

POPULATION ABUNDANCE AND DIVERSITY OF REPTILES IN THE EAST
MOJAVE, SODA SPRINGS AREA

A Thesis

Presented to the

Faculty of

California State University, Fullerton

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

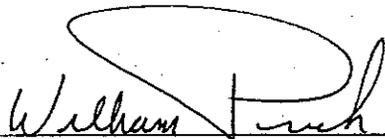
in

Biology

By

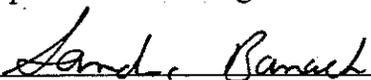
Jason Kenneth Wallace

Approved by:



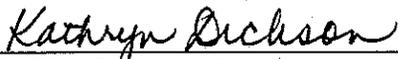
William Presch, Committee Chair
Department of Biological Science

Nov. 17, 2003
Date



Sandra Banack, Member
Department of Biological Science

12 November 2003
Date



Kathryn Dickson, Member
Department of Biological Science

15 November 2003
Date

ABSTRACT

Limited quantitative data exist regarding the relative abundance and habitat associations of reptiles. The purpose of this research was to determine, over a 24 consecutive month period (January 2000-December 2001), the effects of seasonal changes and environmental conditions on the abundance and diversity of the desert reptiles residing in the East Mojave, Soda Springs area. This information was compared with a period of similar data previously collected at the same study site (June 1991-May 1993). Of the total 16 reptile species captured, 7 were abundant enough to conduct a habitat utilization analysis. *Urosaurus graciosus*, *Callisaurus draconoides*, and *Coleonyx variegatus* represent 40.1% of all captures during June 1991-May 1993 but only 4.5% of all captures during January 2000-December 2001. A lack of juvenile recruitment in the 2000 sampling year compared to 2001 was a result of low precipitation levels. No significant difference in capture position (row) and day of capture was found for the adult males, adult females or juveniles of either *Uta stansburiana* or *Cnemidophorus tigris*. An overall trend was found for *Cnemidophorus tigris* regarding a yearly migration of capture success moving up the slope 0.05 rows (1 m) per day. A detailed analysis of trap success reveals a lack of evenness between the four habitat types. Evidence suggests this difference is due to patterns of habitat use by the resident reptiles.

TABLE OF CONTENTS

ABSTRACT.....	ii
LIST OF TABLES	v
LIST OF FIGURES.....	vi
ACKNOWLEDGEMENTS	ix
Chapter	
I. INTRODUCTION	1
II. METHODS.....	11
Data Collection	11
Habitat Classification.....	17
Trap-grid Success.....	18
Abundance and Diversity.....	18
Environmental Factors	21
Habitat Usage.....	21
Age Class and Gender.....	22
III. RESULTS.....	25
Habitat Classification.....	25
Trap-grid Success.....	26
Population Estimates.....	38
Abundance and Diversity.....	38
Environmental Factors	51
Habitat Usage.....	56
Age Class and Gender.....	68
IV. DISCUSSION.....	85
Trap-grid Success.....	85
Environmental Factors	88
Notes on the Common Species Collected.....	88
Notes on the Rare Species Collected	97

Habitat Usage.....	100
Abundance and Diversity.....	101
V. CONCLUSION.....	110
APPENDICES	115
LITERATURE CITED	145

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1. Reptiles captured in this study	39
2. Total reptiles captured a) June 1991-May 1993 b) January 2000-December 2001 c) Total overall (June 1991-May 1993 and January 2000-December 2001)	40
3. Direct comparison of a) the total captures and relative abundance per species for June 1991-May 1993 vs. January 2000-December 2001 ($p = 0.000$; $\chi^2 = 116.153$; d.f. = 8), and b) the total captures and relative abundance per species for June 1991-May 1993 vs. January 2000-December 2001 after removing <i>Urosaurus graciosus</i> , <i>Callisaurus draconoides</i> and <i>Coleonyx variegatus</i> from the capture lists ($p = 0.730$; $\chi^2 = 2.803$; d.f. = 5). Differences in the relative abundance of each species were tested using Chi-squared analysis.....	44

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Map of study site location, Soda Springs, Zzyzx, San Bernardino County, CA, (35° 8' N, 116° 6' W).....	12
2. Diagram of pitfall trap grid divided into four habitat types	14
3. Diagram of pitfall trap grid divided into five equal sections, each containing 5 rows (except for section #5 which contains 6 rows).....	23
4. The percentage of total reptiles captured per column, June 1991-May 1993 and January 2000-December 2001 combined. Chi-squared analysis was used to test for evenness of column capture success.....	27
5. The percentage of actual reptile captures vs. expected reptile captures (assuming captures were even through out) per column set (A) vs. (B,C,D) vs. (E). Edge effect was tested using Chi-squared analysis. Data collected June 1991-May 1993 and January 2000-December 2001 have been combined.....	29
6. The percentage of total reptiles captured per a) habitat type and b) divided section. The capture success of each was tested for evenness, relative to its respective size, using Chi-squared analysis. The data collected June 1991-May 1993 and January 2000-December 2001 have been combined.....	32
7. The percentage of total traps that successfully captured at least one reptile per sampling year and the percentage of total traps that captured multiple reptiles per sampling year	34
8. Comparison of individual trap success a) June 1991-May 1993 b) January 2000-December 2001	36
9. Qualitative comparison of dominance diversity curves a) June 1991-May 1992, June 1992-May 1993, January 2000-December 2000 and January 2001-December b) May 1991, May 1992, May 2000 and May 2001	49

<u>Figure</u>	<u>Page</u>
10. Shannon diversity index $E(H')$ with standard error bars, Pielou's evenness index (J) and Simpson's index of diversity (Ds) calculations for the data collected in May of 1992, 1993, 2000 and 2001.....	52
11. Total abundance of a) reptile species and b) reptile individuals captured vs. average maximum and minimum temperatures for each monthly collecting period (June 1991-May 1993 and January 2000-December 2001). Regression analysis was used to correlate maximum and minimum temperature levels with reptile diversity and abundance. The best fit regression equations for reptile diversity: no. species = $0.1894 \times \text{max. temp } ^\circ\text{C} - 2.0709$ ($R^2 = 0.6758$, $p = 0.000$, d.f. = 45); no. species = $0.1949 \times \text{min. temp } ^\circ\text{C} + 1.3325$ ($R^2 = 0.5331$, $p = 0.000$, d.f. = 45). The best fit equations for reptile abundance: no. individuals = $1.1741 \times \text{max. temp } ^\circ\text{C} - 17.439$ ($R^2 = 0.5128$, $p = 0.000$, d.f. = 45); no. individuals = $1.2501 \times \text{min. temp } ^\circ\text{C} + 3.1833$ ($R^2 = 0.4334$, $p = 0.000$, d.f. = 45)	54
12. Direct comparison of the cumulative annual precipitation for, 1992, 1993, 1999, 2000, 2001 and 2002.....	57
13. Total abundance of a) reptile species and b) reptile individuals captured vs. cumulative annual precipitation levels for each monthly collecting period. (June 1991-May 1993 and January 2000-December 2001). Regression analysis was used to correlate cumulative precipitation levels with reptile diversity and abundance. The best fit regression equation for reptile diversity: no. species = $0.6333 \times \text{cumulative precipitation} + 1.6283$ ($R^2 = 0.2355$, $p = 0.001$, d.f. = 46). The best fit regression equation for reptile abundance: no. individuals = $4.7688 \times \text{cumulative precipitation} + 3.7296$ ($R^2 = 0.2173$, $p = 0.001$, d.f. = 46)	59
14. The percentage of total reptile captures per habitat type (left) and divided section (right) compared to the percentage of the total size of each habitat type (left) and divided section (right) for a) <i>Uta stansburiana</i> b) <i>Cnemidophorus tigris</i> c) <i>Urosaurusgraciosus</i> d) <i>Callisaurus draconoides</i> e) <i>Chionactis occipitalis</i> f) <i>Dipsosaurus dorsalis</i> and g) <i>Coleonyx variegatus</i> . The distribution of each species was tested for evenness by habitat type and overall using Chi-squared analysis	63
15. Comparison of adult male and female <i>Uta stansburiana</i> captures (January 2000-December 2001). The time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by sex and sampling year	70

<u>Figure</u>	<u>Page</u>
16. Comparison of adult and juvenile <i>Uta stansburiana</i> captures (January 2000-December 2001). The time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by age class. Differences in sampling year were not compared since virtually no juveniles (n = 4) were captured in 2000	72
17. Capture comparison of <i>Uta stansburiana</i> adult males, adult females, and juveniles by sampling year. Data collected January 2000-December 2001	74
18. Comparison of adult male and female <i>Cnemidophorus tigris</i> captures (January 2000-December 2001). The time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by sex and sampling year. Dashed lines represent the overall significant trend (p = 0.000; d.f. = 46) The best fit regression equation for January 2000-December 2000: row number = 0.0788 x day of the year - 2879.4 (R ² = 0.3819). The best fit regression equation for January 2001-December 2001: row number = 0.0794 x day of the year - 2931.3 (R ² = 0.2602)	77
19. Comparison of adult and juvenile <i>Cnemidophorus tigris</i> captures (January 2000-December 2001). The time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by age class. Differences in sampling year were not compared since virtually no juveniles (n = 2) were captured in 2000. Dashed lines represent the overall significant trend (p = 0.001; d.f. = 94). The best fit regression equation for January 2000-December 2000: row number = 0.0514 x day of the year - 1875.3 (R ² = 0.2208). The best fit regression equation for January 2001-December 2001: row number = 0.0649 x day of the year - 2393.6 (R ² = 0.1879)	79
20. Comparison of total <i>Cnemidophorus tigris</i> captures for each year (January-December) a) 2000 and 2001 combined b) 1992, 2000 and 2001 combined. In both cases, regression analysis results in a significant positive correlation. The best fit regression equation for 2000 and 2001: row number = 0.0627 x day of the year - 2335.2 (R ² = 0.2009, p = 0.000, d.f. = 94). The best fit regression equation for 1992, 2000, and 2001: row number = 0.0492 x day of the year - 1812.4 (R ² = 0.1121, p = 0.000, d.f. = 155)	81
21. Capture comparison of <i>Cnemidophorus tigris</i> adult males, adult females, and juveniles by sampling year. Data collected January 2000-December 2001	83

ACKNOWLEDGEMENTS

I would like to acknowledge all of those people whose contributions made this thesis possible. First and foremost I would like to thank my advisor Dr. William Presch for his knowledge, insight, support, and most importantly his patience. There is no way I could have done this without him. I would also like to thank Melissa Presch for her previous work, which is the foundation that this study sits upon. I would like to thank my committee members Dr. Sandra Banack who has always been there to lend a helping hand or put a lab roof over my head. Words cannot express my gratitude. Also Dr. Kathryn Dickson who supported this project and helped me through the maze that is IACUC.

I would like to thank Dr. Karen Messer for her enthusiasm and expertise. Without her statistical help this would not be a thesis, just a collection of semi-organized numbers. I would like to thank Lori Jennex for her help and patience in the research permitting process. I would also like to thank Bob Allen for his positive attitude, sense of humor, computer assistance and fireside jam sessions.

I would like to thank those out at the Desert Studies Center for their generous support and assistance. Thank you Robert Fulton for your hospitality, weather data, assistance in the maintenance of the trap grid, and for answering my endless stream of questions, you are the man! Thank you Sandy Fulton for always being so kind and helpful. I would like to thank Marcelo Aguirre for letting me stay in his room on occasion and Eric Lindemann

for his great taste in music and his mastery of the kitchen. Thanks for throwing a few tasty bones to this hungry dog. I would like to also thank Norma Charest for being so helpful and patient with all of my schedule changes.

I would like to thank those that assisted me in my fieldwork. You are all really good sports. Kelli Flaagan for helping me with the formatting of this thesis and literature cited section, Clay Elliot for your hard work and insightful conversations, and Nichole Johanson for helping out at the very beginning. Most importantly I would like to thank Kelly Garron for sharing your enthusiasm and love of the desert with me. It is something I will never forget, Thank you. As for the rest of you (too many to name here), thank you very much.

I would like to thank the entire Biology department faculty at CSUF for treating me more as a colleague than as a lowly graduate student. Thank you Dr. Douglas Eernisse, Dr. Barry Thomas, Dr. Darren Sandquist, Dr. Charles Sylber, Dr. Joel Weintraub, Dr. Mike Horn and Dr. Gene Jones to name a few. I would also like to include Dr. Allen Schoenherr and Frank Wegscheider, thank you for your insight and encouragement.

I would like to thank my fellow graduate students, Karen Eiler, Donovan German, Lisa Crummett, Hawkins Dowis and Andrea Jones (to name a few). Thank you for making this one of the best time of my life. It was an honor to share this experience with you. I would also like to thank my family and friends for their support, both financial and emotional. Thank you for allowing me the opportunity to undergo this amazing journey. Lastly, I would like to thank the town of Baker, CA (my home away from home), Hunter S. Thompson, Johnny Cash, Pike's watering hole and the world's tallest thermometer, all

of which were enough of a distraction to assist me in the maintenance of my sanity throughout this experience.

This thesis is dedicated to the memory of my Grandmother, Bernadine F. Wallace (1924 - 2000), who was an inspiration to all, and to the man who still loves her as much today as he did the day he married her. Thank you.

CHAPTER I

INTRODUCTION

Deserts can be classified by a number of characteristics including low, unevenly distributed precipitation (less than 10 inches [250 mm] per year), nutrient-poor soils and low rates of primary productivity (Schoenherr, 1992). This lack of water coupled with low productivity results in an environment where food is in short supply. The total amount of biomass that can be supported under these conditions is less than that of any other terrestrial ecosystem (Schoenherr, 1992). With that considered, the diversity of life that does exist under these harsh desert conditions is remarkable. Joshua Tree National Park, consisting of nearly 800,000 acres (320,000 ha) of both Colorado desert (south end) and Mojave desert (north end) supports 18 species of lizard, 25 species of snake, 1 tortoise, 3 species of amphibian and 52 species of mammal (Kaye, 2003).

Water, a major limiting factor (Pianka, 1970), is scarce; when it is available it does not last long on the dry, parched desert floor. The Mojave Desert is characterized by winter precipitation (October-April), although there is the occasional summer thunderstorm. Yearly precipitation is what drives a desert ecosystem. Fluctuations in rainfall amount and seasonal distribution are correlated with plant and arthropod productivity. These factors are reflected in the dynamics of lizard communities (Whitford and Creusere, 1977). Winter ephemeral plants in the Mojave number more than a

hundred species, whereas summer ephemeral plants consist of only 10-15 species (Bender, 1982). The productivity of a desert landscape can double in a wet year as a result of this annual vegetation. Animals that have short lives, are small in size, and have high reproductive rates (i.e., arthropods and reptiles) are adapted to take full advantage of such sudden increases in productivity (Schoenherr, 1992).

Esler and Rundel (1999) compared the plant community structure and seasonal growth dynamics of two winter rainfall deserts: the succulent Karoo of South Africa and the Mojave Desert. In the Karoo, they found that the moderate minimum temperatures allow plant growth to begin in the late summer and continue throughout the winter. This results in a plant community characterized by low diversity with shallow root systems evolved to harvest water soon after it rains. Low winter temperatures in the Mojave Desert can inhibit growth until early spring. At that point of the year, a mean of 74% of the precipitation has already occurred. This results in a highly diverse plant community that must rely on deeper stores of water for spring and early summer growth.

In order to germinate, winter ephemeral plants require 1 inch (25 mm) or more of precipitation in late September or early October resulting in a spring bloom. If this is not received, 2 inches (50 mm) of precipitation coupled with warm temperatures must occur by early April. For example, during a five-year dry period in California's deserts, high levels of precipitation in March of 1991 resulted in the germination of some winter ephemeral plants (Schoenherr, 1992). Late precipitation must be coupled with warm temperatures to ensure rapid growth (Schoenherr, 1992).

A strong correlation exists between net primary production and total annual precipitation (Pianka, 1970). The higher the level of primary productivity, the more energy there is available to the system. Most desert lizards serve as the primary and secondary carnivores of this system (Pianka, 1970). Because of the high availability of insect prey, most carnivores in the desert are insectivorous (Schoenherr, 1992). A relationship was shown linking moisture with plant and arthropod productivity (Whitford and Creusere, 1977), along with a link between the surface activity of ants and termites (Schumacher and Whitford, 1976; Whitford and Creusere, 1977). Revell (1997) studied the arthropod diversity associated with creosote bush (*Larrea tridentata*) and saltbush (*Atriplex polycarpa*) in the East Mojave Desert just north of Soda Springs. The total number of individual arthropods collected per month was greatest shortly after the greatest monthly rainfall. An increase in arthropod production caused by an increase in primary productivity, the result of high levels of precipitation, assists the resident reptiles in egg production (species perpetuation) and fat lipid deposition (over winter survival), both of which increase the total abundance of individuals the following season. For example, recent rainfall has been linked to the reproductive status of *Xantusia vigilis* (Zweifel and Lowe, 1966), the genus *Uma* (Mayhew, 1967), and *Uta stansburiana* (Hoddenbach and Turner, 1968).

In an environment of such variable resources, opportunism seems to be the most successful foraging strategy. Many desert reptiles have rather generalized insectivorous dietary requirements. But how can such a variety of species all rely on the same resource

for survival? The key to avoiding this competition problem is niche partitioning based on size, habitat preference, and food preference (Schoenherr, 1992).

Lizards partition their environment spatially; each species with its own preferred method of foraging and micro-habitat preference (Pianka, 1967). *Uta stansburiana* and *Urosaurus graciosus* are small insectivorous lizards that are very similar morphologically, but have very different strategies for survival. *U. graciosus* lives in shrubs and bushes. Its coloration works as camouflage allowing it to sit-and-wait, making a meal of any unsuspecting insect that crosses its path (Stebbins, 1985). *U. stansburiana* is also a sit-and-wait predator, but this species prefers to hunt out in the open (Stebbins, 1985; Cornett, 1987). *Uma scoparia* is highly adapted to sand dunes while *Callisaurus draconoides* lies in wait along desert washes, preferring a harder substrate for better traction while running (Pianka, 1970; Stebbins, 1985). *Cnemidophorus tigris* is an active hunter that eats large numbers of termites (Pianka, 1970). Although *U. stansburiana* and *C. draconoides* rely more and more on grasshoppers in their diet as the summer progresses, *C. tigris* does not utilize this available resource to a large extent (Pianka, 1970). *Xantusia vigilis* also relies on termites for survival. However, this small lizard lives primarily under fallen Joshua trees (*Yucca brevifolia*) and is rarely found out in the open, away from cover (Pianka, 1970; Cornett, 1987). *Phrynosoma platyrhinos* is specialized to eat ants (Stebbins, 1985; Cornett, 1987; Schoenherr, 1992). *Dipsosaurus dorsalis* is a large lizard that is, for the most part, herbivorous. It has the ability to tolerate higher temperatures than most other desert lizard species (Stebbins, 1985; Cornett, 1987).

Being active at night is a good strategy to avoid both the heat of the day and direct competition with diurnal species. *Coleonyx variegatus* is a small nocturnal insectivorous lizard that prefers a rocky terrain. *Chionactis occipitalis* is a small nocturnal insectivorous snake. It is adapted to soft sandy areas; "sand swimming" rather than actual burrowing, it surfaces at night to hunt. *Leptotyphlops humilis* is another small nocturnal insectivorous snake that prefers soft soil. However, this species burrows underground for its food (Stebbins, 1985).

Crotaphytus insularis and *Gambelia wislizenii* are both large diurnal lizards that feed primarily on other lizards. *C. insularis* is an active hunter that easily leaps from boulder to boulder in its preferred rocky habitat, whereas *G. wislizenii* relies on its camouflage coloration to allow it to sit and wait on the ground to ambush an unsuspecting meal (Stebbins, 1985).

Shared habitat can also be partitioned by species' response to environmental conditions. Kay (1970) compared the mean body temperature (MBT) of four lizards (*Uta stansburiana*, *Callisaurus draconoides*, *Cnemidophorus tigris* and *Dipsosaurus dorsalis*) collected at Saratoga Springs, Death Valley, CA. *U. stansburiana* significantly had the lowest MBT, which suggests that it utilizes the lower end of the thermal spectrum. The MBT of *C. draconoides* was significantly lower than that of *D. dorsalis*, but not that of *C. tigris*. *D. dorsalis* had a significantly higher MBT than *U. stansburiana* and *C. draconoides* but not *C. tigris*. Cloud cover resulting in a drop in temperature affected *U. stansburiana* first because of its small body size. The high surface to volume ratio of its body causes it to gain heat and lose heat quickly in response to environmental changes

(Cornett, 1987). Conversely, wind affected *D. dorsalis* the most because of its large body size; a larger body will get pushed around in the wind more than a smaller body. During wind events, *C. tigris* was found to shift into more sheltered areas before ceasing activity, while *C. draconoides* was found to tolerate more wind than the other three species before reducing its own activity.

Pituophis melanoleucus, *Arizona elegans* and *Masticophis flagellum* are all large snakes that eat small vertebrates. *A. elegans* is mainly a nocturnal hunter. *P. melanoleucus* and *M. flagellum* are both diurnal. *M. flagellum* has the ability to tolerate high temperatures. It is active on hot sunny days, whereas *P. melanoleucus* avoids such situations. Since large snakes are secondary and tertiary carnivores, the limited amount of energy available within a desert ecosystem restricts their population size, making these snakes relatively scarce (Schoenherr, 1992).

Few studies have examined the dynamics of a reptile community over an extended period of time (Whitford and Creusere, 1977). Limited quantitative data exist regarding relative abundance and habitat associations of reptiles (Jorgensen and Demarais, 1998). Turner (1968) emphasized the importance of extending work on desert lizard populations over two or more consecutive seasons. Long-term studies of entire reptile communities, although necessary, are rarely conducted due to constraints such as time and manpower (Whitford and Creusere, 1977). Most research on North American desert reptiles has been conducted at the autecological level rather than at the community level (Bury, 1982; Whitford and Creusere, 1977). The purpose of such studies i.e., *Uta stansburiana* (Turner et al., 1970), *Cnemidophorus tigris* (Pianka, 1970), *Urosaurus ornatus* (Mahrt, 1998),

Callisaurus draconoides (Pianka and Parker, 1972), *Uma inornata* (Durtsche, 1992), *Phrynosoma platyrhinos* (Tanner, 1999), *Dipsosaurus dorsalis* (Kay, 1970), *Coleonyx variegatus* (Kingsbury, 1989), *Chionactis occipitalis* (Goldberg and Rosen, 1999), is to gather data and information for each individual species and piece them together into a general theoretical framework (Pianka, 1970). Scott and Campbell (1982) remind us that a community is more than just the sum of its parts. In a holistic analysis, single species studies can be misleading. Studying a community of reptiles from a particular geographic area can result in information about each individual species as well as important aspects of community structure (Bury, 1982).

Until the mid 1960s, herpetological studies were mostly descriptive, documenting species activity, habitat preference, demography, abundance, food habits and predators. Community analysis became more sophisticated in the 1960s with the application of theoretical, mathematical quantification of these variables (Scott and Campbell, 1982). Eric Pianka was a leader in utilizing quantitative methods to test hypotheses dealing with reptile community structure (Pianka, 1966, 1967). The dynamics of entire lizard communities dominated his work. More is known about the ecology of diurnal desert lizard communities than any other group of reptiles (Pianka, 1975, 1977). Modern quantitative reptile community studies have evolved from classical descriptive natural history, now asking "how" and "why" these communities function the way they do (Scott and Campbell, 1982). Kay (1970) compared the environmental responses of lizards at Saratoga Springs in Death Valley. Whitford and Creusere (1977) compared two communities of Chihuahuan desert lizards inhabiting different ecosystems on the same

watershed over a continuous five-year period. Barbault and Maury (1981) studied the niche relationships of a Chihuahuan desert diurnal lizard community. Bury (1982) compared the species diversity, relative abundance and biomass relationships of reptile communities found at eight different sites in the Mojave desert. Baltosser and Best (1990) analyzed the seasonal occurrence and habitat utilization of lizards in southwestern New Mexico. Coventry (1996) compared the reproductive biology, ecological preference and diet of reptiles found in the Chinaman Well area of the Big Desert, Victoria (western Australia). Jorgensen and Demarais (1998) compared the herpetofauna associated with the uplands and arroyos of Chihuahuan desert foothills.

Studies involving the collection of reptiles include a variety of capture techniques such as hand grabs, noosing, elastic bands, .22 caliber dust shot, road cruising, funnel traps, pitfall traps and drift fences. Fair and Henke (1997) compared the effectiveness of pitfall traps, funnel traps, systematic searches and road cruising for capturing *Phrynosoma cornutum*. Henke (1998) studied the effects of observer bias when utilizing distance-restrained and time-restrained direct search methods. Campbell and Christman (1982) discuss the effectiveness of a system of pitfall and funnel traps associated with drift fences. They suggest combining many techniques to obtain a complete herpetofaunal species list. Studies that rely on pitfall and/or funnel traps to capture reptiles discuss overall capture results but fail to include any detailed account of the overall evenness of trapping success (Gibbons and Semlitsch, 1982; Campbell and Christman, 1982; Jorgensen and Demarais, 1998).

Reptiles are key critical components of desert ecosystems (Jorgensen and Demarais, 1998). Trophically they serve as both predator and prey. Fluctuations in rainfall amounts and seasonal distribution correlated with plant and arthropod productivity are all reflected in the dynamics of lizard communities (Whitford and Creusere, 1977). While reptiles and amphibians make up 30% (455 of 1,500 species) of the native North American vertebrates found north of Mexico (excluding fish; Boltosser and Best, 1990), they are often excluded from resource management considerations (Jorgensen and Demarais, 1998). Explanations of observed desert ecological patterns are based largely on elevation, although research suggests that many ecological processes occur at a much finer scale (McAuliffe, 1994).

The purpose of this research was to determine, over a 24 consecutive month period (January 2000-December 2001), the effects of seasonal changes and environmental conditions on the abundance and diversity of the desert reptiles residing in the East Mojave, Soda Springs area. This information was compared with a period of similar data previously collected at the same study site (June 1991-May 1993; Hamilton and Presch, unpublished data). This kind of data is important for the effective management of herpetofauna at both the ecosystem and landscape levels (Jorgensen and Demarais, 1998). The following null hypotheses were tested: (1) Trap grid success does not differ between sampling years. (2) Trap grid success does not differ between columns. (3) Trap grid success does not differ between the four habitat types. (4) Diversity of reptile species captured does not differ between sampling years. (5) Abundance of reptile individuals captured does not differ between sampling years. (6) Habitat type does not have an effect

on the abundance and diversity of reptiles captured. (7) Habitat utilization does not differ between reptile species. (8) Environmental conditions (precipitation / temperature) do not affect abundance and diversity of reptiles.

CHAPTER II

METHODS

This study was conducted at the Desert Studies Center located at Soda Springs (35° 8' N, 116° 6' W), 12.7 km southwest of Baker, California, and 95.2 km east of Barstow in the Mojave National Preserve (Figure 1). A grid of 129 pitfall traps was used for reptile capture. This grid consists of 26 rows of traps arranged in 5 columns, each 20 m apart (Figure 2). They are located on a creosote (*Larrea tridentata*) covered alluvial fan covering an area of 55,000 m² that increases 70 m in elevation (288 m-358 m). This area is representative of habitat found throughout the Mojave Desert including many different types of terrain such as dry lakebed, loose sand, washes, eroded gullies, compacted sand with small rocks, and rocky soil with large rocks.

Substrate pitfall traps are 18.5 L (5 gallon) plastic buckets that have been sunk into the ground and set to be flush with the ground surface. Each trap has a lid that is removed only while the traps are active. These traps, designed to capture animals as they move across the ground, are a very simple, non-intrusive method for collecting reptile species. This method works best for the resident lizards, however, pit-fall traps are also effective for snakes whose lengths are less than the depth of the bucket (Gibbons and Semlitsch, 1982).

Figure 1. Map of study site location, Soda Springs, Zzyzx, San Bernardino County, CA,
(35° 8' N, 116° 6' W).

Fig. 1

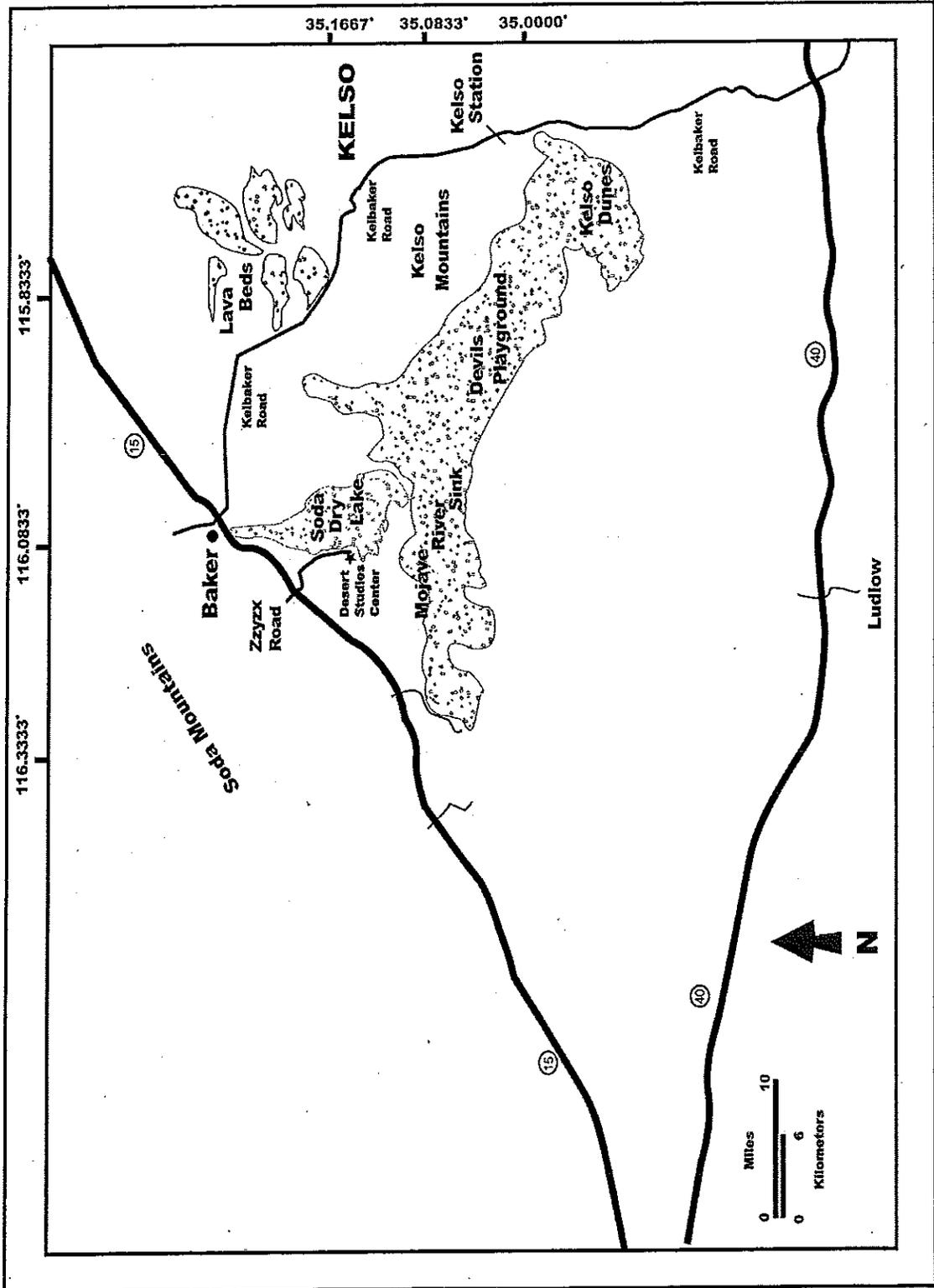
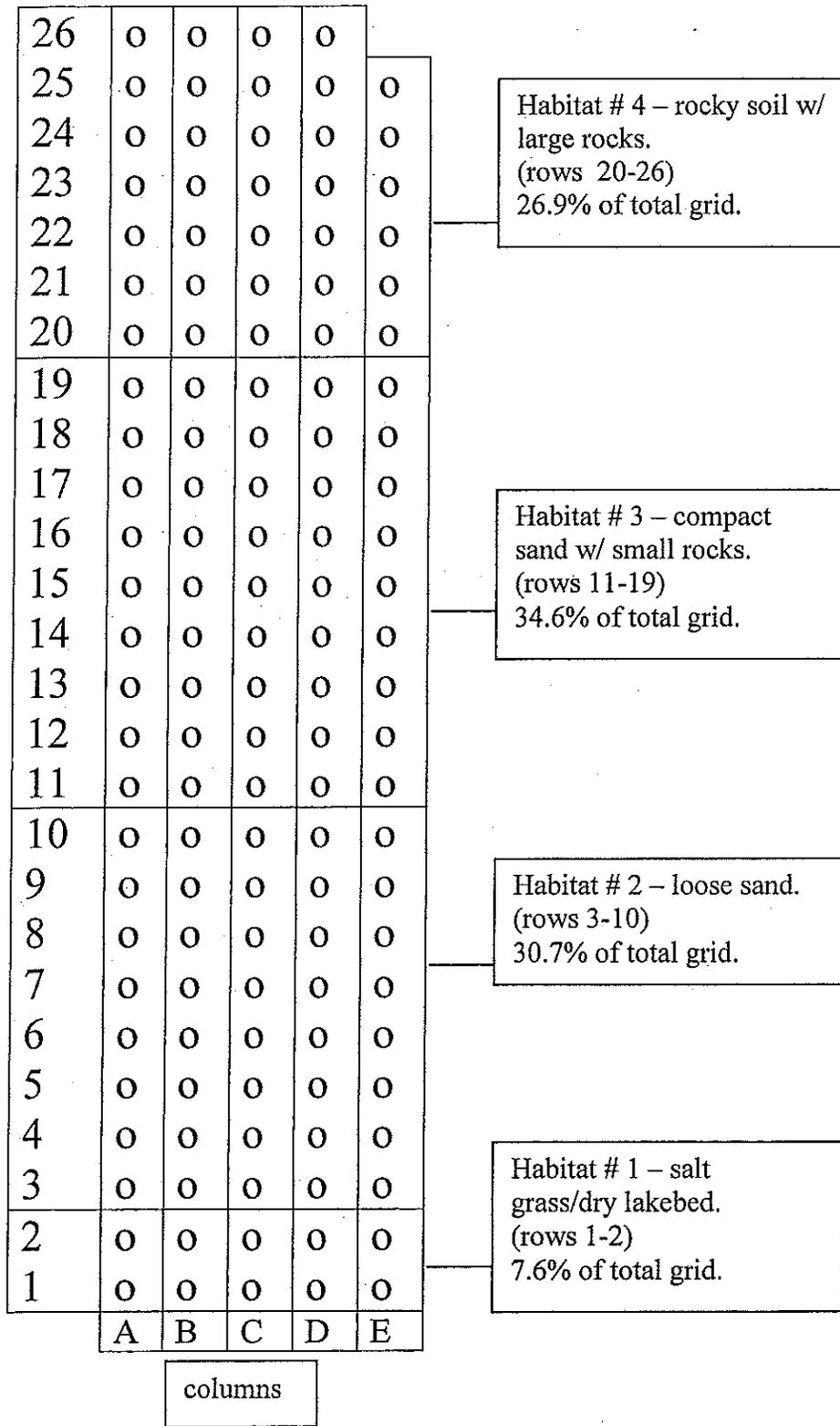


Figure 2. Diagram of pitfall trap grid divided into four habitat types.

