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THREE-YEAR MOVEMENT PATTERNS OF ADULT DESERT TORTOISES AT YUCCA MOUNTAIN

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Abstract. We studied the home-range size and site fidelity of adult (>180-mm MCL) desert tortoises (*Gopherus agassizii*) at Yucca Mountain, Nevada, during 1992-1994. Of 67 adult tortoises monitored at Yucca Mountain during this period, we evaluated the movements of 22 female and 16 male radiomarked tortoises that were located >50 times during each of the 1992, 1993, and 1994 activity seasons. By including only tortoises that were located many times in all three years, we may have biased our sample toward the resident tortoises that were easiest to locate. We used two methods to measure annual and three-year home range size: 100% minimum convex polygon (MCP) (Mohr 1947) and 95% cluster (Kenward 1987). MCP represents the maximum area a tortoise used, whereas 95% cluster represents the area a tortoise used most often. To evaluate whether tortoises used the same areas in consecutive years, we measured the shift in arithmetic-mean center of activity (Hayne 1949) and the overlap (i.e., the percent of one year's home range included in the previous year's home range) in consecutive annual home ranges (MCP only). In addition, we measured the percentage of each tortoise's three-year home range used annually (MCP only). Analysis of variance was used to test for differences ($P < 0.05$) among years and sexes for all criteria.

Males had larger ($P < 0.01$) annual MCP home ranges ($\bar{x}$ = 53 ha, SD = 51) than females ($\bar{x}$ = 18 ha, SD = 12). The average three-year MCP home range also differed ($P < 0.01$) between

males ($\bar{x}$ = 93 ha, SD = 27) and females ($\bar{x}$ = 27 ha, SD = 17). MCP home ranges did not differ (P = 0.22) among years ($\bar{x}$ = 33 ha, SD = 39).

Males also had larger ($P < 0.01$) annual cluster home ranges ($\bar{x}$ = 17 ha, SD = 25) than females ($\bar{x}$ = 4, SD = 6). The average three-year cluster home ranges also differed between ($P <$ 0.01) males ($\bar{x}$ = 25, SD = 31) and females ($\bar{x}$ = 7, SD = 4). Cluster home ranges during 1994 ($\bar{x}$ = 5 ha, SD = 7) were smaller ($P < 0.01$) than 1992 ($\bar{x}$ = 10 ha, SD = 18) or 1993 ($\bar{x}$ = 14 ha, SD = 24).

Males had larger ($P < 0.01$) shifts in arithmetic-mean center of activity between consecutive years ($\bar{x}$ = 151 m, SD = 130, n = 32) than females ($\bar{x}$ = 83 m, SD = 85, n = 44). There was no difference (P = 0.56) in shift ($\bar{x}$ = 112 m, SD = 111) between consecutive year groups.

The average overlap in consecutive annual MCP home ranges was 78% (SD = 19, range = 7-100%, n = 76). Only one annual home range had <30% of its area in common with the previous year's home range, while 41 annual home ranges had >80% of their area in common with the previous year's home range. Overlap of 1993 on 1992 ($\bar{x}$ =72%, SD = 21) was smaller ($P < 0.01$) than 1994 on 1993 ($\bar{x}$ = 83%, SD = 14), indicating that in 1994, as compared to 1993, tortoises used fewer areas that they did not use the previous year. There was no difference (P = 0.78) in percent overlap between sexes across the year groups.

Tortoises used an average of 65% of their MCP three-year home range annually (SD = 20, range = 17-100%). The percentage of the three-year home range used in 1994 ($\bar{x}$ = 54%, SD = 18) was smaller ($P < 0.01$) than in 1992 ($\bar{x}$ = 69%, SD = 19) or 1993 ($\bar{x}$ = 70%, SD = 18). This measure did not differ (P = 0.49) between sexes.

We conclude that males have larger home ranges than females and that tortoise movements vary annually, possibly in response to differences in rainfall. Adult tortoises at Yucca Mountain moved less during 1994, which was drier than the previous two years. Although average MCP home range size did not differ among years, tortoises had smaller cluster home ranges in 1994, indicating that they spent most of their time in smaller areas. Tortoises also used smaller portions of their three-year home range in 1994 than they did in the previous two years. In addition, tortoise used fewer areas different from the previous year in 1994 than in 1993. We also conclude that most adult tortoises at Yucca Mountain show strong site fidelity. One reason for this conclusion is that shifts in arithmetic-mean center of activity between consecutive years were small compared to home range sizes. In addition, overlap in consecutive annual home ranges and percentage of the three-year home range used annually were relatively large. It should be noted, however, that a few tortoises we monitored at Yucca Mountain, but did not include in this analysis because we were unable to locate them often enough, moved great distances and had little site fidelity.

LITERATURE CITED

Hayne, D.W. 1949. Calculation of size of home range. Journal of Mammalogy 30:1-18.

Kenward, R. E. 1987. Wildlife Radio Tagging. Academic Press, London. 222 pp.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:233-249.

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Three Year Movement Patterns of Adult Tortoises at Yucca Mountain

1995 Tortoise Council, Las Vegas

Presentation Outline by Eric A. Holt (EG&G)

I. Introduction

I'd like to first mention that this work was funded by the U.S. Department of Energy, Yucca Mountain Site Characterization Project.

Slide 1

The concept of a home range is based on the belief that animals do not wander around randomly; instead, they use specific areas and return to those areas that provide resources that they require, such as food, shelter, and mates.

The size of a home range provides some idea of how much space an individual uses during a given time period. The few studies that have been done on movements of desert tortoises, have found that over a one to two year period, males use about 20-45 ha and females use about 10-20 ha. Today I will report the home range sizes of adult tortoises at Yucca Mountain during the last three years.

There is another aspect of space use that is seldom reported, and that is site fidelity. What I am referring to as site fidelity is the use of the same areas in different years. Today I will also address this issue of site fidelity.

Slide 2

At Yucca Mountain, we began monitoring radiomarked tortoises in 1989, and have been locating about 100 tortoises per year since 1992.

We locate our radiomarked tortoises twice weekly during the activity season, and when located we record information on behavior and location.

Slide 3

Locations are recorded as UTM coordinates and for the data used in this presentation, about 54% of the UTM coordinates were obtained using dGPS, which is accurate to within 5 meters.

The remaining locations were obtained using regular GPS or map and compass, which have assumed accuracies of 30 meters.

Slide 4

To study 3-year movement patterns, we chose from our sample of radiomarked tortoises all individuals >180 mm Mid-Carapace Length that were located at least 50 times during the 1992, 93, and 94 activity seasons.

The resulting sample consisted of 22 female and 16 male radiomarked tortoises.

II. QUESTIONS

Slide 5

When deciding how to evaluate the three-year movement patterns of adult tortoises at Yucca Mountain, we came up with three questions:

First, what is the size of the area tortoises use each year, or, what is their annual home range?

Second, what is the size of the area tortoises used during a 3-year period?

And lastly, did individual tortoises use the same area each year? In other words, did they show site fidelity.

I'm going to break the next part of my talk into 2 parts. First I will describe our methods and results for our first 2 questions, which deal with annual and 3-year home range size. After that I will discuss the methods and results for our question of site fidelity.

