Desert Tortoise Recovery Plan Assessment

Tracy, C.R., R. Averill-Murray, W. I. Boarman, D. Delehanty, J. Heaton, E. McCoy, D. Morafka, K. Nussear, B. Hagerty, P. Medica

Dedication

This report is dedicated to our colleague and friend David Morafka.

Assessment Committee

C. Richard Tracy (Chair)
Professor of Biology
University of Nevada, Reno
Reno, Nevada

Roy Averill-Murray
Biologist
Arizona Game and Fish Department
Phoenix, Arizona

William I. Boarman
Biologist
U.S. Geological Survey/ BRD
San Diego, California

Dave Delehanty
Assistant Professor of Biology
Idaho State University
Pocatello, Idaho

Jill Heaton
Assistant Professor of Geography
University of Nevada, Reno
Reno, Nevada

Jeff Lovich
Biologist
U.S. Geological Survey
Flagstaff, Arizona

Earl McCoy
Professor of Biology
University of South Florida
Tampa, Florida

Phil Medica
Biologist
U.S. Geological Survey
Las Vegas, Nevada

Dave Morafka
Research Associate
California Academy of Sciences
San Francisco, California

Ken Nussear
Research Ecologist
U.S. Geological Survey
Las Vegas, Nevada

Bridgette Hagerty
Ph.D. Student
University of Nevada, Reno
Reno, Nevada

Table of Contents

DESERT TORTOISE RECOVERY PLAN ASSESSMENT I

DEDICATION II

ASSESSMENT COMMITTEE III

TABLE OF CONTENTS IV

TABLE OF TABLES XII

TABLE OF RECOMMENDATIONS XIII

ACKNOWLEDGEMENTS XIV

BULLETED ABSTRACT OF FINDINGS AND RECOMMENDATIONS XVI

EXECUTIVE SUMMARY XVII

1. INTRODUCTION 1

1.1 Charge of the Desert Tortoise Recovery Plan Assessment Committee 1

1.2 Desert Tortoise Recovery Plan Assessment Committee Members 2

1.3 Scientific Evaluation of the Recovery Plan 7
1.3.1 Recovery Prescriptions from the Recovery Plan 7
1.3.2 Topics Addressed in the Scientific Evaluation 9
1.3.3 Overview of Observations from the Assessment 11

2. QUANTITATIVE LITERATURE REVIEW: THE STATE OF KNOWLEDGE 16

2.1 Translocation 19
Translocation Recommendations 22

3. DISTINCT POPULATION SEGMENTS 27

3.1 Definition and intentions of Distinct Population Segments 27
3.1.1 Background 27
3.1.2 Discreteness 28
3.1.3 Significance 30
Direct Life-History Measures: 32

Ecological/Demographic Indicators:....32
Possible Environmental Correlates: 32
3.1.4 Conservation Status 32

3.2 DPSs of the Desert Tortoise....33
3.2.1 Reappraisal of 1994 Recovery Units 33
3.2.2 Provisional Revised List of DPSs....36
DPS Recommendations 38

4. STATUS AND TRENDS.... 40

4.1 Recovery Plan Implementation 40
Recovery Action Review and Implementation Recommendations: 44

4.2 Trend Analyses of Populations 46
4.2.1 History of Long-Term Study Plots 46
4.2.2 Trends Range-wide (East and West) 51
4.2.3 Trend Analyses by Recovery Unit....52
Upper Virgin River Recovery Unit (and DPS) 54
Northeastern Mojave Recovery Unit 55
Eastern Mojave Recovery Unit 56
Northern Colorado Recovery Unit....56
Eastern Colorado Recovery Unit....57
Western Mojave Recovery Unit (and DPS) 58
4.2.4 Trend Analyses by Distinct Population Segment 59
Lower Virgin River DPS 59
Eastern Mojave and Colorado DPS....60
Northeastern Mojave DPS 61
4.2.5 Summary of Trend Analyses....61

4.3 Spatial Analyses....62
4.3.1 History of Desert Tortoise Transects....63
Total Corrected Sign Transects 63
Distance Sampling Transects 64
4.3.2 Observation Rates 66
4.3.3 Presence/Failure to Detect....68
4.3.4 Conditional Probability of Live Encounter 70
Resampling 70
Logistic Regression....71
4.3.5 Kernel Analyses 73
4.3.6 Nearest Neighbor Clustering....84

4.4 Implications of Population and Spatial Analyses....86
Plot and Spatial Analysis Recommendations....88

4.5 Status and Trends of Habitat and Environmental Setting for Tortoise Populations 89
4.5.1 Road Case Study 89
Road Case-Study Recommendations....91
4.5.2 Patterns of Precipitation Case Study....97
Patterns of Precipitation Case Study Recommendations....99
4.5.3 Disease Case Study....99
What is known and what is not known? 100
Risk from disease threats 103

Disease Case-Study Recommendations 105

5. LINKING IMPACTS, HABITAT, AND DEMOGRAPHY TO RECOVERY 108

5.1 Cumulative, Interactive, and Synergistic Impacts of Multiple Threats 109
5.1.1 Threats Network 112
Threats Recommendations 119

6. MONITORING, EVALUATING, AND DELISTING 122

6.1 Strategies of Desert Tortoise Monitoring 123
6.1.1 Historical Background for Desert Tortoise Monitoring 123
6.1.2 Scope and Purpose of Modern Monitoring 124
6.1.2 Categories of Monitoring 126

6.2 Monitoring Desert Tortoises 128
6.2.1 Monitoring Desert Tortoise Populations 128
Long-Term Study Plots 129
Distance Transect Sampling 130
6.2.2 Monitoring Individual Desert Tortoises 134
Condition indices 134
Behavior 134
Behavior of Embryos and Neonates 136
Behavior of Juveniles 136
Behavior of Adults 137

6.3 Habitat monitoring 138
Monitoring Recommendations 138

6.4 Delisting Criteria 142
Criterion 1 142
Criterion 2 142
Criterion 3 142
Criterion 4 142
Criterion 5 142

7. INTEGRATING RESEARCH AND MANAGEMENT 146

7.1 Synopsis of Recommendations 146
7.1.1 Research and Monitoring 146
• Re-evaluating the status of DPSs and the positioning of DWMAs 146
• Improve population sampling methods 146
• Develop tools 147
• Improve the focus on the recovery goal 147
• Improve information gathering 148
• Improving information dissemination 148
• Improve the utility of monitoring efforts 149
• Improve the focus on recovery goals 149
• Develop research agendas 149
• Employing “outside” expertise 150
• Improve information dissemination/access 150
7.1.3 Data Management 150

• Improve information dissemination/access 150
• Re-evaluate the status of DPSs and the positioning of DWMAs 150
• Improve the focus on the recovery goal 150

7.2 Adaptive Management 151
7.2.1 Ingredients of Inventory, Monitoring, and Research 151
7.2.2 Relationships among Inventory, Monitoring, Research, and Adaptive Management 153
7.2.3 Definitions 153
7.2.4 Inventory 154
7.2.5 Monitoring 154
7.2.6 Research 156
7.2.7 Adaptive Management Decision Making 156
7.2.8 The Circle of Status and Trends and of Monitoring 157

7.3 Cooperation and Coordination 157
7.3.1 Desert Tortoise Recovery Office 160
7.3.2 Science Advisory Committee 160

7.4 Data Management 163
7.4.1 Distribution of Monitoring Resources 163
7.4.2 Data Management Plan 164
7.4.3 Types and Sources of Errors 164
7.4.4 Errors Detection and Correction 166

APPENDIX A. DTRPAC RESPONSES TO COMMENTS 168

APPENDIX B. DTRPAC MEETING MINUTES 177

LITERATURE CITED 237

Table of Figures

Fig. 2.1 *Distribution of all literature types before and after the publication of the Recovery Plan. 17*

Fig. 2.2 *Distribution of literature among the major research categories.....17*

Fig. 2.3 *Distribution of professional journal literature in the research categories before and after the publication of the Recovery Plan. The proportion of Recovery Plan prescriptions associated with each major research topic are included for comparison with the distribution of professional journal literature.18*

Fig. 2.4. *Percent of early life stage documents in professional journals that focused on ecology and autecology.....19*

Fig. 3.1. *Depiction of recovery units proposed in the 1994 Recovery Plan. Green outlines within the recovery units are proposed DWMAs. 34*

Fig. 3.2. *Ratio of rainfall in winter compared to summer in the Mojave Desert. Weather stations, and the longitudes for those stations, are given in the table. 35*

Fig. 3.3 *Map of the proposed distinct population segments for desert tortoise. 37*

Fig. 4.1 *Relative number of threats to desert tortoises in each critical habitat unit (i.e., DWMA), as identified by the Recovery Plan in 1994. .....40*

Fig. 4.2 *Relative number of threats to desert tortoises in each critical habitat unit (i.e., DWMA), as identified by the Desert Tortoise Management Oversight Group in 2003. .....41*

Fig. 4.3 *Relative numbers of management actions recommended for each DWMA in the 1994 Recovery Plan. 42*

Fig. 4.4 *Relative numbers of management actions by DWMA reported to the USFWS that have been at least partially implemented by 2002. .....43*

Fig. 4.5 *Locations of desert tortoise permanent study plots within the federally listed range of desert tortoises in the southwestern United States. 47*

Fig. 4.6 *Trends in relative population densities for desert tortoises in the eastern and western permanent study plot sites. 52*

Fig. 4.7 *Active (green tortoise symbols) and discontinued (orange triangles) permanent study plots grouped within the 1994 Recovery Units.....54*

Fig. 4.8 *Plot of adult densities over time for the City Creek permanent study plot located within the Upper Virgin River Recovery Unit. Error bars are 95% confidence intervals for the density estimate. 55*

Fig. 4.9 *Plot of adult densities over time for the study plots located within the Northeastern Mojave Recovery Unit. Error bars are 95% confidence intervals for the density estimate. 55*

Fig. 4.10 *Plot of adult densities over time for the study plots located within the Eastern Mojave Recovery Unit. Error bars are 95% confidence intervals for the density estimate.....56*

Fig 4.11 *Plot of adult densities over time for the PSPs located within the Northern Colorado Recovery Unit. Error bars are 95% confidence intervals for the density estimate.....57*

Fig. 4.12 *Plot of adult densities over time for the PSPs located within the Eastern Colorado Recovery Unit. Error bars are 95% confidence intervals for the density estimate. 57*

Fig. 4.13 *Plot of adult densities over time for the permanent study plots located within the Western Mojave Recovery Unit. Error bars are 95% confidence intervals for the density estimate. 58*

Fig. 4.14 *Active (green tortoise symbols) and discontinued (orange triangles) study plots grouped by Distinct Population Segment. 59*

Fig. 4.15 *Plot of adult densities over time for the Lower Virgin River Distinct Population Segment. Error bars are 95% confidence intervals for the density estimate.....60*

Fig. 4.16 *Plot of adult densities over time for the Eastern Mojave and Colorado Distinct Population Segment. Error bars are 95% confidence intervals for the density estimate. 60*

Fig. 4.17 *Plot of adult densities over time for the Northeastern Mojave Distinct Population Segment. Error bars are 95% confidence intervals for the density estimate.....61*

Fig. 4.18 *The ratio of carcasses to live tortoises for DWMAs.....67*

Fig. 4.19 *Presence/"Failure to Detect" tortoises and carcasses for combined distance sampling (2001-2003) and total corrected sign (1998, 1999, and 2001) transects. Dark green areas are those in which a tortoise and/or scat were present. Light green areas are those in which a tortoise and/or scat and carcasses were present. Red areas indicate only carcasses were present. White areas indicate no tortoises, scat, or carcasses were found. Light tan areas indicate no distance sampling or total corrected sign transects were conducted.....69*

Fig. 4.20 *Results from the resampling analysis - Areas depicted in red are points in bins 6 and 12, which had lower than average probabilities of live encounters; green points are bins 7 and 16, which had higher proportions of live animals. Points in all other bins are blue in color.....71*

Fig. 4.21 *Results from the logistic regression analysis. Cooler colors indicate higher probabilities of encountering a live tortoise, and warmer colors indicate a lower probability.....73*

Fig. 4.22 *Kernel analysis for the Upper Virgin River DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map....75*

Fig. 4.23 *Kernel analysis for the Beaver Dam Slope / Mormon Mesa / Gold Butte-Pakoon DWMAs. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map. 76*

Fig. 4.24 *Kernel analysis for the Coyote Springs Valley DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon.*

Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map. 77

Fig. 4.25 *Kernel analysis for the Piute-Eldorado Valley DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.* 78

Fig. 4.26 *Kernel analysis for the Chuckwalla DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.* 79

Fig. 4.27 *Kernel analysis for the Pinto Mountain and Joshua Tree DWMAs. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.* 80

Fig. 4.28 *Kernel analysis for the Chemehuevi DWMA The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.* 81

Fig. 4.29 *Kernel analysis for the Ivanpah DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.* 82

Fig. 4.30 *Kernel analyses for Fremont-Kramer / Superior-Cronese, and Ord-Rodman DWMAs. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.* 83

Fig. 4.31 *Nearest Neighbour Hierarchical Cluster analysis for the Western Mojave. Green areas are clusters of living tortoises; red outlines are clusters of carcasses.* 85

Fig. 4.32 *Routes in the Western Mojave DWMAs in 1985-87. Blue routes were designated as open, brown as either closed, limited, undetermined, or non-route. Large roadless areas such as southwest Ord-Rodman, and the most southwestern portion of Fremont-Kramer were not without roads in 1985-87, but were instead not inventoried. On the other hand, the DTNA was designated by the BLM as an Area of Critical Environmental Concern and fenced in the late 1970's, thus creating a roadless area.* 92

Fig. 4.33 *Routes in the Western Mojave DWMAs in 2001. Orange routes were designated as open, brown as either closed, limited, or non-BLM owned routes. The most southwestern portion of Fremont-Kramer remains un-inventoried as does portions of northern Fremont-Kramer, excluding the DTNA.* 93

Fig. 4.35 *Comparison of 1985-87 and 2001 designated open BLM routes. The red routes represent 2001 routes not formally designated as open in 1985-87. The lack of designation as open in 1985-87 could be a result of the fact that the route was inventoried in 1985-87 but not designated as open, not inventoried in 1985-87 but existing, or not existing in 1985-87.* 95

Fig. 4.36 *Comparison of 2001 and 1985-87 designated open BLM routes. The blue routes represent 1985-87 routes not formally designated as open in 2001. The lack of designation as open in 2001 could be the result of the fact that the route was inventoried in 2001 but not designated as open, not inventoried in 2001 but existing, or not existing in 2001.* 96

Fig. 4.37 *Seasonal rainfall in the Mojave Desert, 1930-2000.....98*

Fig. 5.1 *Network of threats demonstrating the interconnectedness between multiple human activities that interact to prevent recovery of tortoise populations. Tier 1 includes the major land use patterns that facilitate various activities (Tier 2) that impact tortoise populations through a suite of mortality factors (Tier 3).....113*

Fig. 5.2 *A section from the Threats Network from Fig. 5.1 that shows how multiple land uses and human activities provide food subsidies to predators on tortoises, thereby increasing mortality.....115*

Fig. 5.3 *A section from the threats network from Fig. 5.1 showing just the primary activities associated with utility corridors. The causes of tortoise mortality associated with physical structures are also shown. 117*

Fig. 5.4 *A subsection of the Threats Network shown in Fig. 5.1 that illustrates the mortality factors directly associated with unpaved roads used for maintenance of utilities.....118*

Fig. 5.5 *A much more complex web showing the interconnectedness among many activities associated with utilities and their impacts on tortoise populations.....119*

Fig. 6.1 *Idealized population trends before recovery planning implemented, as a result of implementing recovery planning, and after delisting.....123*

Fig. 6.2 *Dimensions of elements important to recovery, and therefore, needing monitoring. 125*

Fig. 6.3 *Kernel analysis of presence data for living desert tortoises (green polygons) and carcasses (red outlines.....128*

Fig.6.4 *Simulated population growth at a 2% growth rate with (a) a 10% coefficient of variation around the trend and (b) a 40% coefficient of variation around the same trend. 129*

Fig. 6.5 *Tortoise activity measured over a three year period at Bird Spring Valley, NV. Tortoise activity is expressed as the proportion of animals active for each hour during each week of the year and ranges from 0 to 1. The gray areas represent times for which tortoise activity was not sampled. Warmer colors indicate high proportions of animals active, and cooler colors indicate fewer animals active.....132*

Fig. 7.1 *Relationships among the desired objectives of a recovery program, a conceptual model of the functional relationships among species, and monitoring activities in the adaptive management.....155*

Fig. 7.2 *Relationships among factors contributing to disease important to demography of the desert tortoise. 159*

Fig. 7.3 *Relationships among offices, teams, committees, etc. functioning to produce strategies for recovery and implementation of the listed species. 162*

Fig. 7.4 *Kinds of activities associated with monitoring. 163*

Table of Tables

Table 1.1. *Schedule of DTRPAC meetings* *1*

Table 2.1 *Research categories used in quantitative literature review.* *16*

Table 4.1. *Recovery actions listed in the Recovery Plan (and DWMA supplement) reported by management agencies as implemented through 2002 (Redlands Institute (2002a-f). 0 = No Implementation; 1 = Implementation Initiated; blanks indicate actions not applicable to that unit, according to the Recovery Plan.* *45*

Table 4.2 *Years surveyed on permanent study plots for desert tortoises. A number (0 or 1) indicates that data were taken at this plot. A zero indicates that the data are not available or sufficient for analysis, and a one indicates that data were available for analyses in this report.* *48*

Table 4.3 *Citations for sources of data used in permanent study plot analyses* *50*

Table 4.4 *Study plots from which data were used to assess trends in population size in the original Recovery Plan.* *51*

Table 4.5 *Summary of data, year, and region used for each analysis. TCS = total corrected sign surveys; LDS = line distance sampling.* *63*

Table 4.6 *Percentages of live animals and dead animals found on LDS transects. The third column is the ratio of the percent of dead animals encountered to the percent of live animals encountered.* *66*

Table 4.7 *Observed ratios of live to dead tortoises. The P values indicate bins of transects in which the ratios were different from that expected at random. The sign of the observed value indicates the direction of the difference.* *70*

Table 4.8 *Statistical table for the logistic regression analysis.* *72*

Table 4.9 *The estimated coefficients for the logistic regression model.* *72*

Table 4.10 *Weather stations in the Mojave Desert used in analysis of precipitation (Fig. 4.37).* *97*

Table 7.1 *Summary of sources and types of error that have been found in Line Distance Sampling.* *165*

Table of Recommendations

Bulleted Abstract of Findings and Recommendations xv

Recommendations on Translocations 23

Recommendations on Distinct Population Segments 38

Recommendations for Recovery Action Review and Implementation 44

Recommendations on Study Plot and Spatial Analyses Techniques 88

Recommendations from Road Case Study 91

Recommendations from Precipitation Case Study 99

Recommendations from Disease Case Study 105

Recommendations for Dealing with Threats 119

Recommendations on Monitoring 138

Considerations for Delisting Criteria 143

Synopsis of Overall Recommendations 146

Acknowledgements

We would like to thank U.S. Fish and Wildlife Service staff, which assertively provided an interface between the DTRPAC and the public during the process leading to this report. The Biological Resources Research Center at the University of Nevada, Reno provided most of the logistic support for the process of creating this report. The University of Redlands, the Redlands Institute, and Lisa Benvenuti helped in producing maps. The Western Ecological Research Center of The U.S. Geological Service provided some financial and staff support. The Arizona Heritage Fund and a State Wildlife Grant (USFWS) supported Roy Averill-Murray as a member of DTRPAC. U.S. Fish and Wildlife Service provided funds for this project.

