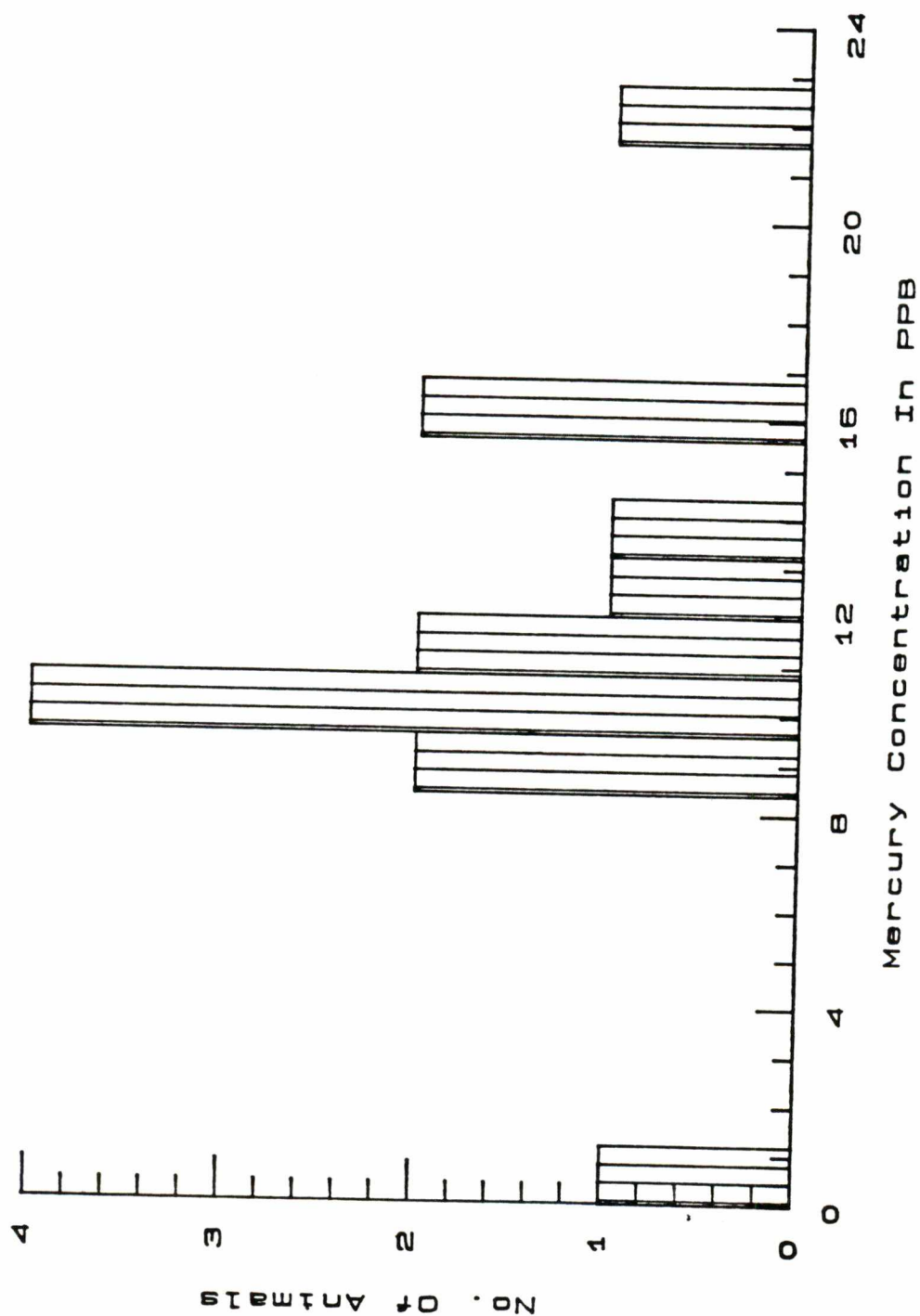


Fig. F 4.3. The Distribution of Mercury Levels For White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.

**Frequency Tabulation Of The Age Of Animals From
Chuck Swan, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		.500		27	.2872	27	.287
1	.500	1.500	1.00	20	.2128	47	.500
2	1.500	2.500	2.00	10	.1064	57	.606
3	2.500	3.500	3.00	20	.2128	77	.819
4	3.500	4.500	4.00	6	.0638	83	.883
5	4.500	5.500	5.00	5	.0532	88	.936
6	5.500	6.500	6.00	6	.0638	94	1.000
above	6.500			0	.0000	93	1.000

Mean = 2.47

Standard Deviation = 1.83

Median = 2.0

Males

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		.500		10	.2857	10	.286
1	.500	1.500	1.00	12	.3429	22	.629
2	1.500	2.500	2.00	5	.1429	27	.771
3	2.500	3.500	3.00	5	.1429	32	.914
4	3.500	4.500	4.00	2	.0571	34	.971
5	4.500	5.500	5.00	0	.0000	34	.971
6	5.500	6.500	6.00	1	.0286	35	1.000
above	6.500			0	.0000	35	1.000

Mean = 1.96

Standard Deviation = 1.44

Median = 1.5

Females

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		.500		17	.2881	17	.288
1	.500	1.500	1.00	8	.1356	25	.424
2	1.500	2.500	2.00	4	.0847	30	.508
3	2.500	3.500	3.00	15	.2542	45	.763
4	3.500	4.500	4.00	4	.0678	49	.831
5	4.500	5.500	5.00	5	.0847	54	.915
6	5.500	6.500	6.00	5	.0847	59	1.000
above	6.500			0	.0000	59	1.000