III. METHODS/RESULTS

Slide 6

We used two different methods to estimate home range size:

the 100% minimum convex polygon method, because we feel it represents the maximum area a tortoise used,

and the 95% Cluster method, because we feel it represents the area a tortoise used the most.

The software package "Ranges" was used to estimate these home ranges.

Slide 7

This slide shows an example of a convex polygon. As you can see this method draws a single polygon around the outer locations and measures the area of the polygon.

Based on this method, an adult male identified as 209, had a convex polygon home range of 33 ha, in 1992.

Slide 8

This histogram shows the average annual and 3-year **convex polygon** sizes for males and females.

Based on analysis of variance males had significantly larger annual convex polygon home ranges than females.

The average annual convex polygon size for males was 53 ha. 53 ha is about the size of a circle with a diameter of 800 meters.

Females, on the other hand, had an average size of only 18 ha. 18 ha is about the size of a circle with a diameter of 500 meters.

Males also had statistically larger **3-year** convex polygon home ranges. Males averaged 93 ha, which is about one square kilometer, and females averaged 27 ha.

There was no statistical difference in convex polygon size between the three years.

However, in 1994, convex polygon size did decrease for both males and females with males showing a 33% decrease and females a 12-19% decrease.

Slide 9

In comparison to the convex polygon method, the **Clustering** method draws multiple polygons around groups of locations clumped together.

As you can see by this slide, the area between clusters are not included in the measurement of home range, and thus cluster home ranges are smaller than convex polygon home ranges.

Referring back to tortoise 209, its 1992 cluster home range was only 5 ha, as compared to its convex polygon home range for the same year of 33 ha.

Slide 10

This histogram shows the average annual and 3-year cluster sizes for males and females.

Based on analysis of variance, there was again a statistical difference in annual

homerange size between sexes, with males averaging 17 ha and females averaging 4 ha. On average, annual cluster size was 1/4th the size of convex polygons.

Males also had significantly larger **3-year** cluster home ranges. Males averaged 25 ha and females averaged 7 ha.

There **was** a statistical difference in annual cluster home range size between the three years, with 1994 being smaller

We have now answered our questions about home range size, so I will now move on to discuss the question of site fidelity.

Slide 11

To determine site fidelity, we calculated three things:

shift in arithmetic mean-center of activity between consecutive years,

convex polygon overlap between consecutive years,

and the % of the 3-year convex polygon used each year.

Slide 12

Shift in mean-center of activity is defined as the distance between the arithmetic mean locations for two consecutive years.

The arithmetic mean location is calculated by taking the average of the northing and easting coordinates.

This slide shows a map of tortoise 209s 1992 and 1993 active season locations. I have also included the convex polygons for the same years.

The large spheres represent the arithmetic mean location for each year.

Based on this, you can see that 209s center of activity shifted 100 meters to the south east from 1992 to 1993, this is a fairly small distance when compared to annual home range size.

Slide 13

These histograms show the distribution of shift in center of activity.

Since there was no statistical difference between years, I combined the data among years and only present the data by sex.

As with home range size, males had statistically larger shifts in center of activity than females.

The average shift for females was 83 m while the average shift for males was 151 m.

If you remember that the average annual convex polygon home range for males is equivalent to a circle with a diameter of 800 meters, you realize that a shift in center of activity of 151 meters, is relatively small.

Slide 14

The second parameter we measured to evaluate site fidelity was convex polygon overlap between consecutive years.

% overlap between consecutive years is defined as the percent of a given years home range that was used, or is in common with, the previous years home range.

This slide shows the convex polygon home ranges for tortoise 209 during 1992 and 1993. As you can see, approximately 61% of his 1993 home range is in common with his 1992 home range.

Thus, in 1993 this tortoise mostly used areas that it also used in 1992.

Slide 15

These histograms show the convex polygon overlap distribution for 1993 on 1992, and 1994 on 1993.

Since there was no statistical difference between sexes, I combined the data by sex and only present the results by the two-year combinations.

The average amount of 1993 home ranges used in 1992 was 72%, with 11 tortoises only using areas in 1993 that they also used in 1992.

The average amount of 1994 home ranges used in 1993 was 83%, with 16 tortoises only using areas in 1994 that they used in 1993.

Based on analysis of variance, we found that 1994 overlapped on 1993 more than 1993 did on 1992.

This indicates, that in 1994, tortoises used fewer areas different from what they used in 1993, as compared to areas shared between 1993 and 1992. In other words, in 1994 they restricted their movements to mostly areas they used the previous year, but in 1993 they used many areas not used in the previous year.

Slide 16

And finally, the third parameter measured to evaluate site fidelity was the percent of a tortoises 3-year convex polygon used during a given year.

This measurement is easily seen on this slide.

The large polygon represents the 3-year home range of an adult female, called 798, and the smaller polygon represents her 1994 home range.

Thus, in 1994 this tortoise used 20% of her three year home range.

Slide 17

These histograms show the distribution of the % of 3-year home range used each year.

Since there was no statistical difference between sexes, I again combined the data by sex and am presenting the results by years only.

As you can see, the distribution and means for 1992 and 1993 are very similar.

Then, in 1994, the distribution shifted left and the mean dropped to 54%.

Based on analysis of variance, in 1994, tortoises did use less of their three year convex polygon home ranges.

Based on the results of our analysis of annual overlap we conclude that this decrease in % of 3-year home range used in 1994 was because tortoises restricted their movements to a smaller part of the area they used previously, not because they used new areas.

IV. CONCLUSIONS

Slide 18

In conclusion, we determined that males have larger **annual** convex polygon home ranges than females.

Males averaged 53 ha and females average 18 ha.

Males also had larger annual **cluster home** ranges than females.

Males averaged 17 ha and females averaged 4 ha.

Slide 19

We also concluded that males have larger **3-year** convex polygon home ranges than females.

Males averaged 93 ha and females average 27 ha.

Males also had larger 3-year **cluster home** ranges than females.

Males averaged 25 ha and females averaged 7 ha.

Slide 20

Third, because we found a year differences in cluster home range size, annual overlap, and percent of 3-year home range used each year, we concluded that tortoise movement is dependent upon a year factor.

Our best guess is that precipitation, temperature, and their influence on plant productivity are probably the main factors influencing tortoise movements.

In 1994, the driest of the three years and one of the hottest summers on record, tortoises spent most of their time in small areas.

In addition, in 1994 they used fewer areas different from the previous year and

they used smaller portions of their 3-year home range.

Slide 21

Our final conclusion is that adult tortoises at Yucca Mountain show strong site fidelity, at least over our three year sampling period.

We conclude this because shifts in mean center of activity are small when compared to home range size. Males had an average shift of about 150 meters and females had an average shift of about 80 meters.

In addition, convex polygon overlap between consecutive years is large with annual averages ranging from 72 to 83%.

And finally, the % of the three-year home range used each year is also large, averaging 70% in 1992 and 1993 and 54% in 1994.

THREE YEAR MOVEMENT PATTERNS OF ADULT TORTOISES AT YUCCA MOUNTAIN

(TORTOISE SLIDE)

QUESTIONS

- What is the Size of the Area Tortoises use Each Year and During a 3-year Period?