Preface

This report of the assessment of the Desert Tortoise Recovery Plan of 1994 is the result of more than a year of work by a committee who spent many hours conducting analyses and writing the report. A thorough understanding of the assessment process and products requires reading the entire report. Appendix B contains the minutes of all working meetings of the committee. This appendix allows a general tracking of the discussions and the process by which the report was assembled. For those who wish only to read the recommendations resulting from the report, there are three sources of recommendations. There is a one-page bulleted list of the general recommendations on page xv. The Executive Summary on page xvi presents an abstract of the report. All recommendations associated with each chapter of the report can be located by using the Table of Recommendations on page xii.

Bulleted Abstract of Findings and Recommendations

- The Recovery Plan of 1994 was fundamentally sound, but some modifications for contemporary management will likely make recovery more successful.
- Complex meta analyses of tortoise distributions and abundances indicate trends leading away from recovery goals in some parts of the species range. These results indicate a need for more aggressive initiatives to facilitate recovery.
- A USFWS Desert Tortoise Recovery Office (DTRO) should be established to facilitate and coordinate recovery efforts based upon an adaptive-management approach with advice from a Science Advisory Committee (SAC).
- Many of the original prescriptions of the Recovery Plan were never implemented. These prescriptions continue to be appropriate and they should be implemented. However, synergistic, interacting, and cumulative threats, not appreciated by the original Recovery Team, also must be addressed and new prescriptions should be prioritized from analyses of analyses of "threats network topologies" assembled by the DTRPAC to assess redundancies and synergies within individual threats.
- Recovery planning should reflect distinctness of population segments within the species range. The genetic distinctness of tortoise populations and of their pathogens must be assessed to guide all manipulative management (e.g., head starting, translocation, habitat restoration, corridor management, etc.). A newly proposed (by the DTRPAC) delineation of DPSs should be revised with new scientific information.
- Status and trends of populations/metapopulations within DPSs are potentially impossible based only upon assessment of tortoise density because assessing density of populations for rare and cryptic species is exceedingly difficult (and potentially impossible). Thus, monitoring the efficacy of management actions should be based upon a comprehensive assessment of the status and trends of threats and habitats as well as population numbers.
- A new definition of recovery is needed as assessing recovery defined in terms of a population that is demonstrably increasing or remaining stable may not be possible. The new definition should be based upon achievable assessment of progress toward recovery as assessed in the status and trends of threats, habitats, and population distribution and abundance.
- The original paradigm of desert tortoises being recovered in large populations relieved of intense threats may be flawed as tortoises may have evolved to depend upon metapopulation dynamics. Assessing the appropriateness of the metapopulation paradigm is very important as management under this paradigm could require more intense actions (including head starting, genetics management, habitat management and facilitated dispersal, herd immunization, and other artificially facilitated ecosystem processes).

EXECUTIVE SUMMARY

The Desert Tortoise Recovery Plan Assessment Committee (DTRPAC) was appointed by the U.S. Fish and Wildlife Service (USFWS) in 2003 and charged with carrying out a scientific assessment of the Desert Tortoise Recovery Plan published in 1994. The assessment committee consisted of credentialed academic and agency scientists with expertise in ecology, tortoise biology, conservation biology, geography and GIS technologies, scientific ethics and philosophy of science, the Endangered Species Act of 1973 as amended and the implementation of that law, and desert natural history. Additionally, the assessment committee solicited input from nationally recognized scientists to provide expert advice and opinion in highly technical areas central to tortoise recovery including tortoise epidemiology, remote sensing, and multi-scale population monitoring.

The resultant assessment reviews the Recovery Plan in the context of scientific and analytical advances made since the Recovery Plan was published in 1994. The primary goal of this assessment is to provide a critical scientific evaluation of the Recovery Plan prior to any renewal or revision of the plan. The assessment produced by DTRPAC is not a Recovery Plan, and it does not seek to make social, legal, or political decisions on desert tortoise recovery. Rather, the assessment is a scientific evaluation of the current state of scientific knowledge regarding tortoise recovery, and the assessment reveals directions, via analytical examples, towards the scientific knowledge necessary to achieve desert tortoise recovery. The committee explicitly demonstrates how recent analytical advances can be applied to desert tortoise recovery by carrying out original and rigorous analyses of existing data. Not only are these analyses meant to provide a detailed scientific perspective for a possible future recovery plan panel to consider, the examples also demonstrate the power of analyses now available for tortoise recovery when appropriate data exist and the true loss in potential information incurred when tortoise data acquisition is poorly planned or only intermittently carried out.

The DTRPAC found that original Recovery Plan was fundamentally strong but could benefit substantially from modification. Modifications center on the following areas: (1) recognition of new patterns of diversity within the Mojave desert tortoise population, (2) explicit implementation of original Recovery Plan prescriptions, (3) greater appreciation of the implications of multiple, simultaneous threats facing tortoise populations, and (4) applying recent advances in analytical techniques to desert tortoise recovery.

Much of the inability to implement the original Recovery Plan owes to the lack of coordinated, range-wide tracking and reporting of management implementation. The DTRPAC recommends that a much more aggressive coordination and facilitation effort should become the responsibility of the USFWS. A Desert Tortoise Recovery Office (DTRO) should be established in the USFWS to implement the needed oversight, tracking, and reporting of new information about the efficacy of management actions and the methods by which that efficacy is assessed. This office should empanel a Science

Advisory Committee (SAC - including members from academia and USGS) to serve in an advisory role to the DTRO.

Research and management efforts can and should be integrated to increase the likelihood of tortoise recovery. It appears that many opportunities to accumulate scientifically rigorous data to examine tortoise and habitat trends, as well as to explore mechanisms underlying tortoise population dynamics, have been missed. Recovery depends upon a substantially greater understanding of tortoise behavior, genetics, disease transmission, and demography, and the DTRO should facilitate increased scientific understanding in these areas by increasing research activity outlined in the original Recovery Plan and here, and working to improve cooperation between managers and research scientists. Scientists need to emphasize research that will address urgent management needs and their efforts will benefit from consulting with managers on their "on-the-ground knowledge" of tortoise populations. Managers can contribute to recovery by collaborating and consulting with researchers on data acquisition, storage, and access. Additionally, sophisticated data oversight and management as well as independent expertise in data acquisition design and statistical analysis are essential to the process leading to desert tortoise recovery.

The recovery prescriptions of the original Recovery Plan were only partially implemented and, as implemented, the Recovery Plan neither appears to be leading to desert tortoise recovery, nor is it likely to do so. In particular, explicit recommendations for research designed to provide rigorous data essential to understanding desert tortoise demography and population dynamics were not carried out. The failure to implement research recommendations means that the understanding of desert tortoise demography and population dynamics has advanced very little. The call for rigorous data was an essential part of the adaptive management approach at the core of the original Recovery Plan. In adaptive management, management actions are modified based upon incoming data that assesses whether or not current management actions are working. Establishing an aggressive DTRO will help us avoid missing more opportunities to facilitate recovery.

Desert tortoises face an array of threats, which act simultaneously and synergistically. The far-reaching implications of this concept were not fully appreciated in the original Recovery Plan. Multiple, simultaneous threats are particularly insidious to formulating recovery actions because it is possible that potential gains made in tortoise numbers through one action can be lost when potentially "saved" tortoises perish or fail to reproduce due to a different threat not alleviated by the management action. The synergism of multiple threats refers to the biological fact that effects from one threat can be magnified when the threat co-occurs with another threat. The original Recovery Plan does not fully appreciate that threats to tortoises can act in this non-additive way.

Due to the natural progression of science, the original Recovery Plan does not incorporate technological and analytical techniques now available. The DTRPAC reviewed the scientific literature, sought to acquire recent data in the "gray" literature (agency reports, etc.), and applied a suite of analytical techniques to existing desert tortoise data. These

analyses were meant to yield new insights into desert tortoise biology and recovery, to provide examples of approaches that a new recovery plan could employ, and also to underscore the true need for, and benefit of, rigorous and scientific data that directly address issues underlying desert tortoise recovery.

The assessment presents a modified set of desert tortoise Distinct Population Segments (DPS) relative to the original Recovery Plan. The new DPS delineations reflect the committee's review and interpretation of recent desert tortoise and conservation biology literature. The DTRPAC delineations reflect the prevailing concepts of subpopulation "discreteness, " and "significance," and incorporate morphological, behavioral, genetic, and environmental information. The DTRPAC suggestion reduces the number DPSs from six to five by leaving the original Upper Virgin River and Western Mojave units intact and recombining the four central units into three reconfigured units.

The assessment provides a highly detailed meta-analysis of desert tortoise population status and trends. The DTRPAC found the data on status and population trends often to be statistically unwieldy due to inconsistencies in data collection, suboptimal data collection design, and the truly daunting task of measuring animals that are difficult to detect and that occupy a harsh environment. Because much of the data currently available to address tortoise recovery was originally collected for purposes other than tortoise recovery, the DTRPAC analyses are meta-analyses using data of mixed quality. To adjust for very low statistical power in current data sets, DTRPAC used transect sampling carried out by various agencies and managers to derive tortoise occurrence data, then used spatial analysis of tortoise occurrence to map tortoise status and possible trends. Results are complex, but resulting maps suggest that in many areas tortoise populations appear be facing continued difficulty. Spatial analyses did not indicate zones of recovery. Kernel analyses of transect data – limited to only one year due to lack of additional sufficient data – identified several regions that may have experienced significant local die-offs. Statisticians consulting with DTRPAC derived an original analysis called "Conditional Probability of Being Alive" that spatially illustrated regions of low, intermediate, and high probability of encountering live tortoises during surveys. These analyses identified large regions within historic desert tortoise habitat as being associated with having a low probability of detecting live tortoises during surveys. In other words, probably few tortoises occur in these areas currently. The West Mojave recovery unit stood out within overall tortoise range as unambiguously experiencing continued population decline.

The DTRPAC also performed spatial analyses of habitat and other geographic trends with special emphasis on potential impacts of roads and disease: two issues of historic importance in desert tortoise recovery. GPS technology and renewed survey effort indicate that more roads currently are documented in the western Mojave zone of tortoise decline than were documented in 1987. Some portion of the increase in roads probably represents legal or illegal road creation from 1987-2001. Some portion probably represents new documentation of previously existing roads. The relationship between road type and road density to tortoise decline needs to be clarified. Expert consultation

with wildlife disease epidemiologists and emerging evidence from tortoise studies indicate that the relationship between ELISA-positive assays of live tortoises, *Mycoplasma* infection, and tortoise decline is not a simple and easily predicted relationship. Disease experts sought out by the DTRPAC described a growing awareness that the probability of infection leading to death in tortoises may be a function of chronic stress (e.g., malnutrition) and the strain of infectious agent. This means that the presence of disease alone is not sufficient to explain tortoise die-offs. For example, it is possible that habitat degradation results in physiologically stressed tortoises that then succumb to disease agents that are normal at background levels in healthy populations. The relationships between disease, physiological status, and tortoise death are scientifically tractable, but they have not been rigorously addressed.

The assessment presents a threats network topology. This network illustrates the profoundly daunting array of threats facing the desert tortoise and should discourage a future recovery team, if it is necessary to form one, from viewing threats in overly simplistic way. A substantial body of evidence indicates that tortoises face a complex suite of threats. It is naïve to propose a recovery action that addresses a single threat and then anticipates straightforward additive increases in tortoises as a response to the management action.

It is also clear that effective desert tortoise monitoring and the creation of an effective restoration strategy will entail a new and greater level of cooperation and coordination among managers and scientists. Currently, no group is charged with managing scientific data on the desert tortoise, and data often are collected and reported in ways that make them difficult to use in conjunction with other data. Currently, important desert tortoise data are widely scattered among state and federal agencies and the scientific community. Data have been gathered, “organized”, and stored in a multitude of ways. Some data have been organized and other still exists in raw, unanalyzed states. Accessibility of data for managers, scientists, and the public is highly variable. In short, a great deal of important long-term data cannot be used readily. Organizing and “mining” currently existing desert tortoise data could be highly productive and helpful. Establishing a DTRO would help focus attention towards learning from existing data and promoting new scientific initiatives.

The current definition of desert tortoise recovery requires populations within recovery units to be stable or increasing for at least 25 years (one tortoise generation). To demonstrate recovery based on population stability, scientists must be able to distinguish among populations that are truly stable as opposed to populations that superficially appear to be stable because monitoring data are not sufficiently rigorous to detect declines when in fact declines are occurring. A new multi-dimensional monitoring strategy may be the most effective approach for redefining and verifying recovery. The monitoring approach presented in the assessment refers to three tiers of monitoring. Tiers 1 and 2 perform status and trend monitoring by using repeated measures taken over time (tier 1) and inferential statistics applied across broad geographical areas (tier 2). These are designed to meet current management objectives and also to monitor changes over

long time periods. Tier 3 is research monitoring designed to detect or to verify mechanistic links between actions and tortoise responses. Both population and habitat monitoring will require multi-scale approaches to achieve information needed for adaptive management and assessment of recovery.

It is no longer clear that the original population paradigm upon which definitions of recovery were based is correct. Existing data do not exclude the possibility that tortoise populations evolved to be distributed in metapopulations instead of single, large populations. The dynamics of metapopulations, and the conservation prescriptions for metapopulations are entirely different from single, large populations. Thus, the original Recovery Plan prescribed establishing large wildlife management areas and reducing threats within those areas. For metapopulations, it may be additionally necessary to protect corridors among habitat patches, and to recognize that natural metapopulation dynamics require areas suitable for desert tortoises, but periodically vacant of tortoises. Thus, new data and analyses are needed immediately to determine the biological basis for defining recovery in light of the possibility that unforeseen ecosystem processes need to be protected as part of recovery.

"Science can only state what is, not what should be."

Albert Einstein, *Out of My Later Years*. (1950)

1. Introduction

The original Desert Tortoise Recovery Team recognized the importance of including new data and analyses for recovery efforts as they become available. Indeed, the Recovery Team called for the Recovery Plan to be reassessed every three to five years to ensure that recommendations to management were made with the best available scientific information (USFWS 1994, p. 37). Since the Recovery Plan's publication in 1994, there have been no overt efforts to revise the Recovery Plan in light of new information pertinent to desert tortoise recovery, despite the fact that there has been new research on many aspects of desert tortoise ecology, threats, conservation biology, and monitoring, as well as public challenges to the validity of the Plan.

1.1 Charge of the Desert Tortoise Recovery Plan Assessment Committee

The U.S. Fish and Wildlife Service (USFWS) initiated a two-step process to revise the 1994 Desert Tortoise Recovery Plan. Step 1 is a review and assessment of new research and information gathered on many aspects of desert tortoise ecology, threats, conservation biology, monitoring, and recovery actions. Step 2 will be the revision of the Recovery Plan by a newly established recovery team of scientists, agency resource specialists, and stakeholders, if a future recovery team is necessary.

Following is a description of Step 1 of the process that has been initiated by the Desert Tortoise Recovery Plan Assessment Committee (DTRPAC). The charge of the DTRPAC is to review the entire Recovery Plan in relation to contemporary knowledge and, based on that review, prepare recommendations about which parts of the Recovery Plan need updating. Under this charge, the DTRPAC was to assemble and review all new literature pertinent to the Recovery Plan, to hold meetings to conduct an in-depth review of selected topics (disease, monitoring, etc.), and submit a final report to the USFWS. A schedule of DTRPAC meetings, including focal topics for each meeting is shown in Table 1.1. The minutes from each meeting are contained in Appendix B.

TABLE 1.1. Schedule of DTRPAC meetings

Topic	Dates	Location
Orientation and Agenda	11 April 2003	San Francisco, CA
Distinct Population Segments and Threats	15-16 May 2003	Palm Springs, CA
Disease Workshop Debrief, Disease, Status of Threats	9-10 June 2003	San Francisco, CA
Status of Populations, Demography, Finalize Threats	31 July – 1 August 2003	Truckee, CA
Monitoring and Delisting Criteria	4-5 September 2003	Monterey, CA

Habitat Conservation Planning, Research	2-3 October 2003	Tucson, AZ
Review and Report Preparation	6-7 November 2003	Las Vegas, NV
Report Preparation	26-27 February 2004	Reno, NV
Report Preparation	22-23 April 2004	Carlsbad, CA
Address Public Comments	26-27 May 2004	Reno, NV
Finalize Report	14-15 June 2004	Reno, NV

1.2 Desert Tortoise Recovery Plan Assessment Committee Members

The DTRPAC was purposely assembled with scientists and experts diverse in terms of State representation, institutions of employment, gender, and scientific expertise. Some members were chosen who are not doing research on the desert tortoise. The committee was assembled with representatives with the following characteristics:

1. expertise and experience with the desert tortoise and/or ecosystems containing desert tortoises,
2. expertise and experience in conservation biology and other areas important to the DTRP evaluation process,
3. ability to serve as "internal peer-reviewers" (i.e., scientists serving as general science analysts whose job it will be to keep tortoise scientists from becoming myopic while focusing on new data, analyses, and opinions for the desert tortoise),
4. academic and agency scientists,
5. representation of the original Recovery Team,
6. broad representation from the geographic range of the listed species.

The committee included the following members:

C. Richard Tracy (Ph.D.), [Chair of the Committee] Professor of Biology and Director of the Biological Resources Research Center, University of Nevada, Reno, NV

Dr. Tracy is the former Director of the Ecology, Evolution, and Conservation Biology Graduate Program at the University of Nevada, Reno. He currently serves as the science advisor for the Clark County Desert Conservation Program in Nevada. He earned his B.A. and M.S. from California State University, Northridge and his Ph.D. from the University of Wisconsin. He has served on faculties at Colorado State University, the University of Wisconsin, the University of Washington, the University of Puerto Rico, Pepperdine University, the University of Nebraska, and the University of Michigan. He has been honored as a Guggenheim Fellow, as a Distinguished Scholar at Pepperdine University, and as a Fellow of the Association of Western Universities. He also has received an American Society of Zoologists Service Award, a Desert Tortoise Council Conservation Award, a Service Award from the U.S. Fish and Wildlife Service, and he has served in leadership roles in the Ecological Society of America and the American Society of Zoologists. Dr. Tracy is

an ecologist who has published more than 140 articles and book chapters on a wide range of topics in ecology, population biology, physiology, biophysics, and natural history of animals (mostly amphibians and reptiles), and whose studies have included research on herbivorous reptiles since 1977, and on desert tortoises since 1988. He was a member of the original Desert Tortoise Recovery Team, and he is a member of the Houston Toad Recovery Team. He has served as major professor for 37 masters and Ph.D. students, and he has directed theses, dissertations, and postdoctoral research of several graduate students and postdoctoral scholars who have studied the desert tortoise.