Mean = 2.77

Standard Deviation = 1.98

Median = 2.5

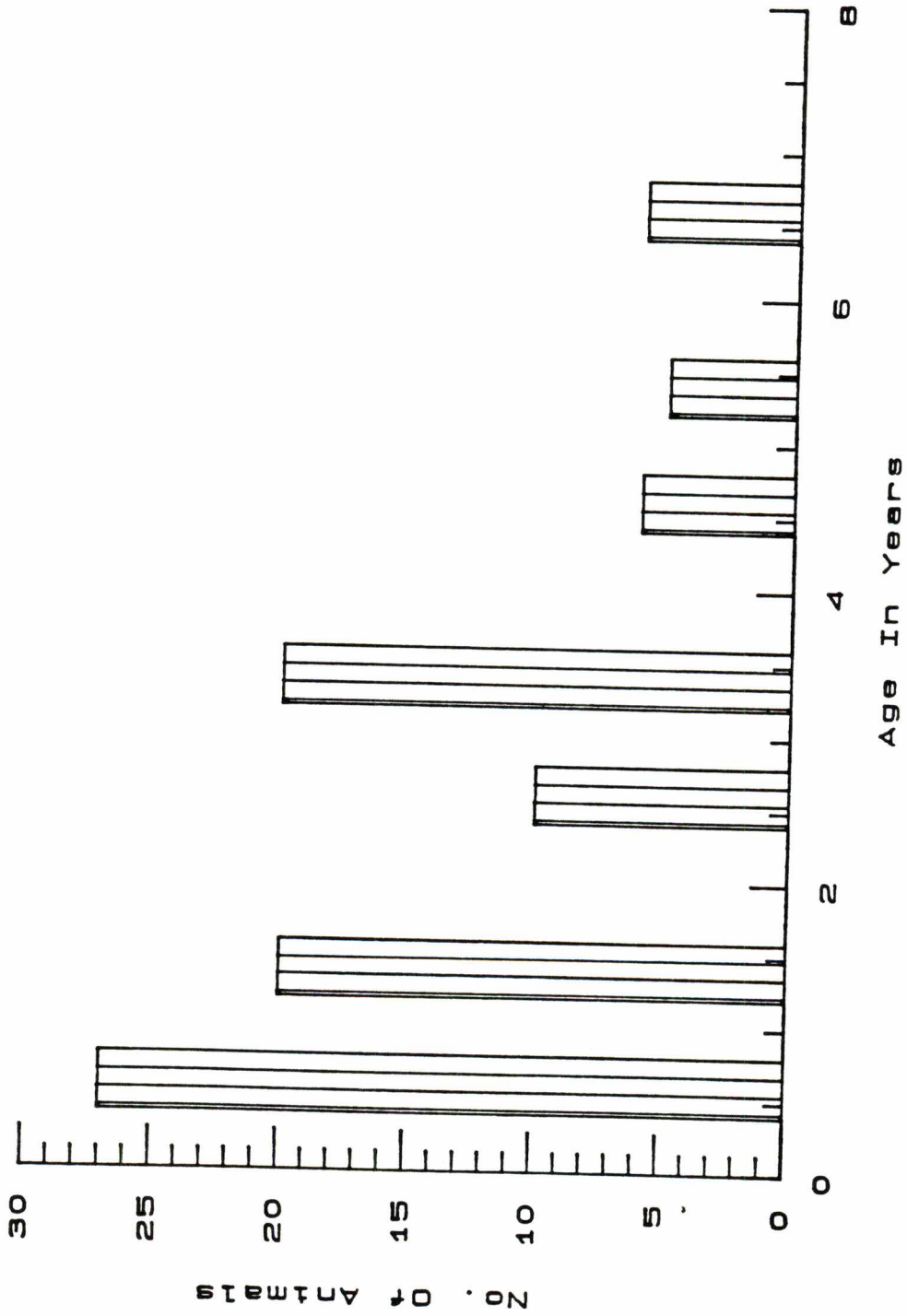


Fig. F 4.4. The Age Of White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.

Frequency Tabulation Of The Weight Of Animals At
Chuck Swan, W.M.A., Tennessee.

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		25.00		0	.0000	0	.000
1	25.00	50.00	37.50	29	.3053	29	.305
2	50.00	75.00	62.50	48	.5053	77	.811
3	75.00	100.00	87.50	15	.1579	92	.968
4	100.00	125.00	112.50	3	.0316	95	1.000
5	125.00	150.00	137.50	0	.0000	95	1.000
above	150.00			0	.0000	95	1.000