- Do Tortoises Use the Same Area Every Year?

STUDY AREA

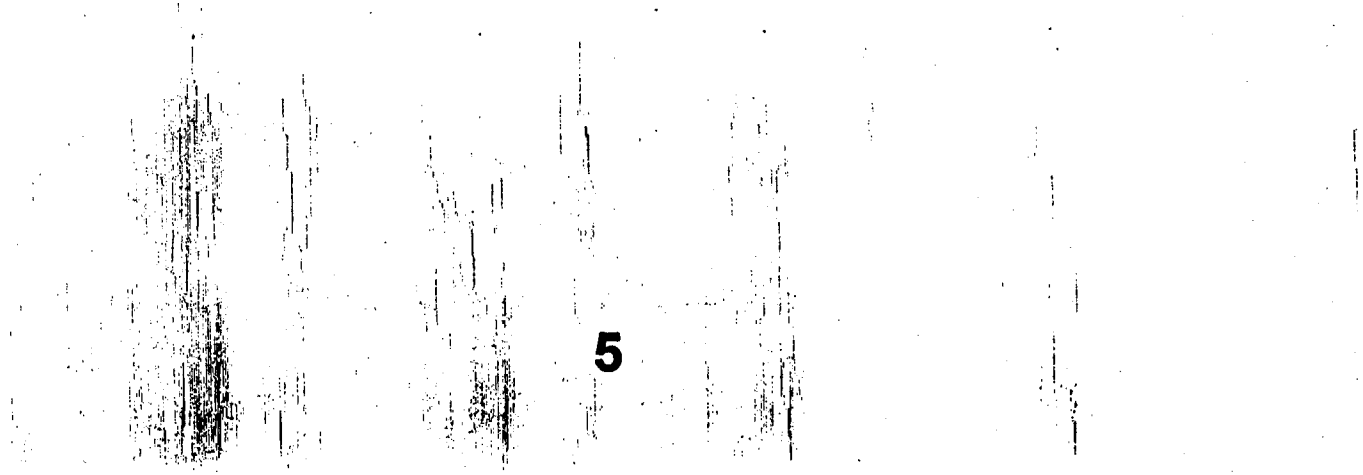
- Northern Edge of the Tortoise Range
- Transition Between Great Basin and Mojave Deserts

METHODS

SAMPLE

- 21 Females and ~~18~~ 17 Males > 180 MCL
- 1992, 1993, and 1994
- >50 Active-Season Locations

(((Slide of somebody doing telemetry)))



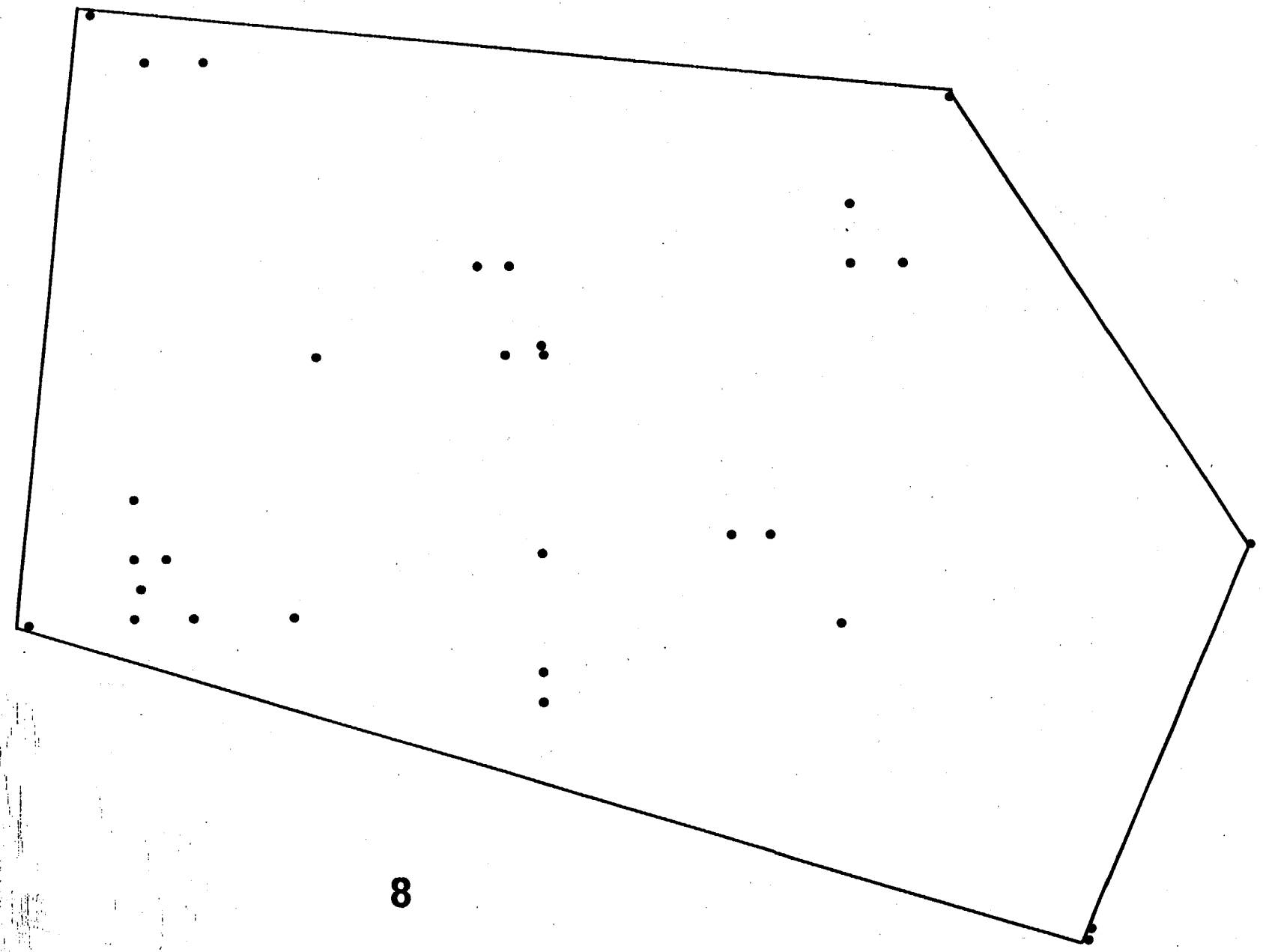
(((Slide of a field GPS unit with antenna on a stick next to a well flagged obviouse burrow)))