Roy C. Averill-Murray (M.S.), Amphibians and Reptiles Program Manager, Arizona Game and Fish Department, Phoenix, AZ

Mr. Averill-Murray earned his B.S. in Wildlife and Fisheries Sciences (cum laude) from Texas A&M University in 1990. In 1993 he earned his M.S. in Wildlife and Fisheries Science from the University of Arizona, where he completed his thesis on estimating density and abundance of desert tortoises in the Sonoran Desert. He began working for the Arizona Game and Fish Department in 1995 as the Nongame Branch's Desert Tortoise Coordinator. As Desert Tortoise Coordinator, he directed the state's population monitoring program; conducted research on desert tortoise ecology, especially reproduction; and co-chaired the Arizona Interagency Desert Tortoise Team. He has published 8 peer-reviewed scientific papers on desert tortoises, including 3 chapters in the new book The Sonoran Desert Tortoise: Natural History, Biology, and Conservation. He assumed the duties of Amphibians and Reptiles Program Manager in 2002, and he is responsible for the management of all amphibians and reptiles in Arizona. He is also co-chair of Partners in Amphibian and Reptile Conservation's Southwest Regional Working Group.

William I. Boarman (Ph.D.), Research Wildlife Biologist, U.S. Geological Survey, Western Ecological Research Center, San Diego, CA

Dr. Boarman received his Ph.D. in ecology from Rutgers University. He has worked for the Department of Interior for 13 years studying the ecology, behavior, and management of the desert tortoise and common raven. His desert tortoise research focuses on the impacts of roads on desert tortoise populations and the effectiveness of barrier fences and culverts at recovering desert tortoise populations. The association between raven ecology and anthropogenic resources to develop means to reduce raven predation on juvenile tortoises is the aim of his work with ravens. He has written a comprehensive evaluation of the state-of-the-art of our knowledge of threats to desert tortoise populations. He is also involved in research on the Salton Sea ecosystem, prairie falcon ecology, and marbled murrelet conservation. He has published 25 papers in peer-reviewed scientific journals.

Dave J. Delehanty (Ph.D.), Assistant Professor of Biology, Idaho State University, Pocatello, ID

Dr. Delehanty received his Ph.D. from the Ecology, Evolution, and Conservation Biology Program at the University of Nevada, Reno in 1997. He has taught

Conservation Biology at UNR and ISU, and he is well known for his innovative approach to this important subject. He has studied mechanisms underlying behavior and the physiological importance of dietary carotenoid pigments on steroid-mediated physiological events involved with sexual maturation, sexual behavior, and reproductive performance in vertebrates. Importantly, he seeks to develop an improved understanding of animal behaviors integral to the success of conservation actions. He is implementing Nevada restoration programs for mountain quail and Columbian sharp-tailed grouse, two native species extirpated from all or part of their historic ranges. This includes developing new restoration techniques that account for behavioral and life history constraints. He is a critical thinker whose prowess in ecology, conservation biology, genetics, statistical analyses, research design, as well as species repatriation makes him an excellent member for the DTRPAC.

Jill S. Heaton (Ph.D.), Assistant Professor of Geography, University of Nevada, Reno, NV

Dr. Heaton was previously an assistant professor in Environmental Studies at the University of Redlands. She was Principal Investigator for the Redlands Institute (RI) Desert Tortoise Project (DTP). The RI and DTP are comprised of numerous research analysts, ecologists, GIS analysts, programmers, and systems analysts, among other positions. She and her DTP research team are building a desert tortoise decision support system. This system uses a scientific knowledge base linked to geospatial data within an application framework allowing users to evaluate decision and management options as well as identify knowledge and data gaps, thus clarifying research priorities. She is an arid lands ecologist, with degrees in biology and geography. She earned her B.S. and M.S. in Biology from the University of North Texas, in 1993 and 1996, respectively. Dr. Heaton earned her Ph.D. in Physical Geography from Oregon State University in 2001. Her research career has been spent in the arid southwest working with mammals in the Chihuahuan Desert and reptiles in the Mojave. She is experienced in applying quantitative and statistical techniques to ecological problems, and integrating ecological theory and principles with the spatial and temporal complexity of the natural environment. She has experience and expertise in habitat modeling, statistical modeling, environmental issues on military installations, urban and development biodiversity boundary interactions, and issues relating to land use and conservation. She is trained in GIS applications, primarily the suite of ESRI GIS products, remote sensing and image analysis, and traditional statistical and geo-statistical analyses. She has extensive fieldwork experience and strives to spend a quarter of her time in the field conducting research.

Jeffrey E. Lovich (Ph.D.), Chief, Grand Canyon Monitoring and Research Center, U.S. Geological Survey, Flagstaff, AZ

Dr. Lovich is the former Director of the U.S. Geological Survey, Western Ecological Research Center. Headquartered in Sacramento, California, the Center employs a staff of over 100 employees, located at 14 duty stations in California and Nevada. He started his federal career in 1979 at the National Museum of Natural History/Smithsonian Institution in the Division of Amphibians and Reptiles while still

an undergraduate student at George Mason University. After finishing his B.S. in Biology, he stayed on at George Mason, earning an M.S. in Biology. From there, he went to the University of Georgia, obtaining a Ph.D. in Ecology in 1990. Most of his tenure at the University of Georgia was spent at the Savannah River Ecology Laboratory, a research facility of the University of Georgia in South Carolina. After a brief Post Doctoral fellowship at the Savannah River Ecology Laboratory, he went to work for the Bureau of Land Management, first as a staff biologist at the California Desert District Office in Riverside, then as the Lead Wildlife Biologist in Palm Springs. As a charter member of the National Biological Survey (now Biological Resources Division of USGS), he conducted research on desert tortoises and desert ecology in southern California. His research on turtles and tortoises spans almost 25 years. During that time he published over 60 scientific papers, most on the ecology and evolution of North American and Asian freshwater turtles. He discovered and formally described three of the world's 280 or so turtle species, including two in the United States and one in Japan. In addition he published two books. He is co-author of the book "Turtles of the United States and Canada" published by the Smithsonian Institution Press in 1994, and co-editor of, and contributor to, the book "Biological Diversity: Problems and Challenges" published by the Pennsylvania Academy of Science the same year.

Earl D. McCoy (Ph.D.), Professor of Biology, University of South Florida, Tampa, FL

Dr. McCoy earned a B.S. in Biology at Florida State University in 1970, a M.S. in Biology at the University of Miami in 1973, and a Ph. D. in Biology at Florida State University in 1977. He has published over 100 peer-reviewed publications, many of which focus on the ecology and conservation biology of gopher tortoises. He has also published extensively on the philosophy of science and the basis of experimental design in ecology, including the book Method in Ecology: Strategies for Conservation Problems. He is currently on the editorial board for three journals, including Ecology and Ecological Monographs. He has been at the University of South Florida since 1977. He has been the associate Chairman for the Department of Biology since 1992. He has also been a Visiting Assistant Professor at the University of Virginia on several occasions. He has mentored three postdoctoral students, 10 Ph.D. students, and 27 masters students. He is currently the primary investigator or a collaborator on several research projects, including a large multi-disciplinary project examining the field epidemiology of the Upper Respiratory Tract Disease in the gopher tortoise.

David J. Morafka (Ph.D.), [*deceased*] Research Associate, Department of Herpetology, California Academy of Sciences, San Francisco, CA

Dr. Morafka was the Lyle E. Gibson Emeritus Professor of Biology, CSU, Dominguez Hills. He earned his B.S. in Biology (with honors) at the University of California at Berkeley in 1967, and a Ph. D. at the University of Southern California in 1974. He was a member of the original Desert Tortoise Recovery Team and a member of the IUCN Freshwater Turtle and Tortoise Conservation Group. He had more than 50 publications and one book on North American desert reptiles and their conservation. He was the principal investigator on neonatology and hatchery nursery

studies of the desert tortoise at Ft. Irwin and Edwards Air Force Base, and of the endangered Bolson tortoise in Mexico.

Ken E. Nussear (Ph.D.), Research Ecologist, U.S. Geological Survey, Western Ecological Research Center, Las Vegas Field Station, Las Vegas, NV

Dr. Nussear is a recent graduate from the Ecology, Evolution, and Conservation Biology Program at the University of Nevada, Reno. He received his B.S. in Zoology (summa cum laude) from Colorado State University. He has published several peer-reviewed publications on the physiology of desert reptiles. He has worked on many research projects involving desert tortoises since 1995. His research has focused on conservation biology, nutritional ecology, and physiological ecology of desert tortoises. These research projects included a multi-site, multi-state translocation project designed to examine the efficacy of translocation as a conservation tool for desert tortoises. The study looked within and beyond the geographic range of desert tortoises and gives insights into the habitat requirements of this species. His work is being used to develop management strategies for desert tortoises in the face of the fastest growing human populations in the country. He had a pre-doctoral fellowship from the University of Redlands to continue his research. This research involves applied biophysical-ecology studies of tortoises to enhance our understanding of tortoise activity and how this impacts monitoring efforts. This work will help to refine desert tortoise monitoring efforts throughout the range of the listed population.

Bridgette E. Hagerty, Ph.D. Student, University of Nevada, Reno (DTRPAC manager)

Ms. Hagerty is a current doctoral student in the Ecology, Evolution, and Conservation Biology Program at the University of Nevada, Reno. She earned her B.A. in Biology (magna cum laude) from St. Mary's College of Maryland in 2000. Prior to beginning her graduate studies, she was an Environmental Management Fellow with the Chesapeake Research Consortium and staffed committees at the EPA Chesapeake Bay Program. Her research focuses on the use of indirect methods to quantify movement among desert tortoise populations in the Mojave Desert. The results of her genetics research will be used to help make decisions concerning distinct populations segments of the desert tortoise.

Phil A. Medica (M.S.), Biologist, U.S. Geological Survey, Western Regional Research Center, Las Vegas Field Station, (USFWS liaison representative)

Mr. Medica is a Wildlife Biologist with the U.S. Geological Survey, Western Ecological Research Center, at the Las Vegas Integrated Science Office. He received his B.S. in Wildlife Management (Game Management) and his M.S. in Biology (Herpetology) from New Mexico State University in 1964 and 1966, respectively. He has worked on reptiles and small mammals throughout the southwestern U.S. for the past 40 years. He began his career working at the Nevada Test Site (NTS) in 1966 as a field technician for Brigham Young University, Department of Zoology, and was subsequently employed as a Staff Research Associate by UCLA, Laboratory of Nuclear Medicine and Radiation Biology from 1967-1981. While with UCLA at

NTS, he studied the effects of gamma irradiation upon natural populations of animals and plants at the Rock Valley facility, documented sterility among the lizard inhabitants, and conducted lizard demographic and reproductive studies. He developed and implemented environmental research studies on natural populations of lizards and small mammals in conjunction with drought upon the ecosystem as well as disturbances, i.e., roads, fire, grading, cratering, and irradiation. From 1992-1993, he served as an Ecologist with the Bureau of Land Management, Las Vegas District Office, and was transferred to the National Biological Survey in 1993. As a Research Wildlife Biologist with the National Biological Survey, subsequently USGS/Biological Resources Division (1993-2000), he conducted extensive field studies pertaining to desert tortoise translocation, reproduction, and survivorship. Most recently, he served as the Mojave Desert Tortoise Coordinator for the U.S. Fish and Wildlife Service (2000-2004), initiating rangewide population monitoring using the Line Distance Sampling technique. He has authored or co-authored 70 reports, scientific papers, and peer reviewed journal articles pertaining to the ecology of desert reptiles and small mammals of the southwestern United States.

1.3 Scientific Evaluation of the Recovery Plan

1.3.1 Recovery Prescriptions from the Recovery Plan

The passage in the following text box is taken directly from the Recovery Plan of 1994. This passage expresses the core of what needs to be compared with current management and knowledge. The comparison we present in this document is meant to be a scientific evaluation of the Recovery Plan in relation to contemporary knowledge of (a) the biology of the desert tortoise and (b) the extent to which the Recovery Plan was implemented.

"The desert tortoise was listed as threatened primarily because of a variety of human impacts that cumulatively have resulted in widespread and severe desert tortoise population decline and habitat loss. The destruction, degradation, and fragmentation of desert tortoise habitat and loss of individual desert tortoises from human contact, predation, and disease are all important factors in the decline of the Mojave population. If the desert tortoise is to be recovered within its native range, the causes of the decline must stop, at least within the DWMAs. Some factors are likely more important than others; for instance, urbanization has probably caused more habitat loss than light cattle grazing. *However, eliminating all factors that are deleterious to desert tortoise populations will certainly result in faster recovery than will selective elimination of a few.*

Accomplishing the prescribed recovery actions is needed to reduce or eliminate human-caused impacts in the recovery units and to implement the recovery strategy described in the Recovery Plan.

1. Establish DWMAs and implement management plans for each of the six recovery units

a. Select DWMAs

b. Delineate DWMA boundaries

i. Reserves that are well-distributed across a species' native range will be more successful in preventing extinction than reserves confined to small portions of a species' range.

ii. Large blocks of habitat, containing large populations of the target species, are superior to small blocks of habitat containing small populations.

iii. Blocks of habitat that are close together are better than blocks far apart.

iv. Habitat that occurs in less fragmented, contiguous blocks is preferable to habitat that is fragmented.

v. Habitat patches that minimize edge to area ratios are superior to those that do not.

vi. Interconnected blocks of habitat are better than isolated blocks, and linkages function better when the habitat within them is represented by protected, preferred habitat for the target species.

vii. Blocks of habitat that are roadless or otherwise inaccessible to humans are better than blocks containing roads and habitat blocks easily accessible to humans.

c. Secure habitat within DWMAs.

d. Develop reserve-level management within DWMAs.

e. Implement reserve-level management within DWMAs.

f. Monitor desert tortoise populations within recovery units.

2. Establish environmental education programs.

a. Develop environmental education programs.

b. Implement environmental education programs.

3. Initiate research necessary to monitor and guide recovery efforts.

a. Obtain baseline data on desert tortoise densities both inside and outside of DWMAs.

b. Develop a comprehensive model of desert tortoise demography throughout the Mojave region and within each DWMA.

i. Initiate epidemiological studies of URTD and other diseases.

ii. Research sources of mortality, and their representation of the total mortality, including human, natural predation, diminishment of required resources, etc.

iii. Research recruitment and survivorship of younger age classes.

vi. Research population structure, including the spatial scale of both genetic and demographic processes and the extent to which DWMAs and recovery units conform to natural population subdivisions.

c. Conduct appropriately designed, long-term research on the impacts of grazing, road density, barriers, human-use levels, restoration, augmentation, and translocation on desert tortoise population dynamics.

d. Assess the effectiveness of protective measures (e.g., DWMAs) in reducing anthropogenic causes of adult desert tortoise mortality and increasing recruitment.

e. Collect data on spatial variability of climate and productivity of vegetation throughout the Mojave region and correlate this information with population parameters (e.g., maximum sustainable population size, see Appendix G).

f. Conduct long-term research on the nutritional and physiological ecology of various age-size classes of desert tortoises throughout the Mojave region.

g. Conduct research on reproductive behavior and physiology, focusing on requisites for successful reproduction."

1.3.2 Topics Addressed in the Scientific Evaluation

The DTRPAC reviewed the Recovery Plan to determine which parts required modification based on new knowledge. As a result of this review, the topics listed in Table 1.1 were addressed. To conduct the topic reviews most efficaciously, the committee invited outside experts to help conduct the reviews. This effectively expanded the panel of experts to very large numbers and provided the expertise needed to conduct

an extremely thorough review of the Recovery Plan. The expertise brought to bear on the topics represented the highest level of scientific expertise available. The panel included:

- Elliott Jacobson, DVM, Tortoise disease
- Mary Brown, Ph.D., *Mycoplasma*
- David Rostal, Ph.D., Tortoise reproduction
- David Thawley, Ph.D., Veterinary epidemiology
- Kristin Berry, Ph.D., Desert tortoise biology
- Barry Noon, Ph.D., Conservation biology of endangered species
- Michael Reed, Ph.D., Conservation biology, population modeling
- Jim Sedinger, Ph.D., Population biology
- Chuck Peterson, Ph.D., Herpetology, reptile ecology
- Mary Cablk, Ph.D., Remote sensing
- Ron Marlow, Ph.D., Conservation planning
- Ann McLuckie, M.S., Conservation planning
- Ray Bransfield, M.S., Conservation planning
- Bryan Manly, Ph.D., Statistics (consultant for user groups)
- Lyman MacDonald, Ph.D., Statistics (consultant for user groups)

USFWS also invited diverse stakeholders to send representatives as observers to the DTRPAC meetings. Some of those representatives contributed substantively to discussions or report preparation and review. Representatives and observers included:

- Clarence Everly, Consultant for the Department of Defense
- John Hamill, Department of Interior and Desert Managers Group
- Rebecca Jones, California Department of Fish and Game
- Ron Marlow, Ph.D., Clark County Habitat Conservation Plan
- Ann McLuckie, Utah Division of Wildlife Resources
- Karen Phillips, U.S. Geological Survey
- Lewis Wallenmeyer, Clark County Habitat Conservation Plan
- John Willoughby, Bureau of Land Management

After completion of the scientific evaluation, the DTRPAC focused on the following major topics for the report.

1. ***Distinct Population Segments*** (DPS) in relation to the Recovery Units designated by the original Recovery Team. Recovering the Mojave population of desert tortoise in all its diversity (genetic, ecological, behavioral) in relation to conservation challenges is basic to a recovery plan. The concept of distinct population segments was mentioned in the original Recovery Plan, but the distinct population segments were referred to as recovery units. The original Recovery Plan suggested that genetic resolution of those recovery units was necessary. Research has been conducted since the original Recovery Plan, so this area certainly needs revisiting by the DTRPAC.
2. ***Knowledge advances*** since the listing of the desert tortoise occurred in the following areas: (a) populations and demography, (b) impacts to habitats, (c)

literature, and (d) recovery plan implementation. Ten years have passed since the original Recovery Plan, so new research and conservation planning needed to be reviewed to assess whether new knowledge naturally leads to old conservation prescriptions or whether new knowledge requires new directions in conservation and management prescriptions.

3. ***Linking impacts, habitat, and demography to recovery*** (Specific threats and their mitigations with special attention to impacts resulting from interactions among individual threats; the relationships among threats and the importance of disease) The original Recovery Plan attempted to list specific threats and link those threats to specific places. For 10 years, the identified threats have been the subject of much debate and planning. Insofar as some evidence has been that some populations are still declining, it was clear that threats needed reevaluation.

4. ***Monitoring, evaluating, and delisting***. Monitoring provides the information necessary to adapt management. Nevertheless, monitoring has been elusive and contentious. The ability to monitor rare and cryptic species has always been difficult, and new approaches to monitoring have been suggested since the original Recovery Plan.

5. ***Integrating research needs and management***. Numerous research needs were published in the original Recovery Plan. Some of those needs have been pursued vigorously and others neglected. This area needed updating and evaluation in light of years of experience.

It is important to note that this summary is intended to serve as a "strategic" review of the current Plan. Although, we have conducted several new analyses of existing data to understand current status better or to illustrate various points, this report primarily provides recommendations for consideration in revising and more effectively implementing the Plan.

1.3.3 Overview of Observations from the Assessment

What follows in this report are evaluations of the original Recovery Plan in light of contemporary knowledge. Immediately below, we make eight general observations that bear on difficulties of implementing the original Recovery Plan or of lack of attempt to implement the original Recovery Plan. The remainder of the report is a more detailed summary of conclusions from this committee.

The desert tortoise invokes three fundamental challenges in understanding its biology and managing its recovery: time scale, detectability, and metapopulation structure.