Mean = 59.7

Standard Deviation = 18.8

Median = 61.0

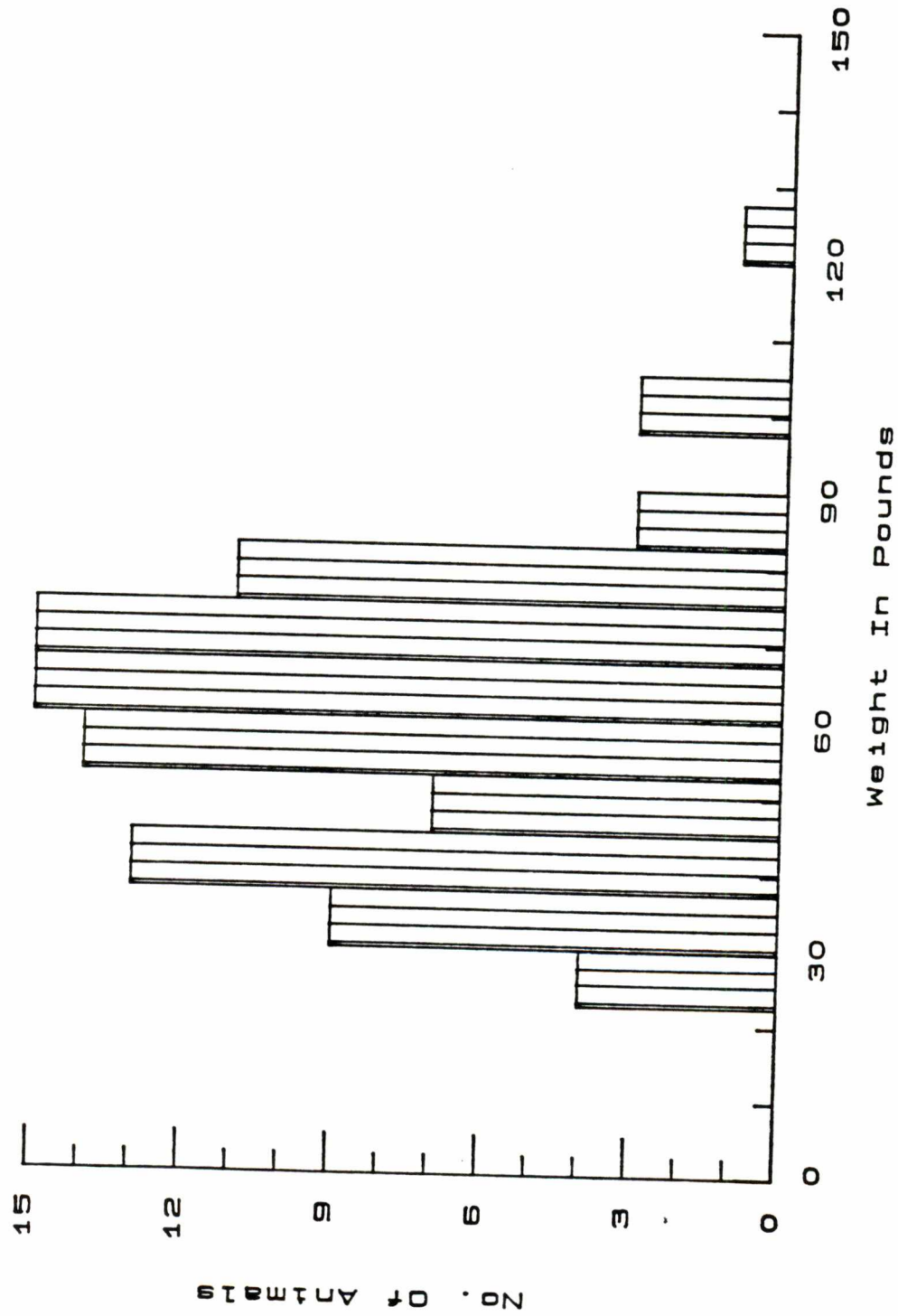


Fig. F 4.5. The Weight Of White-tailed Deer From Chuck Swan WMA, Tennessee, 1986.

**The Regression Analysis Of Lead Levels On Cadmium
Levels For Animals From Chuck Swan, WMA, Tennessee.**

Dependent variable: Lead

Independent variable: Cadmium

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	2.69416	0.372821	7.22641	1.69189E-7
Slope	-0.501337	0.295203	-1.69828	0.0927989

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	32.785760	1	32.785760	2.884148	.09280
Error	1057.1844	93	11.3676		
Total (Corr.)	1089.9701	94			

Correlation Coefficient = -0.173434
 Stnd. Error of Est. = 3.37158
 R-squared = 3.01 percent

**The Regression Analysis Of Lead Levels On Mercury Levels
For Animals From Chuck Swan, WMA, Tennessee.**

Dependent variable: Lead

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	2.01923	0.353442	5.71304	1.54507E-7
Slope	0.256482	0.0735315	3.48806	7.45085E-4

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	126.09706	1	126.09706	12.16657	.00075
Error	963.87306	93	10.36423		
Total (Corr.)	1089.9701	94			

Correlation Coefficient = 0.34013

Std. Error of Est. = 3.21935

R-squared = 11.57 percent

The Regression Analysis of Cadmium Levels On Mercury
Levels For Animals From Chuck Swan, WMA, Tennessee.

Dependent variable: Cadmium

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.534261	0.128712	4.15082	7.33348E-5
Slope	-0.0369483	0.0267779	-1.37981	0.170954

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	2.6168474	1	2.6168474	1.9038697	.17095
Error	127.82745	93	1.37449		
Total (Corr.)	130.44429	94			

Correlation Coefficient = -0.141637
 Stnd. Error of Est. = 1.17239
 R-squared = 2.01 percent

A P P E N D I X G

Table G 4.1. Comparison Of The Total Number Of Males Versus Females Per Age Group, The ERDA Oak Ridge Reservation, Tennessee.

S E X	AGE	0.5	1.5	2.5	3.5	4.5	5.5	6.5
	MALE	9	16	15	3	4	1	0
	FEMALE	13	8	19	7	2	2	0
	TOTAL	22	24	34	10	6	3	0

Table G 4.2. Mean Levels Of Cadmium, Lead, And Mercury Evaluated In The Study Based On Sex And Age, The ERDA Oak Ridge Reservation, Tennessee, 1986.

		CADMIUM				LEAD		MERCURY	
SEX	MALE	0.33				5.15		5.16	
	FEMALE	0.60				3.42		5.65	
AGE		0.5	1.5	2.5	3.5	4.5	5.5	6.5	
CADMIUM		0.23	0.31	0.24	0.33	0.85	0.28	0.00	
		0.69	0.55	0.79	0.39	0.15	0.09	0.00	
LEAD		1.51	2.01	4.23	0.37	33.14	0.46	0.00	
		2.41	1.98	3.59	8.49	1.67	1.71	0.00	
MERCURY		6.20	4.56	5.24	4.05	5.18	5.58	0.00	
		6.20	4.27	5.73	4.71	9.14	5.50	0.00	

NOTE: Cadmium and Lead Results are Expressed in PPM,
Figures for the Mercury Results are in PPB.