METHODS

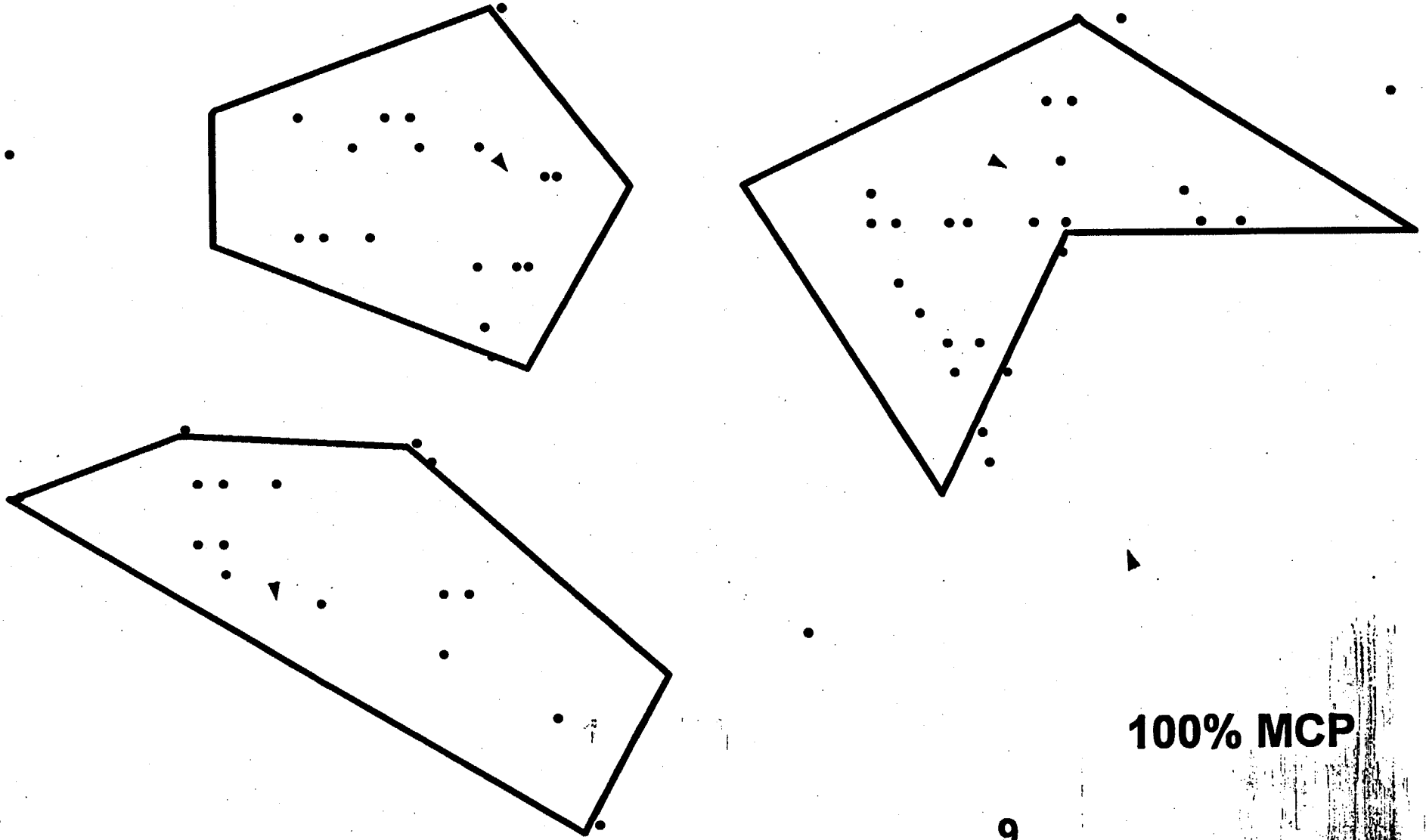
What is the Size of the Area Tortoises Use?

- 100% Minimum Convex Polygon (MCP) Home Range Size
- 95% Cluster Home Range Size

100% MINIMUM CONVEX POLYGON



95% CLUSTER



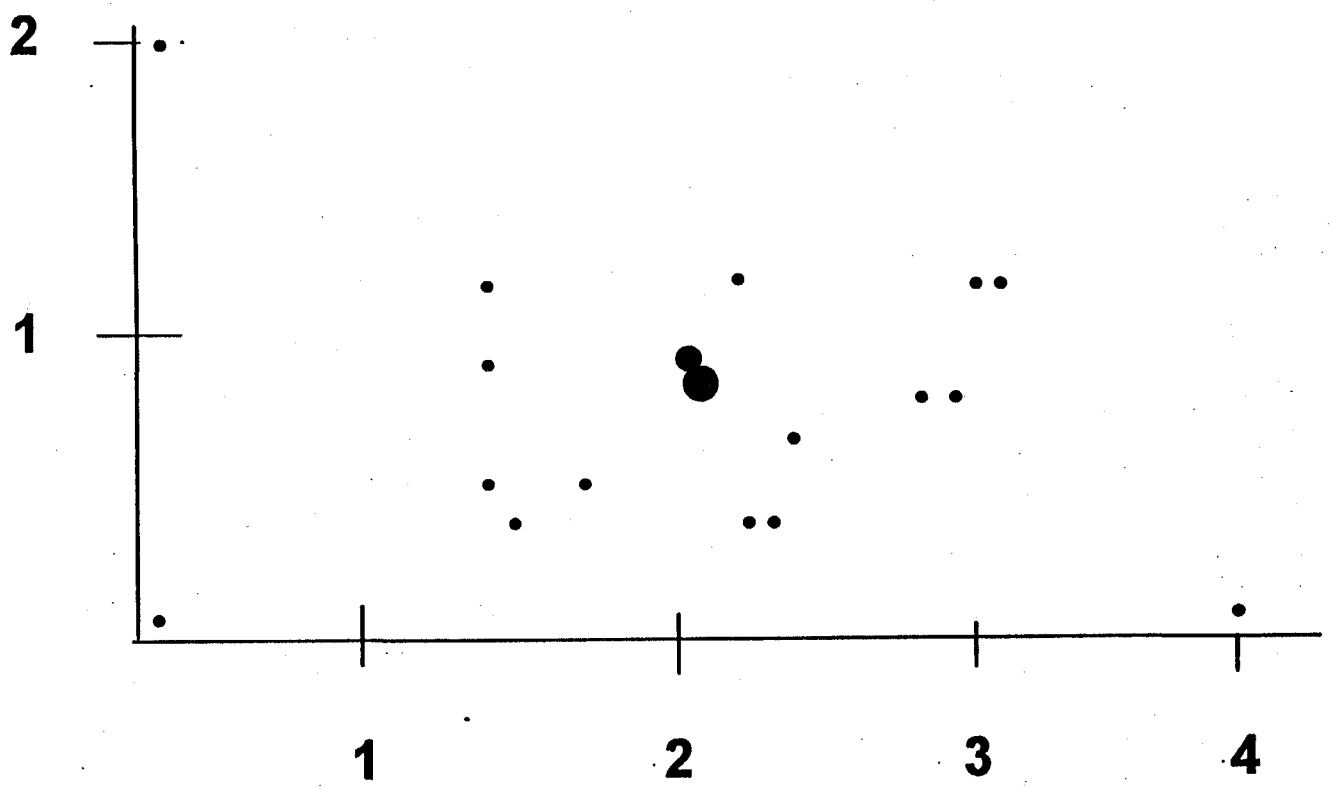
100% MCP

METHODS

DO TORTOISES USE THE SAME AREA EVERY YEAR?