Time Scale – Desert tortoise recovery is fundamentally a demographic problem. Diminished populations require some period of population growth (average lambda > 1.0) to recover. Populations that are stable and secure may fluctuate in size in response to local, prevailing conditions, meaning that population growth rate (lambda) will vary around an overall stable mean (lambda = 1.0). However, desert

tortoise natural history is not well suited to demographic analysis using short-term study. Individual tortoises grow slowly, take many years to reach sexual maturity, and have low reproductive rates during a long period of reproductive potential. This means that studies of 1-10 years, or even longer, do not necessarily yield data of sufficient statistical power to reveal population trends.

Detectability – Desert tortoise behavior and morphology make them very difficult to detect and observe. Other than in the Upper Virgin River Recovery Unit, where tortoise population densities have been high, the personnel and resources necessary to overcome the problem of low detectability have not been appropriate to allow precise estimates of population size of desert tortoise within the Mojave Desert. If desert tortoise density declines in the Upper Virgin River, even this recovery unit may ultimately suffer from problems of low detectability.

Population paradigm – The original paradigm about how tortoise populations are organized, and the prescriptions made within that paradigm might be wrong and dangerously misleading. Existing data are consistent with the possibility that tortoises have evolved to exist in metapopulations. The original Recovery Plan and the original paradigm conceived desert tortoises to be distributed in large populations that required large areas and large densities to recover. Metapopulation theory, on the other hand, conceives that tortoises are distributed in metapopulation patches connected with corridors that allow inefficient and asynchronous movements of individuals among the patches. This paradigm conceives that some habitat patches within tortoise range will have low population numbers or no tortoises at all, and others will have higher population numbers. Movement among the patches is necessary for persistence of the "system." If desert tortoises evolved to exist in metapopulations, then long-term persistence requires addressing habitat fragmentation caused by highways and satellite urbanization. Indeed, mitigating abrogations of natural corridors among habitat patches might require active management of tortoise densities in habitat patches.

Desert tortoises face simultaneous, multiple threats. Tortoises face an array of threats and these threats act simultaneously. This concept is central to recovery, because it portends profound difficulties in formulating effective recovery actions. In particular, a management action that alleviates one threat may not yield meaningful recovery, because the deleterious effects of another threat operating simultaneously suppress the gains sought by the original management action. In other words, one threat can negatively compensate for another threat when threats are simultaneous.

Threats to desert tortoises are interactive and synergistic. The magnitude of the deleterious effects of one threat can be a function of another threat. For example, if increased mortality reduces the lifetime fecundity of a female tortoise by removing that female from the population before she reaches her period of maximum annual fecundity, then deleterious factors to other life stages (e.g., raven predation on neonatal tortoises) may have a greater effect on tortoise demography. Why? The negative effect on neonates by raven predation, for example, now affects a larger proportion of neonates in the population, because new neonates are not produced when adults are killed. Also, disease

may only be an important contributor to population declines during years of drought or to populations stressed by invasion of exotic plants or by off-road vehicles or any number of other stresses. In other words, threats to tortoise populations are complex, because the threats interact to cause impacts rather than creating impacts just directly.

Recommendations made in the original Recovery Plan for carefully controlled experiments to generate data and analyses important to monitoring and recovery have not been implemented. The original Recovery Plan recommended a suite of experimental approaches which, if carried out, could have provided key data and analyses needed for understanding tortoise population dynamics, especially relevant to management effectiveness, important in guiding current recovery. Many of these recommendations appear to have been largely ignored. Unfortunately, ten years of opportunity to collect critical data and perform critical analyses have been diminished or lost for a variety of reasons.

Much of the data currently available to address tortoise recovery was originally collected for purposes other than tortoise recovery (hence we are doing meta-analyses using data of mixed quality to perform analyses that would be more efficacious using data from well designed studies). Perhaps for historical reasons, certain tortoise studies have been carried out more-or-less continuously. For example, permanent study plots have been used to study demography and biology of tortoises in non-random sites. Various forms of distance sampling have been carried out at mixed levels of magnitude and intensity. A more efficient approach for the future might be to design studies using statistical and scientific expertise expressly to obtain key data to address central problems.

Mapping of even poorly collected data reveals very important apparent patterns. Technological advances since the first Recovery Plan have resulted in powerful analytical tools that bear directly on analyzing and monitoring desert tortoise populations. In particular, GIS analyses of data diligently derived from large, disparate data sets that were collected by various agencies are yielding intriguing patterns. “Mining” historical data and applying powerful new analyses or applying older analyses in new ways will be helpful in prescribing recovery actions. As demonstration of the substantial value of this approach, we present several new analyses from existing data. These include (i) a kernel analysis of spatial distribution of live and dead tortoises, (ii) a cluster analysis of spatial distribution of live and dead tortoises, (iii) a spatial analysis of the probability of finding live versus dead tortoises, (iv) a multi-dimensional, multi-scale approach to monitoring, (v) a threats network topology, (vi) a quantitative literature review of all available tortoise literature, (vii) a weighted analysis of variance (ANOVA) of tortoise density from permanent study plots across 24 years, and (ix) a spatial analysis of the implementation of recovery actions from the first Recovery Plan.

No group is charged with managing scientific data on the desert tortoise. Currently, important desert tortoise data are widely scattered among state and federal agencies and the scientific community. Data have been gathered, organized, and stored in a multitude of ways. Some data have been reviewed, collated, or otherwise organized. Other data

have not. Accessibility of tortoise data to managers, scientists, and the public is highly variable. In short, a great deal of important long-term data cannot be readily used. This is an ineffective data management strategy for species recovery. A new infrastructure for ensuring quality, accessibility, and analyses of data is desperately needed. These observations apply equally well to information on and status of recovery action implementation.

Scientific information important for recovery is entirely ad hoc. In general, new knowledge acquisition seems frequently to be directed at land-management agency mandates vis-à-vis management decisions. Thus, the limited supply of tortoise biologists is frequently absorbed into contracts for local issues (e.g., DOD needs for data to comply with NEPA). However, there is a real need to pursue the research agenda outlined in the Recovery Plan of 1994. Some HCPs have scientific oversight and direction, but there is essentially no coordination of the scientific enterprise conducted in different management units in a way to get more than accidental accumulation of necessary knowledge important for recovery of the desert tortoise and its ecosystems.

"Scientific principles and laws do not lie on the surface of nature. They are hidden, and must be wrested from nature by an active and elaborate technique of inquiry."

John Dewey, *Reconstruction in Philosophy*. (1920)

2. Quantitative Literature Review: the state of knowledge

The most recent annotated bibliography (Grover and DeFalco 1995) published on desert tortoises (*Gopherus agassizii*) identified trends in research prior to 1991 and mentioned gaps in knowledge that influenced research prescriptions in the Desert Tortoise Recovery Plan (1994). The original Recovery Team made several recommendations for research necessary to fill information gaps important to the recovery of desert tortoise populations. These items included:

- long-term demography (particularly recruitment and survivorship of younger age classes, sources of mortality, and epidemiology),
- population structure (spatial scale of genetics and demography),
- long-term analysis of impacts,
- effectiveness of protective measures,
- spatial variation in climate and vegetation,
- nutritional and physiological ecology,
- reproductive behavior and physiology, and
- restoration, augmentation, and translocation.

The Recovery Plan highlighted the need for long-term studies, which are necessary to capture temporal variation and ecologically relevant trends. In addition, the Recovery Plan prescribed research on non-reproductive age classes. Few studies have been conducted on survivorship or recruitment rates in young *Gopherus* tortoises due to their cryptic morphology and behavior.

A recent literature review employed a quantitative approach to 1) compare the foci of research before and after the publication of the Recovery Plan, and 2) identify present gaps in desert tortoise knowledge (Hagerty, Sandmeier, and Tracy in prep.). Available desert tortoise literature, obtained by the Clark County Multi-Species Habitat Conservation Plan database (1378 total papers), was classified by age class, literature type, and one or more research categories (Table 2.1). Contingency table analyses were performed to determine differences among the types of research before and after the Recovery Plan was published.

TABLE 2.1 Research categories used in quantitative literature review.

Research Category	Relevant topics included in each category
Ecology	life history characteristics, demography, ecology
Autecology	physiology, behavior, morphology
Conservation	threats, management, effectiveness of conservation efforts
Systematics	molecular and morphological systematics
Disease	pathology, veterinary procedures, pharmacology
History	natural history, evolution, fossil record, paleoecology
Bibliographies	literature reviews and annotated bibliographies

Academic researchers and agency biologists studying desert tortoises communicate their results in professional journals, government documents, Desert Tortoise Council (DTC) symposia, and other professional society meetings. Overall, 22% of catalogued desert tortoise literature was published in professional journals. After the Recovery Plan, the percentage of literature published in professional journals increased, while the percentage of gray literature decreased (Fig. 2.1). The latter result may be an artifact of the availability of government reports, however there was an increased trend for researchers to publish their results in professional journals.

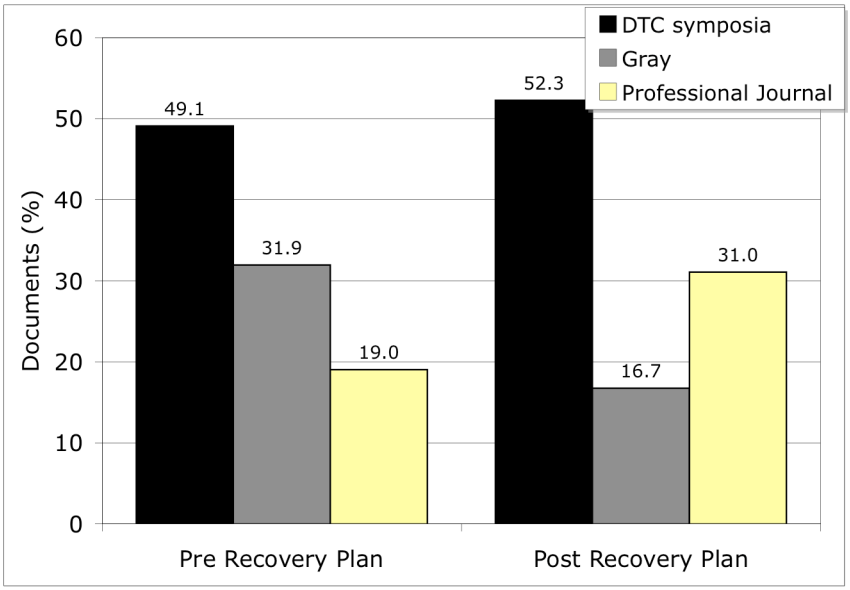

Fig. 2.1 Distribution of all literature types before and after the publication of the Recovery Plan.

Further, professional journal documents were dominated by autecological research, while other documents contained mainly conservation and ecological studies ($\chi^2 = 154.115$, df = 6, $p<0.0001$) (Fig. 2.2). This result may suggest a dichotomy of research being done within agencies and academia, respectively. Tortoise conservation studies consisted mainly of descriptions of threats to tortoises and how these threats are being managed. Population density and habitat studies, which are typically performed by government agencies, are also included in the gray literature category.

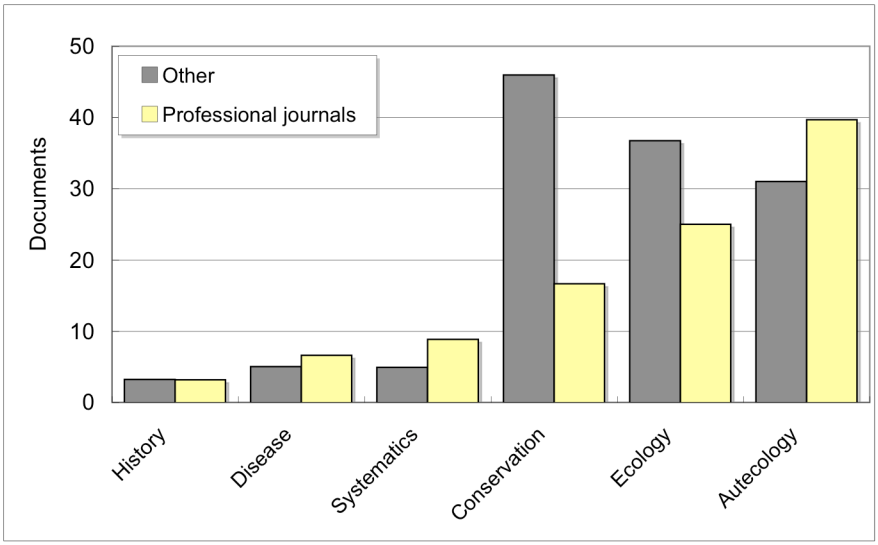

Fig. 2.2 Distribution of literature among the major research categories.

The Recovery Plan prescriptions for future research did appear to have a limited impact on desert tortoise research. After the Recovery Plan was published, more documents in professional journals focused on ecology and implementation of conservation, with a continued emphasis on autecology ($\chi^2 = 25.88$, df = 5, $p<0.0001$) (Fig. 2.3). A change in the distribution of gray literature corresponding to the publication of the Recovery Plan was marginally significant ($\chi^2 = 13.49$, df = 7, $p<0.06$).

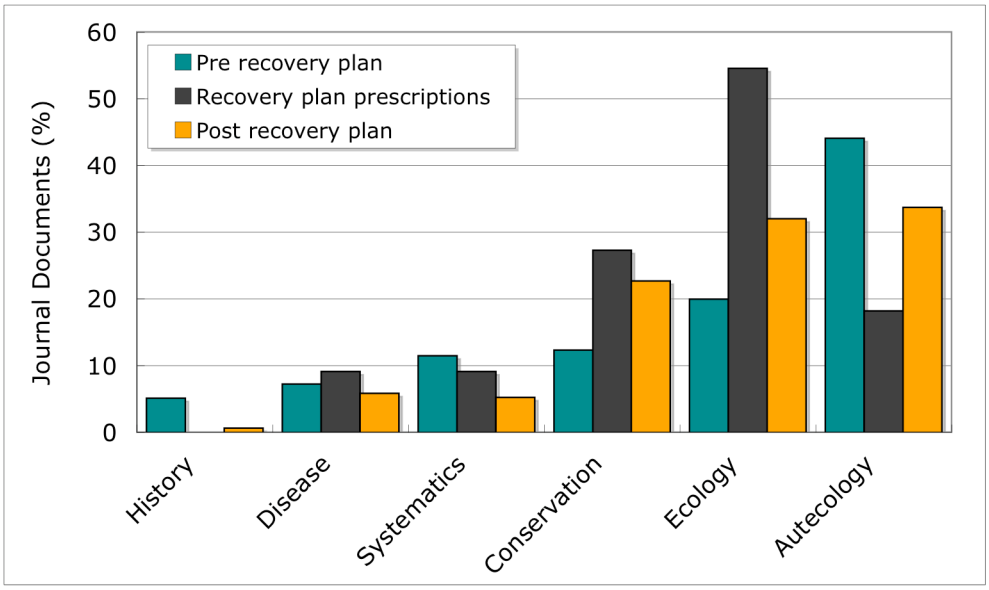

Fig. 2.3 Distribution of professional journal literature in the research categories before and after the publication of the Recovery Plan. The proportion of Recovery Plan prescriptions associated with each major research topic are included for comparison with the distribution of professional journal literature.

Since the Recovery Plan was published, there has been considerable research on some aspects of tortoise biology, in particular nutritional ecology, reproductive physiology, and the effects of several specific impacts on tortoise populations. However, very little research has been published on other recommended topics, such as long-term demography, the effectiveness of recovery actions, translocation (but see below), and climatic and vegetative variability. Virtually no research has been conducted or published on other important topics, such as epidemiology and many long-term impacts on tortoise populations. Some additional areas that have been the topic of active research yet were not identified in the Recovery Plan prescriptions, include disease and health status, habitat conditions, and fire ecology. In the case of disease, recent studies have focused on pathology instead of the focus on epidemiology that was prescribed by the Recovery Plan. These new areas of research are important and may need to be continued at some level, however not in place of the recovery plan recommendations.

Research prescriptions in the Recovery Plan also emphasized the need for research on immature age classes within the categories of ecology and autecology. In particular, the Recovery Plan recommended research on recruitment and survival rates of non-reproductive age classes and their nutritional and physiological ecology. After the Recovery Plan, an increase in the percentage of studies on immature age classes corresponded to general prescriptions in these areas, suggesting that the Recovery Plan prescriptions were followed (Fig. 2.4). However, no studies included in the analyses were conducted that focus specifically on recruitment and survival of young age classes. A quantifiable deficiency in knowledge of the ecology of non-reproductive tortoises remains a missing link to understanding desert tortoise population structure and dynamics. Literature on early life stages is under represented in all age-relevant categories, with only 5% of documents focusing exclusively on immature life stages.

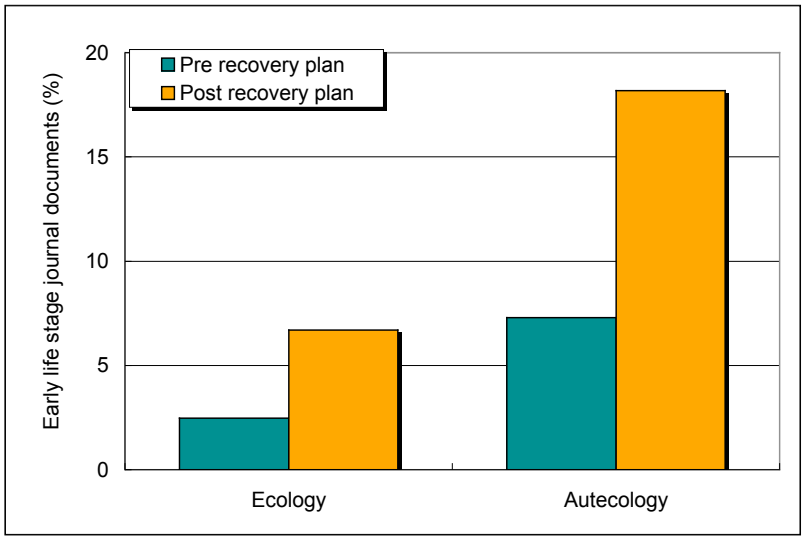

Fig. 2.4. Percent of early life stage documents in professional journals that focused on ecology and autecology.

Implementation of effective management strategies to recover the Mojave population of the desert tortoise requires an accurate characterization of population structure, threats to population persistence, and the effectiveness of protective measures. Determining life history characteristics, such as age-specific survivorship, is critical and requires large sample sizes and long study periods. In addition, hypothesis-based experiments on the long-term effects of recovery actions are also necessary. These gaps in knowledge were identified in the Recovery Plan, have not been addressed, and remain important prescriptions for research.

2.1 Translocation

There were many topics for research recommended by the Recovery Plan that have been the subject of active research and publication over the last decade. Translocation of desert tortoises has recently come to the forefront because of the impending expansion of Ft. Irwin in the West Mojave and the continued urbanization of the Las Vegas Valley.

Because no peer reviewed papers on recent research on translocation of desert tortoises have been published yet on this topic, and at the request from several reviewers of the draft DTRPAC report, we include a brief synopsis of recent translocation studies here. Translocation was regarded by the Recovery Team as both a threat and as a potential conservation measure to mitigate take of tortoises, to augment depleted populations, and re-colonize extirpated populations (USFWS 1994).