**Frequency Tabulation Of The Distribution Of Cadmium Values In
PPM For White-Tailed Deer From Oak Ridge, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		0.00		7	.0700	7	.0700
1	0.000	0.400	0.200	67	.6700	74	.7400
2	0.400	0.800	0.600	15	.1500	89	.8900
3	0.800	1.200	1.000	2	.0200	91	.9100
4	1.200	1.600	1.400	3	.0300	94	.9400
5	1.600	2.000	1.800	3	.0300	97	.9700
6	2.000	2.400	2.200	1	.0100	98	.9800
7	2.400	2.800	2.600	0	.0000	98	.9800
8	2.800	3.200	3.000	0	.0000	98	.9800
9	3.200	3.600	3.400	0	.0000	98	.9800
10	3.600	4.000	3.800	0	.0000	98	.9800
11	4.000	4.400	4.200	0	.0000	98	.9800
12	4.400	4.800	4.600	0	.0000	98	.9800
13	4.800	5.200	5.000	0	.0000	98	.9800
14	5.200	5.600	5.400	1	.0100	99	.9900
15	5.600	6.000	5.800	0	.0000	99	.9900
16	6.000	6.400	6.200	0	.0000	99	.9900
17	6.400	6.800	6.600	0	.0000	99	.9900
18	6.800	7.200	7.000	0	.0000	99	.9900
19	7.200	7.600	7.400	0	.0000	99	.9900
20	7.600	8.000	7.800	1	.0100	100	1.0000
above	8.000			0	.0000	100	1.0000

Mean = 0.471

Standard Deviation = 1.005

Median = 0.22

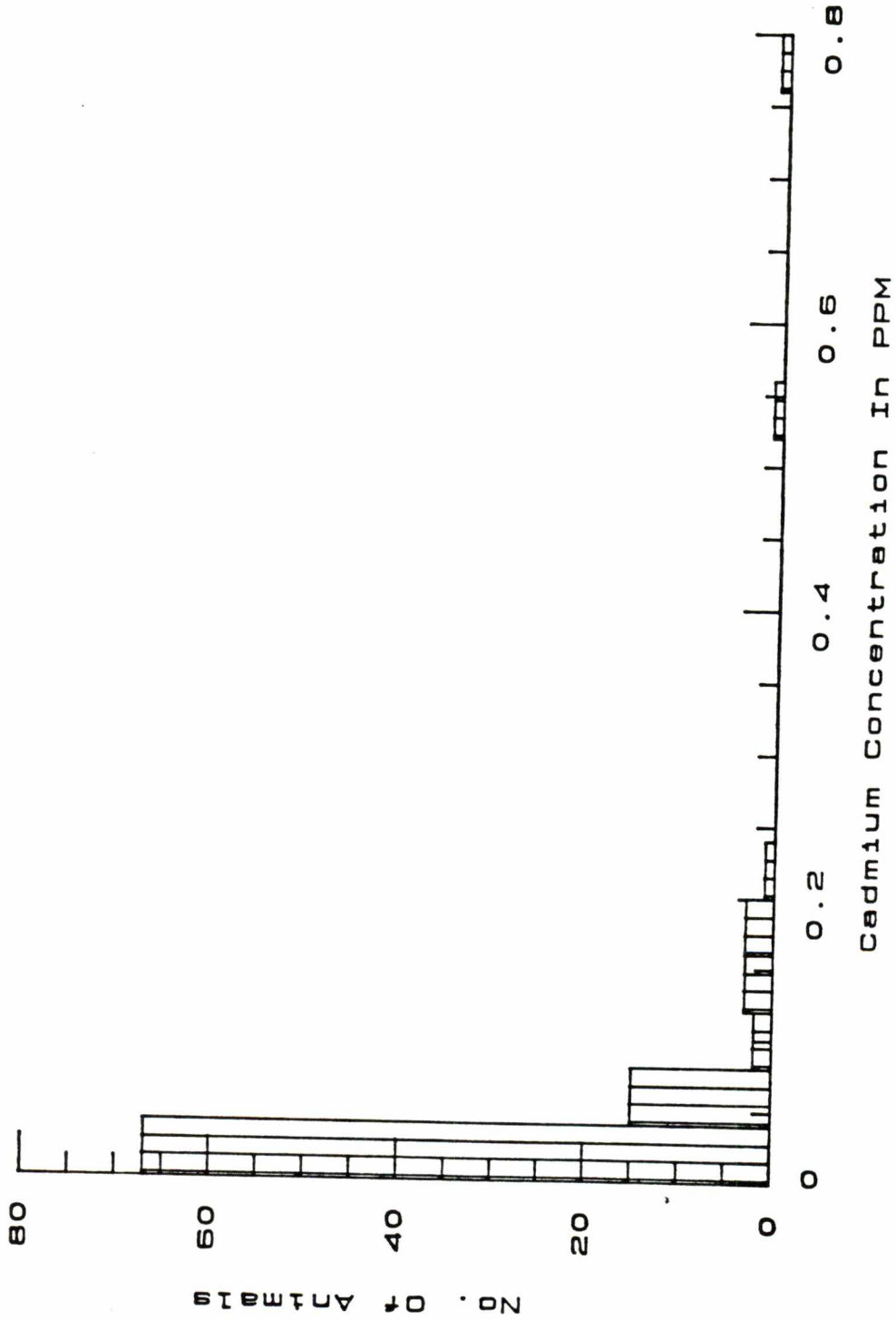


Fig. G 4.1. The Distribution Of Cadmium Levels For White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee, 1986.