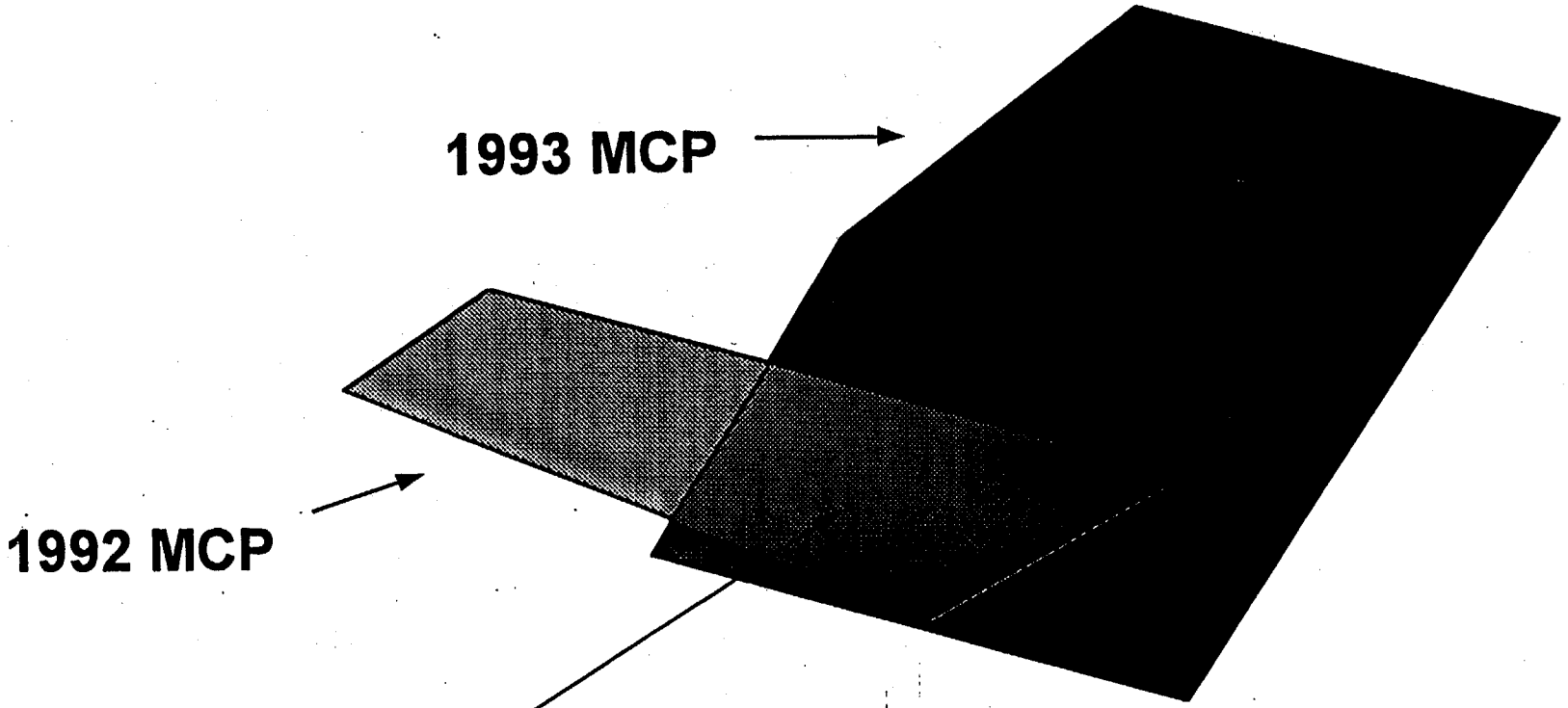
- Shift in Arithmetic-Mean Center of Activity
- MCP Overlap Between Consecutive Years
- % of 3-Year MCP Used Each Year

ARITHMETIC MEAN CENTER OF ACTIVITY (CA)



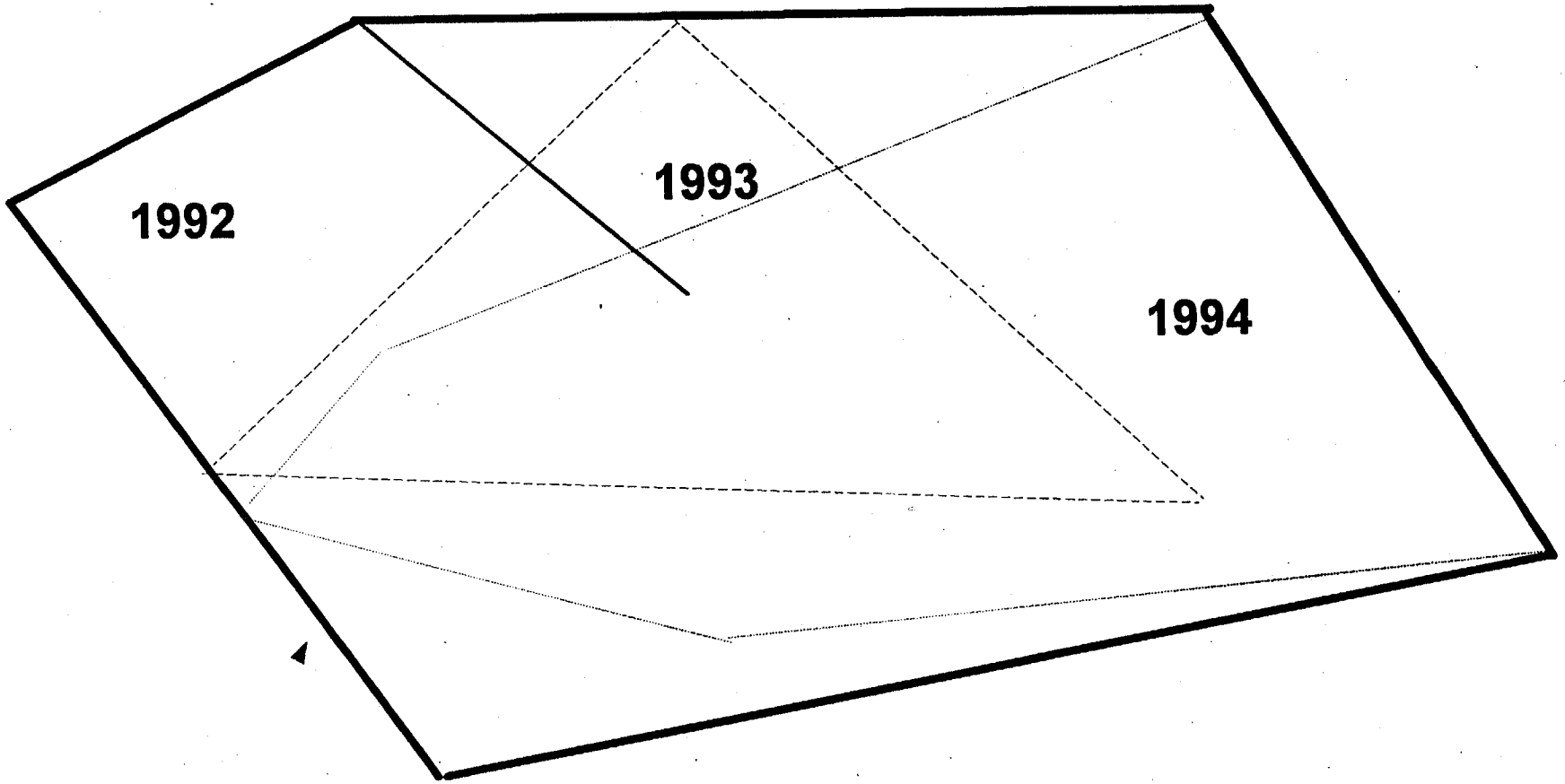
The Point Determined by the Average of the X (east/west) and Y (north/south) Coordinates