Fig. 2



The following procedure was performed monthly for 24 consecutive months (January 2000-December 2001). Once per month the traps remained open a total of four consecutive days. To reduce direct sun exposure, trap lids were situated one inch above the trap leaving a gap for reptile entrance. To prevent flooding after rains, small holes were drilled in the bottom of the buckets to allow for drainage (Gibbons and Semlitsch, 1982). During the four days of collecting, the traps were checked a total of seven times. On the first day, traps were opened in the evening to be checked the following morning. On the second and third day, traps were checked once at dawn, once in the early afternoon, and once at dusk. On the fourth day, traps were checked at dawn then closed by sealing the buckets with lids.

Daily maximum and minimum temperatures were recorded for each four-day collecting period. The annual cumulative precipitation level was also recorded for each sampling year. All measurements were collected using on-site weather stations located at the Desert Studies Center. The habitat type in which the animal was captured was recorded to associate species distributions and abundance with day of the year and habitat preference. The reptiles in the traps were removed by hand, then measured in length (snout-vent, cm), sexed, and marked with a non-xylene based model paint (Boone and Larue, 1999) using standard painting techniques to provide recapture data. Captured animals were released at the location of each capture.

The mark/recapture method consists of the capture and marking of animals, their release, and their subsequent recapture. Recaptured animals were used to calculate

monthly estimates of population density. The mark/recapture method is based on the assumption that the organism captured is representative of the entire population (Heyer et al., 1994). The Schnabel census was used to estimate the abundance of each species (Seber, 1982).

Habitat classification

The pit-fall trap grid used for this study is divided into four unequal habitat types (Figure 2). These four habitat types are described qualitatively as type #1- saltgrass/dry lakebed (7.6 %), type #2- loose sand (30.7 %), type #3- compact sand with small rocks (34.6 %), and type #4- rocky soil with large rocks (26.9 %). These categories were each defined quantitatively as follows. Using a hand shovel, a soil sample of upper substrate was randomly collected from each of the four habitat types. Using an Ohaus triple beam balance (2,620 g capacity), 300 g of substrate was randomly measured from each sample. Five standard testing sieves, each of different mesh size, were used with a CE Tyler portable sieve shaker (model RX-24) to separate the substrate particles into five comparable size categories (Appendix 1). After running 300 g of substrate in the sieve shaker for 5 minutes, the contents of each sieve were weighed using an Ohaus cent-ogram scale (311 g capacity). This procedure was repeated for each of the four habitat types. The percentage of each substrate type in each habitat zone was then calculated.

To help further substantiate the differences between the four habitat types, previously collected vegetation data were incorporated into this study (Garron, unpublished data). These quantitative data were collected on column C and column E of the trap grid, November 2001-September 2001. On both sides of each trap, a five-meter transect was

laid out perpendicular to the column. The species of plant found at each meter mark was recorded along with percent coverage. Regression analysis was used to test for trends in total percent coverage.

Trap grid success

To determine if the trap grid itself was uniformly successful at capturing reptiles, Chi-squared analysis was used. Aspects of the grid analyzed include edge effect, evenness of column success, habitat success, individual trap success and overall success.

Abundance and diversity

Chi-squared analysis was used to compare the reptile abundance and diversity of the two collection periods (June 1991-May 1993 vs. January 2000-December 2001). Data collected June 1991-May 1993 were gathered using the same methods previously outlined for this study. However, no snout-to-vent lengths or sex classifications were recorded. The abundance and diversity of species and individual reptiles of all species were compared for each individual sampling year (12 month period). Dominance diversity curves were plotted to qualitatively compare the biodiversity of the four sampling years. To construct a dominance diversity curve, captured species were ranked by their total abundance (most abundant "1", second most abundant "2", etc.). The natural log of the abundance of each species was then plotted as a function of its rank. A community with high diversity will be rich in species with a low rate of species dominance. Thus, a community with high diversity assumes a curve with a more horizontal aspect (low dominance) while a community with lower diversity assumes a more vertical curve (high dominance). To quantitatively compare seasonal patterns of

species diversity, the Shannon index (H') and Simpson index (D_s) were calculated using PRIMERv5 software (Plymouth Routines In Multivariate Ecological Research). The adjusted Shannon index $E(H')$ and the variance of the estimate $\text{var}(H')$ were also calculated (Hutcheson, 1970), as was Pielou's evenness index (J ; Poole, 1974).

Shannon index

The Shannon index (H') considers both species richness and evenness. It is a measure of uncertainty. The smaller the value, the greater the probability that the next individual encountered will be the same species as the previous one (Smith, 1996). The higher the value of (H'), the greater the diversity.

$$H' = - \sum P_i \ln P_i$$

$$P_i = n_i / N$$

n_i = number of individuals of i th species

The previous equation is a biased estimate of (H'). A more conservative estimate of (H') was found using (Hutcheson, 1970):

$$E(H') = \left[- \sum P_i \ln P_i \right] - \left[\frac{s-1}{2N} \right]$$

s = the total number of species

N = the total number of individuals belonging to all species

The variance of (H') was found using (Hutcheson, 1970):

$$\text{var}(H') = \frac{\left[\sum P_i \ln^2 P_i - (\sum P_i \ln P_i)^2 \right]}{N}$$

The standard error of (H') was found using:

$$\text{Standard error} = \frac{\sqrt{\text{var}(H')}}{\sqrt{s}}$$

Pielou's evenness index

Pielou's evenness index (J) compares the observed Shannon diversity index (H') with the maximum possible diversity (H'_{\max}). The maximum possible diversity (H'_{\max}) occurs when all species present have the same number of individuals in their populations (Poole, 1974). The higher the value of (J), the more even the populations. Pielou's evenness index can be found using (Poole, 1974):

1)

$$H'_{\max} = \ln s$$

2)

$$J = \frac{H'}{H'_{\max}}$$

Simpson's diversity index

Simpson's diversity index (D_s) measures the probability that two individuals taken at random from a community will belong to the same species. It measures the relative degree of dominance of a few species, whereas the Shannon index (H') measures the evenness of all species. Simpson's index gives more weight to the common species and little weight to the rare species. The higher the (D_s) value, the lower the overall

dominance, the lower the overall dominance, the greater the species diversity (Poole, 1974).

$$D_s = 1 - \frac{\sum n_i (n_i - 1)}{N (N - 1)}$$

Environmental factors

The maximum and minimum average temperatures of each four-day monthly collecting period were used to determine the effects of temperature on the abundance and diversity of reptiles over the two collection periods. This was done using regression analysis. Regression analysis was also used to determine what effect the cumulative yearly precipitation levels had on the abundance and diversity of reptiles over the two collection periods. Temperature and precipitation data for January 2000-December 2001 were collected using onsite weather stations. Temperature and precipitation data for June 1991-May 1993 were collected 12.7 km northeast of the study site in the town of Baker, CA.

Habitat usage

To determine habitat usage for this reptile community, the percentage of total captures per habitat type was compared to the size of each habitat type. To test for overall evenness of distribution, the size differences between the habitat types had to be standardized. To do this, the trap grid was divided into five equal sections, each containing 5 rows (except for section #5 which contains 6 rows; Figure 3). The percentage of total captures per section was then compared to the total size of each

section. These five sections are described as Section #1- (rows 1-5), Section #2- (rows 6-10), Section #3- (rows 11-15), Section #4- (rows 16-20), and Section #5- (rows 21-26). Chi-squared analysis was used to determine habitat preference and overall evenness of distribution at both the community and species level.

Age class and gender

The data collected January 2000-December 2001 include sex classification and snout-to-vent measurements. A general linear model (ANCOVA- analysis of covariance) was used to determine any significant patterns involving sampling year, row number, day of capture, gender or age class of captured reptile species. Data of this kind were not available for the first collection period (June 1991-May 1993).

Figure 3. Diagram of pitfall trap grid divided into five equal sections, each containing 5 rows (except for section #5 which contains 6 rows).

Fig. 3

26	0	0	0	0	
25	0	0	0	0	0
24	0	0	0	0	0
23	0	0	0	0	0
22	0	0	0	0	0
21	0	0	0	0	0
20	0	0	0	0	0
19	0	0	0	0	0
18	0	0	0	0	0
17	0	0	0	0	0
16	0	0	0	0	0
15	0	0	0	0	0
14	0	0	0	0	0
13	0	0	0	0	0
12	0	0	0	0	0
11	0	0	0	0	0
10	0	0	0	0	0
9	0	0	0	0	0
8	0	0	0	0	0
7	0	0	0	0	0
6	0	0	0	0	0
5	0	0	0	0	0
4	0	0	0	0	0
3	0	0	0	0	0
2	0	0	0	0	0
1	0	0	0	0	0
	A	B	C	D	E

columns

Divided section #5
 (rows 21-26).
 22.4% of total grid.

Divided section # 4
 (rows 16-20)
 19.3% of total grid.

Divided section # 3
 (rows 11-15)
 19.3% of total grid.

Divided section # 2
 (rows 6-10)
 19.3% of total grid.

Divided section # 1
 (rows 1-5)
 19.3% of total grid.

CHAPTER III

RESULTS

Habitat classification

The pit-fall trap grid used for this study was divided by habitat into four unequal parts (Figure 2). Soil composition analysis was used to quantify these substrate differences. As would be expected on an alluvial fan, the percentage of larger substrate particles decreases as you move down the gradient, while the percentage of fine sand increases (Schoenherr, 1992). In this case, a larger percentage of fine sand was found in type #4 habitat than was found in type #3 (Appendix 2). This does not follow the expected pattern. However, type #4 habitat has larger rocks than type #3. These large rocks provide more shelter from the winds, preventing the loose sand from blowing away.

The results of the plant survey (Garron, unpublished data) associated 13 species (the grass family *Poaceae* is counted as one guild) with the four habitat types (Appendix 3). *Chaenactis carphoclinia* (pebble-pincushion) and *Cleomella obtusifolia* (blunt-leaf stinkweed) were found only in type #1 habitat. *Isocoma acradenia* (goldenbush), *Atriplex canescens* (hoary saltbush) and *Oenothera deltoids* (large desert evening-primrose) were found only in type #2 habitat. *Caulanthus cooperi* (copper's caulanthus) and *Phacelia crenulata* (heliotrope phacelia) were both found in type #2, type #3 and type #4 habitats; however, *C. cooperi* was more abundant in type #2 habitat while *P. crenulata* was more abundant in type #3 habitat. *Opuntia basilaris* (beaver-tail

cactus) was found only in type #4 habitat. *Larrea tridentata* (creosote bush) did not appear until row 7 of type #2 habitat, occupying all habitats except for type #1 (Appendix 4). The grass family, *Poaceae*, was found in all four habitat types. This group was most abundant in type #2 and type #3 (Appendix 3). A significant negative correlation was found ($p = 0.000$; $R^2 = 0.445$; d.f. = 25) between overall percent coverage of vegetation and row number, indicating that the vegetation gets more and more sparse as you move up the gradient (Appendix 5).

Trap grid success

The column capture success was tested for evenness for each of the four sampling years using Chi-squared analysis. No significant difference was found between each of the five columns (Appendix 6). The most variable sampling year was June 1992-May 1993 (Appendix 6b) in which differences in column capture success approached significance ($p = 0.077$; $\chi^2 = 8.41$; d.f. = 4). When all four sampling years were combined, no significant difference was found ($p = 0.165$; $\chi^2 = 6.49$; d.f. = 4; Figure 4). Edge effect was also tested using Chi-squared analysis. Over the four sampling years, no significant difference was found in capture evenness between the outer edge columns (A and E) and the inner columns (B, C, and D; $p = 0.137$; $\chi^2 = 3.96$; d.f. = 2; Figure 5). Overall, no pattern of edge effect or column bias was evident.

The capture success of each habitat type was tested for evenness, relative to its respective size, for each sampling year using Chi-squared analysis. No significant

Figure 4. The percentage of total reptiles captured per column, June 1991-May 1993 and January 2000-December 2001 combined. Chi-squared analysis was used to test for evenness of column capture success.

Fig. 4

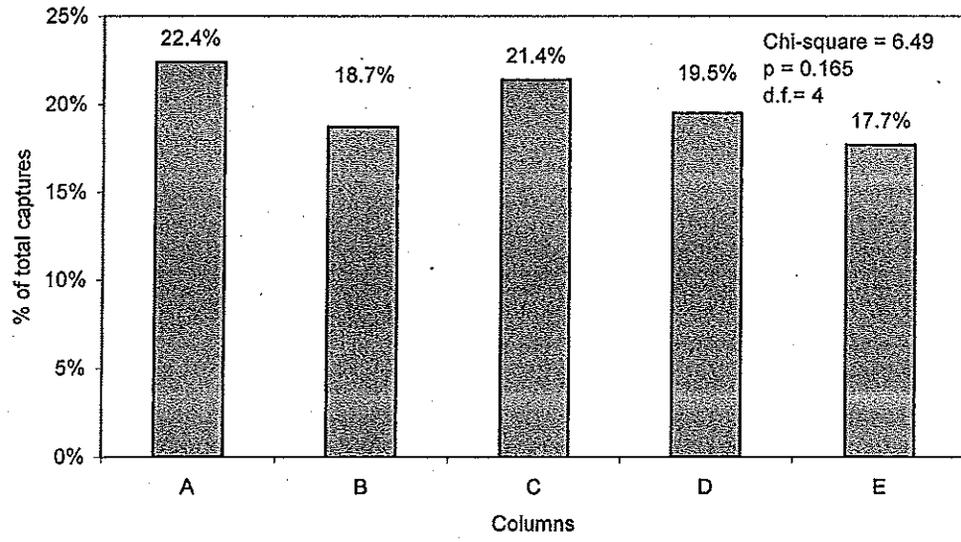
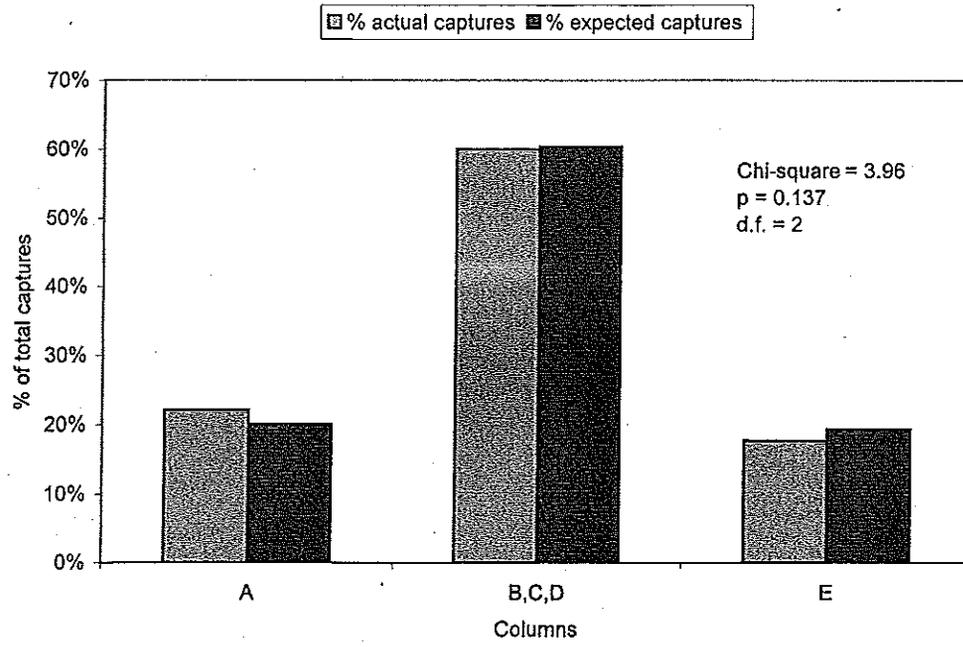


Figure 5. The percentage of actual reptile captures vs. expected reptile captures (assuming captures were even through out) per column set (A) vs. (B,C,D) vs. (E). Edge effect was tested using Chi-squared analysis. Data collected June 1991-May 1993 and January 2000-December 2001 have been combined.

Fig. 5



difference was found for June 1991-May 1992 ($p = 0.273$; $\chi^2 = 3.89$; d.f. = 3; Appendix 7a). A significant difference was found for June 1992-May 1993 ($p = 0.0017$; $\chi^2 = 15.10$; d.f. = 3; Appendix 7b). During that period, more captures occurred in type #3 habitat and less captures occurred in type #4 habitat than would be expected if reptile captures were evenly dispersed. No significant difference was found for January 2000-December 2000 ($p = 0.144$; $\chi^2 = 5.41$; d.f. = 3; Appendix 7c) or for January 2001-December 2001 ($p = 0.478$; $\chi^2 = 2.48$; d.f. = 3; Appendix 7d). Chi-squared analysis was also used to test the evenness of the two collection periods (June 1991-May 1993 and January 2000-December 2001). A significant difference was found for June 1991-May 1993 ($p = 0.0027$; $\chi^2 = 14.09$; d.f. = 3; Appendix 7e). Again, there were more captures in type #3 habitat and less captures in type #4 than would be expected. No significant difference was found for January 2000-December 2001 ($p = 0.334$; $\chi^2 = 3.39$; d.f. = 3; Appendix 7f). When all four sampling years were combined, a significant difference was found ($p = 0.003$; $\chi^2 = 13.70$; d.f. = 3; Figure 6a) following this same pattern. The overall evenness of trap success was also tested using Chi-squared analysis. The data from all four sampling years were combined. The resulting difference was significant ($p = 0.049$; $\chi^2 = 9.51$; d.f. = 4; Figure 6b). Overall, the traps in type #3 habitat were most successful, specifically rows 11-15.

The individual trap success of the entire trap grid was compared between the four sampling years (Figure 7). Traps that captured at least one reptile were distinguished from traps that captured multiple reptiles (Figure 8a-b). During June 1991-May 1992,

Figure 6. The percentage of total reptiles captured per a) habitat type and b) divided section. The capture success of each was tested for evenness, relative to its respective size, using Chi-squared analysis. The data collected June 1991-May 1993 and January 2000-December 2001 have been combined.

Fig. 6

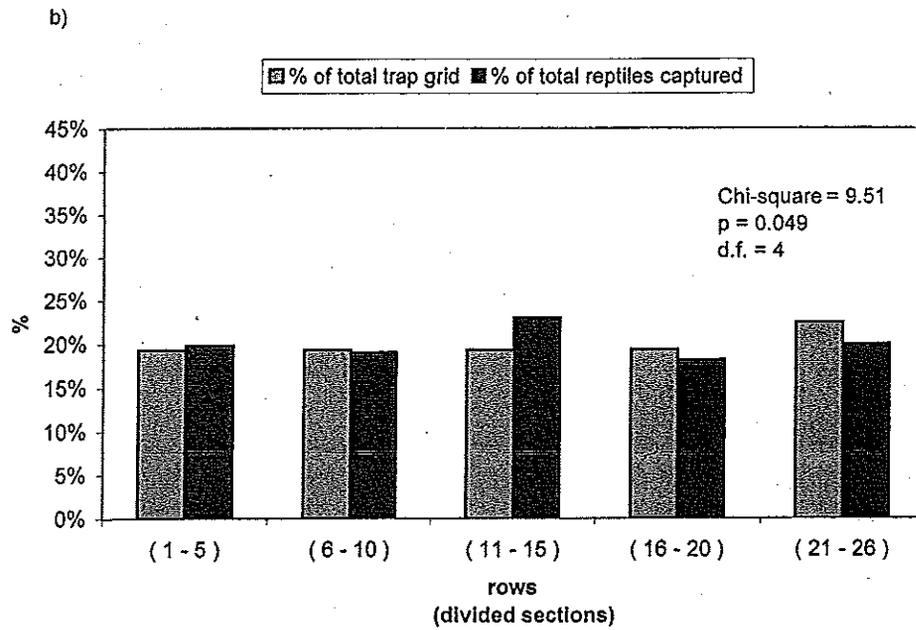
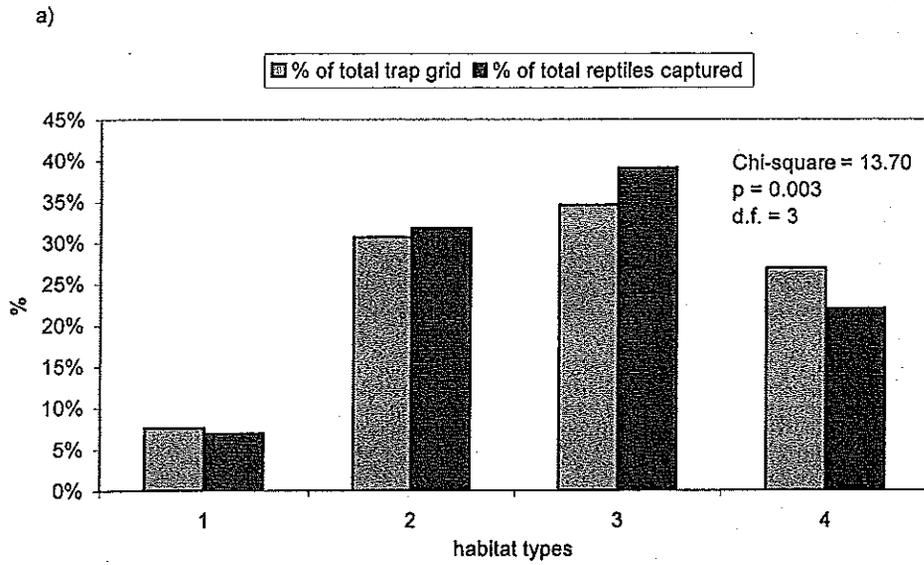


Figure 7. The percentage of total traps that successfully captured at least one reptile per sampling year and the percentage of total traps that captured multiple reptiles per sampling year.

Fig. 7

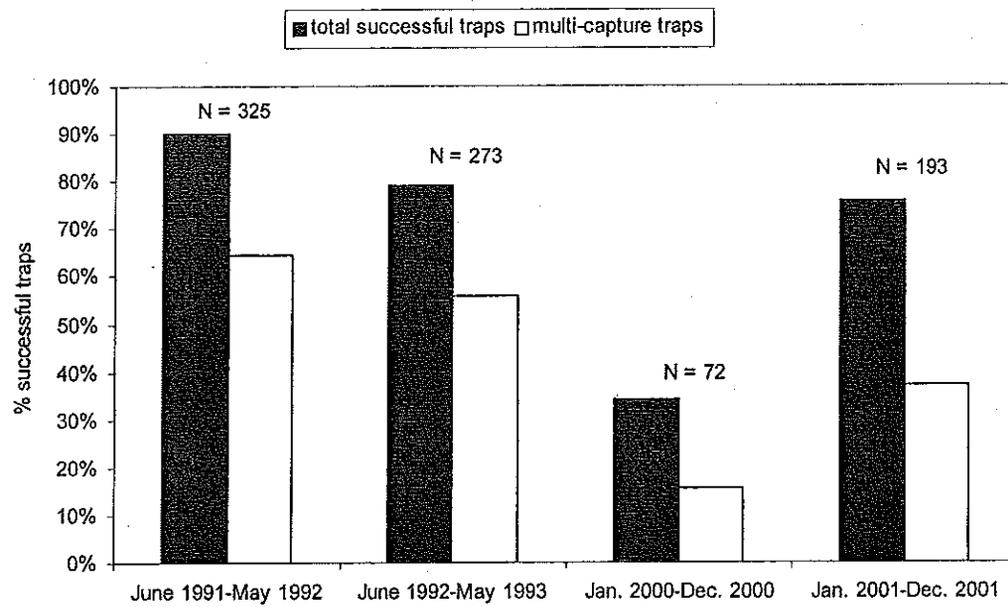
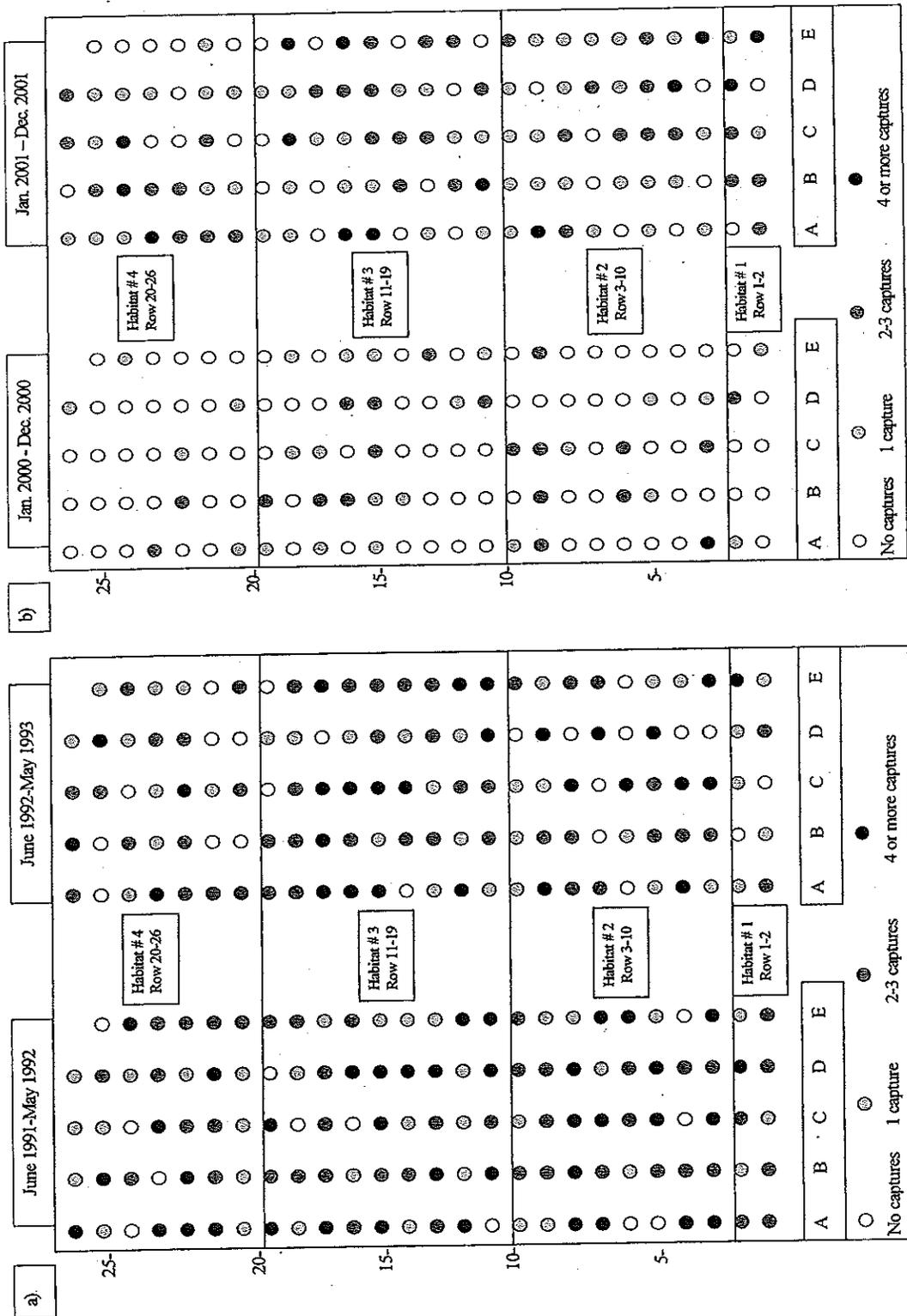


Figure 8. Comparison of individual trap success a) June 1991-May 1993
b) January 2000-December 2001.

Fig. 8



116 of the total 129 traps (89.9%) were successful; of those, 84 had multiple captures (65%). During June 1992-May 1993, 106 of the 129 traps (82.1%) were successful; of those, 72 had multiple captures (55.8%). During January 2000-December 2000, 44 of the 129 traps (34.1%) were successful; of those, 20 had multiple captures (45.5%). During January 2001-December 2001, 98 of the 129 traps (75.9%) were successful; of those, 48 had multiple captures (48.9%). When combining the results from all four sampling years, 128 of the 129 traps were successful at least once. Only trap A-6 failed to ever capture a reptile.

Population Estimates

One of the original goals of this study was to estimate the population size of the resident reptiles (Table 1) month to month for the 2000 and 2001 sampling years using mark/recapture techniques. Unfortunately, not enough data were obtained. Only one species was recaptured in 2000, *Uta stansburiana* (4 recaptures; Appendix 8c), and only three species were recaptured in 2001, *U. stansburiana* (2 recaptures), *Cnemidophorus tigris* (4 recaptures) and *Phrynosoma platyrhinos* (1 recapture; Appendix 8d). Neither year yielded enough recaptures to calculate any kind of reasonable population estimate.

Abundance and Diversity

The total number of reptile species captured per monthly collecting period (Appendix 9a; Appendix 10a) and the total number of individual reptiles of all species captured per monthly collecting period (Appendix 9b; Appendix 10b) for each sampling year were compared. The maximum number of species captured during any one monthly collecting

Table 1. Reptiles captured in this study.