Prior to the publication of the Recovery Plan, few studies of the effects of translocation on desert tortoises had been conducted, and no study was extensive enough to evaluate translocation as a conservation tool for this species. The results of previous efforts are generally reported in government documents (Berry 1974, Berry 1975, Berry 1976), as anecdotes (e.g., see Cook et al. 1978), or unpublished accounts (Crooker 1971, Bryan and West 1972, McCawley and Sheridan 1972, Cook et al. 1978, Corn 1991, SAIC 1993). Because of the dearth of literature on translocation of desert tortoise, the potential for success of translocation in this species had not previously been thoroughly examined, and as a result translocation as a tool for conservation has remained controversial (Berry 1986, Dodd and Seigel 1991, USFWS 1994). Nevertheless, the Recovery Plan recognized the potential of the technique for augmenting populations with tortoises taken outside of DWMAs, and the plan recommended that more thorough research on translocation be conducted.

The definition of success of translocating a species is typically taken to be the ability of the translocated or augmented population to become self-sustaining in the long-term (Griffith et al. 1989, Dodd and Seigel 1991, Fisher and Lindenmayer 2000). Success, however, may be measured at several temporal scales, which may be important precursors to judging the long-term success of a translocation program (Tasse 1989, Dickinson and Fa 2000, Fisher and Lindenmayer 2000). For example, there may be some level of initial mortality above which a translocation study is judged to be unsuccessful (Platenberg and Griffiths 1999). In addition, other goals may be used to judge success in the short-term, such as the colonization of a particular site (Lohoefener and Lohmeier 1986), the social integration of translocated animals into the existing population (Berry 1986, Reinert 1991), and the ability of the animals to find mates and reproduce (Berry 1986, Pedrono and Sarovy 2000).

Extensive translocation studies have been conducted in Nevada and Utah that quantified survivorship, growth, pre-release conditions, reproduction, microhabitat use, and movements (one index of behavior, which can be especially important to land-management decisions) of translocated and resident animals in six locations spanning elevations from 500 to 1500 meters (Field 1999, Field et al. 2003, Nussear 2004, Nussear et al. in prep.). These projects included tracking more than 300 tortoises (resident and translocated) for several years. Some tortoises were translocated to habitats with vegetation not normally associated with desert tortoise populations (in order to assess the mechanistic determinants of geographic range in tortoises). Some tortoises were translocated into areas cleared of any resident tortoises and some into areas containing populations with resident tortoises (to assess the effect of translocation both on the animals translocated and on the tortoises already present in the habitat). Some translocated tortoises were formerly pet tortoises

moved from urban settings to wild locations, and some tortoises were wild tortoises translocated from one wild location to another (to assess the potential to repatriate tortoises that had been removed from the wild for long periods prior to their release into the wild). Tortoises were translocated into the wild in three seasons of the year (in order to assess the extent to which season predicts success in translocation) (Field et al. 2003). Only tortoises certified as not having an immune response to *Mycoplasma agassizii* were translocated, and all areas studied had populations with resident tortoises having immune responses to *Mycoplasma agassizii*.

In general, translocated tortoises had the same survivorship and reproductive success as resident animals. This result was the same in drought years and in El Niño years. Tortoises moved to atypical habitat generally moved until they reached habitat more commonly associated with desert tortoise presence. Even when desert tortoises were translocated into typical tortoise habitat, they tended to move greater distances in the first year after translocation, but their movements in the second year were indistinguishable from resident tortoises. Knowing how translocated tortoises displace after translocation is necessary in order to plan for any needed fencing of managed areas, or to determine the size of translocation release areas. Important in any of these measures of success are comparisons between translocated and resident animals in the area. This allows the effect of translocation to be statistically separated from factors normally expected in resident populations in particular areas.

The results of these translocation studies indicate a very optimistic potential for success in translocating individual tortoises in a wide variety of circumstances. The mortality documented in previous translocation experiments on desert tortoises was largely because animals were translocated during the most stressful thermal environments of the year (e.g., when the weather is stressfully hot). The results of these recent studies suggest that both wild and pet tortoises can thrive and reproduce after translocation. These results also suggest that it is necessary to plan for translocated tortoises to move great distances in the first year after translocation. It is especially important to recognize that tortoises cannot be moved to unnatural habitats and expected that the tortoises will remain in those habitats (unless confined by fencing). Indeed, the fact that tortoises do not accept being translocated to atypical habitats suggests that some needs for the tortoises are only met in more typical habitat.

Knowing that it is possible to translocate tortoises successfully is important in conservation planning. Translocation should not be substituted for habitat protection as a conservation measure, but translocation can be important as a means to supplement existing populations that may have declined abnormally (e.g., in regions formerly heavily used by recreationists or by construction projects such as gas pipelines, etc.). Translocation can be used to create new populations in areas where populations are known to have existed in the historic past, however, creating new populations always should be regarded as experiments until the reasons why historic populations are absent are known and logic and science suggests that a new population can thrive in the area. Future translocations could be used as an experimental tool to assess the effects of certain

management prescriptions (e.g., fencing, ablation of cattle grazing, reducing the density of unpaved roads, etc.).

The remaining cautions, vis-à-vis translocation, are that the process of translocation may disrupt community interactions and that the impacts of those alterations might be difficult to predict. In other words, we know that individual and population responses to translocation are generally benign and suggest that translocation can be an effective tool in the conservation arsenal for a land manager, but we do not yet know all that is needed about community interactions potentially modified by translocation. Thus, translocating tortoises into an area containing, for example, a strain of pathogen that is foreign to the translocated tortoises may alter the balance between host-pathogen relationships in ways that might not be easily predictable and potentially dangerous. Thus, additional research is needed to increase our understanding of host-pathogen relationships and other community-level interactions (e.g., competition, predator-prey, pathogen, etc.) to support carefully considered translocation programs.

Translocation Recommendations

• Translocation should not be substituted for habitat protection as a conservation measure but rather as a last resort to mitigate the take of displaced animals.

• Translocation can be used to supplement or augment depleted populations, but all translocations should be conducted as an experiment with research to ensure that the threats originally causing the depletion have been removed.

• Translocation can be used as an experimental tool to assess the effects of certain management prescriptions, or to assess the presence of threats that affect the population.

• Translocated animals are likely to have large movements in the first two years. If tortoises are translocated near roads with high traffic volume, these roads should be fenced. In addition, if the goals of the translocation project are to retain animals in a relatively small area, then experimental fencing should be used for a few years as given in the translocation guidelines (Recovery Plan Appendix B).

There are seven guidelines for translocation given in the Recovery Plan (see appendix B). These guidelines, while well intentioned have little chance of all being applied simultaneously. The use of these guidelines requires the knowledge of measures that are currently unavailable, or have poor precision for desert tortoises such as historic densities and carrying capacity. We recommend that these guidelines be revisited in light of recent information on translocation in desert tortoises, and in light of the consideration of realistic management constraints and conditions where translocations are likely to occur.

A summary of each guideline with commentary on its applicability is given below.

Guideline 1 "Experimental translocations should be done outside experimental management zones. No desert tortoises should be introduced into DWMAs—at least until relocation is much better understood."

- Unless experimental management zones, or other areas within DWMAs can be used for translocation, translocated tortoises cannot be assured protection into the future. This is particularly important when long-term conservation of translocated populations comes into conflict with changes to the environment by humans such as urbanization or flood control projects.

Guideline 2 "All translocations should occur in good habitat where the desert tortoise population is known to be substantially depleted from its former level of abundance. Translocation of reproductively competent adults into depopulated areas can have beneficial effects on population growth. Before population growth can occur, however, individuals must establish home ranges and enter into any existing social structure. Desert tortoises should be periodically evaluated against a defined health profile (proportional weight/size, fecal scans, and blood panels)."

- These criteria have two possible limitations. First it tacitly assumes an explicit knowledge of the former abundance of animals (this is usually unavailable for most of the listed range of the tortoise). Second, if this guideline is strictly followed, then tortoises displaced from an area could be translocated to areas where tortoises could have different population composition.

Guideline 3 "Areas into which desert tortoises are to be relocated should be surrounded by a desert tortoise-proof fence or similar barrier. The fence will contain the desert tortoises while they are establishing home ranges and a social structure. If the area is not fenced, past experience suggests that most animals will simply wander away from the introduction site and eventually die. (Fencing is not cheap; estimates range from $2.50 to $5.00 per linear foot). Once animals are established some or all of the fencing can be removed and probably reused."

- The final sentence of this guideline has not been scientifically evaluated. The goals of each proposed translocation should be considered individually. If one of the goals of a translocation program is to populate a specific area, then fencing the area may be desirable (but should be tested scientifically). If however the goal is to move tortoises to a non-specific area, such as a large valley, then fencing may be impractical, and un-necessary.

Guideline 4 "The best translocations into empty habitat involve desert tortoises in all age classes, in the proportions in which they occur in a stable population. Such translocations may not always be possible, since young desert tortoises are chronically underrepresented in samples, often due to observer sampling error, and may now actually be underrepresented in most populations due to poor recruitment and juvenile survivorship

during the last several years. Desert tortoises smaller than the 7-year age-size class are particularly vulnerable to predation and may be a poor investment for translocation, unless predator exclusion (fencing, for example) is incorporated into such endeavors. Mature females would probably be the best sex/age class to introduce into below carrying capacity extant populations because of their high reproductive value (low potential mortality, high potential fecundity for many years)."

- This guideline seems to provide different recommendations. First it recommends that the best case would be to translocate all size classes, but it also suggests that juveniles may be a poor investment. Fencing of translocated tortoises is recommended as a protection from predation but this has not been confirmed. It is unlikely that most predators would be excluded using fencing, and juveniles have been reported to suffer from avian predation from ravens and other large birds. The concept of carrying capacity may not be appropriate for desert tortoise, and it would be extremely difficult to measure. It is difficult to reconcile the reportedly high tortoise densities prior to the 1980s with the concept of carrying capacity.

Guideline 5 "The number of desert tortoises introduced should not exceed the pre-decline density (if known). If the pre-decline density is not known, introductions should not exceed 100 adults or 200 animals of all age classes per square mile in category 1 habitat (Bureau of Land Management designation for management of desert tortoise habitat) unless there is good reason to believe that the habitat is capable of supporting higher densities. Post-introduction mortalities might be compensated by subsequent introductions if ecological circumstances warrant this action."

- Caution should be used if persistent post-introduction mortality continues over long periods of time. This may signal that threats originally causing are still present. If threats persist, the situation should be considered an opportunity to more about the importance of threats.

Guideline 6 "All potential translocatees should be medically evaluated in terms of general health and indications of disease, using the latest available technology, before they are moved. All translocatees should be genotyped unless the desert tortoises are to be moved only very short distances or between populations that are clearly "genetically" homogeneous. All translocated animals should be permanently marked, and most should be fitted with radio transmitters so that their subsequent movements can be closely tracked."

- The application of radio transmitters should depend on the experimental design of the translocation project, and the questions that are to be asked of the translocated animals. If, for example, the study is to be used for the sole purpose of measuring long-term population genetics, then the costs and the intensive labor required to monitor all of the translocated animals monthly are probably not warranted.

- All translocations should be guided by a genetic management plan. Such a plan will help to ensure that translocated individuals are moved conservatively among populations that are genetically similar.

Guideline 7 "If desert tortoises are to be moved into an area that already supports a population—even one that is well below carrying capacity—the recipient population should be monitored for at least 2 years prior to the introduction. Necessary data include the density and age structure of the recipient population, home ranges of resident desert tortoises, and general ecological conditions of the habitat.

Areas along paved highways can serve as good translocation sites, if properly fenced. Many such areas support good habitats, but vehicle-caused mortalities and/or collecting have substantially reduced or totally extirpated adjacent desert tortoise populations. Any translocation sites should be isolated by a desert tortoise barrier fence or similar barrier next to the highway or road. The purpose of fencing the highway is obvious—to keep translocated animals from being crushed by vehicles on the road. However, fencing the other sides of the translocation area is critical for establishment. If a fenced area or strip of habitat approximately 0.125 to 0.25 mile wide is established along highways, some translocatees should establish home ranges and a social structure within this strip. When the inside fence is removed, the translocated desert tortoises and those from the extant population farther away from the road will eventually expand their home ranges into the remaining low-density areas. A second reason for inside fencing is to prevent any diseased, but asymptomatic, desert tortoises from infecting nearby, healthy populations. In the event that disease is an issue and a resident population is present nearby, double inside fencing should be considered."

- Guideline 7 appears to address two topics. The first topic (monitoring residents) should be the focus of an experiment and not a criterion for all. As with guideline 6, the conditions of this monitoring should be guided by the experimental design for each specific translocation project.

  The second part of this guideline seems overly specific and speculative. While it is true that habitat reclaimed by fencing of major highways could provide receptive habitat, it is unknown if the threats associated with traffic are alleviated by fencing. For example, are tortoises affected by air pollution from traffic, or are raven populations artificially elevated near highways due to the presence of trash, and other animals killed on the road? Until these and other questions are answered the conditions of this guideline may constitute a sound research suggestion not a routine guideline.

"If Einstein had to go through all that is necessary to do science today, who knows what 'e' would equal."

President Josiah Bartlett, *West Wing*. (2003)

3. Distinct Population Segments

3.1 Definition and intentions of Distinct Population Segments

Given the Endangered Species Act's definition of "species" to include "any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature," the 1994 Recovery Plan identified six recovery units of the Mojave population of the desert tortoise. These recovery units were identified under the concept of evolutionary significant units (ESU), as described by Waples (1991) and Ryder (1986), but a specific policy on how distinct population segments (DPS) would be defined and applied would only be formally proposed six months after the publication of the Plan (USFWS and National Oceanic and Atmospheric Administration 1994). A final policy was published in 1996 (USFWS and National Marine Fisheries Service [NFMS] 1996).

Two issues arise from the identification of recovery units as DPSs or ESUs prior to a final DPS policy. First, the current policy identifies specific criteria that must be met in defining a DPS. The current recovery units need to be evaluated in light of these criteria. Second, the Recovery Plan stated that each recovery unit, considered to be separate DPSs, may be individually delisted upon meeting the recovery criteria listed in the Plan. However, DPSs must be designated through a formal listing (or delisting) process. Because the tortoise was listed as a single population throughout the Mojave Desert (USFWS 1990), recovery units may not now be individually delisted without formal DPS designation. This chapter addresses these two issues.

3.1.1 Background

USFWS and NFMS (1996) defined DPSs based upon three elements for recognizing individual sub-populations of a single species for differential protection under the Endangered Species Act (ESA):

(1) **discreteness** of the population segment in relation to the remainder of the species to which it belongs,

(2) **significance** of the DPS relative to the species to which it belongs, and

(3) **conservation status** of the population in relation to the ESA standard for listing.

The criterion of discreteness must be satisfied as prerequisite to recognizing both the physical existence (= geographical reality) and the biological/conservation significance (criteria #2 and 3) of a proposed DPS. The Congressional intent of the DPS provision of the ESA was that "the interests of conserving genetic diversity would not be well served by efforts directed at either well-defined but insignificant units or entities believed to be significant but around which boundaries cannot be recognized" (U.S. Court of Appeals, Ninth Circuit 2003).

DPSs and ESUs were until 1994 largely equated with one another and are still treated as synonyms by NMFS. Since 1994, ESU has become much more narrowly defined in the

discipline of comparative biology, where it is most often used. Typically, ESU refers to conspecific populations that are distinguishable by substantial and mutually monophyletic differences in their mitochondrial or nuclear DNA sequences (Moritz 1994, 2002; see also its use by Avise 2000), differences sufficient to reflect past geographical isolation by "vicariance events" (Berry et al. 2002). Currently only NMFS still utilizes a narrow, genetic definition to designate DPS status, most prominently for salmonid fish (Pennock and Dimmick 1997) and fresh water mussels (Nammack 1998). For most taxa, both Services apply the much broader definition of DPS, provided above, for reasons reviewed by Pennock and Dimmick (1997). In terms of legal policy, agency and court precedence, and practicality, it is the broader definition of DPS that is particularly appropriate for defining subdivisions of the desert tortoise (Berry et al. 2002). Regardless of the historical divergence of ESU from the broader DPS, these concepts share a common objective of conserving genetic diversity and divergent evolutionary trajectories, whether these trajectories are demonstrated specifically through DNA (ESU *sensu stricto*) or inferred through both direct and indirect evidence (DPS *sensu lato*). In some sense, these units replace the poorly defined and highly subjective anachronism of subspecies (Frost and Hillis 1990, Frost et al. 1992). Influenced in part by the traditional use of morphology, and more recently genetics, in defining subspecies, USFWS and NMFS cite the use of these lines of evidence as appropriate parameters by which to define DPSs. However, these criteria were not to exclude other important information.

The expressed Congressional intent was that differential protection of DPSs be applied "sparingly" to avoid important losses of genetic diversity. While genetics is generally recognized as the primary determinant of distinction, the definition and precedent use of DPSs for the ESA allows genetic, and by extension, evolutionary significance, to be inferred from other parameters. Even compelling differences in conservation status among subdivisions of a species may be invoked both to define and justify a DPS (e.g., differential conservation across international boundaries).

Difficulties in the application of the term DPS largely hinge on the following questions.

(1) What degree of genetic/evolutionary distinctness, either demonstrated or inferred, justifies DPS designation for a specific spatial entity as "discrete"?

(2) What degree of ecological or behavioral differentiation, conservation status, and/or internal homogeneity would make a DPS significant?

(3) To what extent do our existing databases for the desert tortoise subpopulations north and west of the Colorado River make it possible to discern distinctness and document both ecological significance and conservation status?

3.1.2 Discreteness

Resolution of the issue of discreteness is the first requirement in the justification of a DPS. A population may be considered discrete if 1) it is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors, which may be evidenced by genetics or morphology, or 2) it is delimited by international boundaries within which significant differences in control of

exploitation, management of habitat, conservation status, or regulatory mechanisms exist (USFWS and NFMS 1996). Determining discreteness is intrinsically challenging, because it involves diverse criteria, subjective judgments about degrees of distinctness, and a perspective from comparative biology that places discreteness in context of its particular taxonomic unit. The difficulty of determining distinctness has been exacerbated by the historical commingling of terms like DPS, ESU, and Recovery Unit as in the 1994 Recovery Plan (Pennock and Dimmick 1997, Berry et al. 2002). Furthermore only core areas of most DPSs are resolved by current databases; discrete borders of DPSs are less easily delineated (see McLuckie et al. (1999) for illustration of the complexity of even using the Colorado River as boundary).

Discreteness traditionally has referred to reproductive isolation from other conspecific population units (Nammack 1998). Yet, by definition, DPS units are recognized as conspecific, so reproductive isolation may be less than complete reproductive incompatibility. Reproductive isolation may be based on geographical, ecological, physiological, or behavioral difference(s), and quantitative genetics or morphology may be used as evidence of such difference(s). Although quantitative genetics is an arbiter to assist determination of discreteness (e.g., Spidle et al. 2003), other evidence of reproductive isolation may be considered (e.g., Haig et al. 2002), especially in the context of current policy definition of DPS. In the case of the desert tortoise, quantitative biochemical/genetic information is available (Rainboth et al. 1989, Britten et al. 1997, Lamb and Lydehard 1994, and McLuckie et al. 1999), and it should be used as the primary database.