**Frequency Tabulation Of The Distribution Of Lead Values In
PPM For White-Tailed Deer From Oak Ridge, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		0.00		7	.0700	7	.0700
1	0.00	5.00	2.50	77	.7700	84	.8400
2	5.00	10.00	7.50	6	.0600	90	.9000
3	10.00	15.00	12.50	3	.0300	93	.9300
4	15.00	20.00	17.50	4	.0400	97	.9700
5	20.00	25.00	22.50	1	.0100	98	.9800
6	25.00	30.00	27.50	0	.0000	98	.9800
7	30.00	35.00	32.50	0	.0000	98	.9800
8	35.00	40.00	37.50	0	.0000	98	.9800
9	40.00	45.00	42.50	1	.0100	99	.9900
10	45.00	50.00	47.50	0	.0000	99	.9900
11	50.00	55.00	52.50	0	.0000	99	.9900
12	55.00	60.00	57.50	0	.0000	99	.9900
13	60.00	65.00	62.50	0	.0000	99	.9900
14	65.00	70.00	67.50	0	.0000	99	.9900
15	70.00	75.00	72.50	0	.0000	99	.9900
16	75.00	80.00	77.50	0	.0000	99	.9900
17	80.00	85.00	82.50	0	.0000	99	.9900
18	85.00	90.00	87.50	1	.0100	100	1.0000
19	90.00	95.00	92.50	0	.0000	100	1.0000
20	95.00	100.00	97.50	0	.0000	100	1.0000
above	100.00			0	.0000	100	1.0000

Mean = 4.251

Standard Deviation = 10.280

Median = 1.33

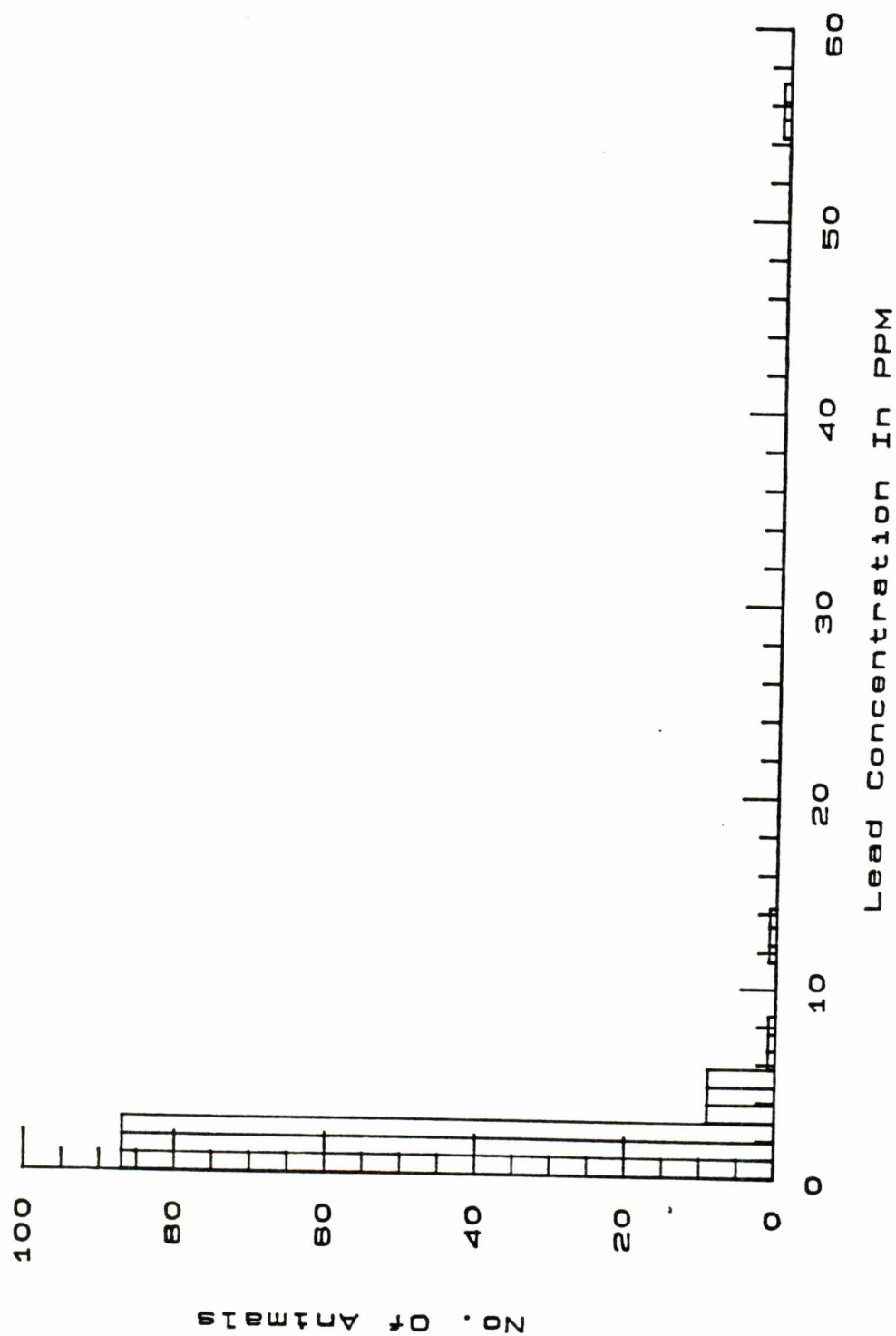


Fig. G 4.2. The Distribution Of Lead Levels For White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee, 1986.