Order	Family	Genus species	Common name
Sauria	Crotaphytidae	<i>Crotaphytus insularis</i>	Collared lizard
		<i>Gambelia wislizenii</i>	Long-nosed Leopard Lizard
	Gekkonidae	<i>Coleonyx variegatus</i>	Western Banded Gecko
	Iguanidae	<i>Dipsosaurus dorsalis</i>	Desert Iguana
	Phrynosomatidae	<i>Callisaurus draconoides</i>	Zebra-tailed Lizard
		<i>Phrynosoma platyrhinos</i>	Desert Horned Lizard
		<i>Uma scoparia</i>	Mojave Fringe-toed Lizard
		<i>Urosaurus graciosus</i>	Long-tailed Brush Lizard
		<i>Uta stansburiana</i>	Side-blotch Lizard
	Teiidae	<i>Cnemidophorus tigris</i>	Western Whiptail Lizard
	Xantusiidae	<i>Xantusia vigilis</i>	Desert Night Lizard
Serpentes	Colubridae	<i>Arizona elegans</i>	Glossy Snake
		<i>Chionactis occipitalis</i>	Western Shovel-nosed Snake
		<i>Masticophis flagellum</i>	Coachwhip
		<i>Pituophis melanoleucus</i>	Gopher Snake
	Leptotyphlopidae	<i>Leptotyphlops humilis</i>	Western Blind Snake

Table 2. Total reptiles captured a) June 1991-May 1993 b) January 2000-December 2001 c) Total overall (June 1991-May 1993 and January 2000 December 2001).

a)

Total June 1991 – May 1993
Total no. species captured - 13

Species captured	Individuals captured
<i>Uta stansburiana</i>	167
<i>Urosaurus graciosus</i>	156
<i>Cnemidophorus tigris</i>	139
<i>Callisaurus draconoides</i>	60
<i>Coleonyx variegatus</i>	24
<i>Chionactis occipitalis</i>	22
<i>Dipsosaurus dorsalis</i>	19
<i>Phrynosoma platyrhinos</i>	6
<i>Crotaphytus insularis</i>	1
<i>Uma scoparia</i>	1
<i>Gambelia wislizenii</i>	1
<i>Arizona elegans</i>	1
<i>Leptotyphlops humilis</i>	1
Total no. of individuals captured	N = 598

Table 2 - Continued

b)

Total January 2000 – December 2001
Total no. species captured – 12

Species captured	Individuals captured
<i>Uta stansburiana</i>	125 (6 recaptures)
<i>Cnemidophorus tigris</i>	95 (4 recaptures)
<i>Chionactis occipitalis</i>	18
<i>Dipsosaurus dorsalis</i>	7
<i>Urosaurus graciosus</i>	6
<i>Callisaurus draconoides</i>	5
<i>Phrynosoma platyrhinos</i>	4 (1 recapture)
<i>Coleonyx variegatus</i>	1
<i>Xantusia vigilis</i>	1
<i>Masticophis flagellum</i>	1
<i>Arizona elegans</i>	1
<i>Pituophis melanoleucus</i>	1
Total no. of individuals captured	N = 265

Table 2 - Continued

c)

Total	June 1991 – May 1993 and January 2000 – December 2001
Total no. species captured – 16	

Species captured	Individuals captured
<i>Uta stansburiana</i>	292
<i>Cnemidophorus tigris</i>	234
<i>Urosaurus graciosus</i>	162
<i>Callisaurus draconoides</i>	65
<i>Chionactis occipitalis</i>	40
<i>Dipsosaurus dorsalis</i>	26
<i>Coleonyx variegatus</i>	25
<i>Phrynosoma platyrhinos</i>	10
<i>Arizona elegans</i>	2
<i>Gambelia wislizenii</i>	1
<i>Crotaphytus insularis</i>	1
<i>Uma scoparia</i>	1
<i>Leptotyphlops humilis</i>	1
<i>Masticophis flagellum</i>	1
<i>Pituophis melanoleucus</i>	1
<i>Xantusia vigilis</i>	1
Total no. of individuals captured	N = 863

Abundant enough for further analysis
--

period was 8 (April 1993). The maximum number of individuals captured during any one monthly collecting period was 78 (July 1991). Capture lists were compiled for each sampling year, each 24-month collection period, and total overall (Table 2a-c; Appendix 8a-d).

Chi-squared analysis was used to compare the combined capture totals collected January 2000-December 2001 with the combined capture totals collected June 1991-May 1993 (Table 3a). The expected capture rate of each species, for each 24-month collection period, was calculated using its respective overall relative abundance. A highly significant difference ($p = 0.000$; $\chi^2 = 116.15$; d.f. = 8) was found overall between these two collection periods. To discover the cause of this overall significance, the reptile species with the greatest difference in relative abundance between the two collection periods was removed. This was repeated until no overall significant difference was found. The reptile species with the greatest difference in relative abundance was *Urosaurus graciosus*; with its removal, the overall significant difference remained ($p = 0.000$; $\chi^2 = 43.66$; d.f. = 7). The additional removal of *Callisaurus draconoides* also resulted in an overall significant difference ($p = 0.010$; $\chi^2 = 16.84$; d.f. = 6). The additional removal of *Coleonyx variegatus*, however, resulted in an overall non-significant difference ($p = 0.730$; $\chi^2 = 2.803$; d.f. = 5). Thus, after the removal of *U. graciosus*, *C. draconoides* and *C. variegatus*, no overall significant difference was found in the relative abundance, and hence the diversity, of the remaining reptiles captured between the two 24-month collection periods (Table 3b).

Table 3. Direct comparison of a) the total captures and relative abundance per species for June 1991-May 1993 vs. January 2000-December 2001 ($p = 0.000$; $\chi^2 = 116.153$; d.f. = 8), and b) the total captures and relative abundance per species for June 1991-May 1993 vs. January 2000-December 2001 after removing *Urosaurus graciosus*, *Callisaurus draconoides* and *Coleonyx variegatus* from the capture lists ($p = 0.730$; $\chi^2 = 2.803$; d.f. = 5). Differences in the relative abundance of each species were tested using Chi-squared analysis.

a)	June 1991- May 1993		January 2000- December 2001		Total	
	<i>Uta stansburiana</i> #	167	27.5 %	125	47.1 %	292
<i>Cnemidophorus tigris</i> #	139	23.2 %	95	35.8 %	234	27.1 %
<i>Urosaurus graciosus</i> *	156	26.0 %	6	2.2 %	162	18.7 %
<i>Callisaurus draconoides</i> *	60	10.0 %	5	1.8 %	65	7.5 %
<i>Chionactis occipitalis</i> #	22	3.6 %	18	6.7 %	40	4.6 %
<i>Dipsosaurus dorsalis</i>	19	3.1 %	7	2.6 %	26	3.0 %
<i>Coleonyx variegatus</i> *	24	4.0 %	1	0.3 %	25	2.8 %
<i>Phrynosoma platyrhinos</i>	6	1.0 %	4	1.5 %	10	1.1 %
Other	5	0.8 %	4	1.5 %	9	1.0 %
Total	598		265		863	$p = 0.000$

(*) – The relative abundance significantly decreased when comparing individually.

(#) – The relative abundance significantly increased when comparing individually.

Table 3 -- Continued

	June 1991- May 1993		January 2000- December 2001		Total		
	<i>Uta stansburiana</i>	167	46.6 %	125	49.4 %	292	47.7 %
<i>Cnemidophorus tigris</i>	139	38.8 %	95	37.5 %	234	38.2 %	
<i>Chionactis occipitalis</i>	22	6.1 %	18	7.1 %	40	6.5 %	
<i>Dipsosaurus dorsalis</i>	19	5.3 %	7	2.7 %	26	4.2 %	
<i>Phrynosoma platyrhinos</i>	6	1.6 %	4	1.5 %	10	1.6 %	
Other	5	1.3 %	4	1.5 %	9	1.4 %	
Total	358		253		611		p = 0.730

For a more specific look, the same analysis (Chi-squared) was used to test each species individually (June 1991-May 1993 vs. January 2000-December 2001). The expected capture rate of each individual species was calculated using its respective overall relative abundance.

Uta stansburiana (Table 3a)

The total captures of *U. stansburiana* dropped from $n = 167$ (June 1991-May 1993) to $n = 125$ (January 2000-December 2001). The relative abundance significantly increased ($p = 0.000$; $\chi^2 = 20.10$; d.f. = 1) from 27.5 % to 47.1 %, representing the largest significant increase of any species captured.

Cnemidophorus tigris (Table 3a)

The total captures of *C. tigris* dropped from $n = 139$ (June 1991-May 1993) to $n = 95$ (January 2000-December 2001). The relative abundance significantly increased ($p = 0.010$; $\chi^2 = 10.76$; d.f. = 1) from 23.2 % to 35.8 %, representing the second largest significant increase of any species captured.

Urosaurus graciosus (Table 3a)

The total captures of *U. graciosus* dropped from $n = 156$ (June 1991-May 1993) to $n = 6$ (January 2000-December 2001). The relative abundance significantly decreased ($p = 0.000$; $\chi^2 = 55.52$; d.f. = 1) from 26.0 % to 2.2 %, representing the largest significant decrease of any species captured.

Callisaurus draconoides (Table 3a)

The total captures of *C. draconoides* dropped from $n = 60$ (June 1991-May 1993) to $n = 5$ (January 2000-December 2001). The relative abundance significantly decreased

($p = 0.000$; $\chi^2 = 16.18$; d.f. = 1) from 10.0 % to 1.8 %, representing the second largest significant decrease of any species captured.

Chionactis occipitalis (Table 3a)

The total captures of *C. occipitalis* dropped from $n = 22$ (June 1991-May 1993) to $n = 18$ (January 2000-December 2001). The relative abundance significantly increased ($p = 0.049$; $\chi^2 = 3.84$; d.f. = 1) from 3.6 % to 6.7 %.

Dipsosaurus dorsalis (Table 3a)

The total captures of *D. dorsalis* dropped from $n = 19$ (June 1991-May 1993) to $n = 7$ (January 2000-December 2001). No significant difference was found ($p = 0.676$; $\chi^2 = 0.17$; d.f. = 1) for relative abundance, though it did decrease from 3.1 % to 2.6 %.

Coleonyx variegatus (Table 3a)

The total captures of *C. variegatus* dropped from $n = 24$ (June 1991-May 1993) to $n = 1$ (January 2000-December 2001). The relative abundance significantly decreased ($p = 0.003$; $\chi^2 = 8.38$; d.f. = 1) from 4.0 % to 0.3 %, representing the third largest significant decrease of any species captured.

Phrynosoma platyrhinos (Table 3a)

The total captures of *P. platyrhinos* dropped from $n = 6$ (June 1991-May 1993) to $n = 4$ (January 2000-December 2001). No significant difference was found ($p = 0.523$; $\chi^2 = 0.40$; d.f. = 1) for relative abundance, though it did increase from 1.0 % to 1.5 %.

Urosaurus graciosus was the most collected species June 1991-May 1992 ($n = 105$), representing 32.3% of all captures in that sampling year (Appendix 8a). In June 1992-May 1993 it dropped to third most collected species ($n = 51$), representing

18.6% of all captures (Appendix 8b). When these two sampling years are combined, June 1991-May 1993, it was the second most collected species ($n = 156$), representing 26.0% of all captures during the first collection period (Table 2a; Table 3a). The second collection period marked a dramatic decrease in captures for *U. graciosus* ($n = 6$). This total represents only 2.2% of all reptiles captured during that period.

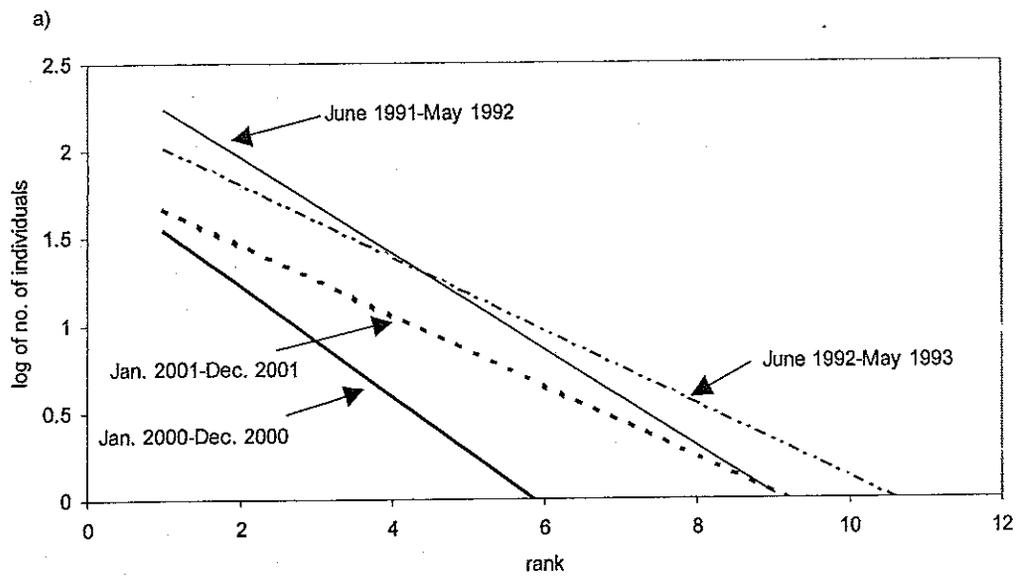
Callisaurus draconoides was consistently the fourth most collected species for the first collection period ($n = 60$), representing 10.0% of all captures that occurred June 1991-May 1993 (Table 2a; Table 3a). That total dropped dramatically during the second collection period ($n = 5$). This total represents only 1.8% of all captures occurring January 2000-December 2001 (Table 2b; Table 3a).

Coleonyx variegatus was the fifth most collected species in June 1991-May 1992 ($n = 12$) and the sixth most collected species June 1992-May 1993 ($n = 12$). These totals represent 3.7% and 4.4% of the total captures, respectively. This species was ranked fifth overall ($n = 24$) during the first collection period, representing 4.0% of all captures (Table 2a; Table 3a). During the second collection period, only one individual was collected ($n = 1$). This single individual represents 0.3% of all captures January 2000-December 2001 (Table 2b; Table 3a).

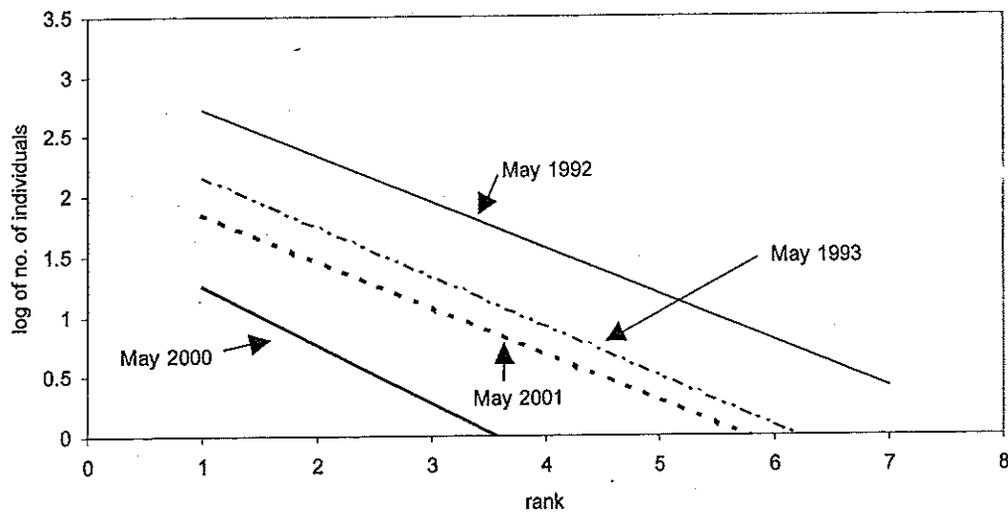
A dominance diversity curve was graphed for each sampling year to compare species diversity qualitatively (Figure 9a). The slopes of the four curves are similar, suggesting that there is not much of a difference in diversity. Dominance diversity curves were then graphed using only the data collected in the month of May for each sampling year (Figure 9b). Whitford and Creusere (1977) used data collected in the month of June to calculate

Figure 9. Qualitative comparison of dominance diversity curves a) June 1991-May 1992, June 1992-May 1993, January 2000-December 2000 and January 2001-December 2001
b) May 1991, May 1992, May 2000 and May 2001.

Fig. 9



b) May



the species diversity (H') of two reptile communities in the Chihuahuan desert, 1970-1974. They chose June because, at that point in each season, all lizards had emerged from winter dormancy and hatching had not yet taken place. For this study, the month of May was chosen over June because the data collected in June of 2001 included many hatchlings (Appendix 18; Appendix 19). The slopes of these dominance diversity curves are similar, again suggesting that there is not much of a difference in diversity between the sampling years (Figure 9b).

To quantify species diversity, a Shannon index (H'), Simpson index (D_s) and Pielou's evenness index (J) were calculated using data from the month of May for 1992, 1993, 2000 and 2001. The adjusted Shannon index $E(H')$ was greatest for 1992 and least for 2000. Simpson's index (D_s) was greatest for 1993 and least for 2001. Pielou's evenness index (J) was greatest for 1992, gradually stepping down each year to its lowest value for 2001 (Figure 10; Appendix 11).

Environmental factors

The maximum and minimum average temperatures for each four-day monthly collecting period were compared (Appendix 12). Regression analysis was used to correlate maximum and minimum temperatures with the diversity of reptile species (Figure 11a) and the abundance of individuals of all reptile species (Figure 11b) in the area. This analysis shows a positive correlation between maximum temperature and both the diversity of species captured ($p = 0.000$; $R^2 = 0.676$; d.f. = 45) and the abundance of individuals of all species captured ($p = 0.000$; $R^2 = 0.513$; d.f. = 45). This analysis also shows a positive correlation between minimum temperature and both the diversity of

Figure 10. Shannon diversity index $E(H')$ with standard error bars, Pielou's evenness index (J), and Simpson's index of diversity (D_s) calculations for the data collected in May of 1992, 1993, 2000 and 2001.

Fig. 10

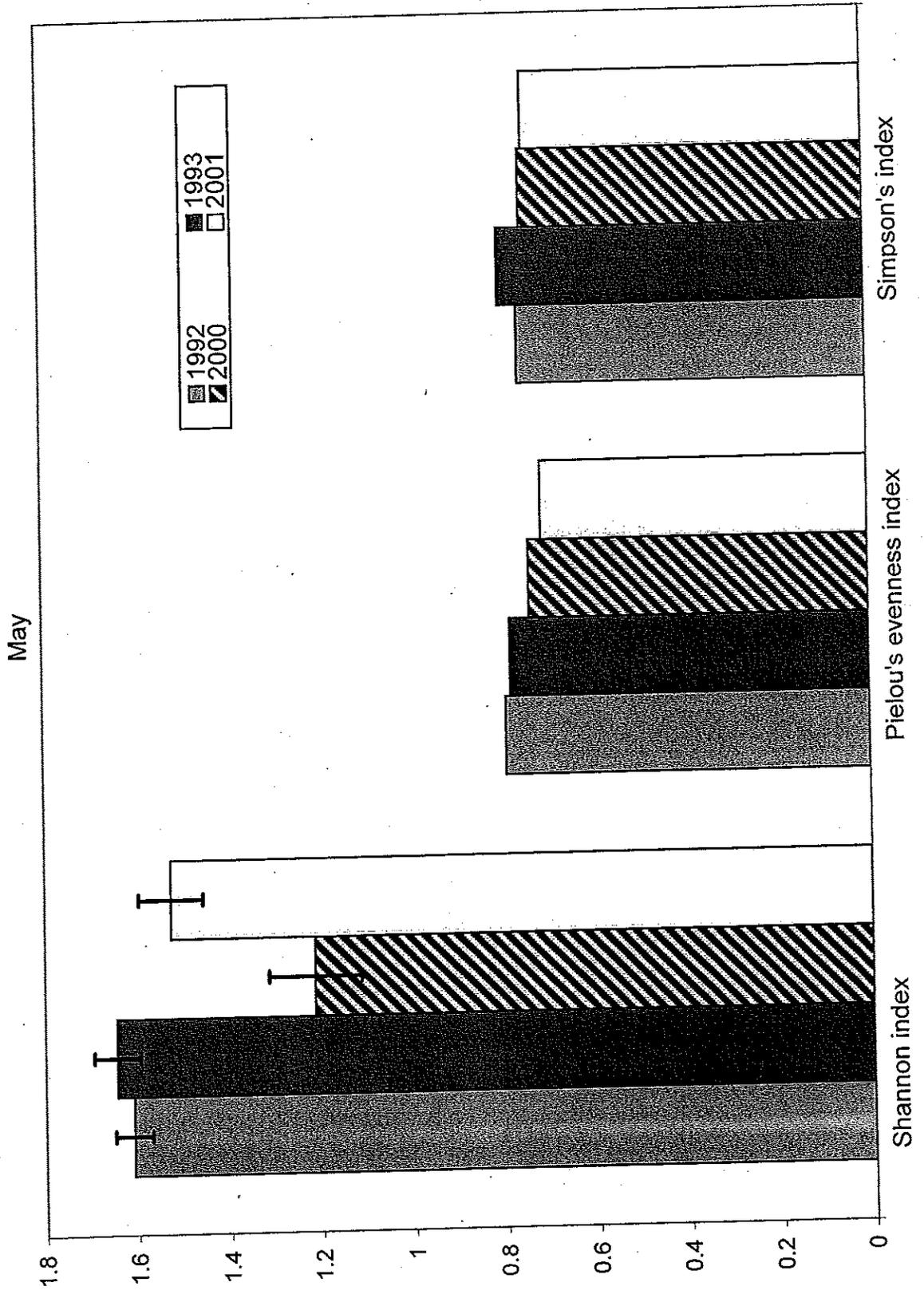
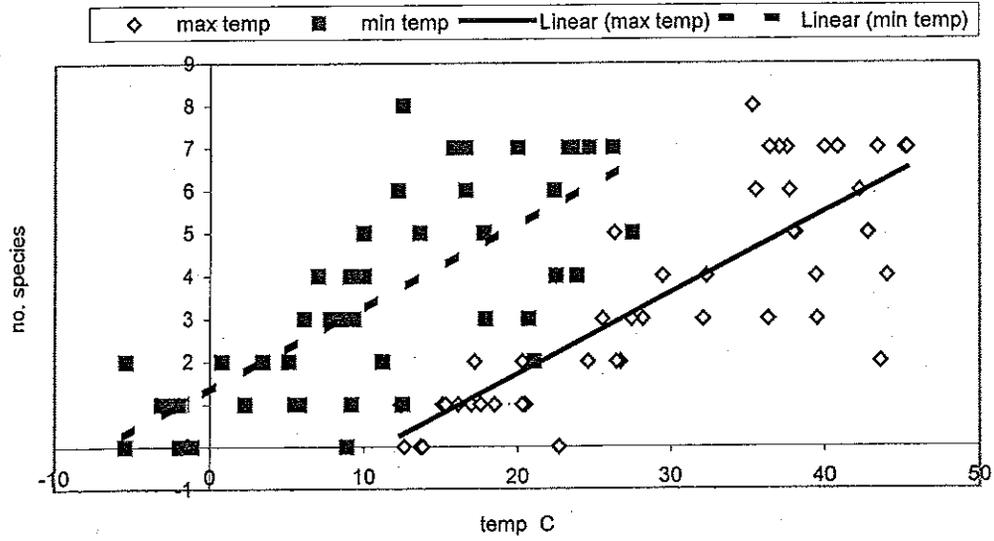


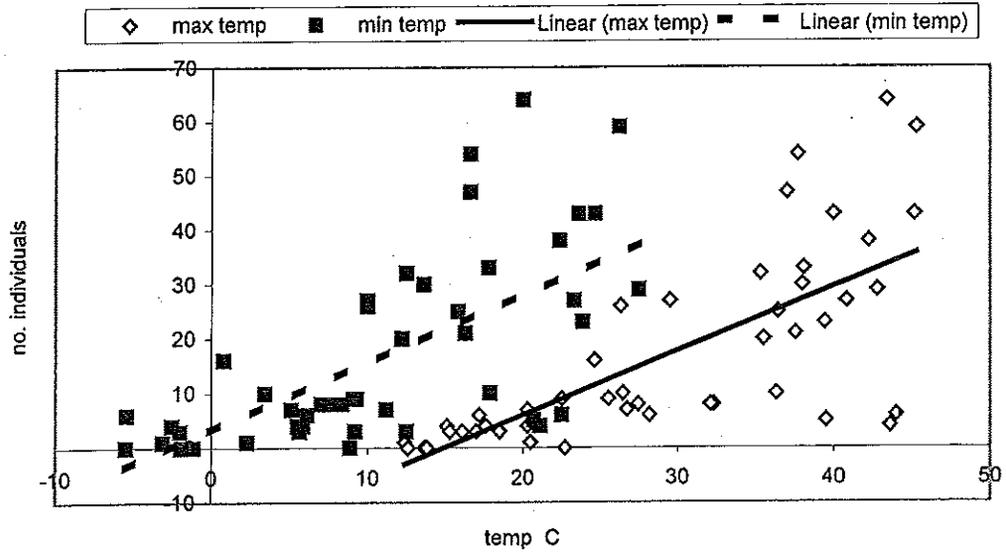
Figure 11. Total abundance of a) reptile species and b) reptile individuals captured vs. average maximum and minimum temperatures for each monthly collecting period (June 1991-May 1993 and January 2000-December 2001). Regression analysis was used to correlate maximum and minimum temperature levels with reptile diversity and abundance. The best fit regression equations for reptile diversity: no. species = $0.1894 \times \text{max. temp } ^\circ\text{C} - 2.0709$ ($R^2 = 0.6758$, $p = 0.000$, d.f. = 45); no. species = $0.1949 \times \text{min. temp } ^\circ\text{C} + 1.3325$ ($R^2 = 0.5331$, $p = 0.000$, d.f. = 45). The best fit regression equations for reptile abundance: no. individuals = $1.1741 \times \text{max. temp } ^\circ\text{C} - 17.439$ ($R^2 = 0.5128$, $p = 0.000$, d.f. = 45); no. individuals = $1.2501 \times \text{min. temp } ^\circ\text{C} + 3.1833$ ($R^2 = 0.4334$, $p = 0.000$, d.f. = 45).

Fig. 11

a) species



b) Individuals



species captured ($p = 0.000$; $R^2 = 0.533$; d.f. = 45) and the abundance of individuals of all species captured ($p = 0.000$; $R^2 = 0.433$; d.f. = 45).

The cumulative yearly precipitation was recorded for 1991, 1992, 1993, 1999, 2000, 2001 and 2002 (Figure 12; Appendix 13a-g). Regression analysis was used to correlate cumulative precipitation levels with the diversity of reptile species (Figure 13a) and the abundance of individual reptiles of all species (Figure 13b). This analysis shows a positive correlation between cumulative precipitation levels and both the diversity of species captured ($p = 0.001$; $R^2 = 0.235$; d.f. = 46) and the abundance of individuals of all species captured ($p = 0.001$; $R^2 = 0.217$; d.f. = 46).

The total number of reptile species captured per sampling year (Appendix 14a) and the total number of reptile individuals of all species captured per sampling year (Appendix 14b) were also directly compared. The maximum number of species captured during any one sampling year was a tie; 11 species were captured in both June 1992-May 1993 and January 2001-December 2001. The maximum number of individuals captured during any one sampling year was 325 (June 1991-May 1992).

Habitat usage

Of the 16 reptile species captured during this study, 7 were abundant enough for further analysis (Table 2c). Chi-squared analysis was used to test how evenly distributed each species is over the entire trap grid in two ways. First, the percentage of total captures per habitat was compared to the total size of each habitat. Second, the percentage of total captures per divided section was compared to the total size of each section. These five

Figure 12. Direct comparison of the cumulative annual precipitation for 1991, 1992, 1993, 1999, 2000, 2001 and 2002.

Fig. 12

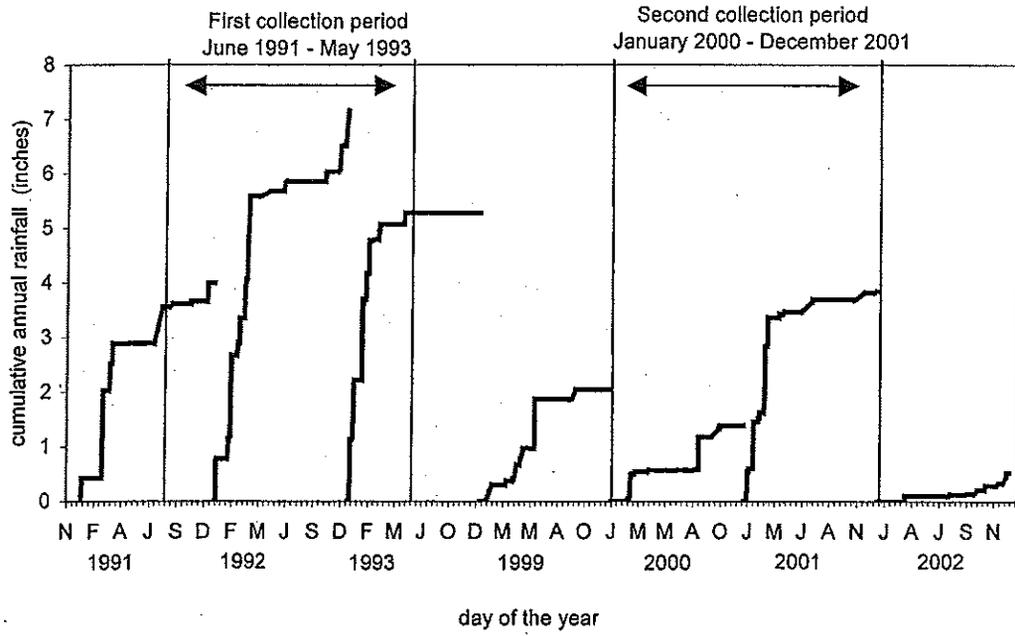
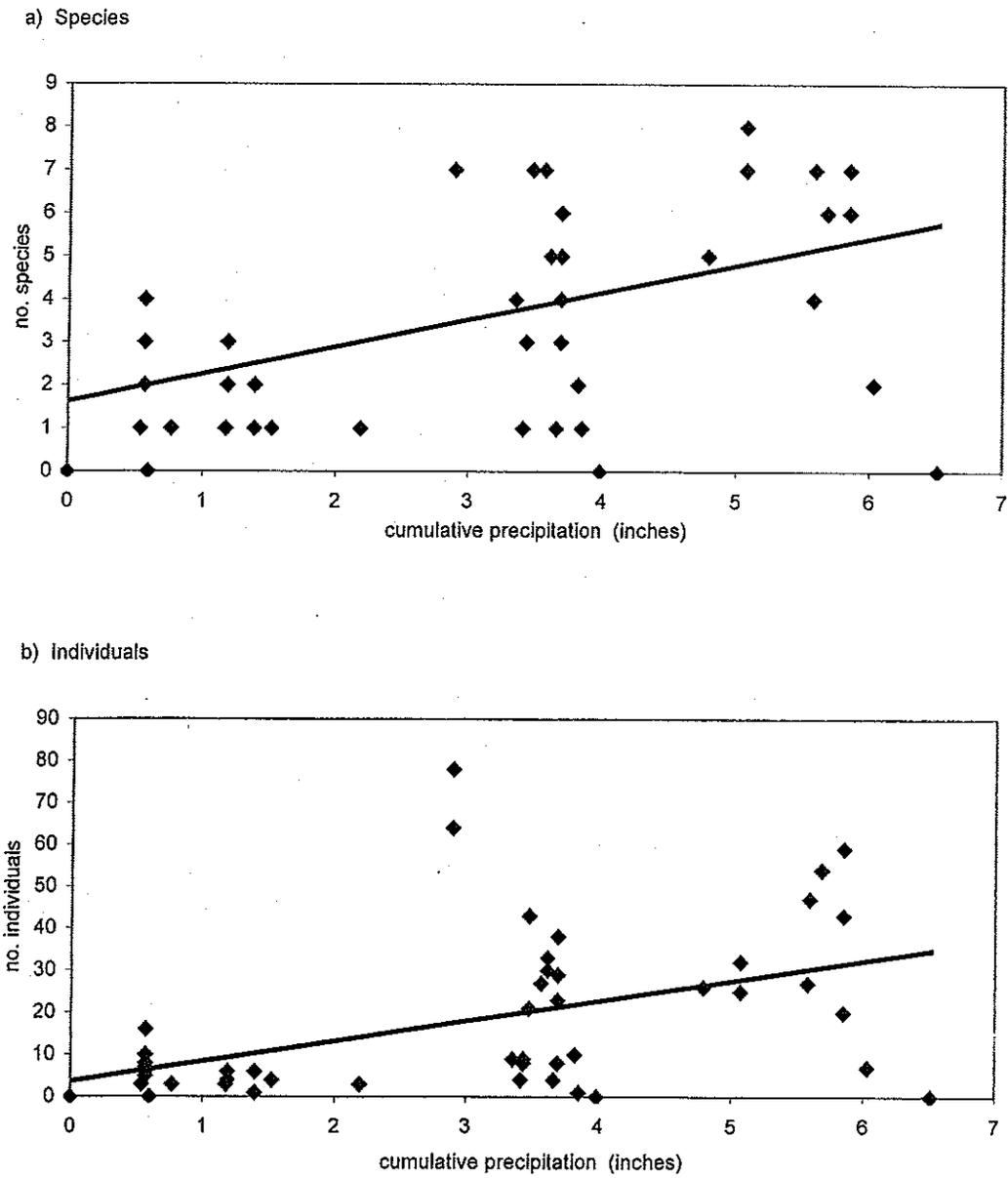


Figure 13. Total abundance of a) reptile species and b) reptile individuals captured vs. cumulative annual precipitation levels for each monthly collecting period. (June 1991-May 1993 and January 2000-December 2001). Regression analysis was used to correlate cumulative precipitation levels with reptile diversity and abundance. The best fit regression equation for reptile diversity: no. species = $0.6333 \times \text{cumulative precipitation} + 1.6283$ ($R^2 = 0.2355$, $p = 0.001$, d.f. = 46). The best fit regression equation for reptile abundance: no. individuals = $4.7688 \times \text{cumulative precipitation} + 3.7296$ ($R^2 = 0.2173$, $p = 0.001$, d.f. = 46).