A second obvious source of comparative data is morphology. Morphological/meristic differences are traditional tools of taxonomists. Indeed, virtually all chelonian species and subspecies have been defined almost exclusively in terms of morphology. Such evidence may be misleading, especially at the subspecies level, particularly given the susceptibility of tortoise shell ontogeny to environmental factors (e.g., diet, seasonality, temperature regimes, etc., see Berry et al. 2002 and Jackson et al. 1976) that are not heritable. If, however, reproductive isolation is not detected because of incompleteness of genetic or morphological sampling, recentness of the isolating mechanism, anthropogenic translocations of individuals, or other reasons, then a case may be made for (1) additional quantitative genetic sampling in specific locations and/or (2) recognition of a DPS based on other criteria. However, such designations would be difficult justify, because they would require extensive knowledge of organism-environment interactions (actually it might well require more knowledge than we are able to obtain within the foreseeable future).

The more generous definition in current use by USFWS (Pennock and Dimmick 1997) conveys “discreteness” to DPS units using criteria that would not justify discreteness in a literal evolutionary sense, but which are very relevant both to the conservation of species like the desert tortoise, in particular. Examples include recognizing populations fragmented or isolated by international boundaries and those demonstrating marked physical, physiological, ecological, or behavioral differences. Behavioral and ecological differences among populations may be used both to infer genetic/reproductive isolation

and to establish the ecological significance of a proposed DPS, but the two concepts are so intertwined that they will be discussed together in the following section.

In most cases, only DPS core areas may be defined but their boundaries are rarely discerned. Both spatially inadequate and genetically incomplete sampling precludes the resolution of such boundaries. This task needs to be addressed for many reasons, but especially when new DPS units are being subdivided from old, or when a pre-existing unit is subsumed into another.

3.1.3 Significance

Ecological and behavioral criteria need to be considered under the current definition of DPS. Genetic evidence generally comes from small samples of the genome of the species, and phenotypic differences in ecology and behavior also can provide evidence of genetic distinctness. Ecological differences help establish the "significance" of differences among populations. Thus, if a sub-population already has been demonstrated to be genetically "distinct," when should it be considered ecologically "significant"? The USFWS and NFMS (1996) determine the significance of a discrete population by considering the following non-exclusive factors.

(a) Persistence of the discrete population segment in an ecological setting unique or unusual for the taxon.

(b) Evidence that loss of the discrete population segment would result in a gap in the range of a taxon.

(c) Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range.

(d) Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

A "significant" subdivision refers to evolutionary legacy. Thus, a DPS should either represent an independent component in the evolution of the species (Nammack 1998) or an irreplaceable component in the conservation of the species in its full diversity (Pennock and Dimmick 1997).

What would be convincing ecological evidence that a DPS represents an independent evolutionary component or irreplaceable component in the conservation of a species? We propose that an important piece of evidence would be a difference in life history trait(s) such that individuals in the putative DPS may be affected differently from individuals elsewhere when faced with the same threat(s) to population persistence. Unfortunately, this criterion is not independent of existing threat(s) because data prior to the existence of threats are lacking. Thus, a more tractable criterion might be difference(s) in life history trait(s) such that individuals in the putative DPS may be affected differently from individuals elsewhere when faced with new threat(s).

Life history traits are adaptations influencing survivorship and reproduction. These adaptations include age and size at reproductive maturity, length of reproductive life, clutch size and size of hatchlings, number of clutches per year, sex ratios, mating systems and sperm storage, etc. Differences in these traits are the result of selection in different environments. Thus, life-history theory predicts that when stochastic selective pressures differentially select against young tortoises, then there should be life-history adaptations to increase the length of reproductive life of adults. Alternatively, when stochastic selective pressures differentially select against adult tortoises, then there should life-history adaptations to produce larger clutches of eggs. When there are differences in life histories among populations, and when there are threats to a sensitive species, then the adaptations to environments can be inadequately matched to environments. Thus, the life-history traits most likely to contribute to the evolutionary independence of a sub-population are those that reflect the adaptation to place and contribute to ecological success.

Sometimes an understanding of these important life-history traits can be captured with a small number of population-level attributes. For example, age-specific mortality rates, clutch size and number of clutches each year, bodily growth rate, body size at reproductive maturity, and primary and secondary sex ratios (e.g., Tanner 1978). More recently, ecologists have been able to infer much of importance in ecological attributes contributing to the evolutionary independence of a sub-population from genetics, dispersion and dispersal, and size and arrangement of habitat patches (see Krebs 1994 and Ricklefs and Miller 1999). A fundamental list of population-level attributes for monitoring species recovery would be very similar and include population size, demographic rates, mode of reproduction, and age at sexual maturity (e.g., Hoekstra et al. 2002).

Even though the information needed to understand the basic ecology of a species is reasonably clear, lack of knowledge about the basic biology of rare species often plagues recovery plans (Tear et al. 1993, Schemske et al. 1994, Crouse et al. 2002). While such information is largely lacking or inadequate to characterize existing DPS units within the threatened Mojave tortoise population, a robust set of life-history characteristics, both stable and pronounced in their differences, distinguish the Mojave desert tortoise from its counterpart in the Sonoran desert. The degree of isolation between populations east and west of the Colorado River correlates well with parallel genetic data used to separate the two currently conspecific groups of populations (Lamb and McLuckie 2002). For this reason, we do not entirely discount the eventual discovery of similar, if less pronounced, life history differences within Mojave tortoise populations.

With the list of important population-level attributes in hand, we are in a position to develop a hierarchy of ecological evidence that can be used to determine if a putative DPS actually represents an independent evolutionary component. A suggested list follows, arranged from the most- to the least-convincing evidence.

Direct Life-History Measures:

(a) survivorship
(b) fecundity (clutch size and frequency)
(c) dispersion rates
(d) seasonality of mating and hormonal cycles
(e) size at reproductive maturity
(f) bodily growth rate and sex ratio

Ecological/Demographic Indicators:

(a) age distribution/size distribution
(b) population growth rate
(c) sex ratio/mating system
(d) age at sexual maturity/generation time
(e) reproductive value (per age class)
(d) body size/number of clutches/timing of reproduction
(e) population density

Possible Environmental Correlates:

(a) vegetation – both for diet/shelter
(b) rainfall
(c) soils
(d) burrow size, shape, and orientation; hibernacula
(e) other habitat variables (slope, proximity to ephemeral water channels, etc.)

At least three caveats accompany this list. (1) Short- and long-term variability in any of these measures, indicators, or correlates could be important in concert with each other or independently. (2) It is not likely that direct demographic measures will be available from throughout a putative DPS, so establishing boundaries may require use of indicators and correlates, once their relationships to direct demographic measures have been established. Likewise, the establishment of long-term (10-20 year) study sites could verify correlates (they could even serve to ”ground truth” remote sensing inferences). (3) Standard statistical techniques can be used to establish significant differences in any of these measures, indicators, or correlates between locations.

3.1.4 Conservation Status

The conservation status of the species, as measured by the five listing factors identified in Section 4 of the ESA, provides final justification for its legal protection as a discrete and significant entity (i.e., DPS). Particularly germane to desert tortoise populations, so many of which are differentially affected by upper respiratory tract disease and other health threats, is the fact that health status should be used to recognize an individual population as discrete and significant (Pennock and Dimmick 1997).

The emphasis on threat(s) is further re-enforced by recent evaluations of recovery plans. These evaluations have led to several recommendations for improving the use of science in recovery plans (Clark et al. 2002). These recommendations include: (1) make threats a primary focus, (2) specify monitoring tasks for species status and recovery tasks, (3) ensure that species status-trend data are current, quantitative, and documented.

3.2 DPSs of the Desert Tortoise

3.2.1 Reappraisal of 1994 Recovery Units

The 1994 Recovery Plan identified six Recovery Units (Fig. 3.1): Northern Colorado, Eastern Colorado, Upper Virgin River, Eastern Mojave, Northeastern Mojave, and Western Mojave. The current Recovery Units represent appropriate hypotheses of discreteness. Certainly all of the Desert Wildlife Management Areas (DWMAs) within these recovery units are valuable to the conservation of the desert tortoise. However, each of the Recovery Units must be reviewed under the more current and elaborate definition of DPS provided above.

How well justified are these recovery units in terms of modern application of DPSs: should some be split, merged, or eliminated? At the species-wide scale, major differences in genetics, morphology, ecology, and behavior separate Mojave, Sonoran, and Sinaloan assemblages of the tortoise (Woodbury and Hardy 1948, Burge 1977, Jennings 1985, Turner et al. 1986, Weinstein and Berry 1987, Lamb et al. 1989, Glenn et al. 1990, Germano 1993, Lamb and Lydehard 1994, Wallis et al. 1999, Averill-Murray et al. 2002a, Averill-Murray et al. 2002b, Averill-Murray 2002a,). These major genetic assemblages were resolved with a parsimony approach, using relative mitochondrial DNA differences exhibited by the other North American tortoise species (Lamb et al. 1989). Recognizably different shell morphology between populations east and west of the Colorado River corresponds to the two described assemblages north of Mexico (Weinstein and Berry 1987). Each assemblage occupies a unique ecological setting (Berry et al. 2002). There is overwhelming support from several facets of science, which point to a clear separation between the Mojave and Sonoran assemblages of the desert tortoise. Within the Mojave assemblage, finer-scale genetic, morphological, ecological, and behavioral differentiation has been acknowledged in the Desert Tortoise Recovery Plan (USFWS 1994).

The Western Mojave, Eastern Colorado, Northern Colorado, and the eastern end of the Eastern Mojave recovery units have poor justification as separate DPSs from each other, despite the geographical importance of their DWMAs, based on current genetic data (Lamb et al. 1989). Currently, the Eastern Mojave Unit combines distinctive California and Nevada haplotypes. We expect the Western Mojave Recovery Unit to be genetically discrete from other units, but additional research needs to be conducted to confirm genetic differences. Tortoises in the western Mojave Desert produce relatively larger eggs, produce fewer eggs overall, and lay their second clutches later than tortoises in the adjacent eastern Mojave Desert (Wallis et al. 1999). Behaviorally, western Mojave

tortoises are much less active during summer than in other recovery units. Extremely winter-dominant rainfall and resultant effects on the vegetation community, as well as its position on the western end of the distribution, contribute to the significance of this recovery unit (USFWS 1994). Furthermore, range reduction already observed at the western edge of the species' distribution (Bureau of Land Management et al. 2003, Map 3-10) contributes to the significance of this putative DPS on the basis of the gap in the range that would be created by the loss of the DPS if not recovered.

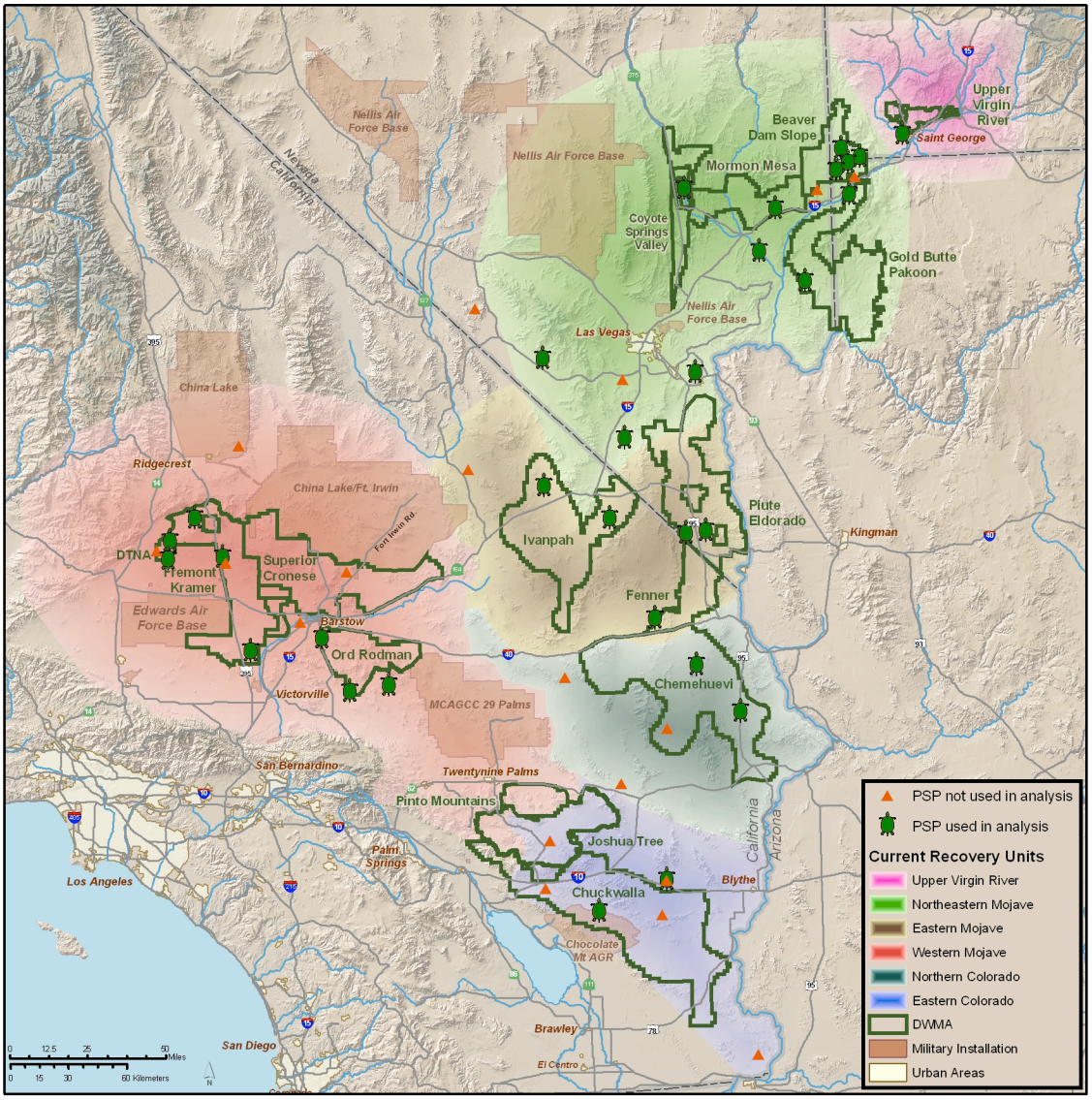

Fig. 3.1. Depiction of recovery units proposed in the 1994 Recovery Plan. Green outlines within the recovery units are proposed DWMAs.

The entire complex east of the Baker Sink needs more data and analyses, as well as comprehensive reevaluation in terms of genetic diversity and ecological geographic boundaries. An attractive division line for the Western Mojave Recovery Unit runs along a line from Saline Valley in California in the north, then south through Death Valley, Silurian Valley, Baker Sink, and Cadiz Valley. It is particularly attractive because the lower elevations and extremely hot climates along this line divides the ecological western Mojave Desert with its quite variable winter-spring precipitation regime, lower elevations, and Mojave River hydrology, from the more eastern Mojave Desert, subject to more predictable winter and summer monsoon precipitation, more variable elevations, and closed basin and Colorado River hydrology. Rainfall pattern differences (Fig. 3.2) induce profound vegetation differences, forage, and possibly reproductive differences (seasonality of mating, egg clutch size, frequency, and timing). Furthermore, rainfall differences create the potential for different interactions among threats (Section 5).

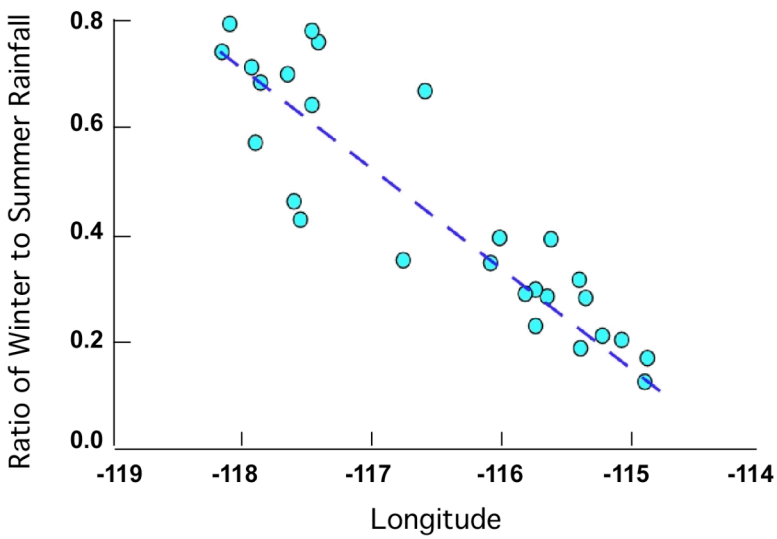

Fig. 3.2. Ratio of rainfall in winter compared to summer in the Mojave Desert. Weather stations, and the longitudes for those stations, are given in the table.

Station	Latitude
Adelanto	117.4167
Apple Valley	117.2167
Barstow	117.0333
Cantil	117.9667
China Lake	117.6833
El Mirage	117.6333
Hesperia	117.3000
Inyokern	117.8167
Lucerne Valley	116.9500
Mojave	118.1667
Randsburg	117.6500
Trona	117.3833
Victorville	117.3000
Boulder City	114.8500
DNWLR	115.3667
Dunn Siding	116.4333
Kyle Canyon	115.6000
Las Vegas	115.1500
Little Red Rock	115.4167
Mitchell Caverns	115.5500
Mountain Pass	115.5500
North Las Vegas	115.1167
Red Rock Canyon	115.4667
Searchlight	114.9167
Sunrise Manor LV	115.0833

While life history patterns and strategies should be expected to differ in tortoise populations east and west of the Baker sink, they have not yet been demonstrated other than for aspects of reproductive ecology noted above between sites in the Western and Eastern Mojave Desert Recovery Units. Tortoises are rare in the lowlands comprising this division, yet they are not entirely absent. Furthermore, neither allozyme nor mitochondrial comparisons yet support differentiation across this axis of potential separation (Rainboth et al. 1989, Lamb and Lydehard 1994).

The western ends of each of the Northeastern Mojave and Eastern Mojave recovery units are indistinguishable genetically (Lamb et al. 1989, Britten et al. 1997). On the other hand, the eastern end of the Northeastern Mojave Recovery Unit falls out genetically distinct from the western end of this unit (Britten et al. 1997). A distinct shell phenotype occurs in the Beaver Dam Slope region of this unit (USFWS 1994).

While we expect that significant differences in genetics and morphology exist, additional study is needed to quantify differences between the Upper Virgin River Recovery Unit and the Northeastern Mojave Recovery Unit (Berry et al. 2002). The Upper Virgin River Recovery Unit is discrete on the basis of behavioral/ecological factors (USFWS 1994) and also has a unique and unusual vegetation community, topography, and soil type (USFWS 1994). Loss of this unit would result in a gap at the northeastern extent of the species' distribution.