MCP Home Range Overlap Among Consecutive Years



1993 Overlaps 80% of 1992

% of Three-Year Home Range Used Each Year



1992 - 1994

1992 Overlaps 30% of 1992-94
1993 Overlaps 30% of 1992-94
1994 Overlaps 60% of 1992-94

HOME RANGE SIZE

- **No Difference Among Years (P = ??)**
- **Males Have Larger Home Ranges (P = ??)**

RESULTS

AVERAGE 100% MCP HOME RANGE SIZE (HA)

YEAR	MALE	RANGE	FEMALE	RANGE
1992	58	13 - 295	18	3-54
1993	53	8 - 149	21	2-77
1994	?		?	
1992-94	?		?	

RESULTS

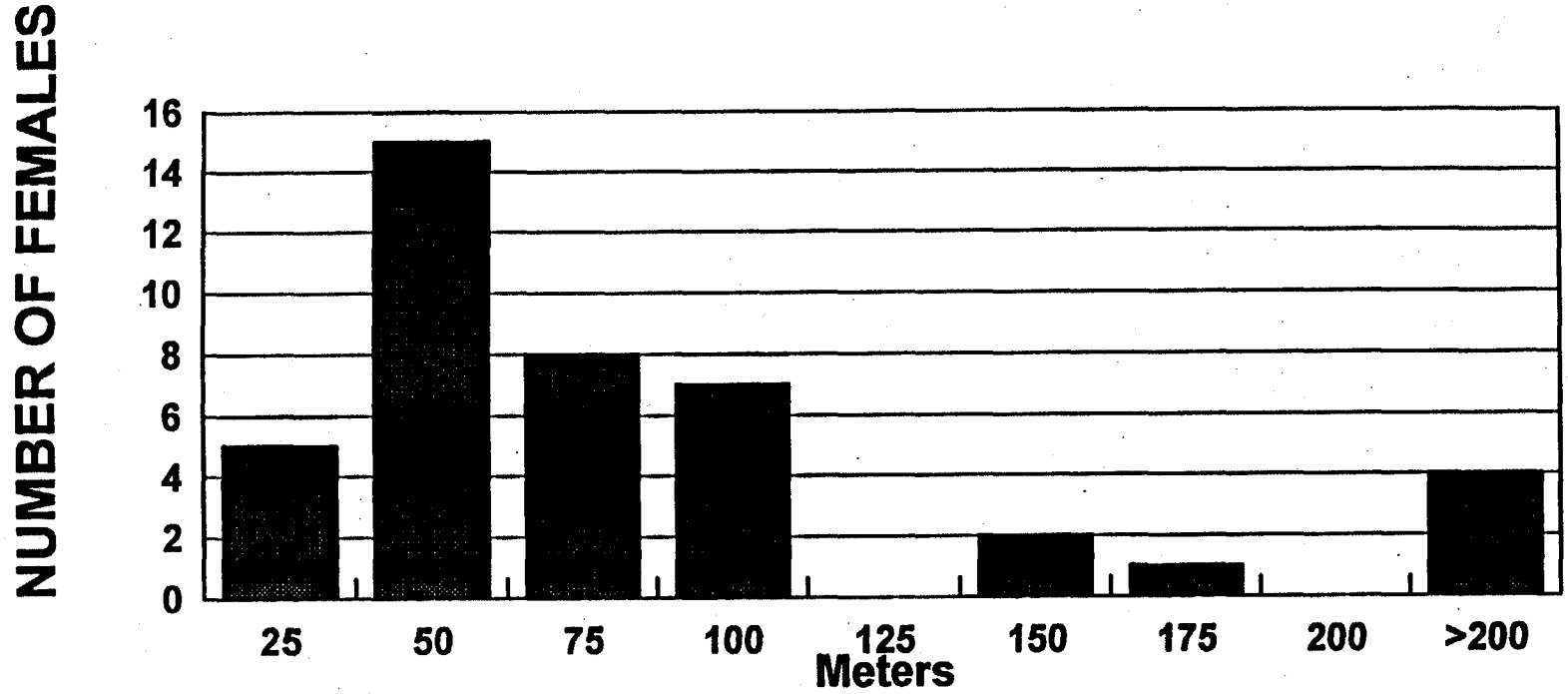
AVERAGE 95% CLUSTER HOME RANGE SIZE (HA)

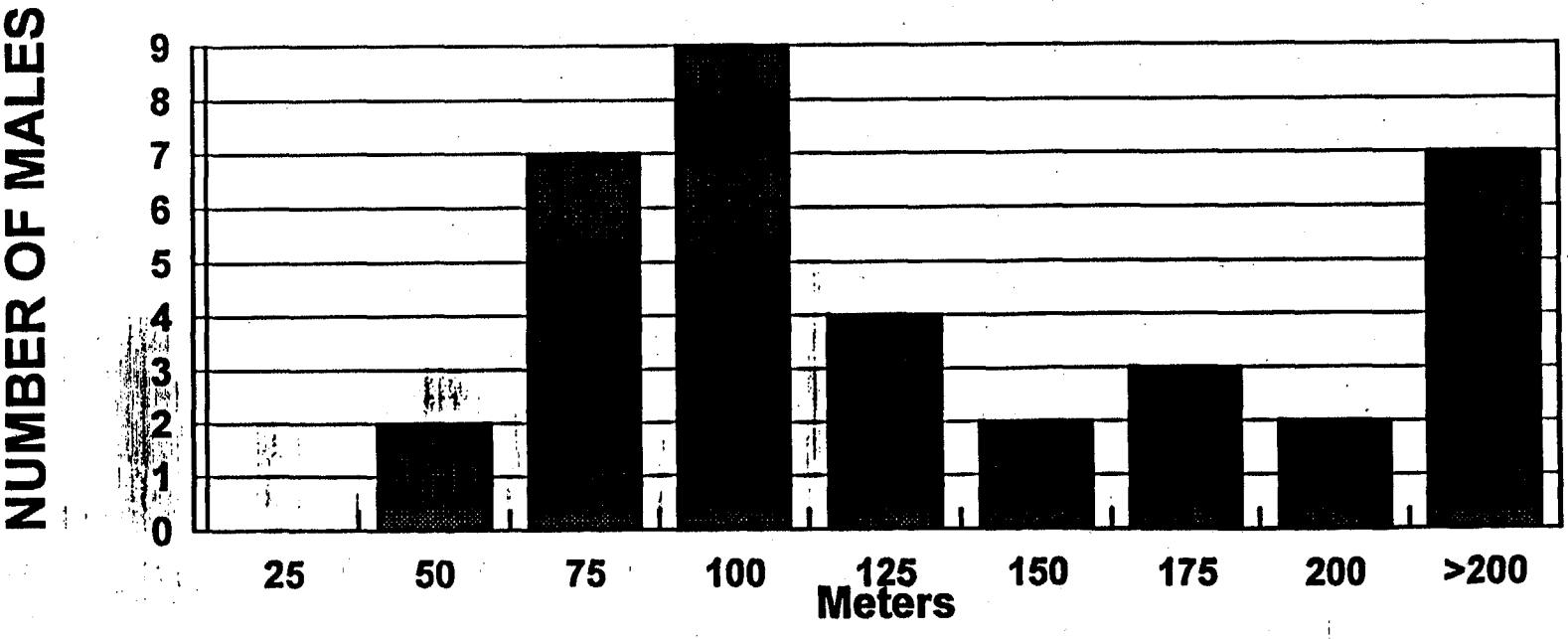
YEAR	MALE	RANGE	FEMALE	RANGE
1992	18	1 - 89	4	1 - 10
1993	18	2 - 77	5	<1 - 20
1994	?		?	
1992-94	?		?	