**Frequency Tabulation Of The Distribution Of Mercury Values In
PPB For White-Tailed Deer From Oak Ridge, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below	0.000			32	.3200	32	.320
1	0.000	0.900	0.450	0	.0000	32	.320
2	0.900	1.800	1.350	2	.0200	34	.340
3	1.800	2.700	2.250	4	.0400	38	.380
4	2.700	3.600	3.150	3	.0300	41	.410
5	3.600	4.500	4.050	6	.0600	47	.470
6	4.500	5.400	4.950	2	.0200	49	.490
7	5.400	6.300	5.850	8	.0800	57	.570
8	6.300	7.200	6.750	5	.0500	62	.620
9	7.200	8.100	7.650	6	.0600	68	.680
10	8.100	9.000	8.550	2	.0200	70	.700
11	9.000	9.900	9.450	10	.1000	80	.800
12	9.900	10.800	10.350	2	.0200	82	.820
13	10.800	11.700	11.250	9	.0900	91	.910
14	11.700	12.600	12.150	2	.0200	93	.930
15	12.600	13.500	13.050	1	.0100	94	.940
16	13.500	14.400	13.950	0	.0000	94	.940
17	14.400	15.300	14.850	3	.0300	97	.970
18	15.300	16.200	15.750	2	.0200	99	.990
19	16.200	17.100	16.650	1	.0100	100	1.000
20	17.100	18.000	17.550	0	.0000	100	1.000
above	18.000			0	.0000	100	1.000

Mean = 5.415

Standard Deviation = 4.877

Median = 5.53

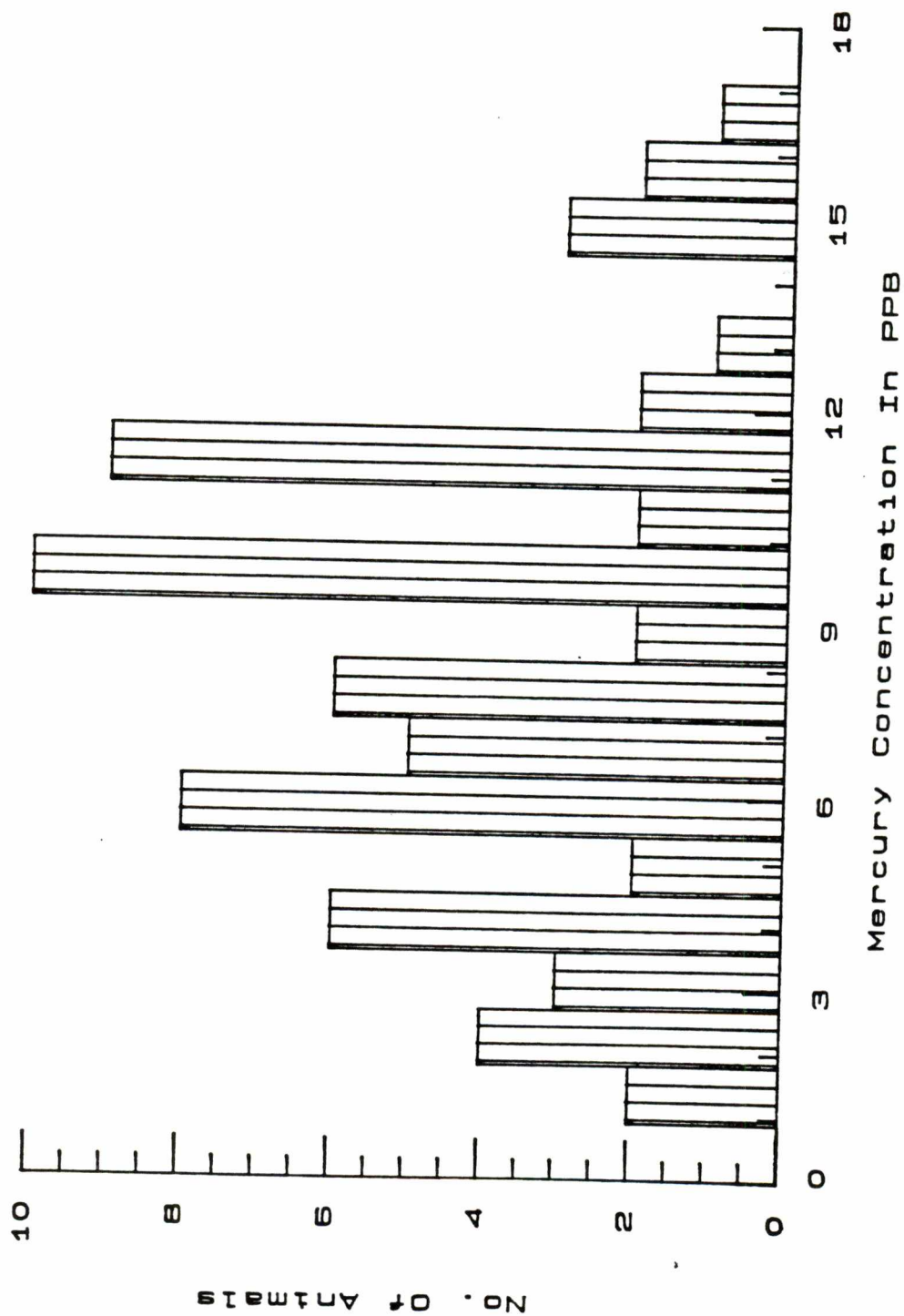


Fig. G 4.3. The Distribution Of Mercury Levels For White-tailed Deer From The ERDA Oak Ridge Reservation, Tennessee, 1986.

**Frequency Tabulation Of The Age Of Animals From
Oak Ridge, Tennessee.**

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		.500		22	.2200	22	.220
1	.500	1.500	1.000	24	.2400	46	.460
2	1.500	2.500	2.000	34	.3400	80	.800
3	2.500	3.500	3.000	10	.1000	90	.900
4	3.500	4.500	4.000	6	.0600	96	.960
5	4.500	5.500	5.000	3	.0300	99	.990
6	5.500	6.500	6.000	1	.0100	100	1.000
above	6.500			0	.0000	100	1.000

Mean = 2.17

Standard Deviation = 1.34

Median = 2.5

Males

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		.500		9	.1875	9	.188
1	.500	1.500	1.000	16	.3333	25	.521
2	1.500	2.500	2.000	15	.3125	40	.833
3	2.500	3.500	3.000	3	.0625	43	.896
4	3.500	4.500	4.000	4	.0833	47	.979
5	4.500	5.500	5.000	1	.0208	48	1.000
6	5.500	6.500	6.000	0	.0000	48	1.000
above	6.500			0	.0000	48	1.000