3.2.2 Provisional Revised List of DPSs

We offer here a provisional recognition of a new set of DPS units (Fig. 3.3): Upper Virgin River Desert, Lower Virgin River Desert, Northeastern Mojave Desert (including Amargosa Valley, Ivanpah Valley, and Shadow Valley), East Mojave and Colorado Desert, and Western Mojave Desert. These include two of the original units (Upper Virgin River and Western Mojave) and add or revise four other units, based largely on the best resolving biochemical/genetic data of Rainboth et al. (1989), Lamb et al. (1989), Lamb and Lydehard (1994), and Britten et al. (1997). We do not consider these divisions definitive. These suggested revisions will require more data and analyses, as well as evaluation and expansion of the analyses of Britten et al. (1997), and may result in additional modification. Prior genetic studies pertinent to the foregoing case and others are largely piecemeal, confined to mtDNA, or limited to allozyme or morphological data. They provide us with little insight with regards to gene flow or discrete boundaries. Depending on the outcome of future studies, various DWMAs could be reassigned to different DPSs than currently proposed. In addition, we note that our provisional recommendations leave a single DWMA within the revised Northeastern Mojave Desert DPS, without specific habitat protection throughout the northern half of this segment. All of the DWMAs/critical habitat units remain well justified to sustain survival of *G. agassizii*: it is only their assignment to particular DPSs that concerns us.

Although we recommend that additional data be collected to refine or revise these proposed DPSs, the evidence for particular DPS designation does not need to be absolute and incontrovertible. Note that an agency must have discretion to rely on the reasonable

opinions of its own qualified experts even if a court might find contrary views more persuasive. Courts, however, must set aside agency actions that are arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law. The standard for reversal of an agency action is if the agency has "relied on factors which Congress has not intended it to consider, entirely failed to consider an important aspect of the problem, offered an explanation for its decision that runs counter to the evidence before the agency, or is so implausible that it could not be ascribed to difference in view or the product of agency expertise" (U.S. Court of Appeals, Ninth Circuit 2003). Note also "the fact that the evidence is weak, and thus not dispositive, does not render the agency's determination arbitrary and capricious" (U.S. Court of Appeals, Ninth Circuit 2003).

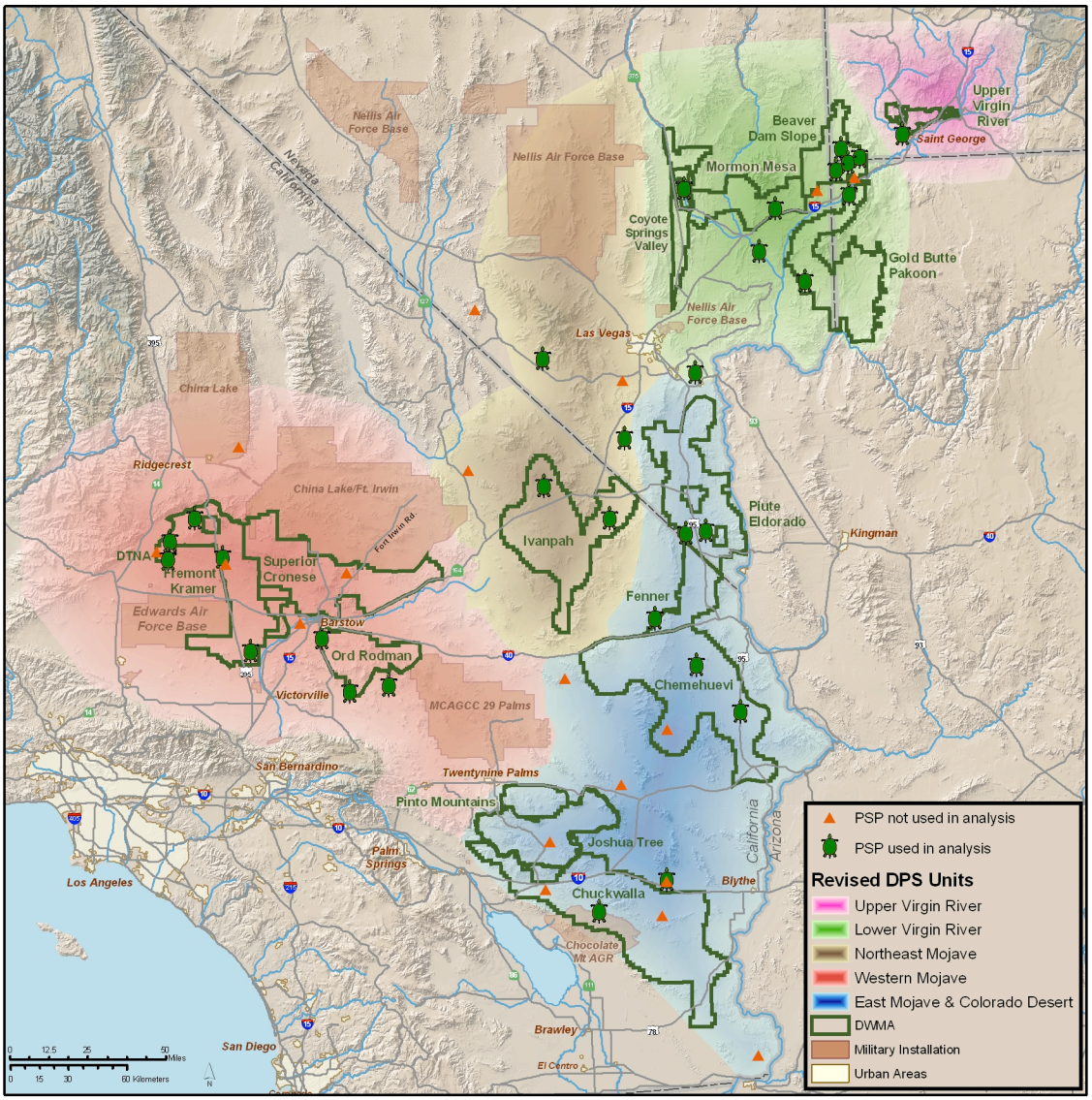

Fig. 3.3 Map of the proposed distinct population segments for desert tortoise.

DPS Recommendations

We recognize that DPSs may not officially be designated in a recovery plan, but revision of the 1994 Plan should lay sufficient groundwork so that DPSs may be formally proposed in future delisting proposals as delisting criteria are met for each DPS (e.g., USFWS 2003). Future revisions will need to respond to the three criteria by which modern DPS units are defined: discreteness, significance, and conservation status. The mechanisms are as follows:

- Genetic core units need to be assessed using both nuclear and mitochondrial genes (Berry et al. 2002).

- The genetic boundaries and gene flow among units need to be critically examined.

- Once these data are available, ecological, morphological, and behavioral attributes should be assigned to each of these genetic units. Correlations should be evaluated among established genetic units and carefully quantified and standardized ecological affinities, health status, life history patterns, and stereotypic behaviors.

- The natural history of host-parasite associations for the major disease relationships for desert tortoise should be more deeply elucidated, including the genetics of hosts and strains of pathogens.

- At least three disparate, long-term study sites should be established within each proposed DPS to verify the reality, consistency, homogeneity, and variability of these defining traits.

- DWMAs within each DPS should be geographically revised to maximize their conservation potential in consultation with ecologists and local resource administrators including the USFWS for coordinating recovery efforts range wide.

"An experiment is a question which science poses to Nature, and a measurement is the recording of Nature's answer."

Max Planck, *Scientific Autobiography and Other Papers*. (1949)

4. Status and Trends

4.1 Recovery Plan Implementation

The Recovery Plan identified specific management actions for each DWMA to address perceived threats identified during the listing of and recovery planning for the desert tortoise. If sheer numbers of threats are used as an indication of threatened status, all but the Chuckwalla DWMA have seen increased numbers in the intervening years between 1994 and 2003 (Fig. 4.1 and 4.2).

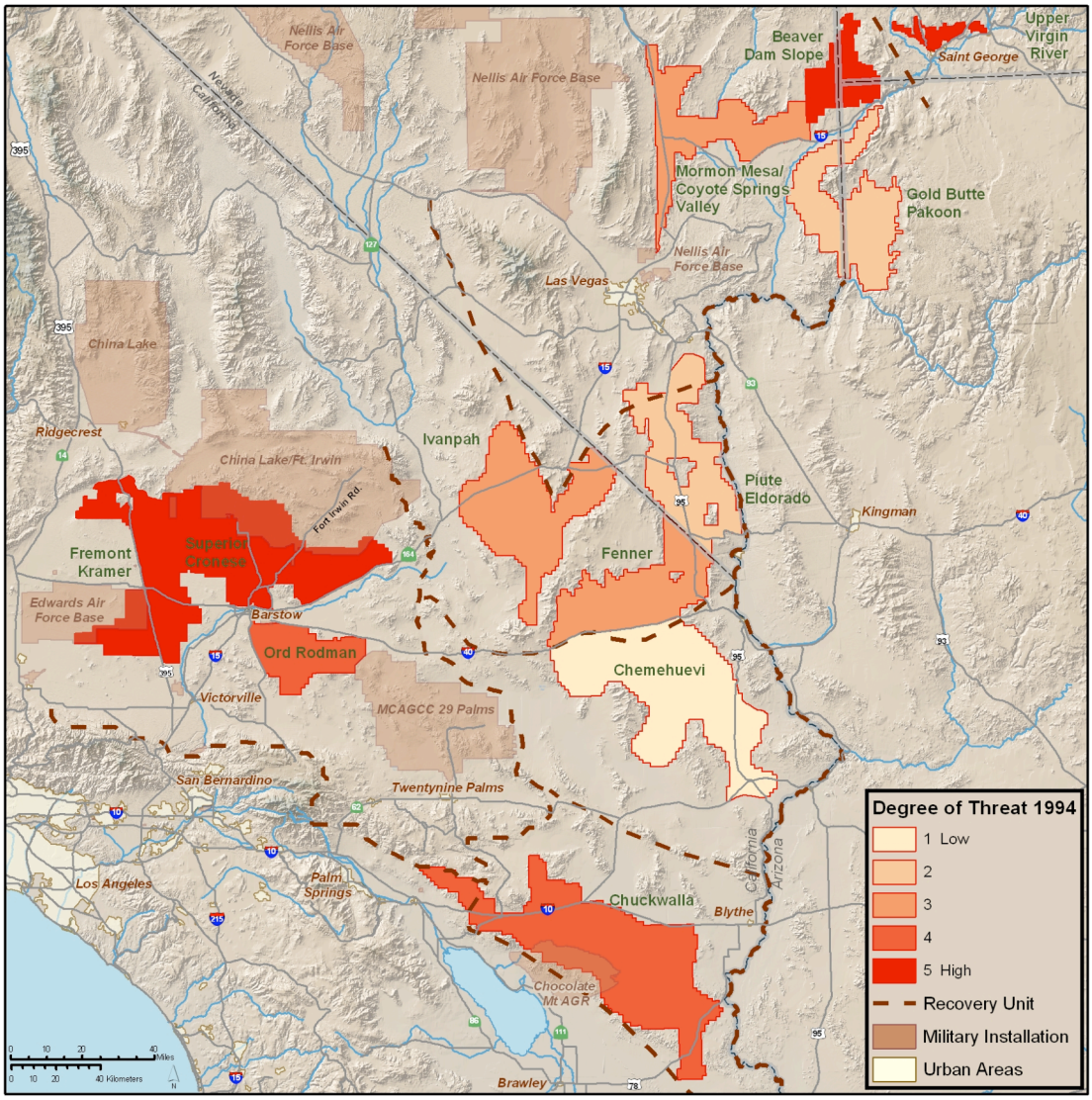

Fig. 4.1 Relative number of threats to desert tortoises in each critical habitat unit (i.e., DWMA), as identified by the Recovery Plan in 1994.

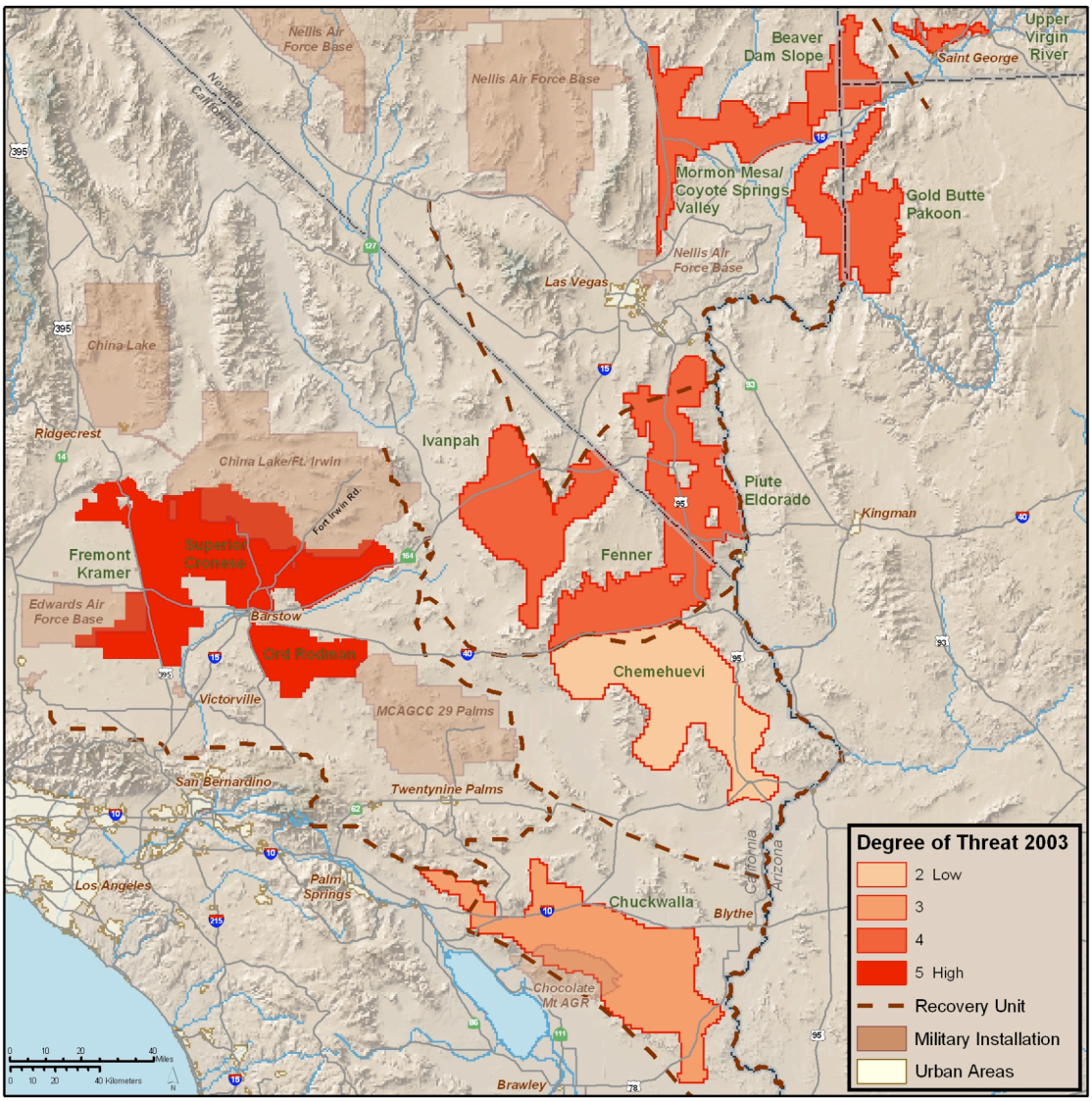

Fig. 4.2 Relative number of threats to desert tortoises in each critical habitat unit (i.e., DWMA), as identified by the Desert Tortoise Management Oversight Group in 2003.

In answer to these threats the Recovery Plan recommended a number of management actions per DWMA. The relative numbers of recommended management actions are illustrated in Fig. 4.3. In 2002 land and wildlife management agencies responded to a questionnaire from the USFWS to document implementation of the Plan (Redlands Institute 2002a- 2002f). Survey responses were not specific enough to quantify the level of implementation for specific actions. Therefore, we did not attempt to interpret the degree to which agencies actually implemented each action, only whether some action had been taken. We intend this brief analysis to simply represent a “first-cut” review of the general status of recovery plan implementation without delving into a comprehensive analysis of each recommendation in the Plan.

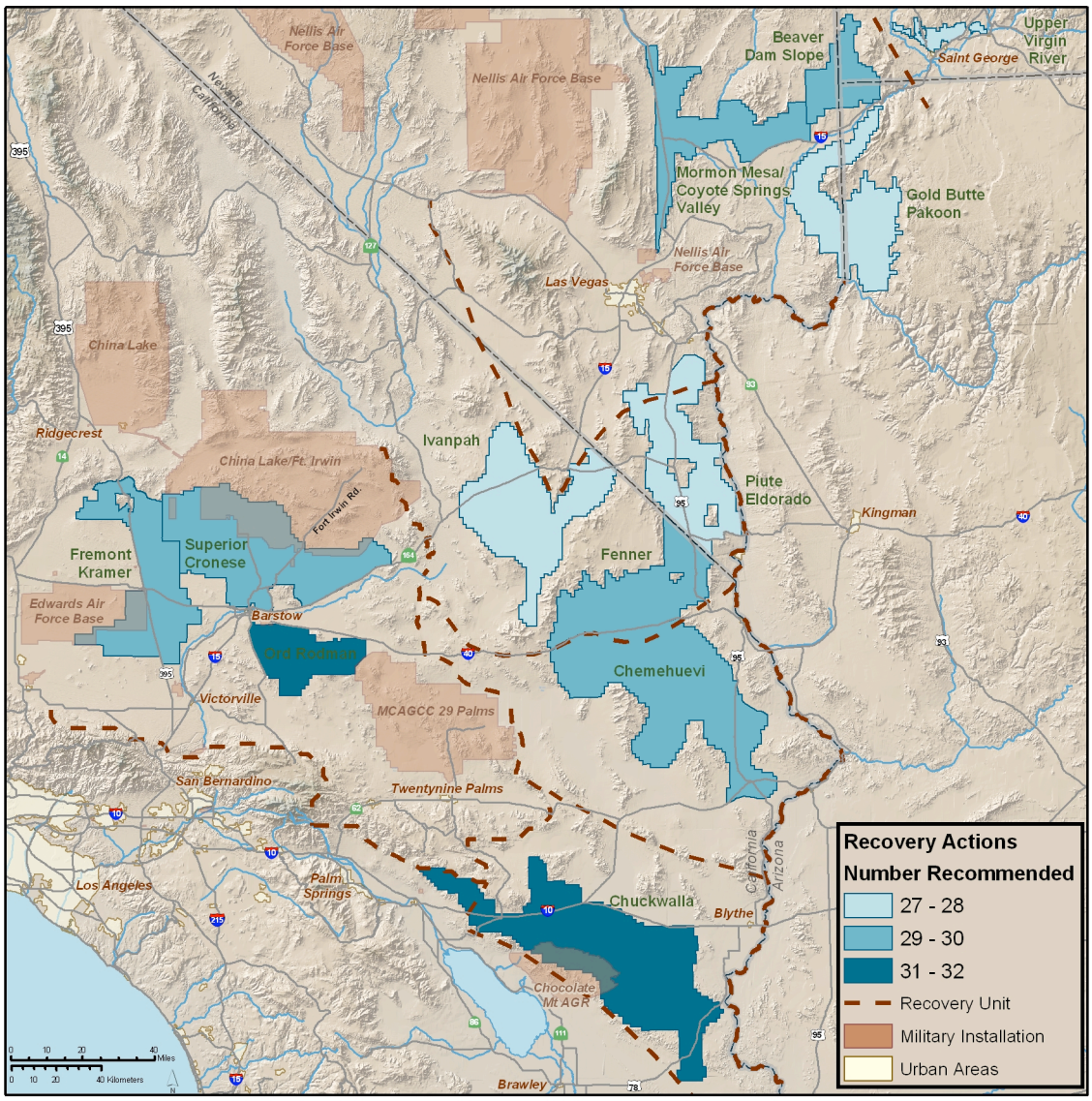

Fig. 4.3 Relative numbers of management actions recommended for each DWMA in the 1994 Recovery Plan.