Fig. 13



sections are described as Section #1- (rows 1-5), Section #2- (rows 6-10), Section #3- (rows 11-15), Section #4- (rows 16-20), and Section #5- (rows 21-26; Figure 3).

Uta stansburiana (Figure 14a; Appendix 15 and 16)

U. stansburiana was found to be evenly distributed by both habitat ($p = 0.739$; $\chi^2 = 1.258$; d.f. = 3) and overall ($p = 0.165$; $\chi^2 = 6.483$; d.f. = 4). This species is the most evenly distributed reptile in this study.

Cnemidophorus tigris (Figure 14b; Appendix 15 and 16)

The distribution of *C. tigris* was found to be uneven for habitat ($p = 0.008$; $\chi^2 = 11.786$; d.f. = 3) and uneven overall ($p = 0.026$; $\chi^2 = 10.978$; d.f. = 4). This species was captured mostly in type #3 habitat.

Urosaurus graciosus (Figure 14c; Appendix 15 and 16)

The distribution of *U. graciosus* was found to be uneven for habitat ($p = 0.000$; $\chi^2 = 56.945$; d.f. = 3) and uneven overall ($p = 0.000$; $\chi^2 = 59.828$; d.f. = 4). This species was mostly captured in type #2 habitat. The majority of the overall captures occurred between rows 1-10, declining as you move up the slope.

Callisaurus draconoides (Figure 14d; Appendix 15 and 16)

The distribution of *C. draconoides* was found to be uneven for habitat ($p = 0.026$; $\chi^2 = 9.233$; d.f. = 3) and uneven overall ($p = 0.012$; $\chi^2 = 12.749$; d.f. = 4). This species was also captured mostly in type #2 habitat, however the majority of the overall captures occurred between rows 6-20. Very few individuals were captured in the first or last five rows of the grid.

Chionactis occipitalis (Figure 14e; Appendix 15 and 16)

Representing the only snake species abundant enough for further analysis, the distribution of *C. occipitalis* was found to be even for both habitat ($p = 0.177$; $\chi^2 = 4.927$; d.f. = 3) and overall ($p = 0.192$; $\chi^2 = 6.089$; d.f. = 4). This species was captured mostly in type #3 habitat, however the majority of the overall captures occurred in rows 11-26. Because of its nocturnal behavior, most individuals were collected during the morning trap checks.

Dipsosaurus dorsalis (Figure 14f; Appendix 15 and 16)

The distribution of *D. dorsalis* was found to be uneven for habitat ($p = 0.004$; $\chi^2 = 13.086$; d.f. = 3) and uneven overall ($p = 0.003$; $\chi^2 = 15.894$; d.f. = 4). This species was captured mostly in type #4 habitat. The number of captures drop steadily as you move down the gradient.

Coleonyx variegatus (Figure 14g; Appendix 15 and 16)

The distribution of *C. variegatus* was found to be uneven for habitat ($p = 0.004$; $\chi^2 = 13.140$; d.f. = 3) and uneven overall ($p = 0.001$; $\chi^2 = 17.131$; d.f. = 4). This species was captured mostly in type #3 and type #4 habitat equally. The majority of captures occurred in rows 11-15 and rows 21-26. Curiously, a substantial drop in captures occurred in rows 16-20. One individual was captured in row 3, representing the only individual captured below row 11 for this species. Because of its nocturnal behavior, most individuals were collected during the morning trap checks.

The habitat preference and overall trap-grid distribution was determined for all 16 species captured over the four sampling years. This was achieved by calculating the

Figure 14. The percentage of total reptile captures per habitat type (left) and divided section (right) compared to the percentage of the total size of each habitat type (left) and divided section (right) for a) *Uta stansburiana* b) *Cnemidophorus tigris* c) *Urosaurus graciosus* d) *Callisaurus draconoides* e) *Chionactis occipitalis* f) *Dipsosaurus dorsalis* and g) *Coleonyx variegatus*. The distribution of each species was tested for evenness by habitat type and overall using Chi-squared analysis.

Fig. 14

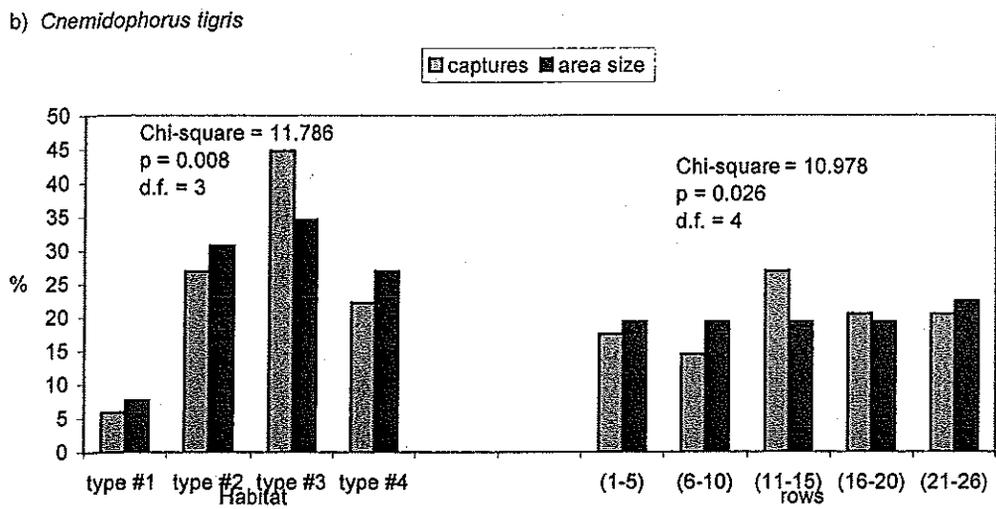
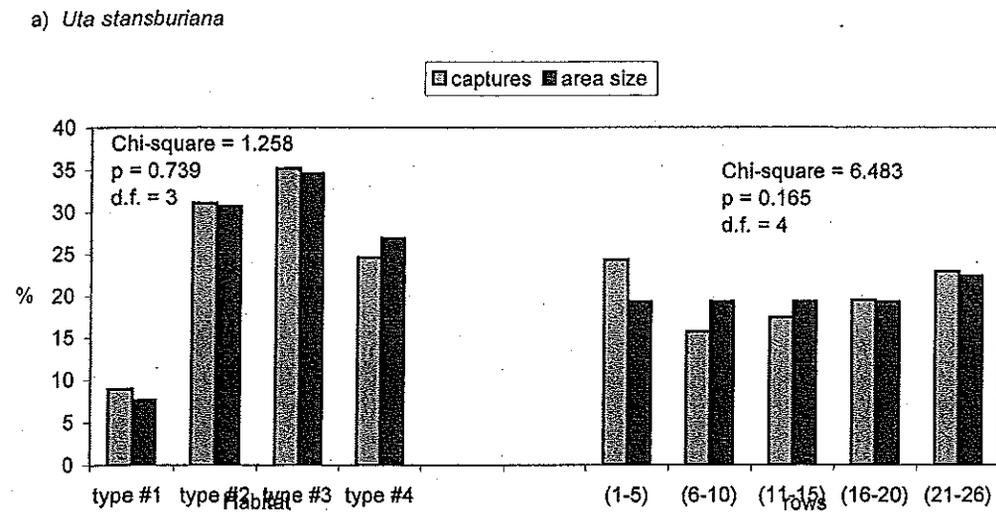


Fig. 14

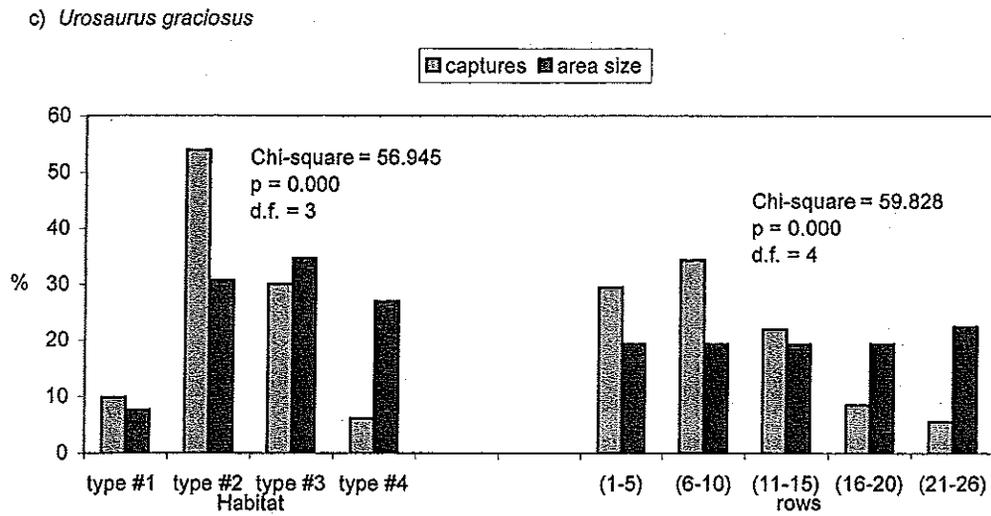
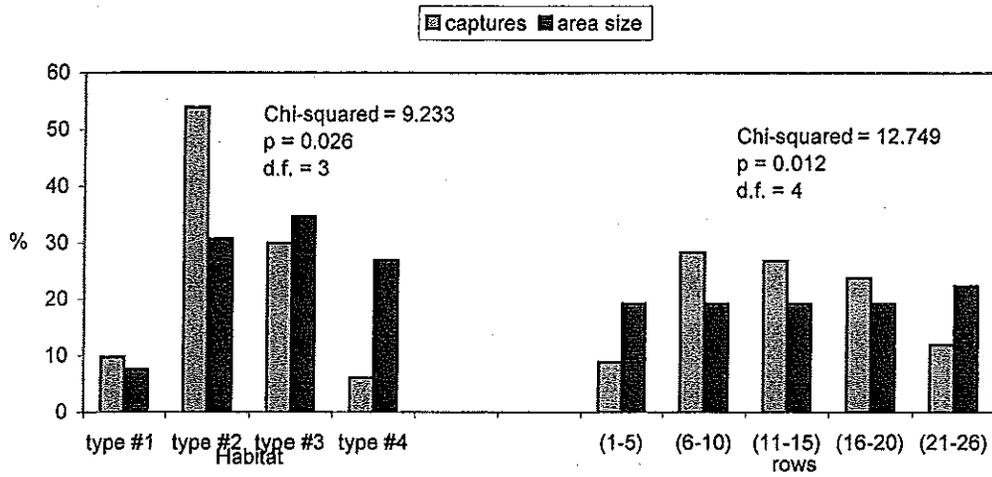
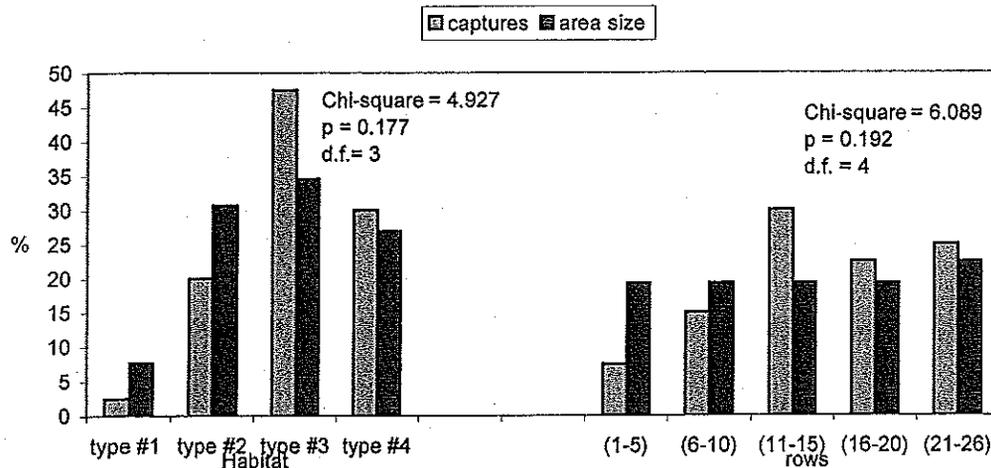
d) *Callisaurus draconoides*

Fig. 14

e) *Chionactis occipitalis*



f) *Dipsosaurus dorsalis*

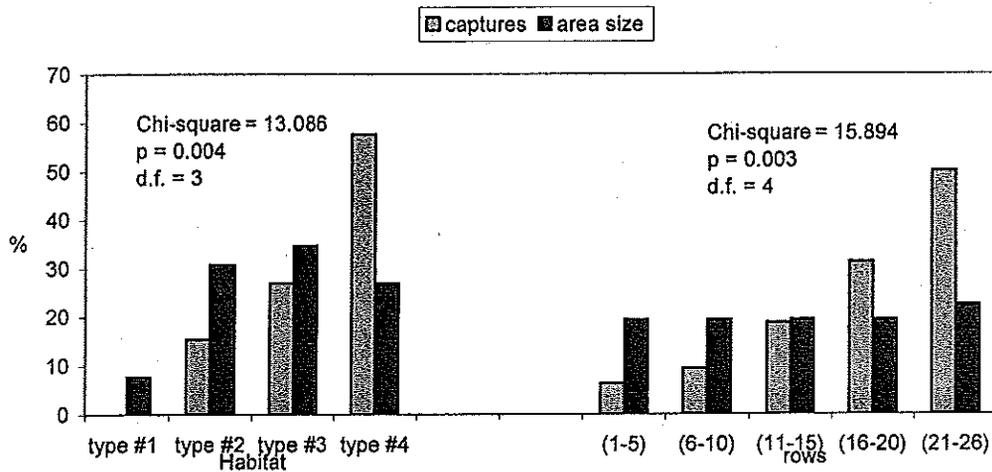
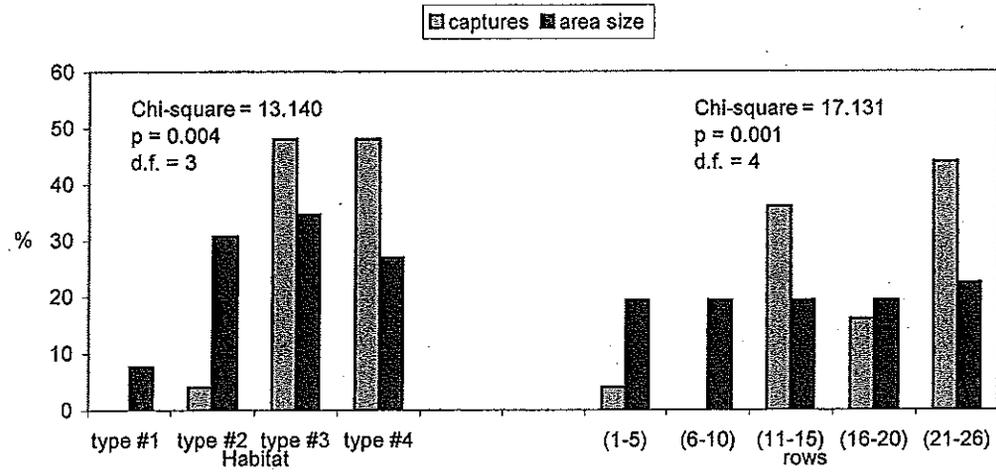


Fig. 14

g) *Coleonyx variegatus*

percentage of total captures per habitat type (Appendix 15) and the percentage of total captures per divided section of the trap-grid (Appendix 16). The total number of species captured per habitat type (Appendix 17a) and divided section (Appendix 17b) were also recorded.

Age class and gender

During January 2000-December 2001, sex and snout-to-vent length measurements were recorded. This additional data allowed for a more detailed analysis to uncover trends in capture position (row) relative to the day of each capture for adult males, adult females, and juveniles. The only reptile species abundant enough for this type of analysis were *Uta stansburiana* (n = 125) and *Cnemidophorus tigris* (n = 95); the two most abundant reptiles captured during this period.

Uta stansburiana

The snout-to-vent length of captured *U. stansburiana* was compared to the day of each capture for each sampling year. Adults were categorized as any individual with a snout-to-vent length ≥ 4.0 cm and juveniles were categorized as any individual with a snout-to-vent length < 4.0 cm (Appendix 18a-b; Stebbins, 1985). For adults, the time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by sex (p = 0.096; d.f.= 63) and sampling year (p = 0.460; d.f.= 63). No significant differences were found, and the trend alone was not significant (p = 0.942; d.f.= 63; Figure 15).

Similarly, the time trend of row of capture by day of capture was compared broken out by age class (adults vs. juveniles; p = 0.462; d.f.= 123). No significant difference was

found, and the trend alone was not significant ($p = 0.557$; d.f.= 123; Figure 16).

Differences in sampling year were not compared since virtually no juveniles ($n = 4$) were captured in 2000.

The total abundance of adult male, adult female and juvenile *Uta stansburiana* were compared between the two sampling years (Figure 17). Between these years, the number of adult males captured dropped by 10%, the number of adult females captured dropped by 47%, and the number of juveniles captured increased by a factor of 14.25.

Cnemidophorus tigris

The snout-to-vent length of captured *C. tigris* was compared to the day of each capture for each sampling year. Adults were categorized as any individual with a snout-to-vent length ≥ 6.0 cm and juveniles were categorized as any individual with a snout-to-vent length < 6.0 cm (Appendix 19a-b; Stebbins, 1985). For adults, the time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by sex ($p = 0.981$; d.f.= 46) and sampling year ($p = 0.695$; d.f.= 46). No significant differences were found in these categories. However, the trend alone was found to be significant overall ($p = 0.000$; d.f.= 46; Figure 18).

Similarly, the time trend of row of capture by day of capture was compared broken out by age class (adults vs. juveniles; $p = 0.748$; d.f.= 94). No significant difference was found in this category. Again, the trend alone was found to be significant overall ($p = 0.001$; d.f.= 94; Figure 19). Differences in sampling year were not compared since virtually no juveniles ($n = 2$) were captured in 2000.

Figure 15. Comparison of adult male and female *Uta stansburiana* captures (January 2000-December 2001). The time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by sex and sampling year.

Fig. 15

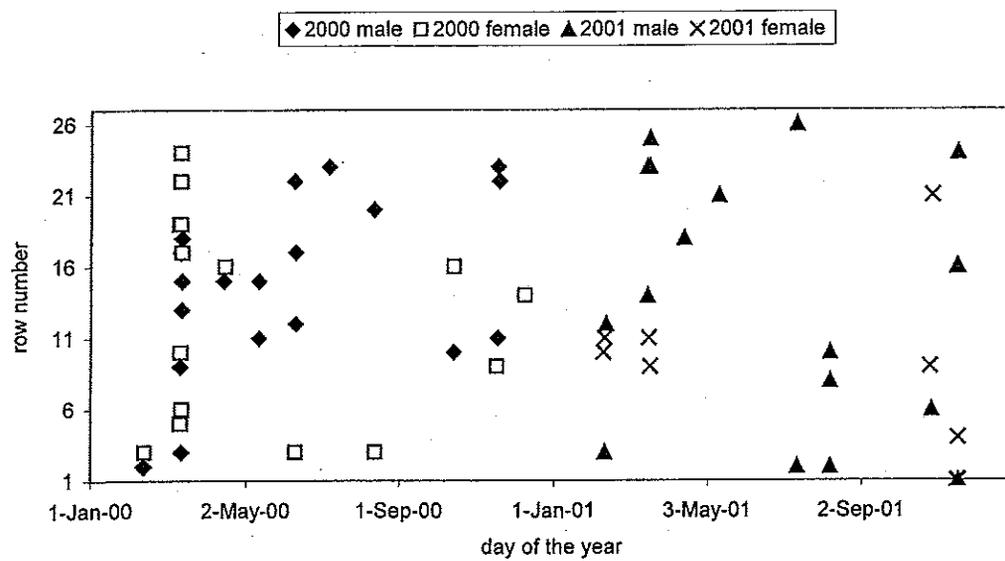


Figure 16. Comparison of adult and juvenile *Uta stansburiana* captures (January 2000-December 2001). The time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by age class. Differences in sampling year were not compared since virtually no juveniles ($n = 4$) were captured in 2000.

Fig. 16

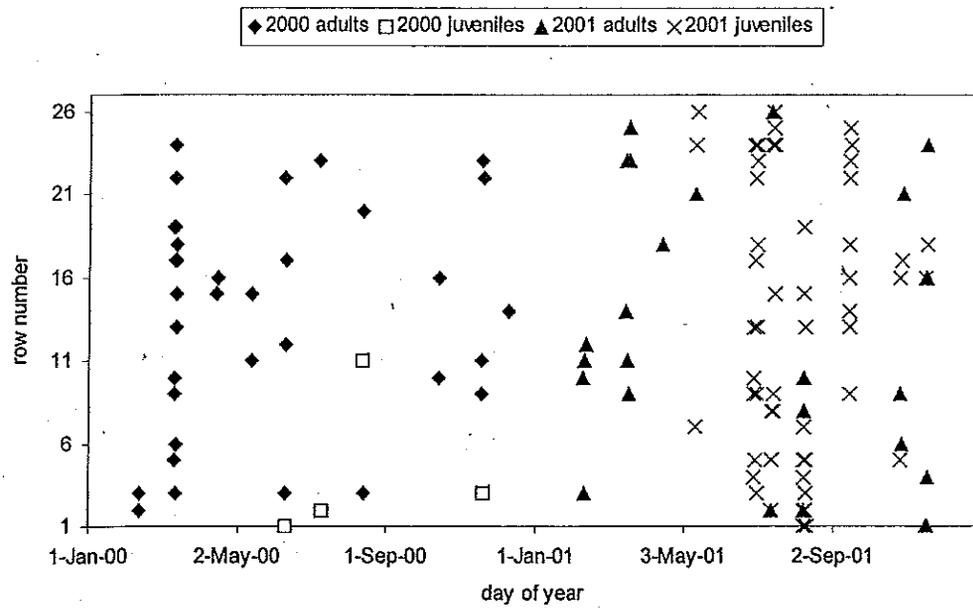
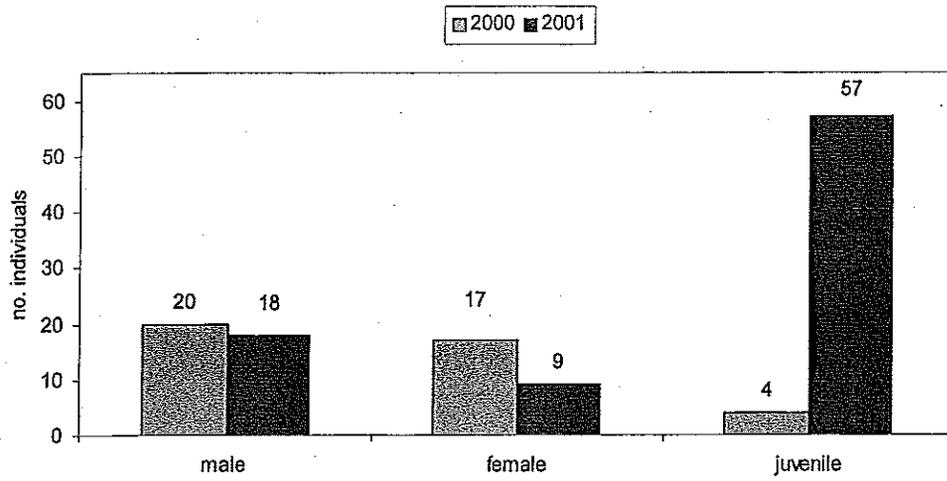


Figure 17. Capture comparison of *Uta stansburiana* adult males, adult females, and juveniles by sampling year. Data collected January 2000-December 2001.

Fig. 17



Given that no significant differences in trend could be found between adult male, adult female or juvenile *Cnemidophorus tigris*, these categories were combined. A positive slope was the result ($p = 0.000$; $R^2 = 0.201$; d.f.= 94; Figure 20a) with a coefficient of 0.06. This result suggests that these reptiles move up the trap-grid an average of 0.06 rows (1.2 meters) per day throughout each sampling year. To test this idea, data collected January 2000-December 2000 and January 2001-December 2001 was compared to data collected January 1992-December 1992. These three sampling periods were used for comparison because they each represent a full calendar year. A general linear model (ANCOVA) was used to compare the row number of all *C. tigris* captures vs. the day of each capture for each year. No significant difference in years ($p = 0.268$; d.f. = 155) was found so they were combined. A positive slope was again the result ($p = 0.000$; $R^2 = 0.112$; d.f.=155) with a coefficient of 0.05 rows (1 meter) per day (Figure 20b).

The total abundance of adult male, adult female and juvenile *Cnemidophorus tigris* were compared between the two sampling years (Figure 21). Between these years, the number of adult males captured did not change, the number of adult females captured increased by a factor of 2.62, and the number of juveniles captured increased by a factor of 23.

Figure 18. Comparison of adult male and female *Cnemidophorus tigris* captures (January 2000-December 2001). The time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by sex and sampling year. Dashed lines represent the overall significant trend ($p = 0.000$; d.f. = 46). The best fit regression equation for January 2000-December 2000: row number = $0.0788 \times \text{day of the year} - 2879.4$ ($R^2 = 0.3819$). The best fit regression equation for January 2001-December 2001: row number = $0.0794 \times \text{day of the year} - 2931.3$ ($R^2 = 0.2602$).

Fig. 18

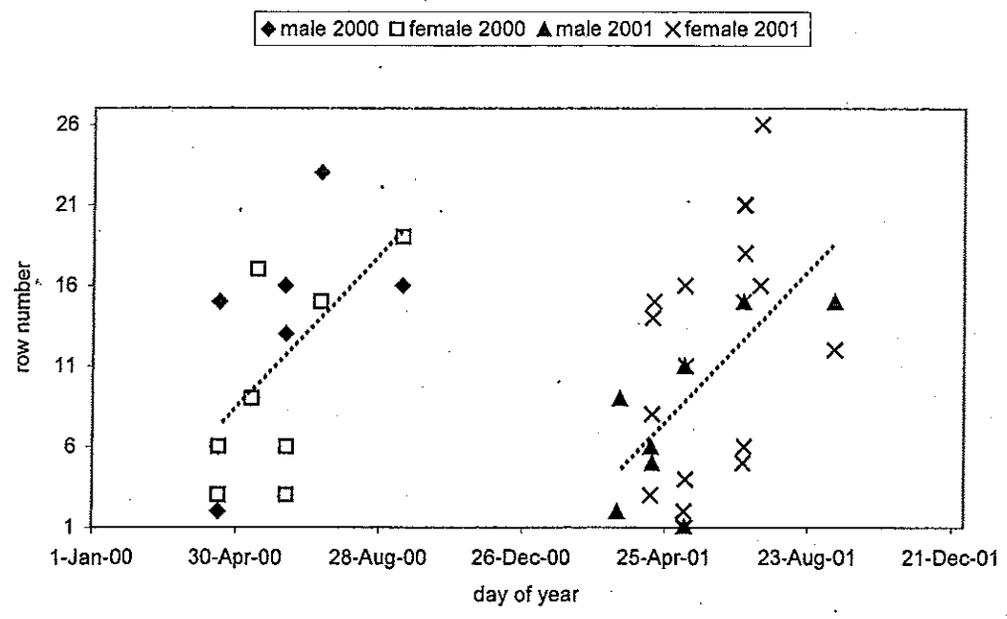


Figure 19. Comparison of adult and juvenile *Cnemidophorus tigris* captures (January 2000-December 2001). The time trend of row of capture by day of capture was compared using a general linear model (ANCOVA) broken out by age class. Differences in sampling year were not compared since virtually no juveniles ($n = 2$) were captured in 2000. Dashed lines represent the overall significant trend ($p = 0.001$; d.f. = 94). The best fit regression equation for January 2000-December 2000: row number = $0.0514 \times \text{day of the year} - 1875.3$ ($R^2 = 0.2208$). The best fit regression equation for January 2001-December 2001: row number = $0.0649 \times \text{day of the year} - 2393.6$ ($R^2 = 0.1879$).

Fig. 19

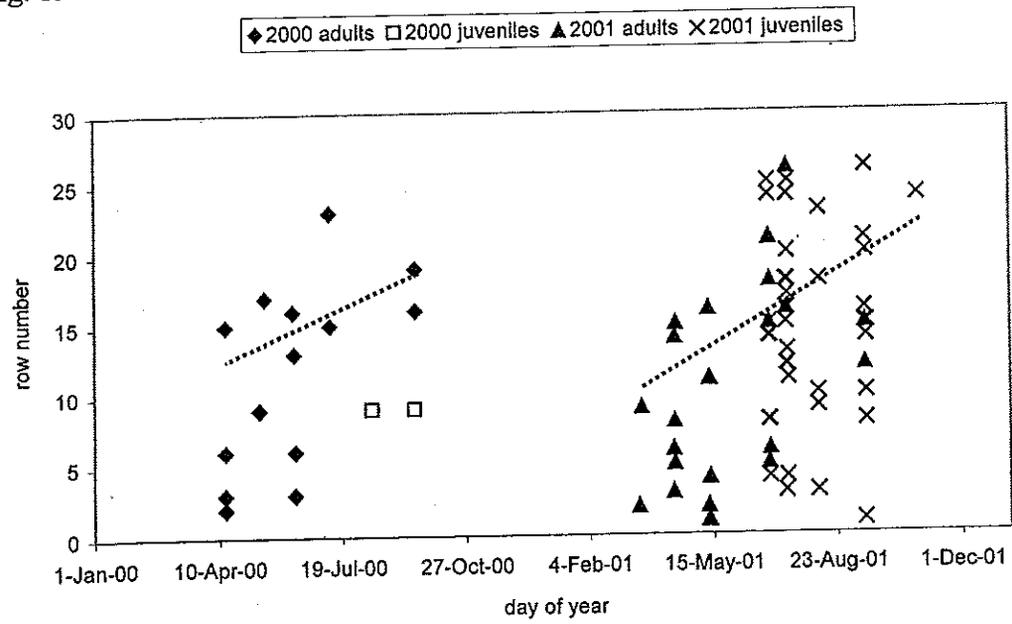
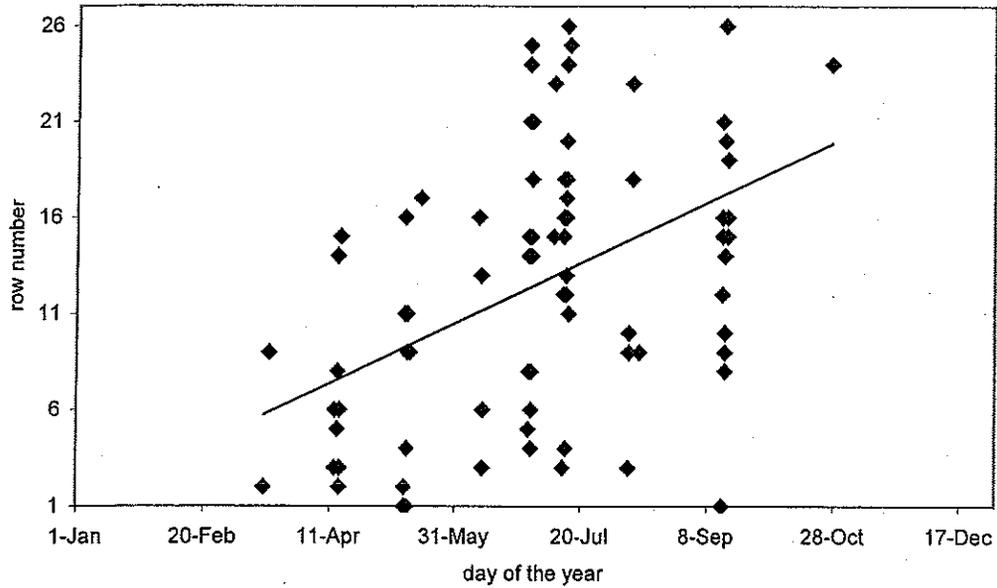


Figure 20. Comparison of total *Cnemidophorus tigris* captures for each calendar year (January-December) a) 2000 and 2001 combined b) 1992, 2000, and 2001 combined. In both cases, regression analysis results in a significant positive correlation. The best fit regression equation for 2000 and 2001: row number = $0.0627 \times \text{day of the year} - 2335.2$ ($R^2 = 0.2009$, $p = 0.000$, d.f. = 94). The best fit regression equation for 1992, 2000, and 2001: row number = $0.0492 \times \text{day of the year} - 1812.4$ ($R^2 = 0.1121$, $p = 0.000$, d.f. = 155).