Mean = 2.08

Standard Deviation = 1.23

Median = 1.5

Females

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		.500		13	.2500	13	.250
1	.500	1.500	1.000	8	.1538	21	.404
2	1.500	2.500	2.000	19	.3654	40	.769
3	2.500	3.500	3.000	7	.1346	47	.904
4	3.500	4.500	4.000	2	.0385	49	.942
5	4.500	5.500	5.000	2	.0385	51	.981
6	5.500	6.500	6.000	1	.0192	52	1.000
above	6.500			0	.0000	52	1.000

Mean = 2.25

Standard Deviation = 1.43

Median = 2.5

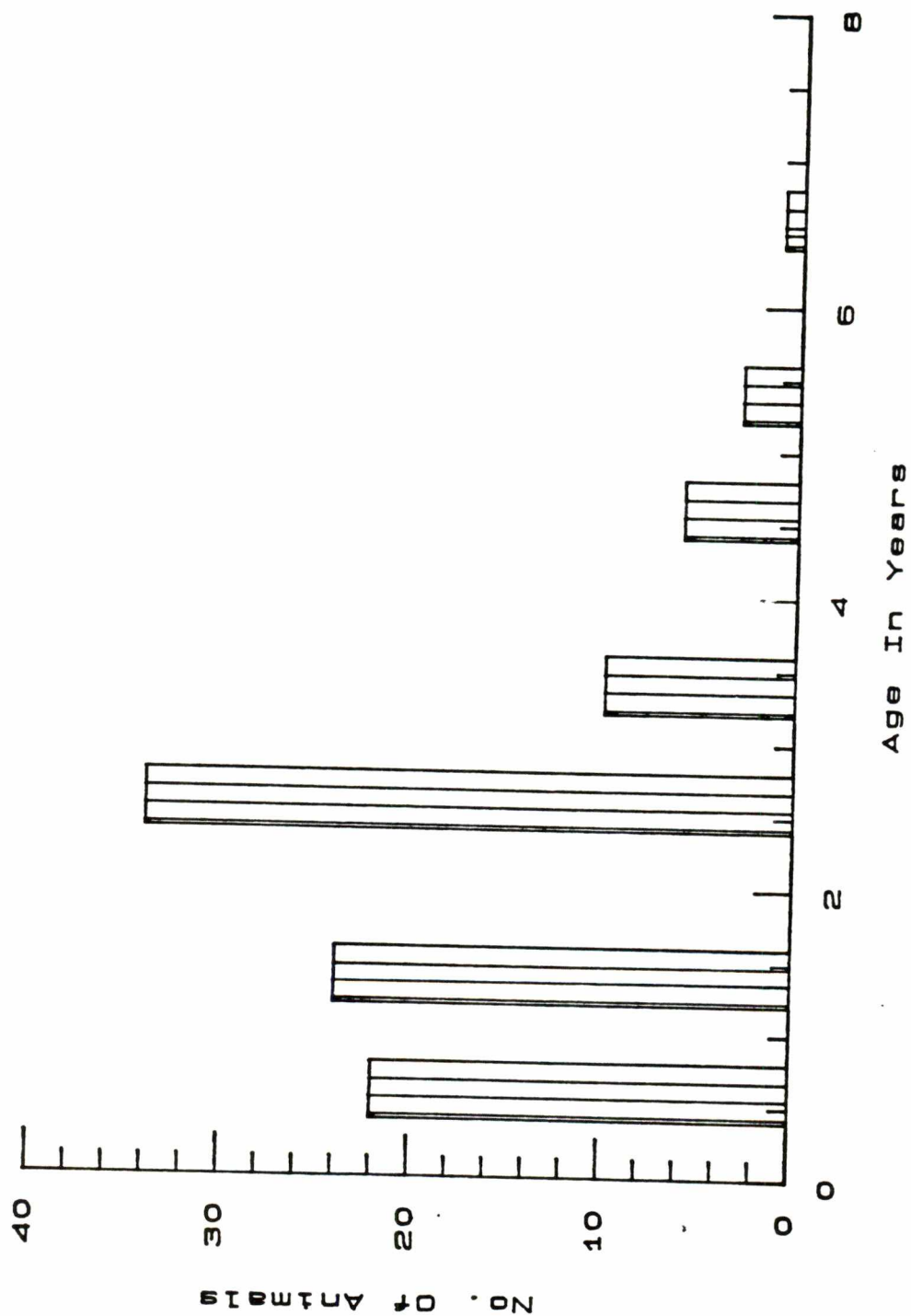


Fig. G 4.4. The Age Of White-tailed Deer From The ERDA Oak Ridge, Reservation, Tennessee, 1986.

Frequency Tabulation Of The Weight Of Animals At The
Oak Ridge Reservation, Tennessee.

Class	Lower Limit	Upper Limit	Midpoint	Frequency	Relative Frequency	Cumulative Frequency	Cum. Rel. Frequency
at or below		25.00		0	.0000	0	.0000
1	25.00	50.00	37.50	5	.0500	5	.0500
2	50.00	75.00	62.50	21	.2100	26	.2600
3	75.00	100.00	87.50	47	.4700	73	.7300
4	100.00	125.00	112.50	19	.1900	92	.9200
5	125.00	150.00	137.50	8	.0800	100	1.0000
above	150.00			0	.0000	100	1.0000