SHIFT IN ARITHMETIC-MEAN CENTER OF ACTIVIY

- **No Difference Between Consecutive Years (P = ??)**
- **Males Had Larger Shifts (P = ??)**

SHIFT IN CENTER OF ACTIVITY

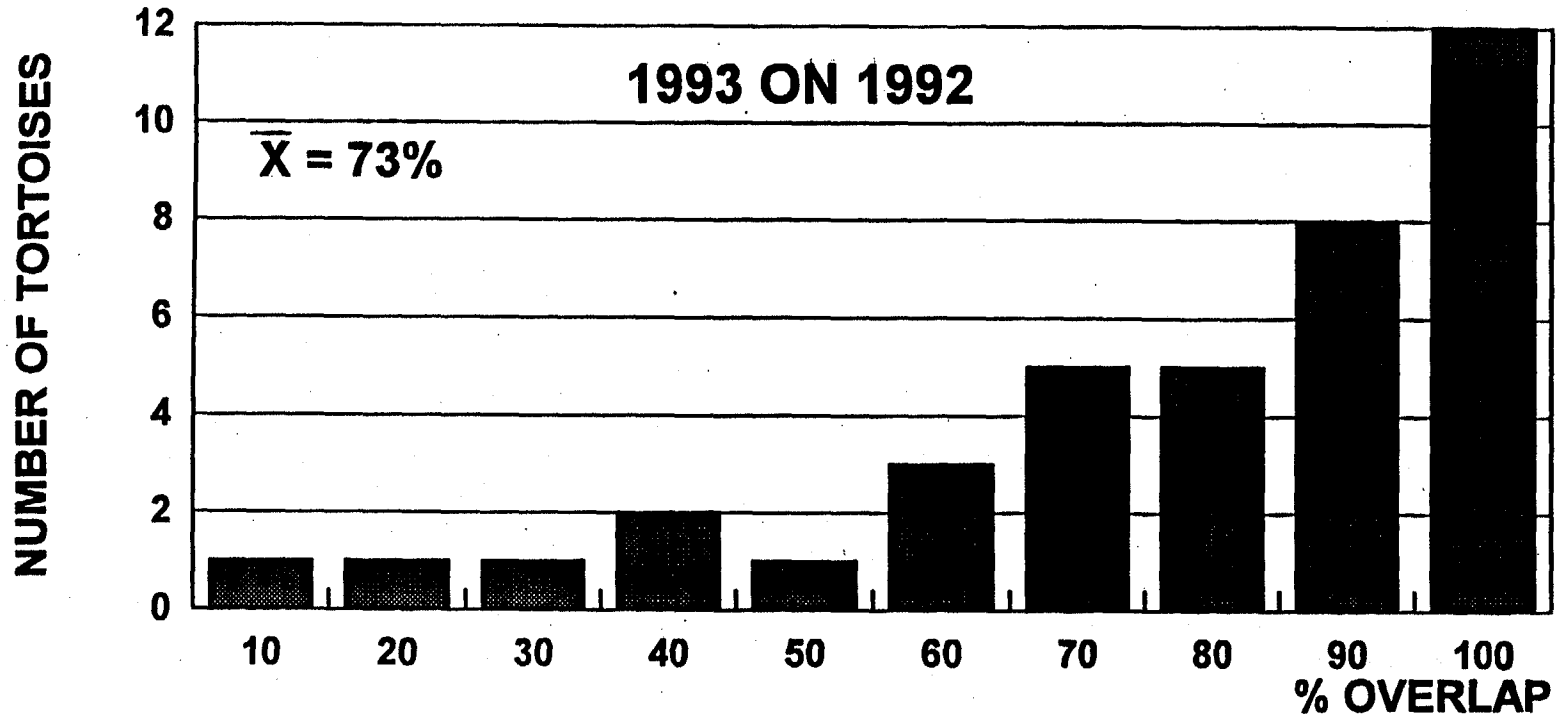


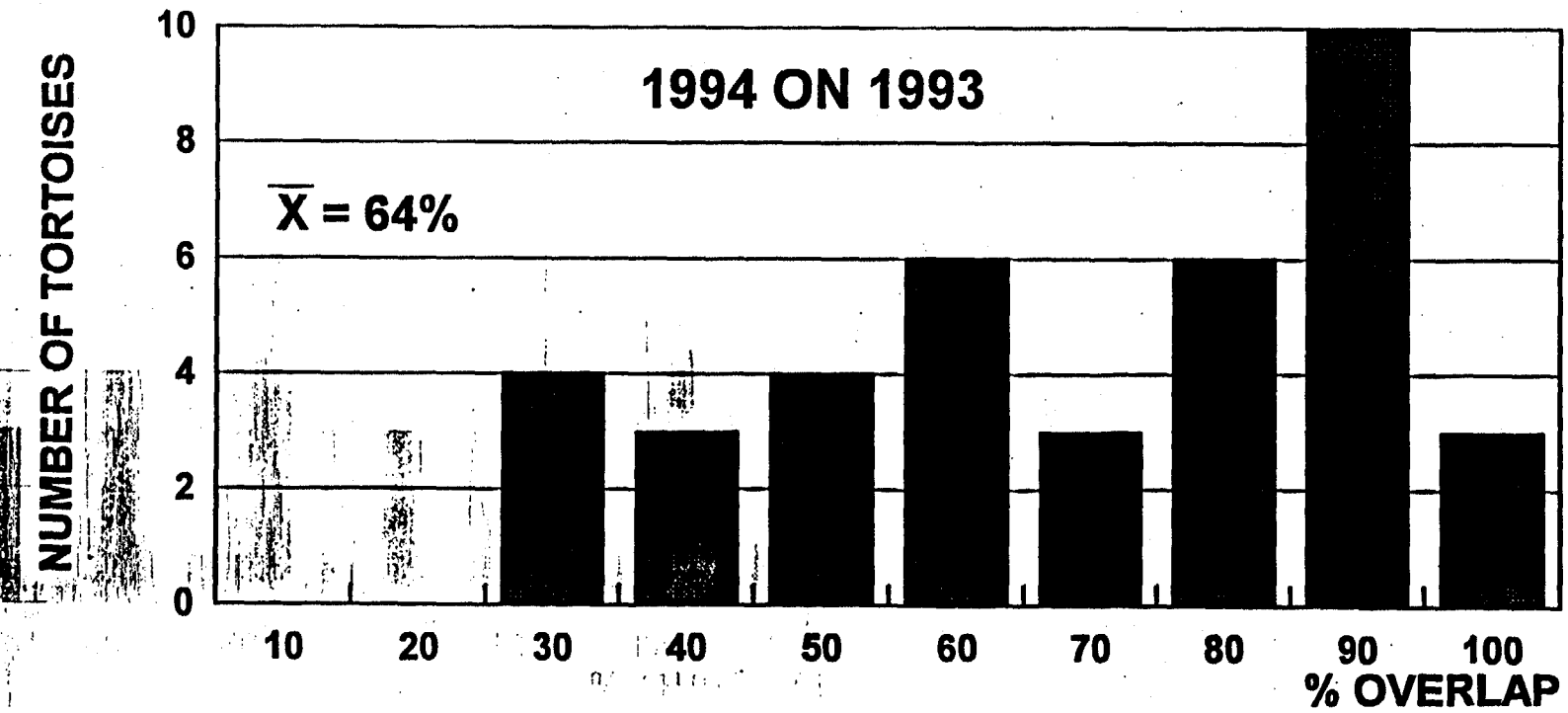


MCP HOME RANGE OVERLAP AMONG CONSECUTIVE YEARS

- No Difference (P = ??) Between Sexes
- 1993 on 1992 Was Higher (P = ??) Than 1994 on 1993

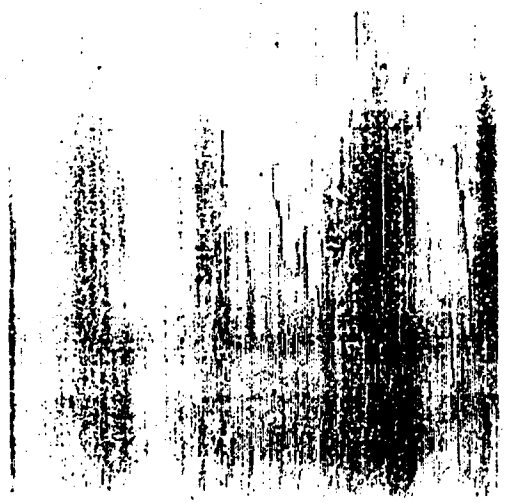
MCP OVERLAP DISTRIBUTION



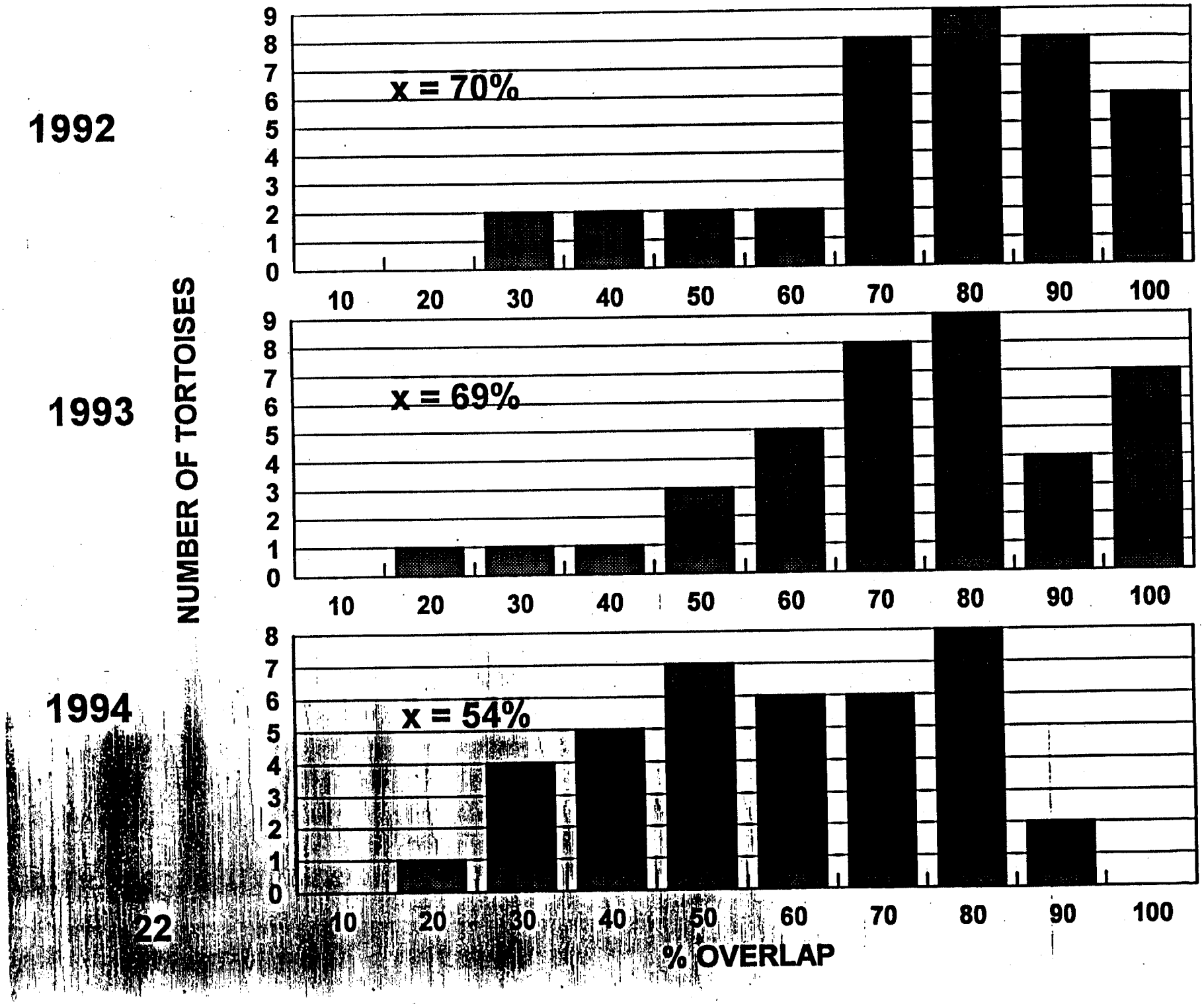


% OF 3-YEAR HOME RANGE USED EACH YEAR

- No Difference (P = ??) Between Sexes
- 1994 was Smaller (P = ??) than 1992 or 1993



ANNUAL 100% MCP OVERLAP ON 3-YEAR 100% MCP



CONCLUSIONS

- **Most Adult Tortoises at Yucca Mountain Show Strong Site Fidelity**
  - Shift in Center of Activity is Small
  - Overlap in Consecutive Annual Home Ranges is Large
  - Percentage of 3-year Home Range Used Each Year is Large

- **Some Tortoises Exhibit Long-Distance Movements**