Fig. 20

a) 2000 and 2001 combined



b) 1992, 2000 and 2001 combined

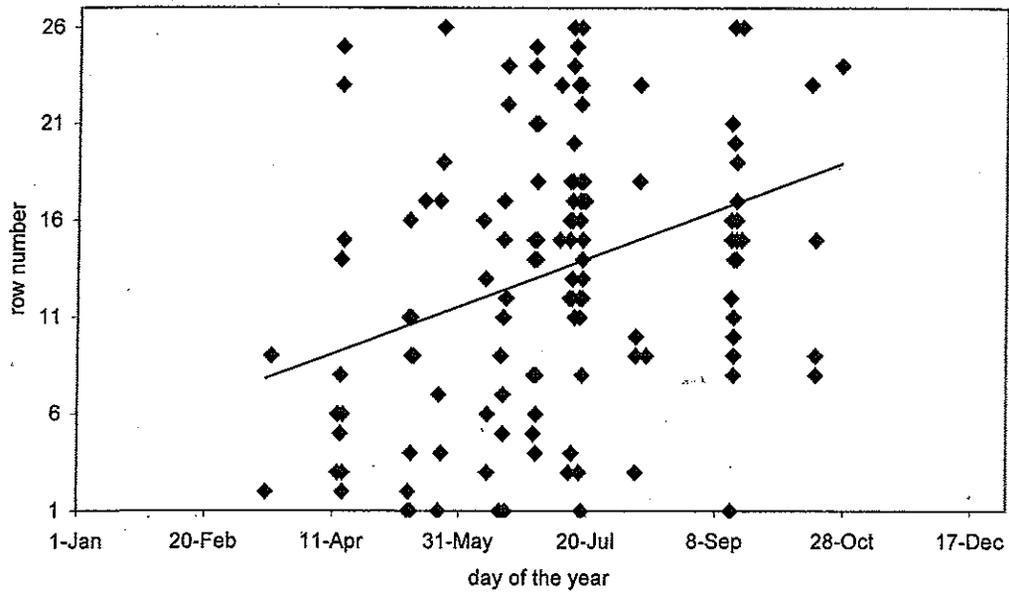
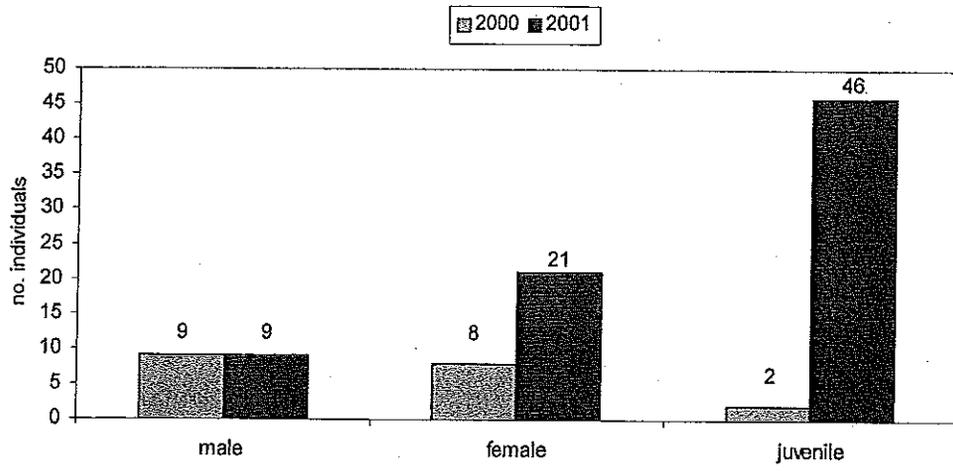


Figure 21. Capture comparison of *Cnemidophorus tigris* adult males, adult females, and juveniles by sampling year. Data collected January 2000-December 2001.

Fig. 21



CHAPTER IV

DISCUSSION

Trap grid success

One of the more interesting aspects of this study is the overall evenness of capture success. Previous studies have discussed overall capture results (Jorgensen and Demarais, 1998; Gibbons and Semlitsch, 1982; Campbell and Christman, 1982) as well as the effectiveness of different collecting techniques (Fair and Henke, 1997; Campbell and Christman, 1982; Enge, 2001). Those studies, however, have failed to include any detailed account of the overall evenness of trapping success. This information is very important, not only to understand reptile distribution in the area, but also to evaluate the effectiveness of the trapping technique itself. The performance of this trap grid has a direct effect on the validity of the results of this study. If only portions of the trap grid are consistently successful, one should reevaluate the experimental design. An assumption I made at the very beginning was that each of the 129 traps had an equal chance of capturing a reptile. The pitfall trap grid for this study incorporates four distinct habitat types, covering 55,000 m² (Figure 2). One aspect of the trap grid I was concerned with was edge effect bias. In other words, were the outer columns of the trap grid more or less likely to capture a reptile than the inner columns? Over the four sampling years, no significant difference was found in capture evenness between the outer edge columns

(A and E) and the inner columns (B, C, and D; $p = 0.137$; $\chi^2 = 3.96$; d.f. = 2; Figure 5). Also, no significant difference was found in capture evenness when comparing the five columns overall ($p = 0.165$; $\chi^2 = 6.49$; d.f. = 4; Figure 4).

A second concern was the possible presence of habitat bias. In other words, did pitfall-trapping work better or worse in any of the four habitat types? Over the four sampling years, a significant difference ($p = 0.003$; $\chi^2 = 13.70$; d.f. = 3) was found in the overall evenness of capture success between habitat types. Type #3 habitat had more captures than expected and type #4 habitat had less captures than would be expected if reptile captures were evenly dispersed (Figure 6a). But does this truly reflect the performance of the pitfall trap grid itself? This result could be biased since some reptile species are restricted to certain areas of the grid because of specific habitat requirements. To test if the trap grid is evenly effective at capturing reptiles, attention was focused on a reptile species that is known to be diverse in habitat preference.

Uta stansburiana was the most abundant species captured in this study ($n = 292$). When Pianka (1970) used the Shannon diversity index to test the habitat utilization of 11 southern desert lizard species, *U. stansburiana* was ranked first. It was also the only species found in all 5 microhabitat categories. In this study, *U. stansburiana* was found to be evenly distributed by both habitat ($p = 0.739$; $\chi^2 = 1.258$; d.f. = 3) and overall ($p = 0.165$; $\chi^2 = 6.483$; d.f. = 4; Figure 14a). Thus, for *U. stansburiana*, the trap grid was evenly successful at reptile capture over all four habitat types.

Urosaurus graciosus was the third most abundant species captured for this study

(n = 162). This species, however, has more specific habitat requirements. Pianka (1970) ranked *U. graciosus* fifth in habitat utilization. It was associated with trees, creosote scrub, and other shrubs in 94.7 % of Pianka's (1970) observations while being associated with rocks 0 %. For this study, the distribution of *U. graciosus* was found to be uneven for habitat ($p = 0.000$; $\chi^2 = 56.945$; d.f. = 3) and uneven overall ($p = 0.000$; $\chi^2 = 59.828$; d.f. = 4; Figure 14c). For *U. graciosus*, the trap grid was not evenly successful at capturing reptiles over the four habitat types. This is because *U. graciosus* is habitat specific.

When looking at the overall evenness of trap grid success, the significant difference found ($p = 0.049$; $\chi^2 = 9.51$; d.f. = 4; Figure 6b) is not necessarily a reflection of the performance of the pitfall traps themselves, it is more a reflection of the habitat preferences of the reptiles residing in the area. More reptile species were captured in type #3 habitat (s = 12; Appendix 17) than in any of the other habitat types. The highest percentage of total individual captures (38.6 %) also occurred in type #3 habitat (Appendix 15). Compared with the other three habitat types, the physical characteristics of type #3 habitat are the most general. Highly adapted, specialized characteristics are not necessarily required for survival in type #3 habitat as they might be for type #1 (very alkaline), type #2 (mostly very loose sand), or type #4 (very rocky).

As for individual trap success, the overall number of successful traps differed for each sampling year (Figure 7). However, the percentage of total successful traps per sampling year correlates positively with the total number of individuals captured (N). This positive correlation also exists with the percentage of traps that were successful more than once

per sampling year (Figure 7). During January 2000-December 2000, a sampling year in which trap success was low overall ($N = 72$), the traps that were successful were scattered over the entire trap grid (Figure 8). Over the four sampling years, 128 of the 129 total traps were successful at least once. Only trap A-6 failed to ever capture a reptile.

Environmental factors

A bloom of ephemeral plants occurred at my site in the spring of 1991, 1993 and 2001. The year of 2000 was very dry (1.39 inches; 34.75 mm) resulting in no ephemeral vegetation (Appendix 13e). As stated earlier, in order to germinate, winter ephemeral plants require 1 inch (25 mm) or more of precipitation in late September or early October which results in a spring bloom. Even though over 1 inch (25 mm) of rain did fall by that time, it was received in such small increments (the most received at any one time being 0.6 inches; 15 mm) that it quickly evaporated. The same circumstances occurred during the 1971 growing season of the Chihuahuan desert. In that season, precipitation was received in several small increments, each < 10 mm. This moisture quickly evaporated resulting in minimal vegetative growth (Whitford and Creusere, 1977).

Notes on the common species collected

Uta stansburiana

Considered one of the most abundant lizard species in arid to semiarid regions of the west (Stebbins, 1985), *Uta stansburiana* was the most abundant species in this study ($n = 292$). The only sampling year it was not the most abundant captured was June 1991-May 1992. During that period it was less abundant than *Urosaurus graciosus*. *U. stansburiana* was the most evenly distributed reptile captured for this study, found

consistently in all habitat types (Figure 14a). Pianka (1970) used the Shannon diversity index to test the habitat utilization and food species diversity of 11 species of southern desert lizard. *U. stansburiana* was ranked first in habitat diversity, being the only species found in all 5 microhabitat categories (creosote, other shrubs, open, trees and rocks). It was ranked second in food species diversity (*Callisaurus draconoides* being ranked first). For this study, *U. stansburiana* was consistently the first species to emerge in the spring and the last species to go down for winter dormancy. The small size of this lizard allows it to heat up to its preferred body temperature (99° F; 37.2° C) rather quickly (Cornett, 1987) allowing it to stay active even in the winter. In the present study, *U. stansburiana* individuals were captured from January to December. Juveniles, when present, were captured starting in May, peaking in abundance June-August (Appendix 18). A lack of juvenile recruitment in the 2000 sampling year (n = 4) compared to 2001(n =57; Figure 17) was correlated with the low levels of precipitation during that period. Low precipitation led to no winter ephemeral vegetation, which led to low insect abundance, which in turn led to reduced clutch size/frequency of resident lizards (Whitford and Creusere, 1977).

Uta stansburiana eats insects, scorpions, spiders, mites, ticks and sow bugs (Stebbins, 1985). Ants are a staple food for juveniles (Cornett, 1987). This is a very successful species because its needs are not very specific. It has a diet that is general, it does well in all habitat types, and is active all year round. Even under extreme drought conditions, arthropods are available to lizards with such general food preferences (Whitford and Creusere, 1977).

Cnemidophorus tigris

This species represents the second most abundant reptile in this study ($n = 234$). *Cnemidophorus tigris* was fairly evenly distributed throughout the study site although it was found significantly more times in type #3 habitat (specifically rows 11-15) than any other (Figure 14b). It is an active lizard that is not very selective when it comes to substrate preferences (it can be found on firm, sandy or rocky soil) as long as the area is open with sparse vegetation so that there is plenty of room for running (Stebbins, 1985). This species has been clocked running 15 mph for short distances (Cornett, 1987). Pianka (1970) used the Shannon diversity index to measure the microhabitat diversity and food species diversity of 11 desert reptiles. Results of that study ranked this relatively long-lived (3-4 years) species second in habitat diversity and third in food species diversity overall. For the present study, *C. tigris* individuals were captured between March and October. Juveniles, when present, were consistently captured June-September (Appendix 19). A lack of juvenile recruitment in the 2000 sampling year ($n = 2$) compared to 2001 ($n = 46$; Figure 21) is correlated with the low levels of precipitation during that period.

Cnemidophorus tigris is a very active hunter that eats insects, spiders, scorpions and other lizards (Stebbins, 1985). Insect larvae are an important food source in the spring, but they become less available as summer progresses. Termites are a major food source consistently over most of the season (Pianka, 1970). An interesting trend was found in this study regarding an overall migration of capture success steadily moving up the trap grid 0.05 rows (1 m) per day (January-December; Figure 20b). *C. tigris* was captured more frequently at the top of the slope in the fall than in the spring. As you move up the

slope, the vegetation gets more and more sparse (Appendix 5). Perhaps as the supply of insect larvae diminishes as the summer progresses, these lizards move up the slope in search of other prey items. Previous studies have also shown various seasonal migrations in the genus *Cnemidophorus*. Baltosser and Best (1990) found that in southwestern New Mexico, *C. tigris* spent all months of the year predominantly in habitat associated with creosote bush and honey mesquite except for September and October. During these months the species spent significantly more time in areas associated with snakeweed, possibly looking for food among the late summer flowers. While comparing the herpetofauna associated with arroyos and uplands in the Chihuahuan desert, Jorgensen and Demarais (1998) found suggestive evidence that *Cnemidophorus exsanguis* was captured more frequently on the uplands in the spring than in the fall. They also found suggestive evidence that *Cnemidophorus tigris marmoratus* was captured more frequently on the uplands in the fall than in the spring. Although the results of these two studies do not follow the same pattern as the results of the present study, they do help to suggest possible seasonal shifts for the genus *Cnemidophorus*. More research is needed.

Urosaurus graciosus

This species represents the third most abundant reptile in this study ($n = 162$). Interestingly, the vast majority of those individuals ($n = 156$) were captured during the first collection period, June 1991-May 1993. *Urosaurus graciosus* was an uncommon find ($n = 6$) during the second collection period, January 2000-December 2001 (Table 3a). *U. graciosus* was captured significantly more times in type #2 habitat (specifically rows 1-10) than any other (Figure 14c). This species is a well camouflaged, tree and

shrub dweller that ambushes its prey. It prefers loose sand with scattered bushes and trees. Creosote bushes, *Larrea tridentata*, with exposed roots are especially preferred (Stebbins, 1985). Type #2 habitat closely matches this described preferred habitat. It is classified as being mostly medium to fine sand that is occupied by creosote bushes and other shrubs (Appendix 2, 3, 4, and 5). In southern desert populations, Pianka (1970) linked *U. graciosus* with trees, creosote bushes and other shrubs in 94.7% of his observations. Pianka (1970) also ranked this species fifth in microhabitat diversity and fourth in food species diversity. For this study, *U. graciosus* was captured between March and October during the first collection period and between March and July during the second collection period. One juvenile was collected in July 2001. *U. graciosus* eats insects, spiders and occasionally parts of plants. Their habit of living in the branches of trees and bushes away from the substrate not only fills a food niche, it also helps to keep them cool. A spot in the shade that is 60 cm off of the hot ground can be cooler by up to 100° F (38° C; Schoenherr, 1992). This extreme difference in temperature takes into account the cumulative effects of air temperature, direct solar radiation, and conduction of heat from the substrate. Hunt (1975) once recorded a ground temperature of 190° F (88° C) in Death Valley, CA.

Callisaurus draconoides

This species represents the fourth most abundant reptile in this study (n = 65). Again the vast majority of these individuals (n = 60) were captured during the first collection period. *Callisaurus draconoides* was an uncommon find (n = 5) during the second collection period (Table 3a). *C. draconoides* was found significantly more times in

type #2 habitat though it seemed to prefer rows 6-20 rather evenly (Figure 14d). This species is adapted for running at high speeds. It has been clocked running 18 mph making it the fastest reptile in the desert (Cornett, 1987). This running ability requires firm soil for traction and lots of open space (Stebbins, 1985). In southern deserts, Pianka (1970) associated *C. draconoides* with open areas in 86.3% of his observations. For this study, this species was not found often in rows 1-5 (too sandy) or rows 21-26 (too many large rocks).

Callisaurus draconoides was captured between March and October. One juvenile was captured in August 2001. *C. draconoides* eats insects, spiders, other lizards and occasionally plants (Stebbins, 1985). When compared to 10 other southern desert lizard species, it was ranked first in food species diversity (Pianka, 1970).

Chionactis occipitalis

This species represents the fifth most abundant reptile in this study. It is also the most abundant snake ($n = 40$). *Chionactis occipitalis* is adapted to life in sandy soils. In general, it lives in washes, dunes, on loose soil, and rocky hillsides with sandy areas between the rocks (Stebbins, 1985). I expected to find more individuals in type #2 (loose sand) habitat than anywhere else. Instead, more captures occurred in type #3 habitat (Figure 14e). This study site being an alluvial fan, the rocky, type #3 habitat contains many sandy areas where the infrequent rains have cut gullies into the desert surface. This rocky/sandy combination could allow for more protection against the predators of this species, leaving it less exposed while roaming around on the surface at night (Stebbins, 1985). No significant difference was found in its distribution (Figure 14e). This species

was captured between May and November. Three juveniles were captured in the 2001 sampling year, two in August and one in October. *C. occipitalis* eats insects and their larva, spiders, scorpions, centipedes, and buried moth chrysalids (Stebbins, 1985).

Dipsosaurus dorsalis

This species represents the sixth most abundant reptile and sole herbivorous species captured for this study (n = 26). The majority of these captures (n = 19) occurred during the first collection period (Table 3a). *Dipsosaurus dorsalis* was found significantly more often in the rocky type #4 habitat (Figure 14f). This species is known to frequent creosote bushes surrounded by loose sand and patches of firm soil scattered with rocks, rocky streambeds, floodplains and bajadas (Stebbins, 1985). In southern deserts, Pianka (1970) linked *D. dorsalis* significantly more with creosote bush than with any other tree or shrub. For this study *D. dorsalis* was captured between March and September. One juvenile was captured in September 2001. This species is the last to emerge from its shallow burrow in the morning, preferring warmer temperatures than most other lizard species (Cornett, 1987). *D. dorsalis* is chiefly herbivorous, eating the fresh leaves, flowers, and buds of the creosote bush and other plants. It supplements this diet with some insects, carrion and its own fecal matter (Stebbins, 1985). Maintaining a high body temperature for long periods of time helps it to break down difficult-to-digest plant matter (Cornett, 1987).

When considering size, this species represents the largest lizard captured in this study with a snout-to-vent length of 12.1 cm. Herbivores can be larger than carnivores for two reasons. First, there is more food available to an herbivore (Schoenherr, 1992). Second,

plants do not try to escape. It is true that more calories are available per bite when eating animals, but it is also true that fewer calories are burned eating plants because the effort to acquire them is low. Herbivores use their energy to get larger, whereas carnivores use much of their energy capturing food (Schoenherr, 1992).

Coleonyx variegatus

This species represents the seventh most abundant reptile as well as the only nocturnal lizard collected in this study (n = 25). All but one of these individuals (n = 24) were captured during the first collection period. *Coleonyx variegatus* was a rare find (n = 1) during the second collection period (Table 3a). This species was found significantly more times in type #3 and type #4 habitats than anywhere else (only one individual was collected below row 11). Curiously, a drop in captures occurred in rows 16-20 (Figure 14g). *C. variegatus* is able to survive extremely dry conditions because of its nocturnal behavior. It is able to hunt at night because of its low active body temperature (84° F, 28.8°C), which is about 10° C cooler than most other North American diurnal lizards (Cornett, 1987). It is often associated with rocks (Stebbins, 1985), which explains why it preferred type #3 and type #4 habitat. This species was collected between April and October. *C. variegatus* eats insects and spiders, searching for food in a style that is a cross between sit-and-wait hunters and active foragers (Kingsbury, 1989). The fat reserve that they store in their tail is a resource that is exploited by some snakes of the genus *Phyllorhynchus*. These snakes are known to prey heavily upon the energy-rich tails of *C. variegatus* (Schoenherr, 1992; Cornett, 1987).

Phrynosoma platyrhinos

This species represents the eighth most abundant reptile in this study ($n = 10$). This number of captured individuals was too low to statistically test for habitat preference. However, six individuals were captured in type #3 habitat and four individuals were captured in type #4 habitat (Appendix 15). Not a single individual was collected below row 11 (Appendix 16). *Phrynosoma platyrhinos* is usually found on desert sandy flats, at the edges of dunes, in washes and on alluvial fans (Stebbins, 1985). The low number of captures for this study may be more a reflection of the behavior of this species than a reflection of its abundance. A pitfall trap works by surprising an individual as it moves across the substrate; the faster the individual, the more likely it will not be able to change its direction to avoid the trap. This species relies on camouflage rather than speed for a meal. It is possible that some individuals were able to avoid the traps because they were moving so slowly. Though few studies report capturing the genus *Phrynosoma* using pitfall traps, it does occur. Over a period of two years in the Sonoran Desert region of Arizona, Parker (1971) captured 10 of 50 *Phrynosoma solare* in pitfall traps. While testing different capture methods for *Phrynosoma cornutum*, Fair and Henke (1997) found that active search methods provided more captures per unit effort than trapping. For the present study, this species was collected between April and November. *P. platyrhinos* is adapted to eat ants, consuming 150-200 ants per day (Schoenherr, 1992). The stomach comprises 13% of the body weight, more than any other desert lizard (Cornett, 1987). This enables them to consume and digest this large quantity of ants to meet nutritional needs. To supplement this diet they also eat other insects, spiders, and

some plant materials (Stebbins, 1985). Perhaps drift fences could be used to improve the capture success of this species. Straight-line drift fences are typically short (5-15 meter) barriers that direct animals traveling on the surface into traps placed at the ends of or beside fences.

Notes on the rare species collected

(Reptiles with capture totals ≤ 2 are considered rare for this study)

Arizona elegans, *Masticophis flagellum* and *Pituophis melanoleucus*

As stated previously, pit-fall traps work best for snakes that have a length less than the depth of the bucket (Gibbons and Semlitsch, 1982). The three snake species *Arizona elegans*, *Masticophis flagellum* and *Pituophis melanoleucus* all have lengths longer than the depth of the bucket, yet they were captured albeit in very low numbers. The key to this is timing. Each trap for this study had its lid situated 1 inch above the trap leaving a gap for reptile entrance. This not only prevents direct sun exposure, but also acts as a makeshift burrow. With the exception of one of the *A. elegans* captures, all collecting took place during the early morning trap checks. *A. elegans*, a nocturnal species, had found a place to rest after a night of foraging for food. *M. flagellum* and *P. melanoleucus*, both diurnal species, had not yet emerged. If the traps had been checked later in the day, these individuals would more than likely have already vacated. *M. flagellum* (n = 1) was captured in July 2001. *P. melanoleucus* (n = 1) was captured in August 2000. *A. elegans* (n = 2) was captured in April 1993 and December 2001. The individual captured in December was collected during the afternoon trap check. This was very odd. Hunting for food in the middle of a cold (52.5° F; 11.4° C) December day is uncharacteristic of this

species. The individual was observed to be atypically thin. I attribute the behavior and condition of this individual to a lack of fat lipid storage necessary to sustain itself through the winter months. As previously stated, we would expect snake populations to be low considering the total amount of energy available within the system (Schoenherr, 1992). This could also explain the low capture success. The addition of drift fences and funnel traps could help to increase the capture rates of these large snakes, resulting in a more realistic idea of their actual abundance in the system (Enge, 2001).

Gambelia wislizenii, *Crotaphytus insularis* and *Uma scoparia*

The three lizard species, *Gambelia wislizenii*, *Crotaphytus insularis*, and *Uma scoparia*, were captured during the first collection period. With only one capture each it is not possible to examine habitat preference. *G. wislizenii* favors an environment of low scattered plants. It will inhabit an area that is or is not rocky, avoiding areas of dense vegetation that could interfere with running (Stebbins, 1985). The individual captured in this study was trapped in upper type #3 habitat, a rocky habitat that is scattered sparsely with vegetation (Appendix 5).

Crotaphytus insularis also favors terrain with sparse vegetation; but it is a rock dweller (Stebbins, 1985). The individual captured for this study was also trapped in the upper type #3 (rocky) habitat. *Gambelia wislizenii* and *C. insularis* were both captured in July 1991.

Uma scoparia is adapted to live on loose sand (Stebbins, 1985). As would be expected, the individual captured in this study was trapped in lower type #2 habitat (loose sand). *U. scoparia* was captured in May 1993.

Leptotyphlops humilis

This species of snake favors washes, canyon bottoms and rocky hillsides with patches of loose soil (Stebbins, 1985). This individual was captured during the first collection period in upper type #3 habitat, June 1992.

Xantusia vigilis

This species of lizard lives primarily under fallen Joshua trees (*Yucca brevifolia*), although they can also be found residing in rock crevices, beneath cow chips and under logs or any other kind of debris (Stebbins, 1985). The fact that only one individual of this species was captured may be just as much a reflection of its behavior, as it is a reflection of its abundance. The Joshua tree, with which they are associated, is a very common species of the Mojave Desert. It grows at an elevation of 606 m-1818 m (2000 ft-6000 ft; Whitman, 1986). My study site lies below that range at an elevation of 288 m-358 m (950 ft-1180 ft), thus there are no Joshua trees in the area. *X. vigilis* is also a very secretive lizard that rarely ventures out away from cover. Of the 27 individuals observed in southern deserts by Pianka (1970), 100% of them were spotted in the shade, under the cover of trees. This secretive behavior, coupled with a lack of its most preferred habitat fixture, the Joshua tree, could explain why only one individual of this species was captured for this study. Collecting this species requires special efforts such as turning over logs and raking through debris (Bury, 1982). This individual was trapped during the second collection period in type #2 habitat, May 2001.

Habitat usage

As stated earlier, most carnivores in the desert are insectivorous, a result of the high availability of insect prey. With the exception of *Arizona elegans*, all of the reptiles captured during this study rely solely or at least partially on arthropods for their diet (Stebbins, 1985). The key to avoiding competition is niche partitioning based on size, habitat preference, and food preference (Schoenherr, 1992). Barbault and Maury (1981) found a poor correlation between lizard body size and prey body size when studying the gut contents of 11 diurnal Chihuahuan desert lizard species. During food shortages, the dietary overlaps of the studied species were low; each species relying on its own preferred prey items. After the rains, when food becomes more abundant, the dietary overlap greatly increased as most lizard species utilized similar abundant prey items.

Results of this study suggest that the resident reptiles of this community partition the resources available to them, at least in part, by habitat preference. Five of the seven most abundant species captured during this study were unevenly distributed overall and by habitat. Although the distributions of these reptile populations were uneven, spatial overlap between species did occur. The majority of this overlap occurred in type #3 habitat ($n = 12$; Appendix 17). Compared to the other three habitat types, the physical characteristics of type #3 habitat are the most general. Highly adapted, specialized characteristics are not necessarily required for survival in type #3 habitat as they might be for type #1 (very alkaline), type #2 (mostly very loose sand), or type #4 (very rocky).

With regards to ecosystem maintenance and preservation, the recognition of natural habitats that possess characteristics suitable for many different species is important when

making land management and resource decisions. This is a very important concept given the large-scale replacement of diverse natural ecosystems with less-diverse managed systems (Naeem and Li, 1997).

Abundance and diversity

Species richness is a component of diversity. Combining species richness with information on the relative abundance (evenness) of the species present in a community provides a useful measurement of community characteristics (Cloudsley-Thompson, 1993). When the abundance and diversity of captured reptiles were compared between the two collection periods (June 1991-May 1993 vs. January 2000-December 2001), significant differences were found. *Urosaurus graciosus*, *Callisaurus draconoides* and *Coleonyx variegatus* each experienced a significant decrease in the relative abundance of their respective populations. When combined, these three species represent 40.1% of all captures June 1991-May 1993, while representing only 4.5% of all captures January 2000-December 2001 (Table 3a).

Although *Urosaurus graciosus*, *Callisaurus draconoides*, and *Coleonyx variegatus* are insectivorous, they are not in direct competition with each other based on their behaviors and habitat preferences. *U. graciosus* is a diurnal sit-and-wait predator that lives in trees and shrubs. Examination of the natural history of the other resident reptiles reveals that this species fills a niche that would not readily be filled in its absence. According to Whitford and Creusere (1977), seasonal amounts of rainfall and rainfall distribution patterns affect primary productivity and hence arthropod availability as food for lizards. It is possible that the low levels of precipitation that occurred during the second

collection period (January 2000-December 2001) resulted in a reduction of insect prey. While an active forager is capable of seeking out its prey, a sit-and-wait predator, such as *U. graciosus*, must wait for its prey to come to it. For a sit-and-wait predator, a decrease in arthropod density could result in a reduction of food availability (predator-prey encounters).

Uta stansburiana is morphologically very similar to *Urosaurus graciosus*. Both are small, insectivorous, sit-and-wait predators. However, while *U. graciosus* lies motionless up in trees and bushes, waiting for a meal, *U. stansburiana* utilizes many different types of habitat, thus increasing its chance of prey encounters. Pianka (1970) ranked *U. stansburiana* first in microhabitat diversity and second in food species diversity. *U. graciosus* was ranked fifth in microhabitat diversity and fourth in food species diversity. When comparing the two collection periods, the relative abundance of *U. graciosus* dropped significantly while the relative abundance of *U. stansburiana* significantly increased (Table 3a). *U. stansburiana* was more successful than *U. graciosus* because its habitat and dietary requirements are more general. Since *U. stansburiana* does not occupy the same microhabitat that *U. graciosus* occupies (up in trees and shrubs), a factor other than habitat availability must be the cause of these population shifts. Due to its method of predation, perhaps the dramatic decline of *U. graciosus* can partly be attributed to a decline of available food resources.

Callisaurus draconoides is a diurnally active hunter that prefers open areas where plant growth is sparse. It is usually not far from firm substrate. Many other reptiles frequent the habitat type it prefers, thus putting it in direct competition with most other

diurnal species, especially *Uta stansburiana* and *Cnemidophorus tigris*. Over both collection periods, *U. stansburiana* was the most frequently captured reptile while *C. tigris* remained in the top three. Although the near disappearance of *C. draconoides* did not result in an increase of *U. stansburiana* or *C. tigris* captures, the relative abundance of each of these lizard populations did increase significantly (Table 3a). *C. draconoides* was ranked first in food species diversity, *U. stansburiana* and *C. tigris* were ranked second and third, respectively (Pianka, 1970). As was stated earlier, even under extreme drought conditions, arthropods are available to lizards with such general food preferences (Whitford and Creusere, 1977); therefore, *C. draconoides* should have maintained its presence in this community, even in a less productive environment. The massive decline in its population does not follow the model; therefore, a factor other than food availability must be the cause. Since it is the fastest reptile in the desert (Cornett, 1987), perhaps the decline of this population can partly be attributed to the high-energy demands of its locomotion.

Coleonyx variegatus is a nocturnal sit-and-wait/active forager, preferring a rocky habitat. Being nocturnal allows it to avoid direct competition with diurnal reptiles. Examination of the natural history of the other resident reptiles reveals that this species is in competition with *Chionactis occipitalis*, the small, nocturnal, insectivorous snake. Although the near disappearance of *C. variegatus* did not result in an increase of *C. occipitalis* captures, the relative abundance of this snake population did increase significantly (Table 3a). These two species have very similar habitat and dietary requirements (Stebbins, 1985; Figure 14e and 14g); these data suggest the near loss of *C.*

variegatus resulted in the competitive release of *C. occipitalis*. The cumulative near loss of *Urosaurus graciosus*, *Callisaurus draconoides*, and *C. variegatus* pushed *C. occipitalis* from sixth most abundant species (June 1991-May 1993; Table 2a) to third most abundant species (January 2000-December 2001; Table 2b).

The decline of biodiversity is a serious and complicated problem that deserves long-term scientific consideration. This decline includes species richness, relative abundance of species, functional diversity (relative abundances of functionally different species), and community diversity (spatial distribution of communities; Walker, 1992). To help prevent the decline of biodiversity, it is necessary to understand its relationship with ecosystem function.

According to the redundancy hypothesis (Walker, 1992), species may be divided into functional groups or guilds (i.e., herbivores, primary producers, decomposers, etc.). Rather than focus on each species individually, species are grouped according to ecological function. In these terms, species belonging to the same functional group are more expendable relative to each other than they are to species outside of the functional group. In other words, species redundancy contributes to the overall resilience of ecosystem function (Ehrlich and Walker, 1998). Resilience, in this context, is defined as an ecosystem's ability to maintain its distinctive patterns and processes when confronted with environmental change (Walker, 1992). Functional groups with little or no redundancy require greater attention with regards to ecosystem maintenance and preservation (Ehrlich and Walker, 1998). This, however, does not mean that we can afford to lose species belonging to a redundant group. The loss of any species, even one

with a high degree of redundancy, reduces the ecosystems overall diversity of responses and hence its resilience to changes in environmental conditions. Different species belonging to the same group each respond to changing environmental conditions differently. A redundant species with a low relative abundance today could be the only species capable of adapting to future environmental changes tomorrow (Ehrlich and Walker, 1998; Walker et al., 1999). In the face of these changes, ecosystem function carries on because minor species (those with low relative abundances) are capable of filling in when dominant species are in decline. Therefore, all species in a functional group can be considered equally significant with regard to overall ecosystem resilience (Walker et al., 1999).