Mean = 87.97

Standard Deviation = 24.3

Median = 90.0

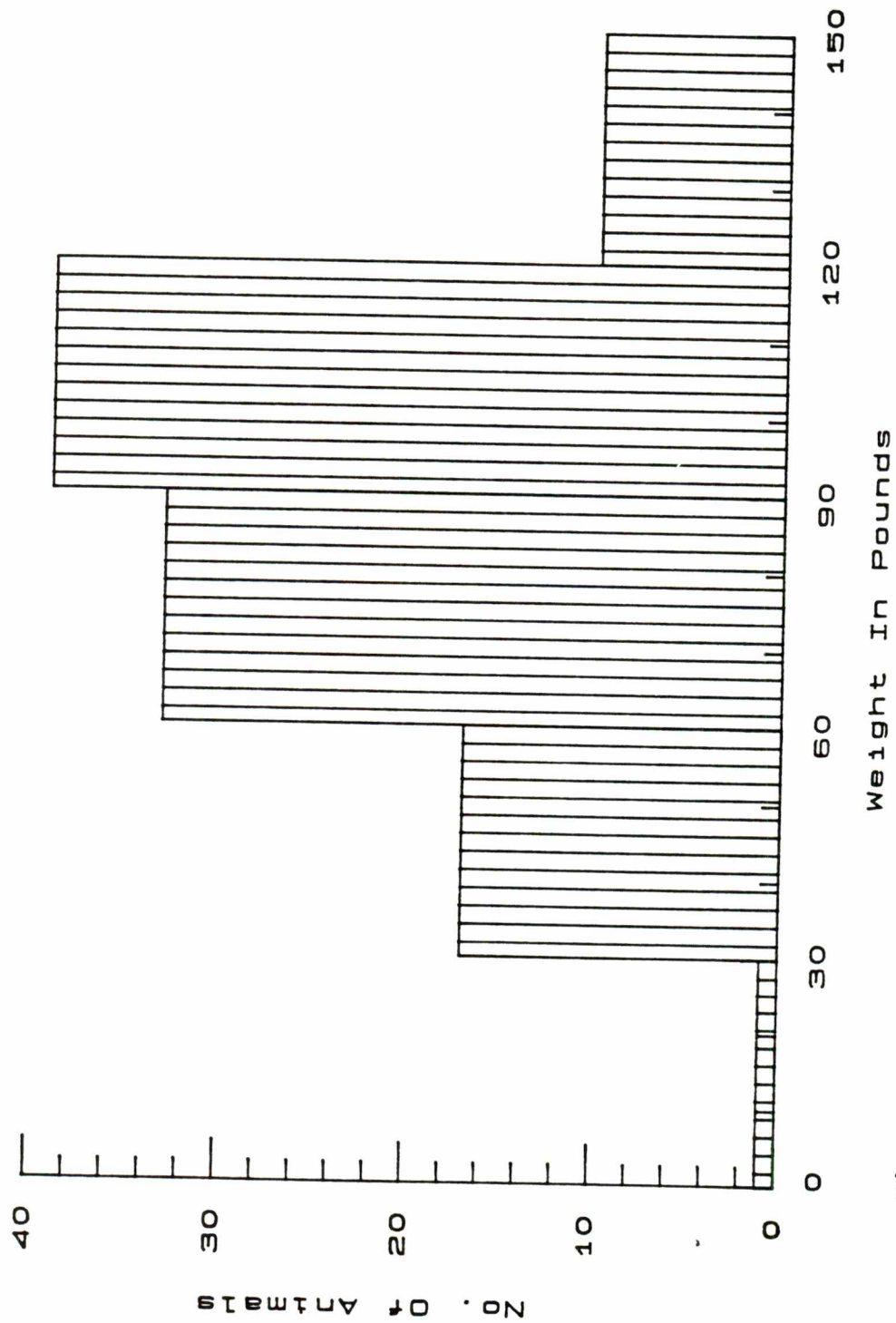


Fig. G 4.5. The Weight Of White-tailed Deer From The ERDA Oak Ridge, Reservation, Tennessee, 1986.

**The Regression Analysis Of Lead Levels On Cadmium Levels
For Animals From The Oak Ridge Reservation, Tennessee.**

Dependent variable: Lead

Independt variable: Cadmium

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.360909	0.113242	3.18706	1.92893E-3
Slope	1.36132	1.02407	1.32932	0.18683

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	1.8533794	1	1.8533794	1.7670848	.18683
Error	102.78578	98	1.04883		
Total (Corr.)	104.63916	99			

Correlation coefficient = 0.133087
 Stnd. Error of Est. = 1.02413
 R-squared = 1.77 percent

**The Regression Analysis Of Lead Levels On Mercury Levels
For Animals From The Oak Ridge Reservation, Tennessee.**

Dependent variable: Lead

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.611634	0.152735	4.00454	1.20989E-4
Slope	-0.344422	0.21006	-1.63963	0.104288

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	2.7938749	1	2.7938749	2.6883890	.10429
Error	101.84528	98	1.03924		
Total (Corr.)	104.63916	99			

Correlation Coefficient = -0.163402
 Stnd. Error of Est. = 1.01943
 R-squared = 2.67 percent

**The Regression Analysis Of Cadmium Levels On Mercury
Levels For Animals From The Oak Ridge Reservation, Tennessee.**

Dependent variable: Cadmium

Independent variable: Mercury

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	0.0673066	0.0148873	4.52108	1.72402E-5
Slope	-0.0371538	0.0204748	-1.81461	0.0726432

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F-Ratio	Prob. Level
Model	.0325112	1	.0325112	3.2928084	.07264
Error	.967592	98	.009873		
Total (Corr.)	1.000103	99			

Correlation Coefficient = -0.180299
 Std. Error of Est. = 0.0993649
 R-squared = 3.25 percent

VITA

Jeffery James Tasca was born in Paterson, New Jersey on July 9, 1961. He attended elementary schools in that city and was graduated from Kinnelon High School in June of 1979. The following September he entered Shippensburg State College, Shippensburg Pennsylvania, and in May 1983 he received a Bachelor of Science degree in Biology with a minor in chemistry. In the summer of 1985 he accepted a research assistantship at The University of Tennessee, Knoxville and began study toward a Master's degree. This degree was awarded in March of 1988.

The author is a member of the American Society of Toxicologists. Mr. Tasca plans to continue his education.