The reptiles captured for this study serve as the primary and secondary carnivores of the system. According to the redundancy hypothesis (Walker, 1992), *Uta stansburiana*, *Cnemidophorus tigris*, *Urosaurus graciosus*, *Callisaurus draconoides*, *Chionactis occipitalis*, *Coleonyx variegatus*, *Phrynosoma platyrhinos*, *Uma scoparia*, and *Xantusia vigilis* could all be included in the functional group of (reptilian) insectivores. A more extensive analysis of ecosystem function is required to further sub-divide these species into more specific categories. It would be interesting to conduct a detailed gut content analysis on each of the reptile species residing in the Soda Springs area, not only to find out what each species is eating, but also to determine if the prey items of each species change seasonally. Information regarding the overall percentages of dietary overlap among these species would be very useful. This would allow further sub-division into more specific functional groups.

Although the relative abundances of these nine species differ, all are equally important to the overall resilience of ecosystem function. Complete functional redundancy only occurs if the removal of one species results in density compensation (competitive release) among the remaining species (Walker, 1992). The near loss of *Urosaurus graciosus*, *Callisaurus draconoides*, and *Coleonyx variegatus* from this group did not result in a catastrophic crash of the system. The remaining members of the functional group continued to fill their similar ecological role. When comparing the two collection periods, the total captures of *Uta stansburiana*, *Cnemidophorus tigris*, and *Chionactis occipitalis* each decreased. The relative abundances of each, however, significantly increased (competitive release; Table 3a). To truly gauge the importance of this functional group in the overall system, one would need to examine more specifically the ecological effects of a change in the abundance of the functional group (Walker, 1992). This would include detailed information on insect abundances, timing and rates of predation, primary productivity, herbivory, decomposition, etc. Acquiring these kind of data would involve site-specific ecological experimentation. In other studies, recent research has been conducted to investigate the connections found between species populations and the functions they provide (Holmlund and Hammer, 1999; Bird, 2000; Kremen et al., 2002; Luck et al., 2003). Unfortunately, information such as this is not available for the present study.

The biodiversity of a system could be considered biological insurance (Naeem and Li, 1997). Every species in the system adds to the overall system genome. Naeem and Li (1997) established replicated microcosms, each with varying numbers of species in each

functional group. They found that an increase in the number of species per functional group resulted in replicate communities with more consistent biomass and density measures. Thus, redundancy within functional groups makes an ecosystem more predictable, enhancing its reliability and resilience. This is a very important concept given the large-scale replacement of diverse natural ecosystems with less diverse managed systems (Naeem and Li, 1997). Considering how complicated the relationships are between ecosystem function and biodiversity, policy decisions should have a large “insurance” bias (Ehrlich and Walker, 1998) toward the protection of biodiversity.

When comparing the diversity of the four sampling years of the present study, it is interesting to see that the values of the adjusted Shannon index $E(H')$, follows the same basic pattern as the yearly cumulative precipitation (Figure 10; Figure 12). Other values that follow this pattern are the totals for individuals captured per sampling year (Appendix 14b) and individual trap success per sampling year (Figure 7). High levels of precipitation result in a greater probability that, in a sequence of captures, the next reptile captured is that of a different species (greater diversity). The low level of precipitation in 2000 resulted in a comparably low Shannon index value (low diversity) for the sampling year.

Bury (1982) measured the species diversity and relative abundance of reptiles at eight different sites in the Mojave Desert. Using the removal method, he concluded that three species of lizard made up 83% of the individuals sampled. In order of abundance they were *Callisaurus draconoides*, *Cnemidophorus tigris* and *Uta stansburiana*. In the present study, the three most abundant reptile species captured June 1991-May 1993

represented 77.2% of all captures (*Uta stansburiana*, *Urosaurus graciosus*, and *Cnemidophorus tigris*). The three most abundant reptile species captured January 2000-December 2001 represented 89.8% of all captures (*U. stansburiana*, *C. tigris* and *Chionactis occipitalis*). This increase in dominance between the two collection periods could suggest, that over time, the community has become less even (less diverse) than when the original data were collected. Because of this overall dominance, the Simpson index (D_s) is more appropriate for determining species diversity than the Shannon index. The Simpson index describes the degree of dominance of the more common species, giving less weight to the rare captures. It is possible that the high levels of precipitation occurring in 1991 and early 1992 resulted in 1993 having the highest Simpson index value (Figure 10). Interestingly, the index values associated with the other three sampling years are almost identical, although they do drop slightly from year to year. The calculated Pielou evenness index values (J) also dropped slightly from year to year (Figure 10). Due to the lack of data in the nearly 10 years separating the two collection periods, it is not possible to determine if the evenness (diversity) of this community has consistently dropped over time, or if it is just part of a natural cycle of species abundance. More data is necessary to make any solid conclusion.

Although long-term studies do have trouble capturing the full range of variability in population sizes (Blaustein et.al., 1994; Pechman and Wilbur, 1994), more data are required to determine any potential trends, patterns or cycles in the population dynamics of this reptile community. Impressions from short-term data sets may be that large declines are "abnormal". Longer records may reveal there is nothing unusual about such

declines (Blaustien et al., 1994). Long-term, ongoing data sets regarding the relative abundance and habitat utilization of reptile species are greatly needed. This kind of information is not only valuable to the further understanding of these communities, it is invaluable to the effective management of land and resources (Zaady and Bouskila, 2002; Baltosser and Best, 1990; Jorgensen and Demarais, 1998), helping to make better land management decisions and ultimately assisting in the maintenance of biological diversity.

CHAPTER V

CONCLUSION

This study describes the abundance and diversity of reptiles at Soda Springs in the East Mojave Desert during two 24 consecutive month collecting periods (June 1991-May 1993 vs. January 2000-December 2001). The changes in abundance and diversity within and between these periods have been described as a function of temperature, precipitation and time of year. The performance of the trap grid has been described as a function of the habitat preference and overall distribution of the resident reptiles. The null hypotheses tested for this study were: (1) Trap grid success does not differ between sampling years [rejected]. (2) Trap grid success does not differ between columns [accepted]. (3) Trap grid success does not differ between the four habitat types [rejected]. (4) Diversity of reptile species captured does not differ between sampling years [rejected]. (5) Abundance of reptile individuals captured does not differ between sampling years [rejected]. (6) Habitat type does not have an effect on the abundance and diversity of reptiles captured [rejected]. (7) Habitat utilization does not differ between reptile species [rejected]. (8) Environmental conditions (precipitation / temperature) do not affect abundance and diversity of reptiles [rejected]. From the reported results of this study, the following conclusions can be drawn.

- 1) Each of the five columns of the trap grid captured reptiles evenly. No edge effect was observed.

- 2) Pitfall traps were not equally successful for each of the four habitat types. Traps in habitat type #3 were more successful than expected. Traps in habitat type #4 were less successful than expected.
- 3) The uneven distribution of captures by habitat was determined to be a function of reptile habitat preference rather than a function of trap performance.
- 4) Compared to the other three habitat types, the physical characteristics of habitat type #3 were determined to be the most general overall.
- 5) More reptile species were captured in type #3 habitat ($s = 12$) than in any of the other habitat types.
- 6) More reptile individuals were captured in type #3 habitat (38.6 %) than in any of the other habitat types.
- 7) The highest percentage of reptile individuals captured overall (23 %) occurred in rows 11-15 of type #3 habitat.
- 8) The percentage of total successful traps per sampling year correlated positively with the total number of individuals captured (N).
- 9) The percentage of total successful traps that captured more than one reptile per sampling year correlated positively with the total number of individuals captured (N).
- 10) Over the four sampling years, 128 of the 129 traps associated with this study were successful. Only trap A-6 failed to ever capture a reptile.
- 11) A positive correlation exists between temperature and the abundance and diversity of captured reptiles.

- 12) A positive correlation exists between cumulative precipitation and the abundance and diversity of captured reptiles.
- 13) *Uta stansburiana* was the most abundant species captured during both collection periods (June 1991-May 1993 and January 2000-December 2001).
- 14) *Uta stansburiana* was the most evenly distributed species captured during both collection periods (June 1991-May 1993 and January 2000-December 2001).
- 15) *Uta stansburiana* was consistently the first species to emerge in the spring and the last species to go down for winter dormancy.
- 16) *Chionactis occipitalis* was consistently the last species to emerge from winter dormancy (May).
- 17) *Dipsosaurus dorsalis*, *Cnemidophorus tigris*, *Urosaurus graciosus*, and *Callisaurus draconoides* all consistently emerged from winter dormancy in the same month (March).
- 18) While *Dipsosaurus dorsalis* was consistently the first species to go down for winter dormancy (October), *Cnemidophorus tigris*, *Urosaurus graciosus*, and *Callisaurus draconoides* all consistently went down for winter dormancy in the same month (November).
- 19) No significant trends were found regarding the row number and day of capture for *Uta stansburiana* adult males, adult females or juveniles.
- 20) No significant trends were found regarding the row number and day of capture for *Cnemidophorus tigris* adult males, adult females or juveniles.

- 21) An overall trend was found for *Cnemidophorus tigris* regarding a migration of capture success steadily moving up the slope 0.05 rows (1 m) per day (January-December).
- 22) This study provides evidence that the resident reptile species avoid resource competition, at least in part, by niche partitioning based on habitat preference.
- 23) Low levels of precipitation in the 2000 sampling year correlated with a reduction of spring annual vegetation.
- 24) The reduction of spring annual vegetation in the 2000 sampling year correlated with a sizeable reduction of juvenile reptile recruitment.
- 25) *Urosaurus graciosus*, *Callisaurus draconoides* and *Coleonyx variegatus* represent 40.1% of all captures occurring June 1991-May 1993. They represent only 4.5% of all captures occurring January 2000-December 2001.
- 26) According to the redundancy hypothesis, *Uta stansburiana*, *Cnemidophorus tigris*, *Urosaurus graciosus*, *Callisaurus draconoides*, *Chionactis occipitalis*, *Coleonyx variegatus*, *Phrynosoma platyrhinos*, *Uma scoparia*, and *Xantusia vigilis* could all be included in the functional group of (reptilian) insectivores.
- 27) The near loss of three species from this functional group, *Urosaurus graciosus*, *Callisaurus draconoides*, *Coleonyx variegatus*, did not result in a crash of the system. The remaining members of the functional group continued to fill their similar ecological role.

- 28) When comparing the two collection periods, the total captures of *Uta stansburiana*, *Cnemidophorus tigris*, and *Chionactis occipitalis* each decreased. The relative abundances of each, however, significantly increased.
- 29) The three most abundant reptile species captured June 1991-May 1993 represented 77.2% of all captures. In order of abundance they were *Uta stansburiana*, *Urosaurus graciosus*, and *Cnemidophorus tigris*.
- 30) The three most abundant reptile species captured January 2000-December 2001 represented 89.8% of all captures. In order of abundance they were *Uta stansburiana*, *Cnemidophorus tigris* and *Chionactis occipitalis*.
- 31) Population estimates were not calculated due to the lack of recapture data.
- 32) The addition of drift fences and funnel traps could help to increase the capture success of *Phrynosoma platyrhinos* and the large resident snake species.

APPENDICES

LIST OF APPENDICES

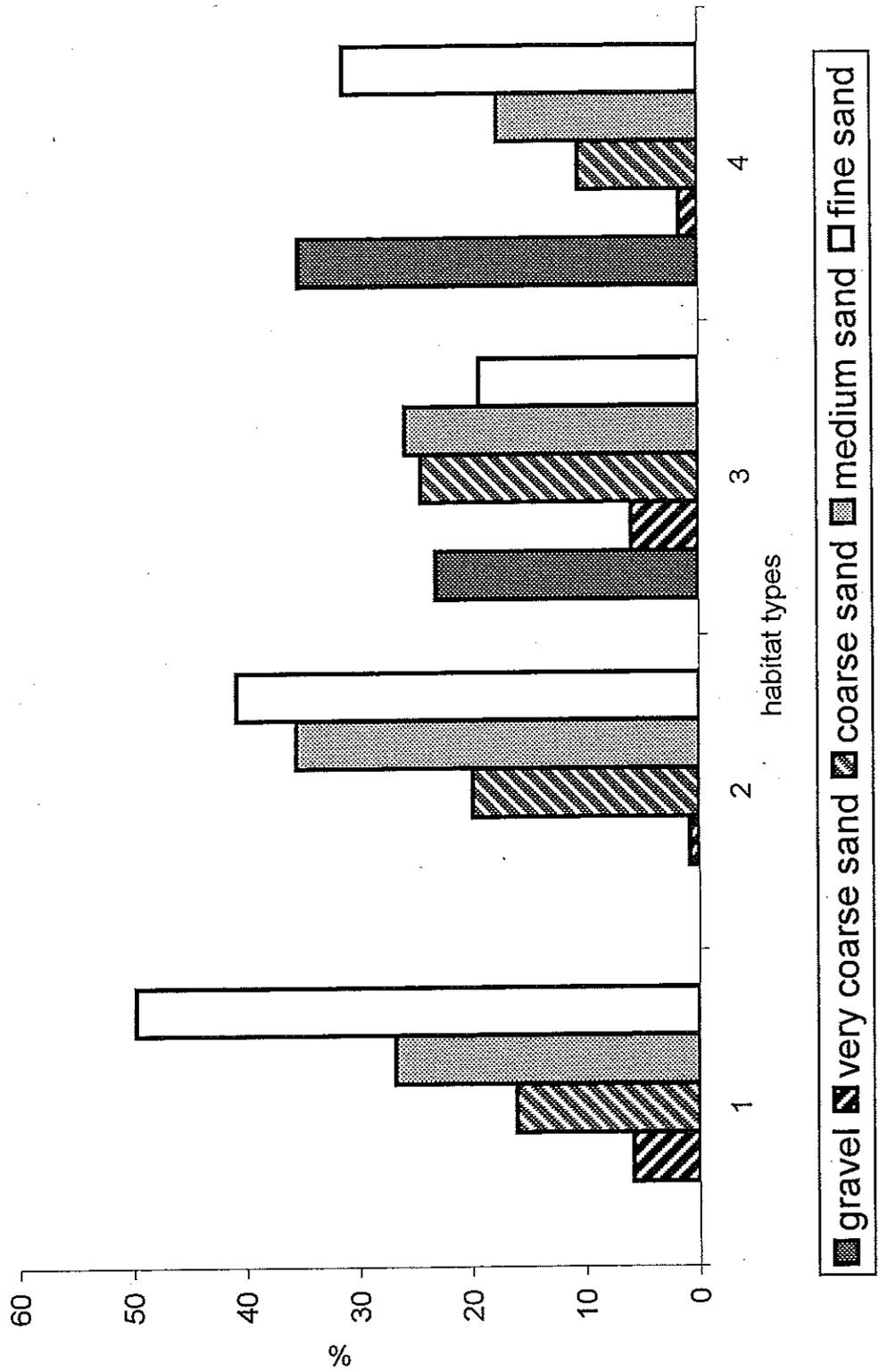
<u>Appendix</u>	<u>Page</u>
1. Soil types categorized by particle size	118
2. Comparison of habitat type by substrate classification.....	119
3. Plant abundance divided by habitat type. Data collected on columns C and E combined. The results of this plant survey (Garron, unpublished data) associates 13 species with the four habitat types. The grass family Poaceae is counted as one guild.....	120
4. Mean percent coverage of <i>Larrea tridentata</i> associated with four distinct habitat types. Data collected at each trap of column C and E (Garron, unpublished data)	121
5. Mean percent coverage of the vegetation associated with four distinct habitat types. Regression analysis results in a significant negative correlation. The best fit regression equation for vegetation coverage: mean % coverage = $0.0094 \times \text{row number} + 0.2789$ (R-square = 0.4454, p = 0.000). Data collected at each trap of column C and E (Garron, unpublished data).....	122
6. The percentage of total reptiles captured per column for a) June 1991-May 1992 b) June 1992-May 1993 c) Jan. 2000-Dec. 2000 d) Jan. 2001-Dec. 2001. Chi-squared analysis was used to test for evenness of column capture success..	123
7. The percentage of total reptiles captured per habitat type for a) June 1991-May 1992 b) June 1992-May 1993 c) January 2000-December 2000 d) January 2001-December 2001 e) June 1991-May 1993 and f) January 2000-December 2001. The capture success of each was tested for evenness, relative to its respective size, using Chi-squared analysis	125
8. Total reptiles captured a) June 1991-May 1992 b) June 1992- May 1993 c) January 2000-December 2000 d) January 2001-December 2001	128
9. Comparison of the total number of a) reptile species and b) reptile individuals captured per month. Data from each sampling year lined up by month for direct comparison. No data collected for August 1992 (**)	130

<u>Appendix</u>	<u>Page</u>
10. Comparison of the total number of a) reptile species and b) reptile individuals captured per month. Data from each sampling year has been lined-up January-December for direct comparison. No data collected for August 1992.....	131
11. Shannon index with standard error calculations along with Pielou's evenness index and Simpson's index of diversity calculations for the data collected in May of 1992, 1993, 2000 and 2001	133
12. Maximum and minimum average temperatures for each monthly collecting period June 1991-May 1993 and January 2000- December 2001.....	134
13. Cumulative annual precipitation per year for a) 1991 b) 1992 c) 1993 d) 1999 e) 2000 f) 2001 and g) 2002	135
14. Total number of captures per sampling year a) reptile species b) reptile individuals of all species.....	139
15. The percentage of total captures per habitat type for each reptile species. Data collected June 1991-May 1993 combined with data collected January 2000-December 2001	140
16. The percentage of total captures per divided section for each reptile species. Data collected June 1991-May 1993 combined with data collected January 2000-December 2001	141
17. Total number of species captured per a) habitat type b) divided section.....	142
18. Snout-to-vent length of captured <i>Uta stansburiana</i> vs. day of the year for a) January 2000-December 2001 b) January 2001-December 2001	143
19. Snout-to-vent length of captured <i>Cnemidophorus tigris</i> vs. day of the year a) January 2000-December 2000 b) January 2001-December 2001	144

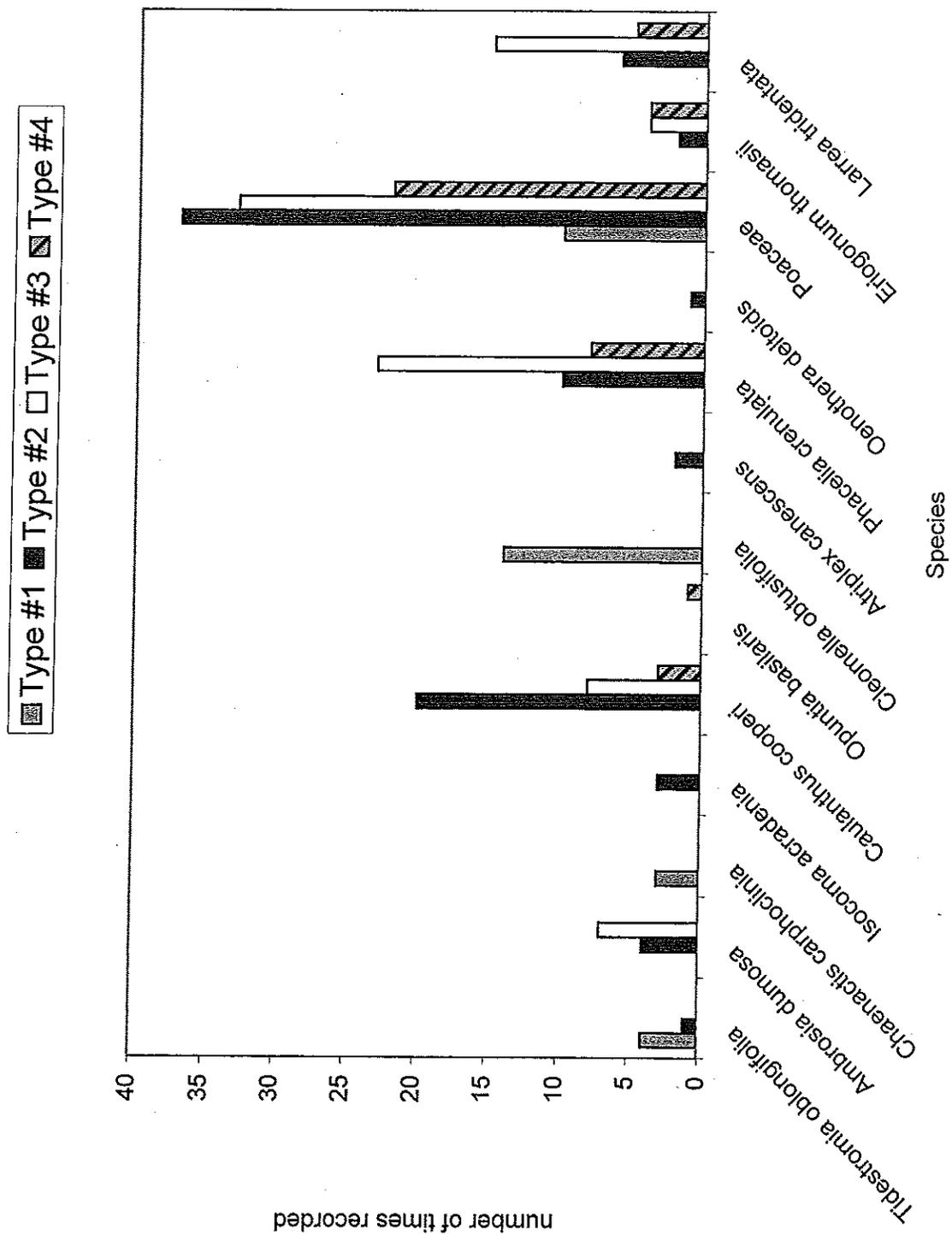
Appendix 1- Soil types categorized by particle size. Classification based on United States Department of Agriculture classification of soil textures.

	Substrate types	Particle size categories	Mesh size
1	Gravel	> 2.0 mm	2.0 mm
2	Very coarse sand	2.0 mm – 1.0 mm	1.0 mm
3	Coarse sand	1.0 mm – 0.5 mm	0.42 mm
4	Medium sand	0.5 mm – 0.25 mm	0.25 mm
5	Fine sand	0.25 mm – 0.10 mm	0.053 mm

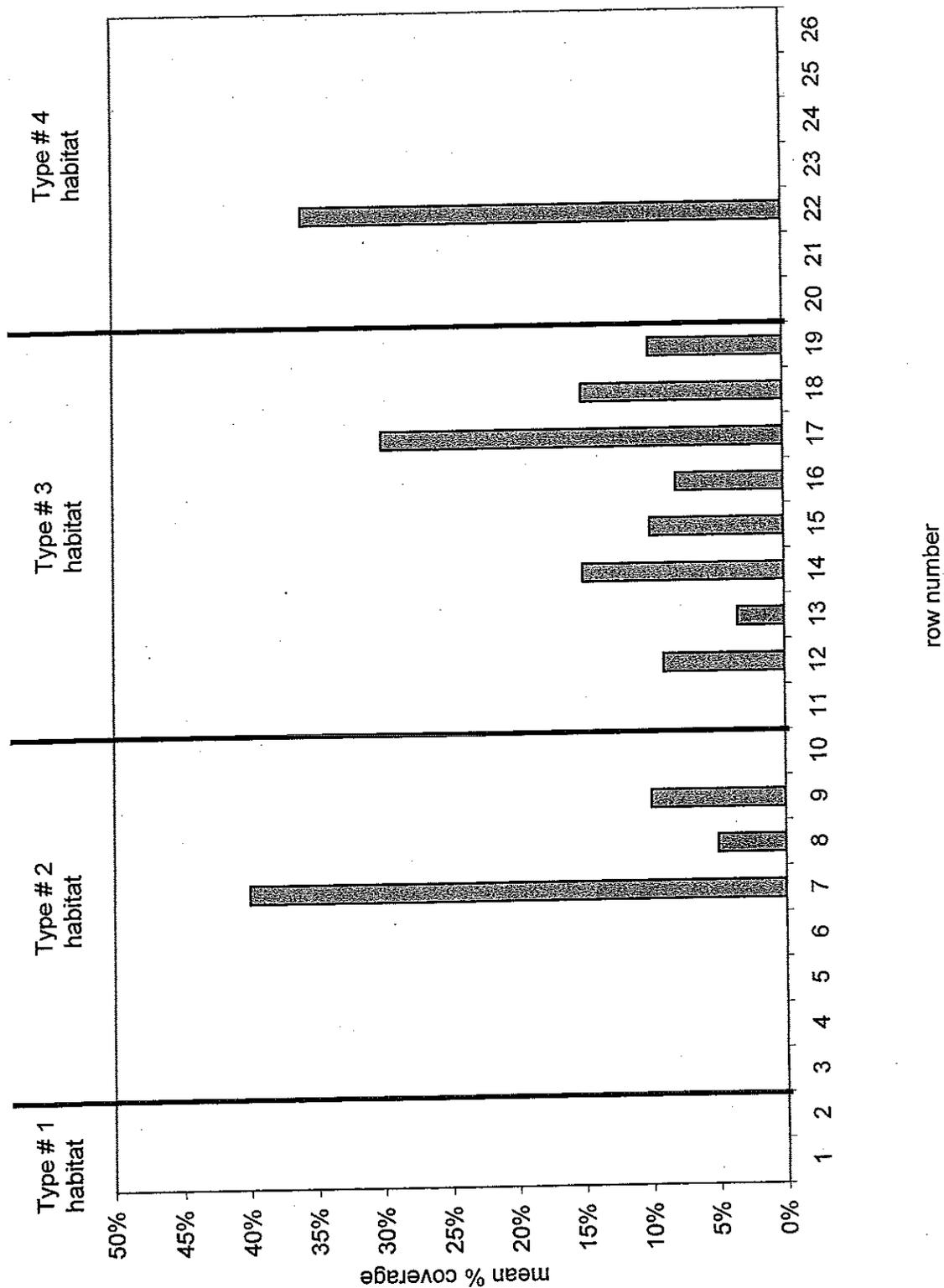
Appendix 2 - Comparison of habitat type by substrate classification



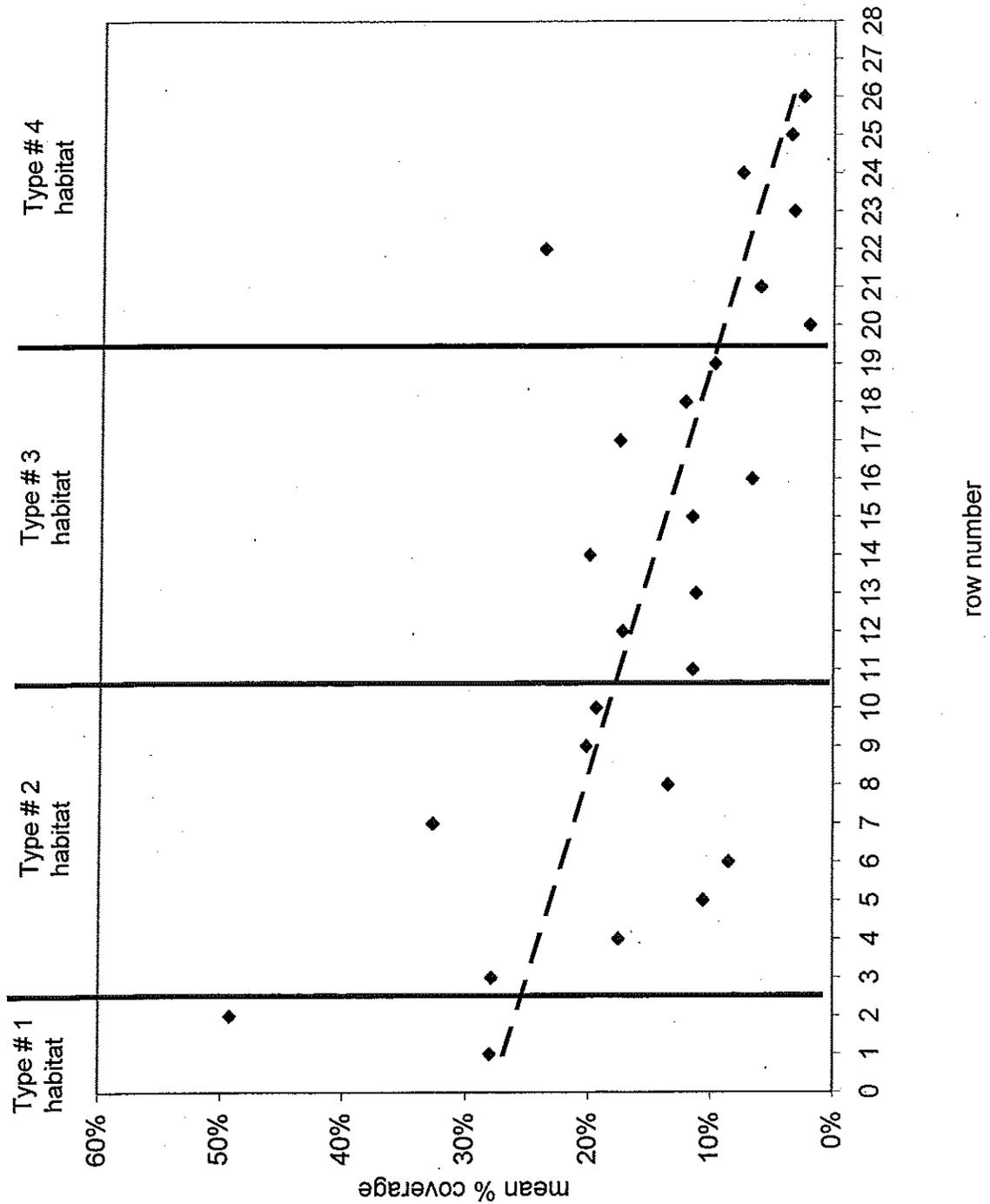
Appendix 3 - Plant abundance divided by habitat type. Data collected on columns C and E combined. The results of this plant survey (Garron, unpublished data) associates 13 species with the four habitat types. The grass family *Poaceae* is counted as one guild.



Appendix 4 - Mean percent coverage of *Larrea tridentata* associated with four distinct habitat types. Data collected at each trap of column C and E (Garron, unpublished data).

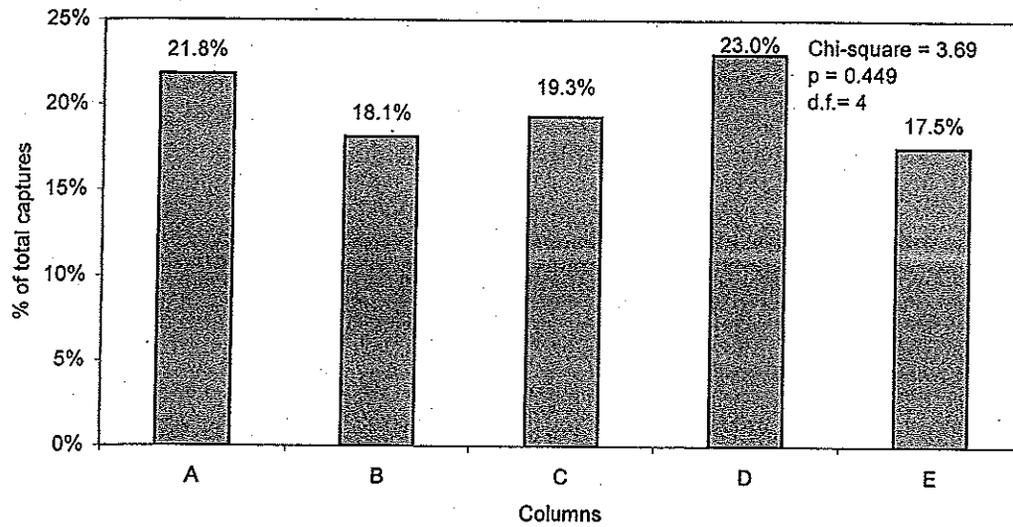


Appendix 5 - Mean percent coverage of the vegetation associated with four distinct habitat types. Regression analysis results in a significant negative correlation. The best fit regression equation for vegetation coverage: mean % coverage = 0.0094 x row number + 0.2789 (R-square = 0.4454, p = 0.000). Data collected at each trap of column C and E (Garron, unpublished data)

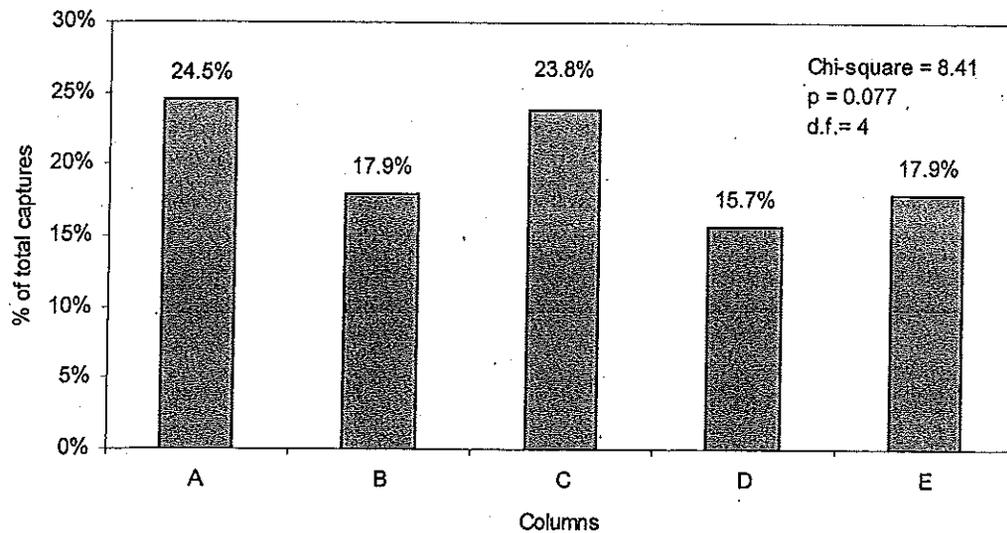


Appendix 6 - The percentage of total reptiles captured per column for a) June 1991 - May 1992 b) June 1992 - May 1993 c) Jan. 2000 - Dec. 2000 d) Jan. 2001 - Dec. 2001. Chi-squared analysis was used to test for evenness of column capture success.

a) June 1991 - May 1992

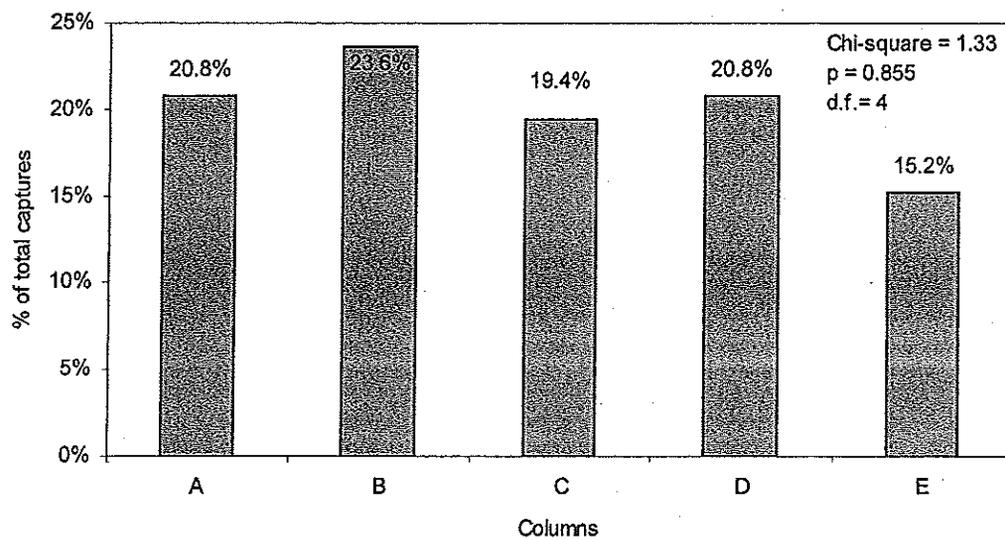


b) June 1992 - May 1993

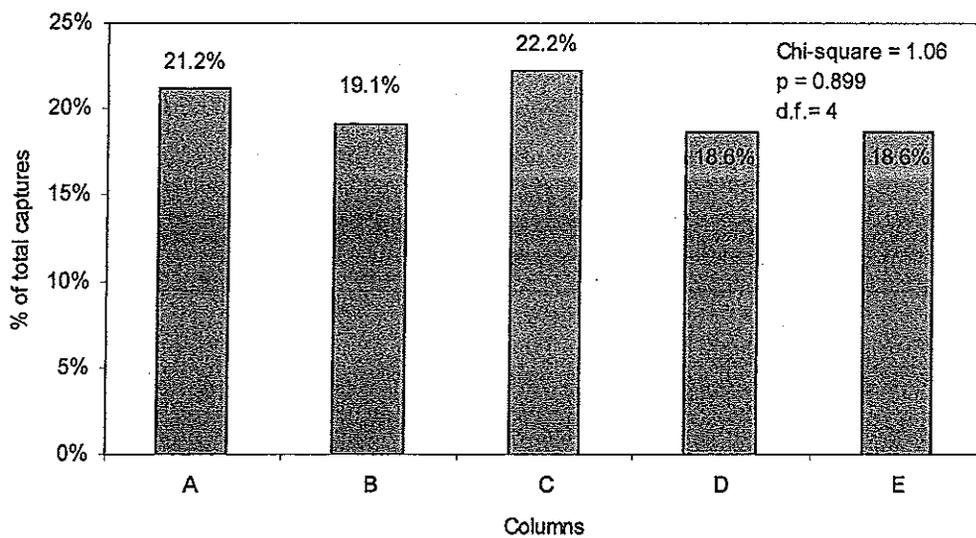


Appendix 6 – Continued

c) January 2000 - December 2000

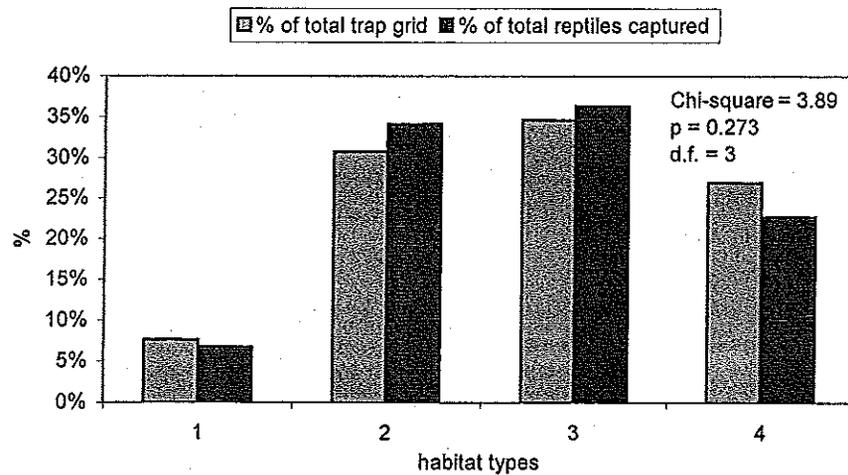


d) January 2001 - December 2001

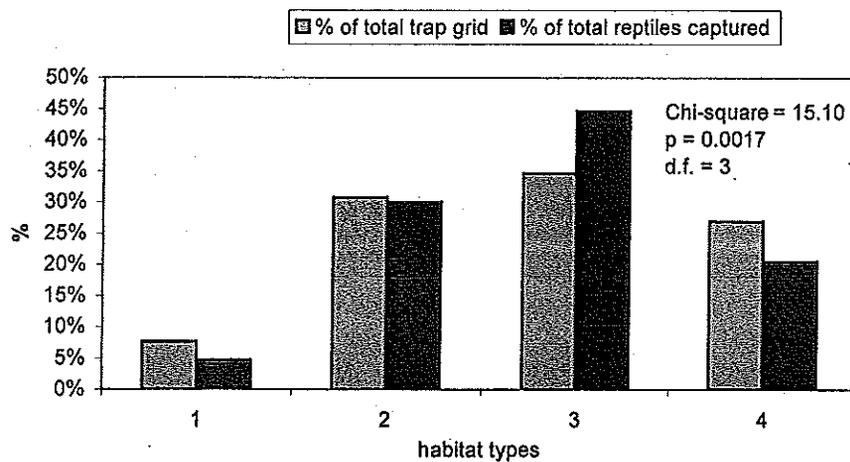


Appendix 7 - The percentage of total reptiles captured per habitat type for a) June 1991–May 1992 b) June 1992–May 1993 c) January 2000–December 2000 d) January 2001–December 2001 e) June 1991–May 1993 and f) January 2000–December 2001. The capture success of each was tested for evenness, relative to its respective size, using Chi-squared analysis.

a) June 1991–May 1992

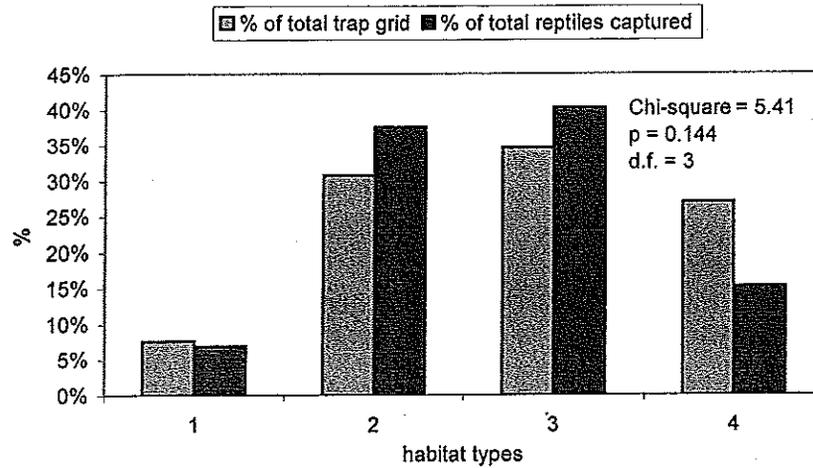


b) June 1992–May 1993

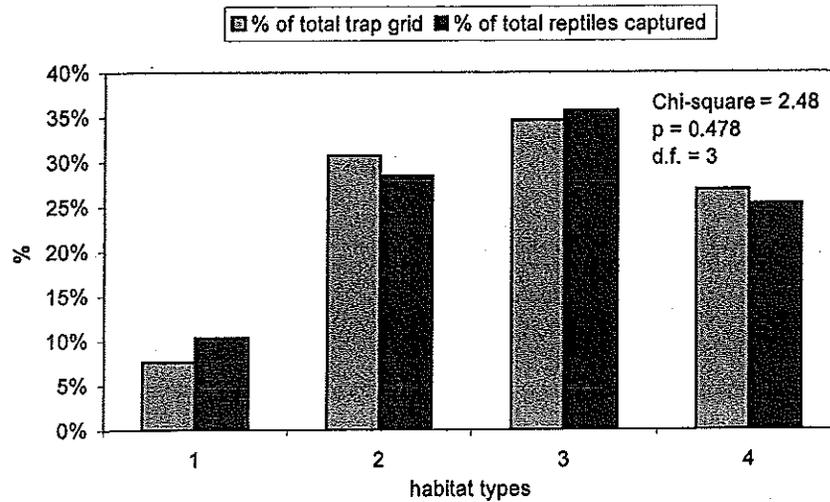


Appendix 7 - Continued

c) January 2000-December 2000

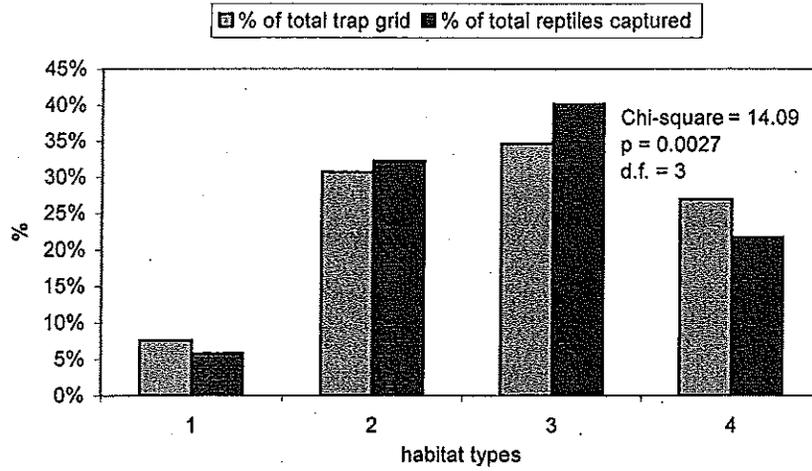


d) January 2001-December 2001

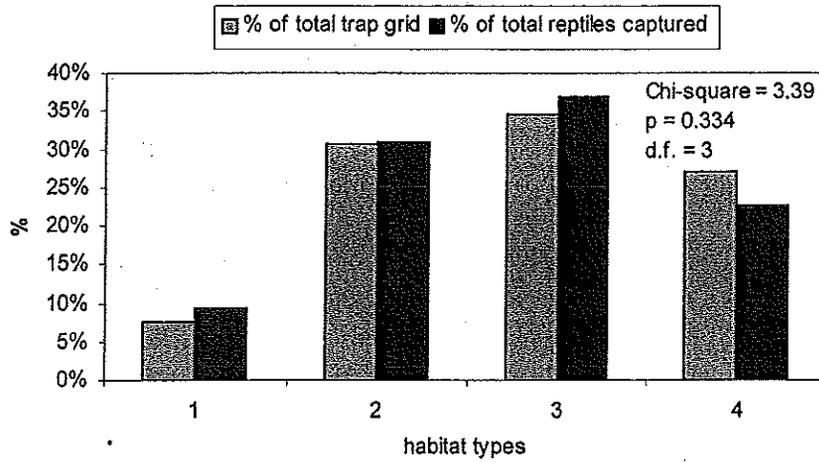


Appendix 7 - Continued

e) June 1991-May 1993



f) January 2000-December 2001



Appendix 8 - Total reptiles captured a) June 1991-May 1992 b) June 1992-May 1993 c) January 2000-December 2000 d) January 2001-December 2001.

a)

June 1991 – May 1992
Total no. species captured – 9

Species captured	Individuals captured
<i>Urosaurus graciosus</i>	105
<i>Uta stansburiana</i>	76
<i>Cnemidophorus tigris</i>	67
<i>Callisaurus draconoides</i>	46
<i>Coleonyx variegatus</i>	12
<i>Chionactis occipitalis</i>	9
<i>Dipsosaurus dorsalis</i>	8
<i>Gambelia wislizenii</i>	1
<i>Crotaphytus insularis</i>	1
Total no. of individuals captured	N = 325

b)

June 1992 – May 1993
Total no. species captured - 11

Species captured	Individuals captured
<i>Uta stansburiana</i>	91
<i>Cnemidophorus tigris</i>	72
<i>Urosaurus graciosus</i>	51
<i>Callisaurus draconoides</i>	14
<i>Chionactis occipitalis</i>	13
<i>Coleonyx variegatus</i>	12
<i>Dipsosaurus dorsalis</i>	11
<i>Phrynosoma platyrhinos</i>	6
<i>Uma scoparia</i>	1
<i>Arizona elegans</i>	1
<i>Leptotyphlops humilis</i>	1
Total no. of individuals captured	N = 273

Appendix 8 - Continued

c)

January 2000 -- December 2000
Total no. species captured - 6

Species captured	Individuals captured
<i>Uta stansburiana</i>	41 (4 recaptures)
<i>Cnemidophorus tigris</i>	19
<i>Chionactis occipitalis</i>	5
<i>Urosaurus graciosus</i>	4
<i>Callisaurus draconoides</i>	2
<i>Pituophis melanoleucus</i>	1
Total no. of individuals captured	N = 72

d)

January 2001 -- December 2001
Total no. species captured -- 11

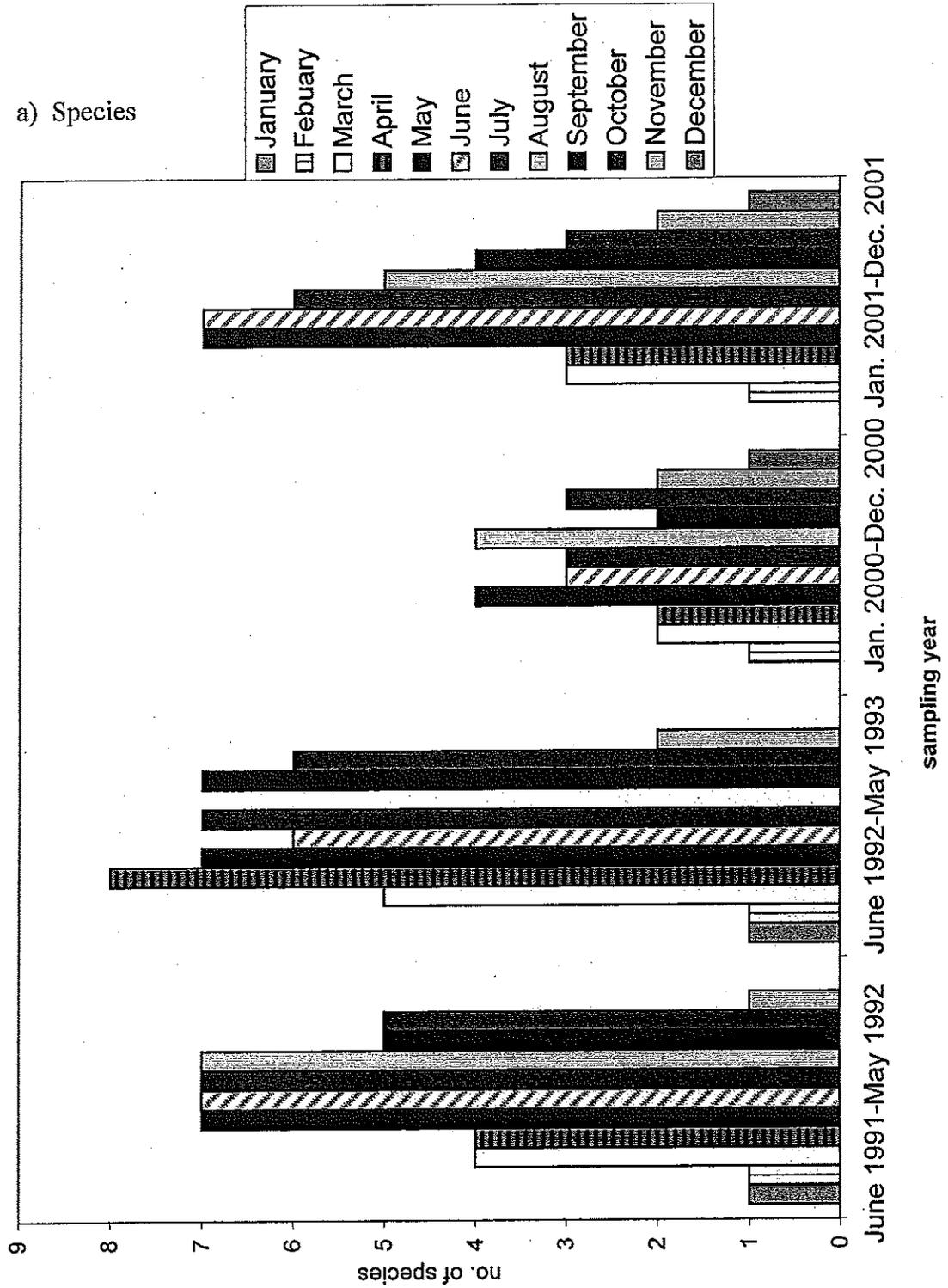
Species captured	Individuals captured
<i>Uta stansburiana</i>	84 (2 recaptures)
<i>Cnemidophorus tigris</i>	76 (4 recaptures)
<i>Chionactis occipitalis</i>	13
<i>Dipsosaurus dorsalis</i>	7
<i>Phrynosoma platyrhinos</i>	4 (1 recapture)
<i>Callisaurus draconoides</i>	3
<i>Urosaurus graciosus</i>	2
<i>Coleonyx variegatus</i>	1
<i>Xantusia vigilis</i>	1
<i>Masticophis flagellum</i>	1
<i>Arizona elegans</i>	1
Total no. of individuals captured	N = 193

Appendix 9 - Comparison of the total number of a) reptile species and b) reptile individuals captured per month. Data from each sampling year lined up by month for direct comparison. No data collected for August 1992 (**).

a) Species	January	February	March	April	May	June	July	August	September	October	November	December
June 91-May 92	1	1	4	4	7	7	7	7	5	5	1	0
June 92-May 93	1	1	5	8	7	6	7	**	7	6	2	0
Jan. 00-Dec. 00	0	1	2	2	4	3	3	4	2	3	2	1
Jan. 01-Dec. 01	0	1	3	3	7	7	6	5	4	3	2	1

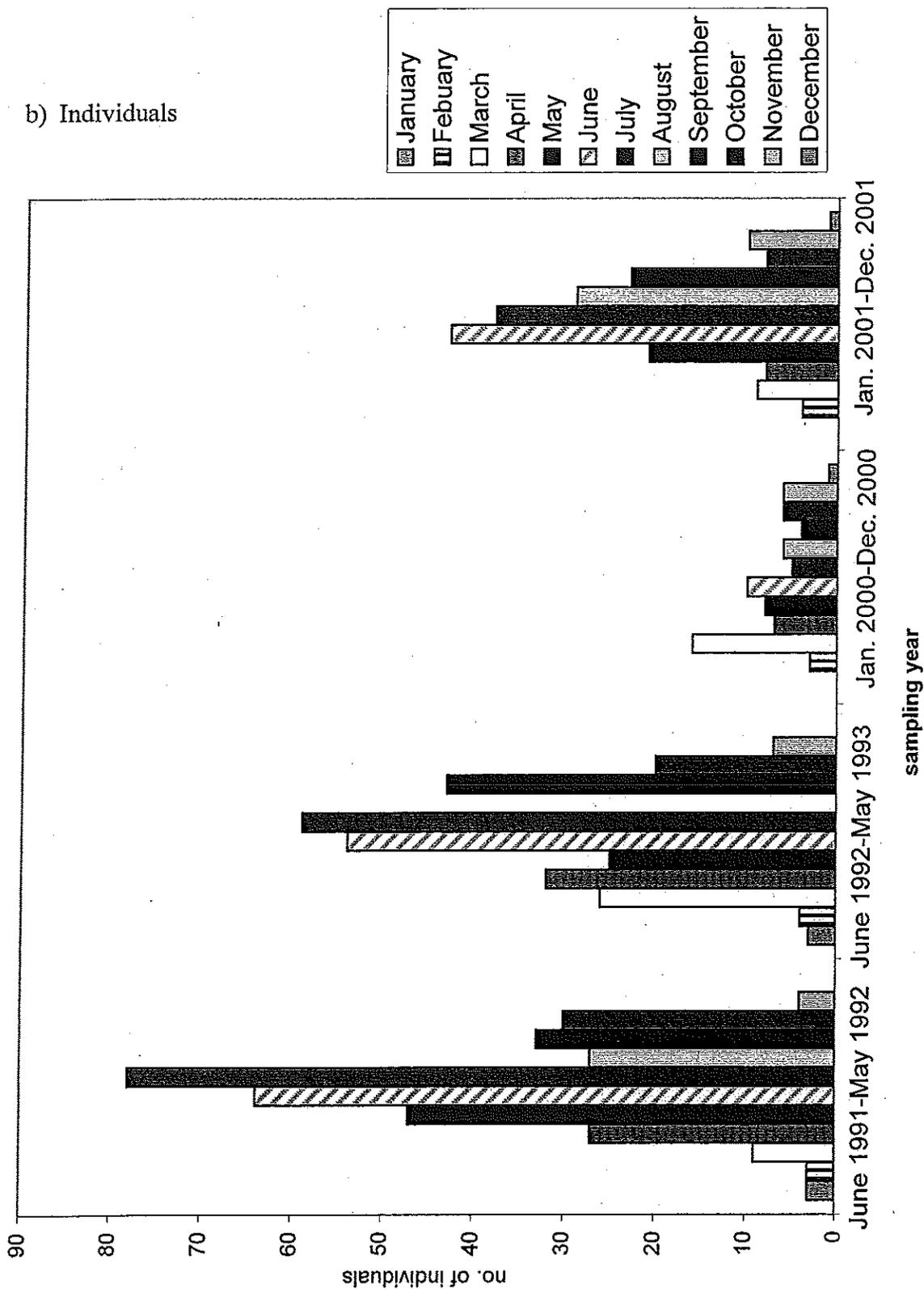
b) Individuals	January	February	March	April	May	June	July	August	September	October	November	December
June 91-May 92	3	3	9	27	47	64	78	27	33	30	4	0
June 92-May 93	3	4	26	32	25	54	59	**	43	20	7	0
Jan. 00-Dec. 00	0	4	16	7	8	10	5	6	4	6	6	1
Jan. 01-Dec. 01	0	3	9	8	21	43	38	29	23	8	10	1

Appendix 10 - Comparison of the total number of a) reptile species and b) reptile individuals captured per month. Data from each sampling year has been lined-up January-December for direct comparison. No data collected for August 1992.



Appendix 10 - Continued

b) Individuals



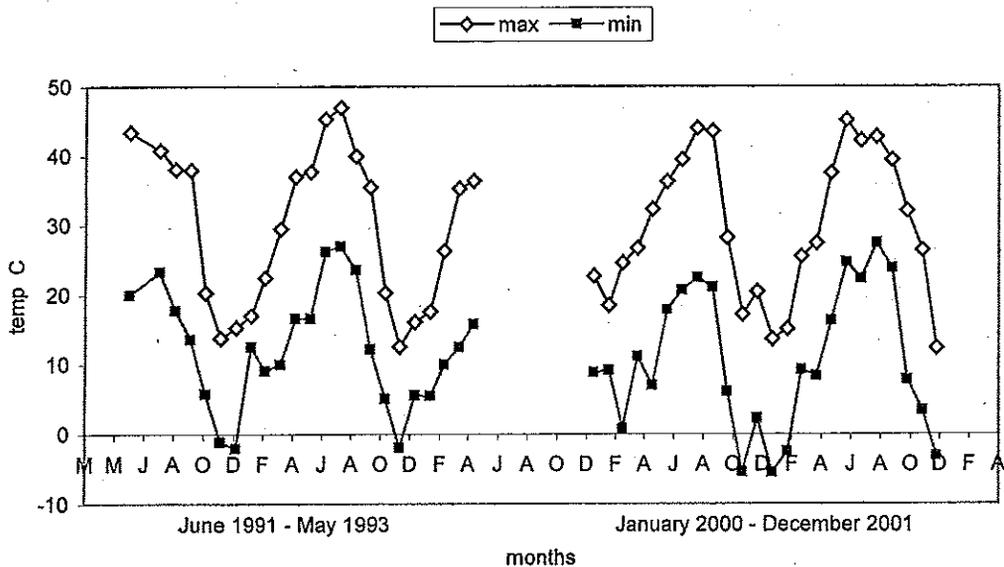
Appendix 11 - Shannon index with standard error calculations along with Pielou's evenness index and Simpson's index of diversity calculations for the data collected in May of 1992, 1993, 2000 and 2001.

May	s	N	Shannon index		Standard error	Pielou's evenness index (J)	Simpson's index (Ds)
			(H')	E(H')			
1992	7	47	1.60	1.54	± 0.04	0.79	0.75
1993	7	25	1.64	1.52	± 0.05	0.78	0.80
2000	4	8	1.21	1.02	± 0.10	0.73	0.75
2001	7	21	1.52	1.38	± 0.07	0.71	0.74

s = no. of species captured.

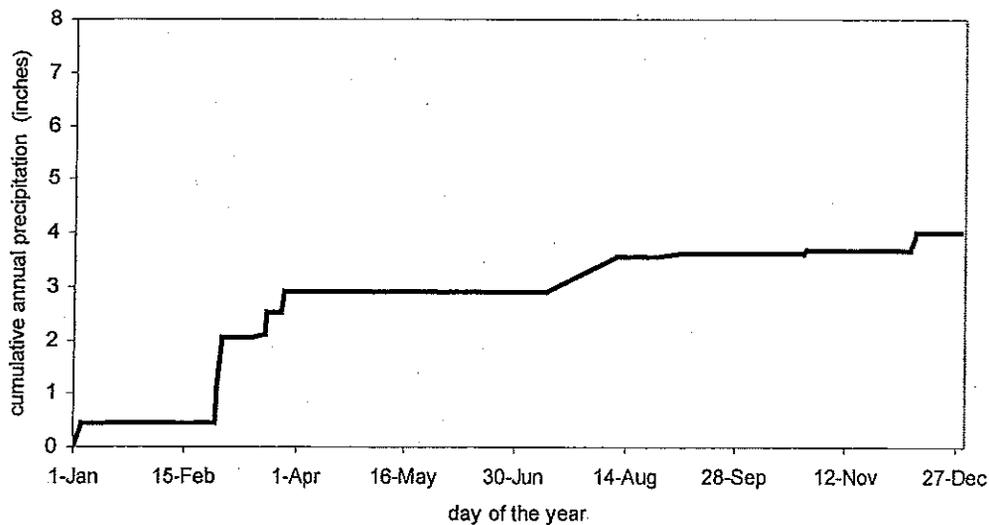
N = no. of individuals of all species captured.

Appendix 12 - Maximum and minimum average temperatures for each monthly collecting period June 1991-May 1993 and January 2000-December 2001.

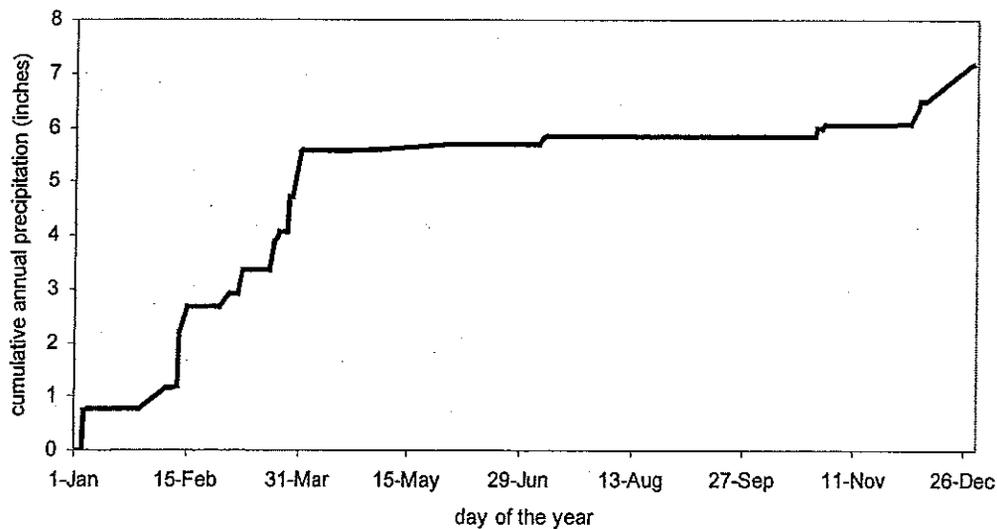


Appendix 13 - Cumulative annual precipitation per year for a) 1991 b) 1992
 c) 1993 d) 1999 e) 2000 f) 2001 and g) 2002.

a) 1991 - Total annual precipitation 3.99 inches (101.34mm)

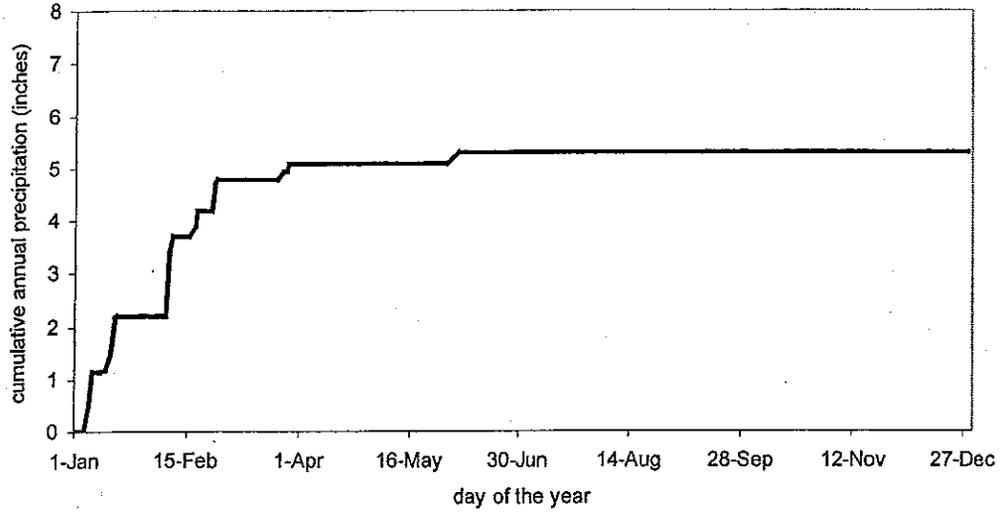


b) 1992 - Total annual precipitation 7.16 inches (181.86mm)

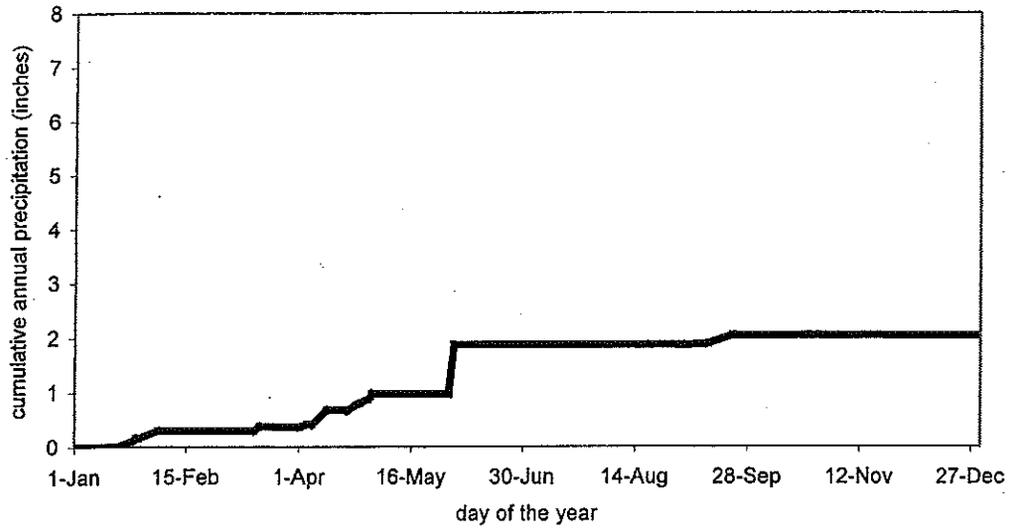


Appendix 13 - Continued

c) 1993 - Total annual precipitation 5.28 inches (134.11mm)

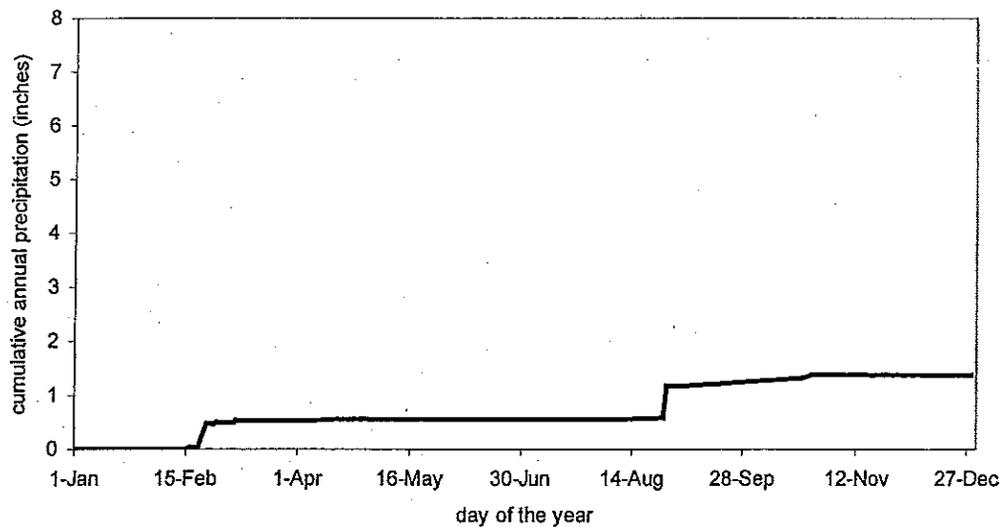


d) 1999 - Total annual precipitation 2.04 inches (51.86mm)

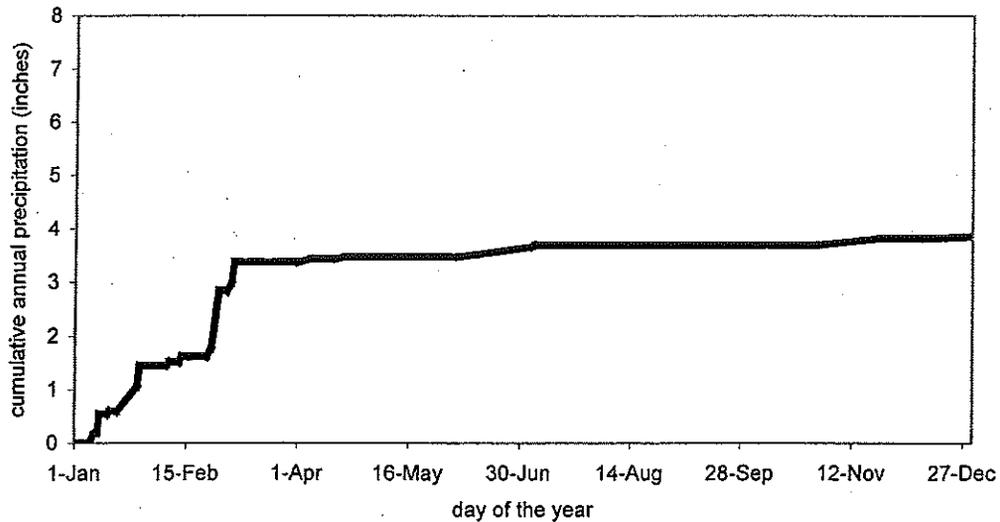


Appendix 13 - Continued

e) 2000 - Total annual precipitation 1.39 inches (34.75mm)

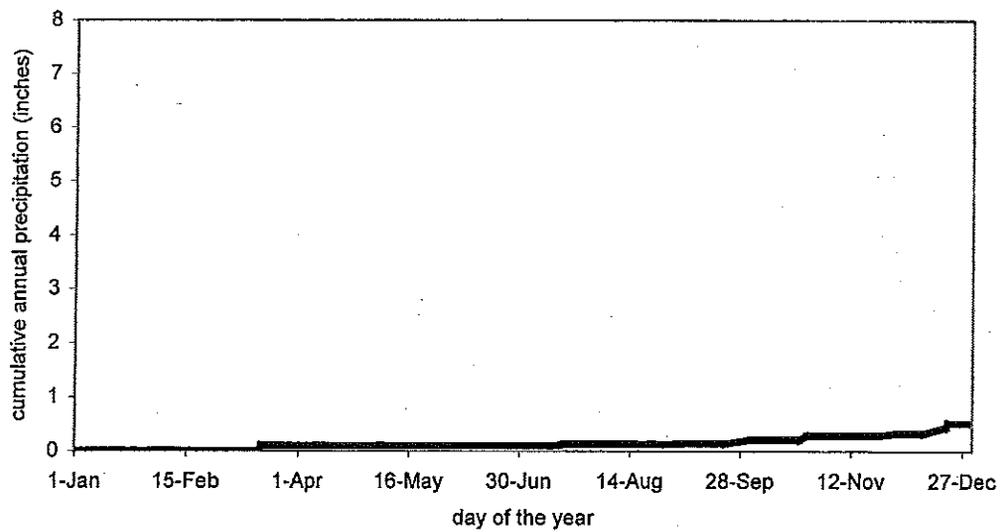


f) 2001 - Total annual precipitation 3.85 inches (97.79mm)



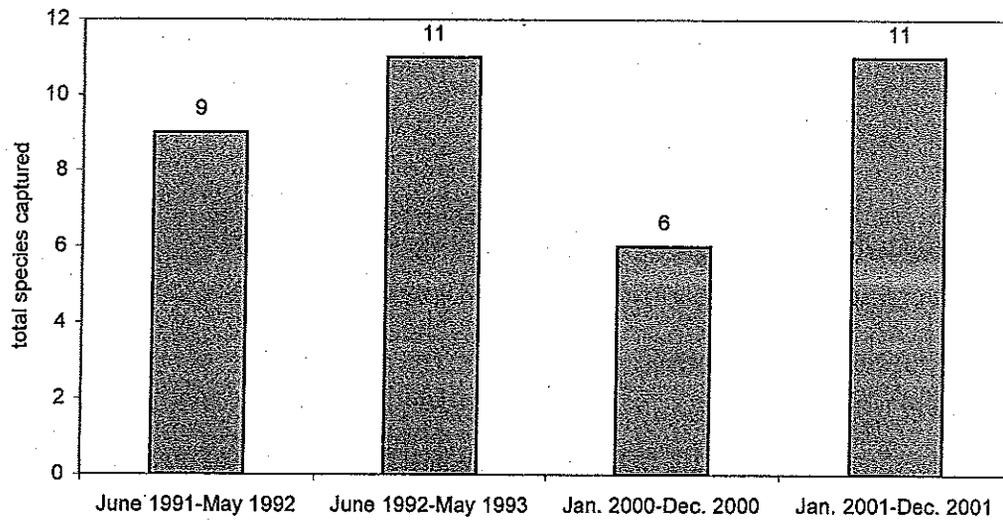
Appendix 13 -Continued

g) 2002 - Total annual precipitation 0.52 inches (13.20mm)

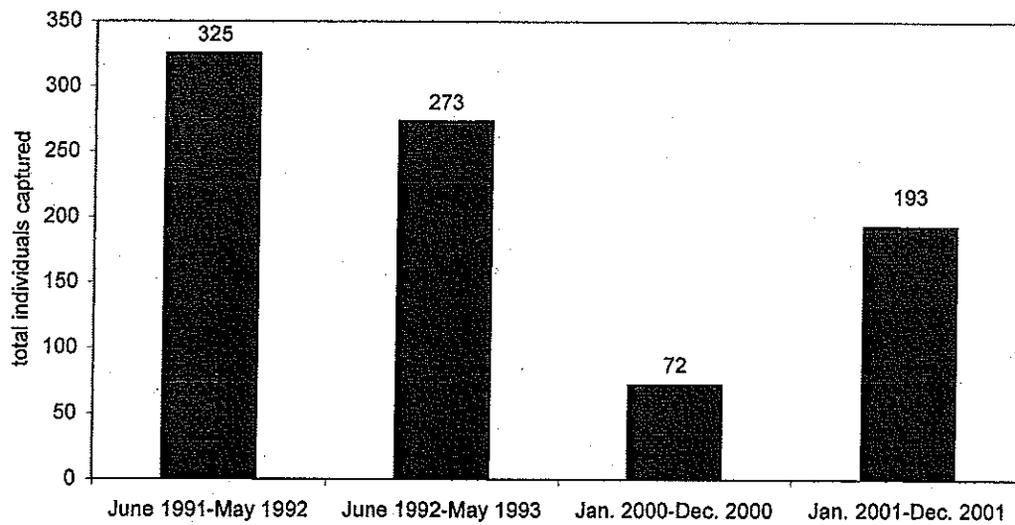


Appendix 14 - Total number of captures per sampling year a) reptile species
b) reptile individuals of all species.

a) Species



b) Individuals



Appendix 15 - The percentage of total captures per habitat type for each reptile species. Data collected June 1991-May 1993 combined with data collected January 2000-December 2001.

Species captured	Habitat types				Total Captured
	Type #1	Type #2	Type #3	Type #4	
<i>Uta stansburiana</i>	8.9 %	31.1 %	35.2 %	24.6 %	292
<i>Cnemidophorus tigris</i>	5.9 %	26.9 %	44.8 %	22.2 %	234
<i>Urosaurus graciosus</i>	9.8 %	53.9 %	30.0 %	6.1 %	162
<i>Callisaurus draconoides</i>	1.5 %	35.9 %	46.1 %	16.9 %	65
<i>Chionactis occipitalis</i>	2.5 %	20.0 %	47.5 %	30.0 %	40
<i>Dipsosaurus dorsalis</i>	0 %	15.3 %	26.9 %	57.6 %	26
<i>Coleonyx variegates</i>	0 %	4.0 %	48.0 %	48.0 %	25
<i>Phrynosoma platyrhinos</i>	0 %	0 %	60.0 %	40.0 %	10
<i>Arizona elegans</i>	0 %	0 %	100 %	0 %	2
<i>Gambelia wislizenii</i>	0 %	0 %	100 %	0 %	1
<i>Crotaphytus insularis</i>	0 %	0 %	100 %	0 %	1
<i>Uma scoparia</i>	0 %	100 %	0 %	0 %	1
<i>Xantusia vigilis</i>	0 %	100 %	0 %	0 %	1
<i>Leptotyphlops humilis</i>	0 %	0 %	100 %	0 %	1
<i>Masticophis flagellum</i>	0 %	0 %	0 %	100 %	1
<i>Pituophis melanoleucus</i>	0 %	100 %	0 %	0 %	1
Total	6.6 %	32.4 %	38.6 %	21.8 %	863

Appendix 16 - The percentage of total captures per divided section for each reptile species. Data collected June 1991-May 1993 combined with data collected January 2000-December 2001.

Species captured	Divided sections of trap grid					Total captured
	Rows (1-5)	Rows (6-10)	Rows (11-15)	Rows (16-20)	Rows (21-26)	
<i>Uta stansburiana</i>	24.3 %	15.7 %	17.4 %	19.5 %	22.9 %	292
<i>Cnemidophorus tigris</i>	17.5 %	14.5 %	26.9 %	20.5 %	20.5 %	234
<i>Urosaurus graciosus</i>	29.4 %	34.3 %	22.0 %	8.5 %	5.5 %	162
<i>Callisaurus draconoides</i>	8.9 %	28.3 %	26.8 %	23.8 %	11.9 %	65
<i>Chionactis occipitalis</i>	7.5 %	15.0 %	30.0 %	22.5 %	25.0 %	40
<i>Dipsosaurus dorsalis</i>	6.2 %	9.3 %	18.7 %	31.2 %	50.0 %	26
<i>Coleonyx variegates</i>	4.0 %	0 %	36.0 %	16.0 %	44.0 %	25
<i>Phrynosoma platyrhinos</i>	0 %	0 %	40.0 %	20.0 %	40.0 %	10
<i>Arizona elegans</i>	0 %	0 %	100 %	0 %	0 %	2
<i>Gambelia wislizenii</i>	0 %	0 %	0 %	100 %	0 %	1
<i>Crotaphytus insularis</i>	0 %	0 %	0 %	100 %	0 %	1
<i>Uma scoparia</i>	100 %	0 %	0 %	0 %	0 %	1
<i>Xantusia vigilis</i>	0 %	100 %	0 %	0 %	0 %	1
<i>Leptotyphlops humilis</i>	0 %	0 %	0 %	100 %	0 %	1
<i>Masticophis flagellum</i>	0 %	0 %	0 %	0 %	100 %	1
<i>Pituophis melanoleucus</i>	0 %	100 %	0 %	0 %	0 %	1
Total	19.8 %	19.0 %	23.0 %	18.1 %	19.9 %	863

Appendix 17 - Total number of species captured per a) habitat type b) divided section.

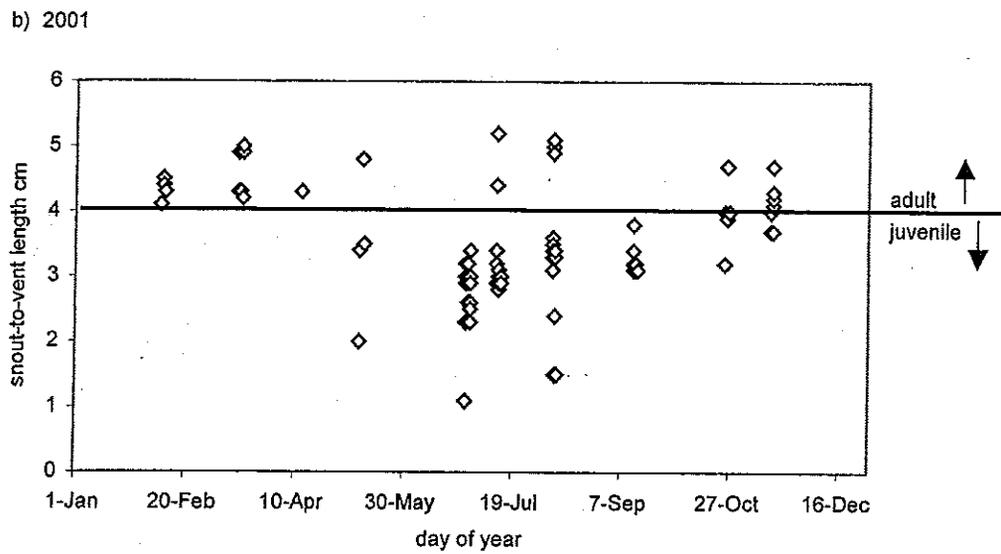
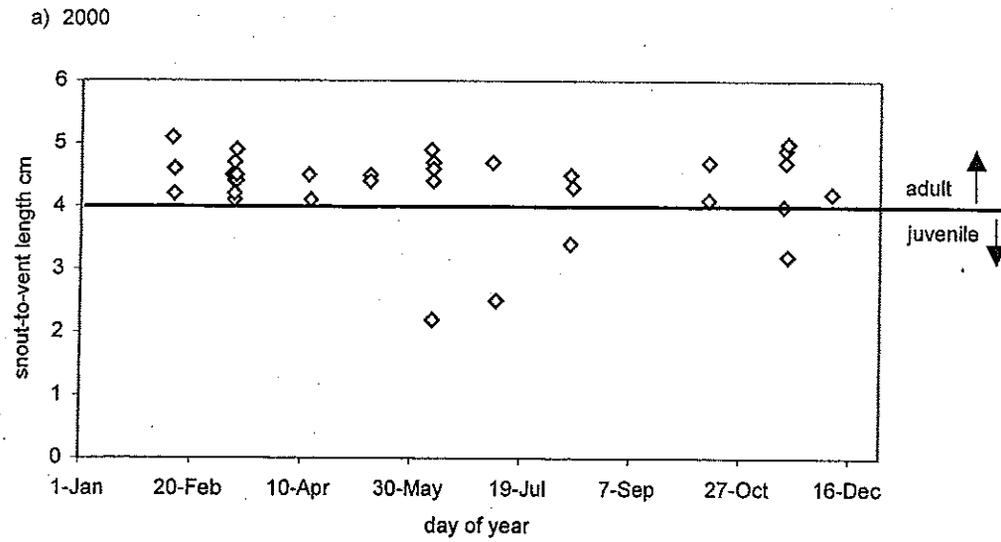
a)

Habitat type	#1 (row 1-2)	#2 (row 3-10)	#3 (row 11-19)	#4 (row 20-26)
Species captured	5	10	12	9

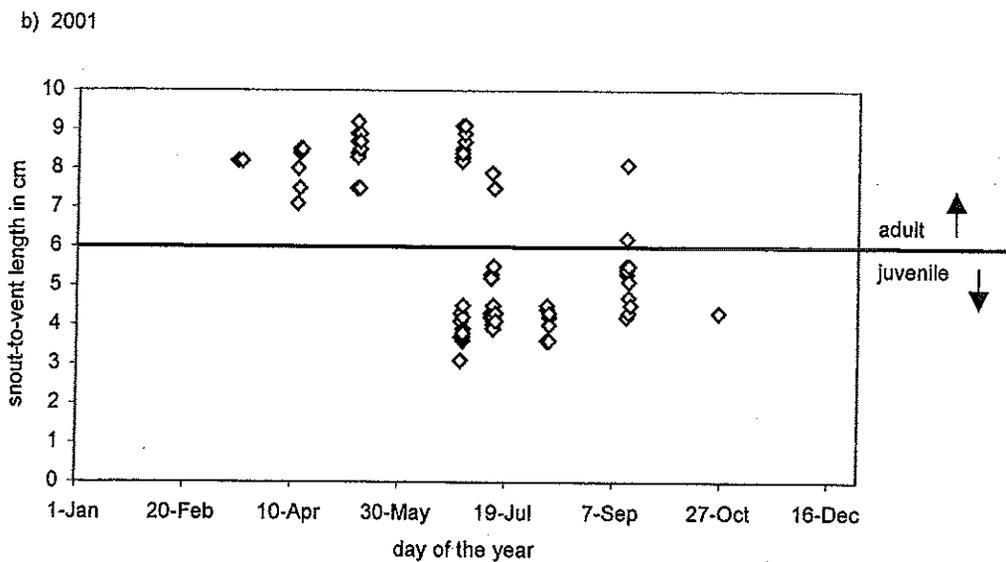
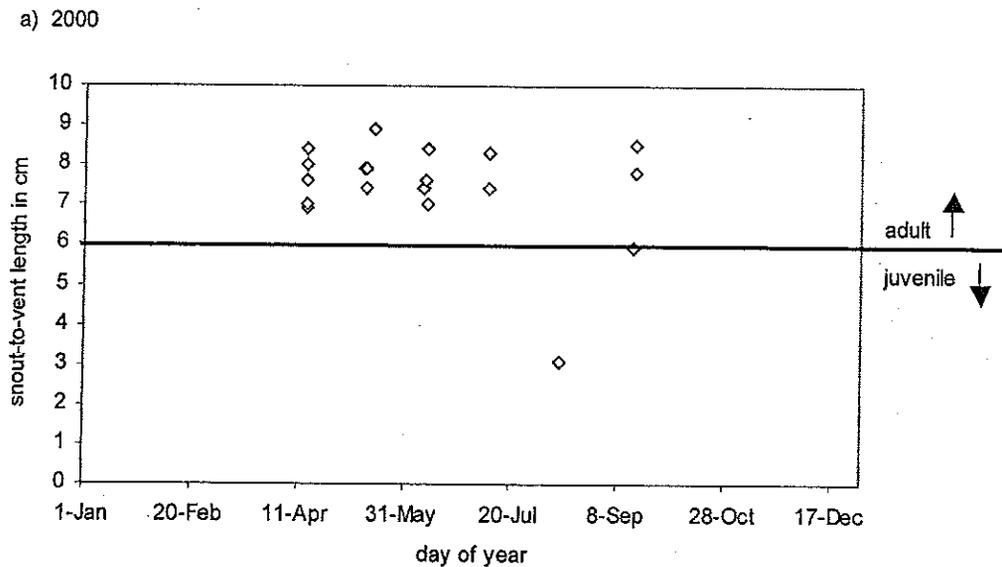
b)

Divided section	#1 (row 1-5)	#2 (row 6-10)	#3 (row 11-15)	#4 (row 16-20)	#5 (row 21-26)
Species captured	8	8	9	11	9

Appendix 18 - Snout-to-vent length of captured *Uta stansburiana* vs. day of the year for
a) January 2000-December 2001 b) January 2001-December 2001.



Appendix 19 - Snout-to-vent length of captured *Cnemidophorus tigris* vs. day of the year
 a) January 2000-December 2000 b) January 2001-December 2001.



LITERATURE CITED

- Baltosser, W. H. and T. L. Best. 1990. Seasonal occurrence and habitat utilization by lizards in southwestern New Mexico. *Southwestern Naturalist* 35:377-384.
- Barbault, R. and M. Maury. 1981. Ecological organization of a Chihuahuan Desert lizard community. *Oecologia* 51:335-342.
- Bender, G. L. 1982. Reference handbook on the deserts of North America. pp 114-158. Greenwood Press Westport, Connecticut.
- Bird, J.A., G.S. Pettygrove and J.M. Eadie. 2000. The impact of waterfowl foraging on the decomposition of rice straw: mutual benefits for rice growers and waterfowl. *Journal of Applied Ecology* 37:728-741.
- Blaustein, A. R., D. B. Wake and W. P. Sousa. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. *Conservation Biology* 8(1):60-71.
- Boone, J. L. and E. A. Larue. 1999. Effect of marking *Uta stansburiana* (Sauria: Phrynosomatida) with xylene-based paint. *Herpetological Review* 30:33-34.
- Bury, R. B. 1982. Structure and composition of Mojave Desert reptile communities determined with a removal method. *In* N.J. Scott (ed.), *Herpetological Communities*, pp.135-142. U.S. Dept. Interior, Fish & Wildlife Service, Washington, D.C.
- Campbell, H. W. and S. P. Christman. 1982. Field techniques for herpetofaunal analysis. *In* N.J. Scott (ed.) *Herpetological Communities*. U.S. Dept. Interior, pp.193-200. Fish & Wildlife Service, Washington, D.C.
- Cloudsley-Thompson, J. 1993. Diversity and ecological analogues among desert reptiles. *British Herpetological Society Bulletin* 43:36-38.
- Cornett, J. W. 1987. *Wildlife of the north American deserts*. pp. 73-94. Nature Trails Press, Palm Springs, CA.
- Coventry, A. J. 1996. The herpetofauna of the chinaman well area of the Big Desert, Victoria. *Proceedings of the Royal Society of Victoria* 108 (2):107-119.
- Durtsche, R. D. 1992. Foraging ecology of the fringe-toed lizard, *Uma inornata*, during periods of high and low food abundance. *Copeia* 1995:915-926.
- Ehrlich, P. and B. Walker. 1998. Rivets and redundancy. *Bioscience* 48:387.
- Enge, K. M. 2001. The pitfalls of pitfall traps. *Journal of Herpetology* 35(3):467-478.
- Esler, K. J. and P. W. Rundel. 1999. Comparative patterns of phenology and growth form diversity in two winter rainfall deserts: the succulent Karoo and Mojave Desert ecosystems. *Plant Ecology* 142 (1/2):97-104(8).

- Fair, W. S. and S. E. Henke. 1997. Efficacy of captive methods for a low density population of *Phrynosoma cornutum*. *Herpetological Review* 28(3):135-137.
- Gibbons, J. W. and R. D. Semlitsch. 1982. Terrestrial drift fences with pitfall traps: An effective technique for quantitative sampling of animal populations. *Brimleyana* 7:1-16.
- Goldberg, S. R. and P. C. Rosen. 1999. Reproduction in the sonoran shovelnose snake (*Chionactis palarostris*) and the western shovelnose snake (*Chionactis occipitalis*) (Serpentes: Colubridae). *Texas Journal of Science* 51:153-158.
- Henke, S. E. 1998. The effect of multiple search items and item abundance on the efficiency of human searchers. *Journal of Herpetology* 32:112-115.
- Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster. 1994. *Measuring and monitoring biological diversity: standard methods for amphibians*. Smithsonian Institution Press, Washington, USA, and London, England.
- Hoddenbach, G. A. and F. B. Turner. 1968. Clutch size of the lizard *Uta stansburiana* in southern Nevada. *American Midland Naturalist* 80:262-265.
- Holmlund, C.M. and M. Hammer. 1999. Ecosystem services generated by fish populations. *Ecol. Econ.* 29:253-268.
- Hunt, C. 1975. *Death Valley: geology, ecology, archeology*. UC Press.
- Hutcheson, K. 1970. A test for comparing diversities based on the Shannon formula. *Journal of Theoretical Biology* 29:151-154.
- Jorgensen, E. E. and S. Demarais. 1998. Herpetofauna associated with arroyos and uplands in foothills of the Chihuahuan desert. *The Southwestern Naturalist* 43(4):441-448.
- Kay, F. R. 1970. Environmental responses of active lizards at Saratoga Springs. Death Valley, California. *Great Basin Naturalist* 20:146-165.
- Kaye, Sandra. "Animals at Joshua Tree National Park" online posting. 26 Feb. 2003. Animals. 5 Mar. 2003. <<http://data2.itc.nps.gov/nature/animals.cfm?alphacode=jotr&loc=1>>
- Kingsbury, B. A. 1989. Factors influencing activity in *Coleonyx variegatus*. *Journal of Herpetology* 23:399-404.
- Kremen, C., N.M. Williams and R.W. Thorp. 2002. Crop pollination from native bees at risk from agricultural intensification. *National Academy of Sciences of the United States of America* 99:16812-16816.
- Luck, G.W., G.C. Daily and P.R. Ehrlich. 2003. Population diversity and ecosystem services. *TRENDS in Ecology and Evolution* 18(7):331-336.
- Mahrt, L. A. 1998. Territorial establishment and maintenance by female tree lizards, *Urosaurus ornatus*. *Journal of Herpetology* 32:176-182.

- Mayhew, W. 1967. Comparative reproduction in three species of the genus *Uma*. In W. W. Milstead (ed.) Lizard ecology, a symposium, pp. 45-65. University Missouri Press, Columbia.
- McAuliffe, J. R. 1994. Landscape evolution, soil formation, and ecological patterns and processes in Sonoran Desert bajadas. *Ecological Monographs* 64:111-148.
- Naeem, S. and S. Li. 1997. Biodiversity enhances ecosystem reliability. *Nature* 390:507-509.
- Parker, W.S. 1971. Ecological observations on the regal horned lizard (*Phrynosoma solare*) in Arizona. *Herpetologica* 27:333-338.
- Pechmann, J. H. K. and H. M. Wilbur. 1994. Putting declining amphibian populations in perspective: natural fluctuations and human impacts. *Herpetologica* 50:65-84.
- Pianka, E. R. 1966. Convexity, desert lizards and spatial heterogeneity. *Ecology* 47:1055-1059.
- Pianka, E. R. 1967. On lizard species diversity: North American flatland deserts. *Ecology* 48:333-351
- Pianka, E. R. 1970. Comparative autecology of the lizard *Cnemidophorus tigris* in different parts of its geographic range. *Ecology* 51(4):703-720.
- Pianka, E. R. and W. S. Parker. 1972. Ecology of the iguanid lizard *Callisaurus draconoides*. *Copeia* 1972:493-508.
- Pianka, E. R. 1975. Niche relations of desert lizards. In M.L. Cody and J.M. Diamond. (ed), *Ecology and Evolution of Communities*, pp. 292-314. Belknap Press, Cambridge, Massachusetts.
- Pianka, E. R. 1977. Reptilian species diversity. In C. Gans and D.W. Tinkle. (ed), *Biology of the Reptilia*. Vol. 7, pp. 1-34. Academic Press. New York.
- Poole, R. W. 1974. An introduction to quantitative ecology. pp. 387-397. McGraw-Hill Co., New York.
- Revell, T. K. 1997. Arthropod diversity on creosote *Larrea tridentata* and desert saltbush *Atriplex polycarpa* in the east Mojave Desert. M.A. Thesis. California State University, Fullerton.
- Schoenherr, A. A. 1992. A Natural History of California. pp. 365-374 & 406-515. University of California Press. Berkeley and Los Angeles, Ca.
- Schumacher, A. and W. G. Whitford. 1974. The foraging ecology of two species of Chihuahuan Desert ants: *Formica perpilosa* and *Trachymyrex smithi neomexicanus* (hymenoptera Formicidae). *Insectes Soc.* 21:317-330.

- Scott, N. J., Jr. and H. W. Campbell. 1982. A chronological bibliography, the history and status of studies of herpetological communities, and suggestions for future research. *In* N.J. Scott (ed.), *Herpetological Communities*. pp. 221-239. U.S. Dept. Interior Fish & Wildlife Service, Washington, D.C.
- Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. pp. 59-184. 2nd (ed.). New York: Macmillan.
- Shannon, C. E. and W. Weaver. 1963. *The mathematical theory of communication*. pp. 117. University of Illinois Press. Urbana.
- Smith, R. L. 1996. *Ecology and field biology*. fifth edition. pp. 602-604. Harper Collins College Publishers. New York.
- Stebbins, R. C. 1985. *Western reptiles and amphibians*. Second edition. pp. 110-214. Houghton Mifflin Company. Boston. New York.
- Tanner, W. W. 1999. Distribution of the species *Phrynosoma platyrhinos* in Utah. *Great Basin Naturalist* 59:295-296.
- Turner, F. B. 1968. Life history of a lizard. *Evolution* 22:841-842.
- Turner, F. B., J. B. Lannom, P. A. Medica and G. A. Hoddenback. 1969. Density and composition of fenced populations of fenced leopard lizards (*Crotaphytus wislizenii*) in southern Nevada. *Herpetologica* 25:247-257.
- Turner, F. B., G. A. Hoddenbach, P. A. Medica and J. R. Lannom. 1970. The demography of the lizard, *Uta stansburiana*, Baird and Girard, in Southern Nevada. *Journal of Animal Ecology* 39:505-519.
- Walker, B.H. 1992. Biodiversity and ecological redundancy. *Conservation Biology* 6:18-23.
- Walker, B., A. Kinzig and J. Langridge. 1999. Plant attribute diversity, resilience, and ecosystem function: The nature and significance of dominant and minor species. *Ecosystems* 2(2):95-113.
- Whitford, W. G. and F. M. Creusere. 1977. Seasonal and yearly fluctuations in Chihuahuan Desert lizard communities. *Herpetologica* 33:54-65.
- Whitman, A. H. 1986. *Familiar trees of North America, western region*. Ninth edition. pp. 174-175. Alfred A. Knopf, New York.
- Zaady, E. and A. Bouskila. 2002. Lizard burrows association with successional stages of biological soil crusts in an arid sandy region. *Journal of Arid Environments* 50:235-246.
- Zweifel, R. G. and C. H. Lowe. 1966. The ecology of a population of *Xantusia vigilis*, the desert night lizard. *American Museum Novitates* 2247:1-57.