Based on survey responses in 2002, it *appears* that implementation has been uneven relative to recommended management (Fig. 4.4, Table 4.1). Many reviewers of the prior draft of this report made it clear that they disagreed with the representation of Recovery Plan implementation in Fig. 4.4 and Table 4.1, both by not crediting implementation where it had occurred and by giving credit for implementation where it may have been negligible. Our main conclusion from this survey is not the specific degree to which the Recovery Plan has been implemented in any given area. Rather, it is clear that the USFWS and other management agencies need to better document and quantify recovery efforts recommended in the Recovery Plan or its revision (Section 4.5.1) provides a

specific example of this), because to date the only source of collated and easily accessible information on the degree to which the Plan's management recommendations have been implemented is a questionnaire that inadequately addresses Plan management recommendations.

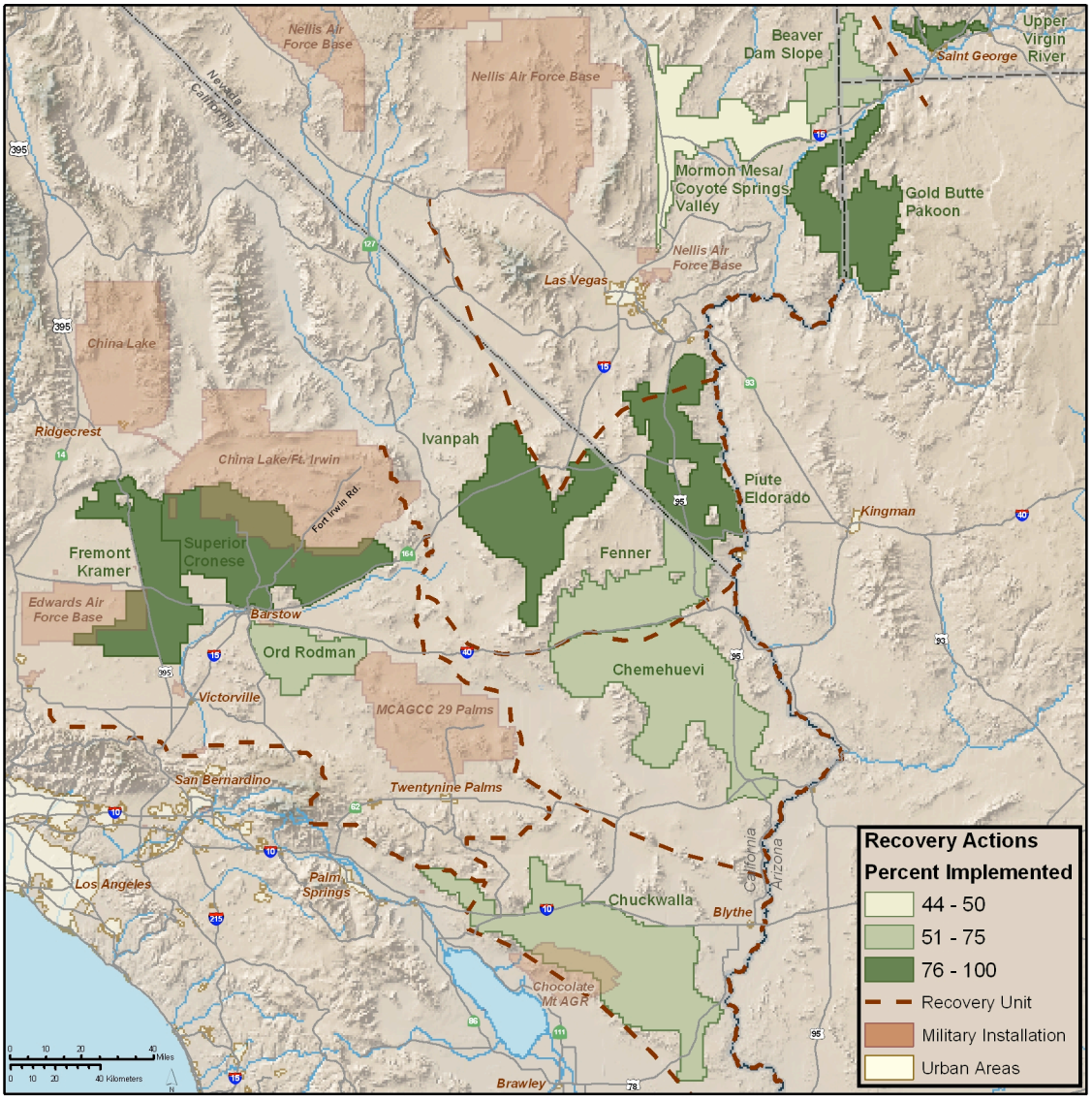

Fig. 4.4 Relative numbers of management actions by DWMA reported to the USFWS that have been at least partially implemented by 2002.

If left to this questionnaire as the only source of information from which to compare range-wide implementation efforts, we would be forced to conclude that little if any implementation has occurred within the western Mojave Desert (Fig. 4.4), even though the Recovery Plan called for a relatively high degree of management in this area (Fig. 4.4). In fact, once again if left to this questionnaire alone, an average of 36% (n = 12;

Coyote Springs Valley is combined with Mormon Mesa and Joshua Tree not included) of the management recommendations per DWMA were not reported as having been implemented as of 2002, ranging from 100% (at least partial) implementation at Upper Virgin River to only 32% implementation at Ord-Rodman (Table 4.1). Only 38% of recommended management actions were reported to be implemented overall in the Western Mojave Recovery Unit, and tortoise populations in this region have shown the most dramatic declines (Section 4.2 or Fig. 4.13).

Recovery Action Review and Implementation Recommendations:

With better planning and implementation of a new questionnaire that specifically addresses Recovery Plan implementation, we will be better able to assess the level of implementation of management recommendations. We offer the following specific recommendations regarding recovery action review and implementation:

- Land managers and policy makers should undertake a coordinated, range-wide effort today, not waiting for the possible formation of a future recovery team, to assess the level to which Plan recommendations have been implemented within each DWMA. This effort should be directly correlated to Recovery Plan management recommendations. Without this effort, it will be impossible to assess the level of Plan implementation and thus objectively assess the reasons why the desert tortoise continues to appear to be declining throughout much of its range.
- At the same time, if a future recovery team is formed, it will be essential that the team review and revise recovery recommendations for each DWMA and/or provisional DPS to ensure that recommended recovery actions address relevant site-specific impacts or threats.
- Most recovery actions should be implemented in an experimental framework (in at least some areas) to determine the effectiveness of those actions. Appropriate response variables (e.g., tortoise numbers or density, reproductive output, nutrition, juvenile survival, etc.) may vary depending on the action. Likewise, the necessary study duration may vary depending on the action and response variable; long-term studies should be expected, given the life history of the tortoise.
- The USFWS and other management agencies should develop a forward-looking, quantitative recovery actions database. Database development should begin during the Recovery Plan revision process with site-specific baseline measures (e.g., miles of authorized/unauthorized roads and trails, number of landfills in a particular DWMA) for each recovery action. Subsequently, agencies should document in the database specific levels of recovery action implementation (e.g., miles of roads closed, number of landfills closed or managed appropriately in a particular DWMA). Lundquist et al. (2002) and Hatch et al. (2002) found that recovery tasks and monitoring were significantly more likely to be implemented for plans with a recovery coordinator or committee and a centralized recovery database.

Table 4.1. Recovery actions listed in the Recovery Plan (and DWMA supplement) reported by management agencies as implemented through 2002 (Redlands Institute (2002a-f). 0 = No Implementation; 1 = Implementation Initiated; blanks indicate actions not applicable to that unit, according to the Recovery Plan.

	Recovery Action	Chemehuevi	Chuckwalla	Upper Virgin River	Fenner	Ivanpah	Piute-Eldorado	Beaver Dam Slope	Gold Butte-Pakoon	Mormon Mesa	Fremont-Kramer	Ord-Rodman	Superior-Cronese
1	Prohibit Vehicles off Roads	1	1	1	1	1	1	1	1	1	0	0	0
2	Prohibit Competitive/Organized Events	1	1	1	1	1	1	1	1	1	0	0	0
3	Prohibit Surface Disturbance	1	1	1	1	1	1	1	1	1	0	0	0
4	Prohibit Grazing	1	1	1	1	1	1	1	1	0	0	0	0
5	Prohibit Burros/Horses	1	1	1	1	1	1	0	1	0	0	0	0
6	Prohibit Vegetation Harvest	1	1	1	1	1	1	1	1	1	0	0	0
7	Prohibit Collection	1	1	1	1	1	1	1	1	1	1	1	1
8	Prohibit Dumping/Littering (+ cleanup)	1	1	1	1	1	1	1	1	0	1	1	1
9	Prohibit Releases	1	1	1	1	1	1	1	1	0	1	1	1
10	Prohibit Uncontrolled Dogs	0	0	1	0	1	1	0	0	0	1	0	0
11	Prohibit Discharge of Firearms	0	0	1	0	0	0	0	0	0	1	0	1
12	Restrict New Roads	0	0	1	0	1	1	1	1	1	0	0	0
13	Close Roads	1	1	1	1	1	1	1	1	0	0	0	0
14	Designate Roads	1	1	1	1	1	1	1	1	1	0	0	0
15	Fence Roads/Install Culverts	0	0	1	0	0	0	1	0	0	1	0	1
16	Law Enforcement	1	1	1	1	1	1	1	1	1	1	1	1
17	Restore Habitat	0	0	1	0	1	1	0	1	0	0	0	0
18	Sign/Fence Boundaries	0	0	1	0	0	1	1	1	0	0	0	0
19	Landfill Management	1	1	1	1	1	1	0	1	1	1	1	1
20	Environmental Education	1	1	1	1	1	1	1	1	1	1	1	1
21	Withdraw Mining	0	0	1	0	0	0	0	0	0	0	0	0
22	DWMA Mgt. Plan	1	1	1	1	1	1	1	1	1	0	0	0
23	Secure Non-federal Lands/Habitat	1	1	1	1	1	1	0	0	0	1	1	1
24	Halt Unauthorized ORV Use										0		
25	Halt Vandalism of Tortoises		0		0	0	0	0		0	0	0	0
26	Install Railroad Barriers/Culverts	0	0		0	0				0	0		
27	Install Aqueduct Barrier	0											
28	Monitor Health of Population	1	1		1	1		1	1		1	1	
29	Evaluate Raven Use		0										
30	Install Urban/Other Barriers			1				0			1	0	
31	Raven Control			1	0		1				1	0	0
32	Distribution/Density Surveys	1	1	1	1	1	1	1	1		1	1	
	% Partially Implemented	67%	64%	100%	64%	78%	85%	67%	80%	44%	47%	32%	36%

4.2 Trend Analyses of Populations

No existing data or analyses are adequate to estimate long term status or trends in (a) desert tortoise populations, (b) habitat for desert tortoises in any recovery unit, and/or (c) threats to tortoise populations regionally. However, we assembled as much data as was possible, within the time constraints for preparing the DTRPAC report, to perform the equivalent of meta-analyses on existing information (Hunter et al. 1982). Our analyses consist of two general approaches: 1) evaluation of long-term trends in the densities of desert tortoises within Recovery Units and within the Distinct Population Segments that are proposed by the DTRPAC, and 2) evaluation of qualitative and quantitative spatial analyses of the presence of live and dead tortoises on transects for (a) "total corrected sign" and (b) distance sampling. These analyses provide insight as to where, within larger management units, tortoises may be doing better or worse than in other areas. The successes of these analyses portend efficacious approaches for exploring data in new and innovative ways that can be terrifically important to the future successes of monitoring programs.

4.2.1 History of Long-Term Study Plots

Long-term permanent study plots were established in California in the early 1970's as part of an inventory of Bureau of Land Management (BLM) resources (Berry 1984). Permanent study plots were also established in Arizona, Nevada, and Utah (Fig. 4.5). These plots originally were established to generate data on demography and population trends as well as ecological relationships with abiotic and biotic factors (Berry 1984). Various methods were used to assess population size in the initial surveys on those plots (e.g., 30-day spring surveys, 20-day fall surveys, and winter den surveys), but eventually a standard method became a 60-day spring survey of a one square mile plot. In this protocol, survey effort was divided into two periods of roughly equal times (capture and recapture periods). Tortoise density has been estimated using the Lincoln-Peterson calculation (Turner and Berry 1984); analyses for most plots limit abundance estimation to tortoises $\geq$180 mm MCL, due to reduced capture probabilities for smaller tortoises, but abundance of tortoises of all sizes on California plots is often estimated with a stratified Lincoln Index (Overton 1971). Additional data collected on study plots include health profiles, burrow or cover characteristics, tortoise size, information on carcasses, and vegetation on the plots. Few of these latter data have been analyzed beyond descriptive summaries.

Plots typically were located on public lands and in areas containing "adequate tortoise densities for sampling," sometimes explicitly where many tortoises had been reported; however, some plots were originally located in areas where strip-transect surveys had previously documented little or no tortoise sign (Berry 1984). Plots were located in areas generally considered to have been the least disturbed "representative habitats" within the desert ecosystems (e.g., Mojave Desert, Colorado Desert, etc.). Several plots on which few tortoises were found have been discontinued (K.H. Berry, pers. comm. 2003). Sixty-day plot surveys began in California in the early 1970's, in Nevada and Utah in 1981, and in Arizona in 1987. Only a small subset of the plots has been surveyed in any one year, and fixed survey intervals have not been maintained (Table 4.2).

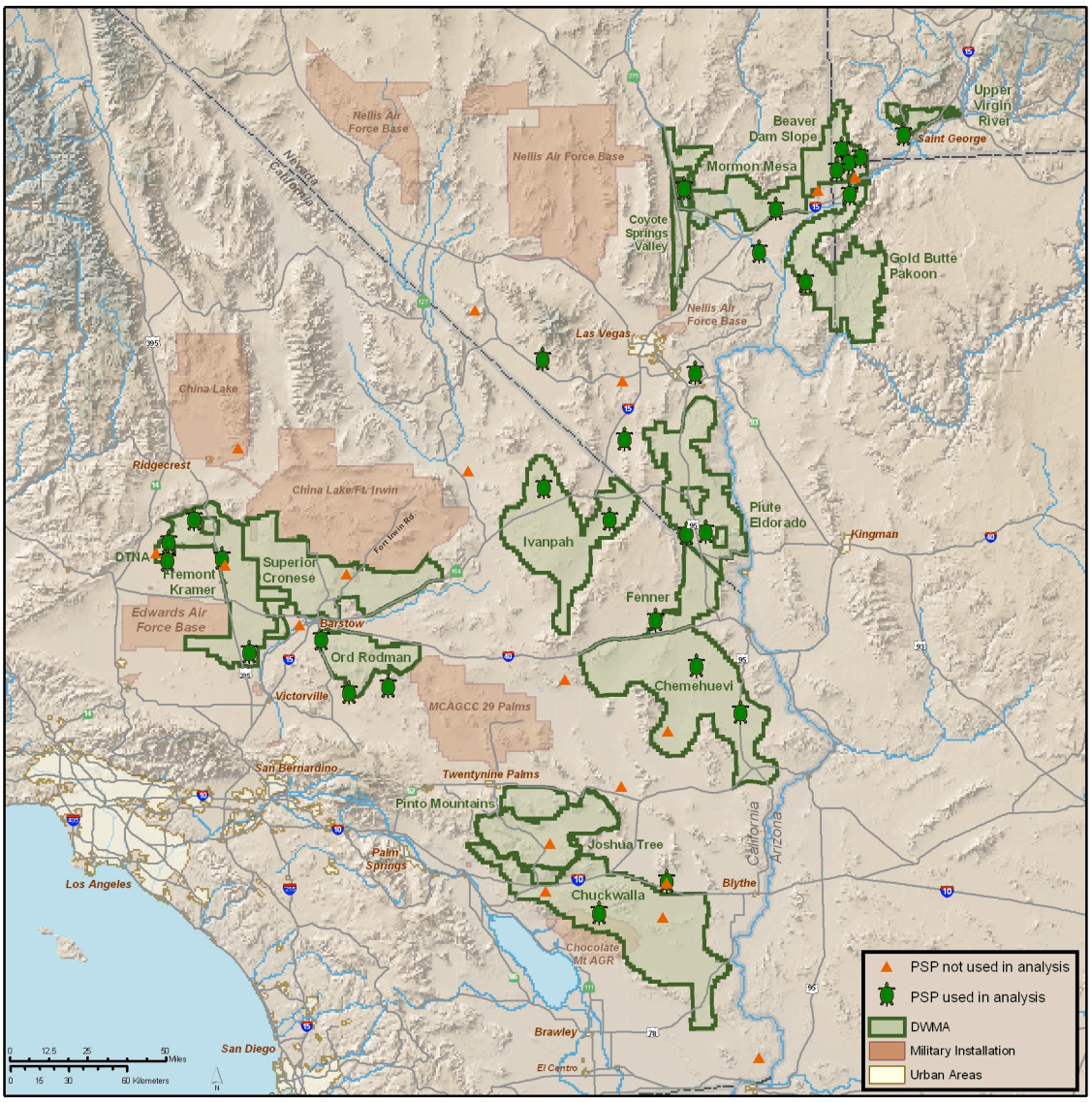

Fig. 4.5 Locations of desert tortoise permanent study plots within the federally listed range of desert tortoises in the southwestern United States.

Permanent study plot data were used to give the committee some insight into the range-wide status of tortoises over the most recent two decades. Density estimates and confidence limits for those estimates were collected from published literature, reports, and from personal communications with researchers who supervised surveys of the permanent study plots within the listed range of the desert tortoise from 1979 to 2002 (Table 4.2). Not all plots were sampled in all years, and not all data were calculated or obtainable for plots that were sampled in some years (Table 4.2).

Table 4.2 Years surveyed on permanent study plots for desert tortoises. A number (0 or 1) indicates that data were taken at this plot. A zero indicates that the data are not available or sufficient for analysis, and a one indicates that data were available for analyses in this report.

Study Site	State	71/72	76/77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
Southern Argus	CA	0																											
Fremont Valley	CA		0		0		1						1				1										1		
DTNA (interior)	CA				1			1						1				1				1						1	
DTNA (inter. Center)	CA				1						1				1				1				0					0	
Fremont Peak	CA		1			1					1				1				1										
Kramer Hills	CA					1		1					1				1				1								
Stoddard Valley	CA						1						1				1												
Lucerne Valley	CA					1						1				1				1									
Johnson Valley	CA					1						1				1				1									
Shadow Valley	CA			0										1				1										1	
Ivanpah Valley	CA				1							1				1				1								1	
Fenner Valley (Goffs)	CA		0			1			0	0	0	0				1				1						1			
Ward Valley	CA					1							1				1				1							1	
Chemehuevi	CA		0	0	1			1						1				1							0				
Chuckwalla Valley	CA					1							1				1												
Chuckwalla Bench	CA		0	0	1			1						1		1		1				0	1						
Last Chance	NV					0																							
Sheep Mountain	NV				1					1								1			1								
Piute Valley	NV				0				0				1		1					1									
Christmas Tree	NV										1						1			1									
Coyote Spring	NV											1						1			1								
Gold Butte	NV											1				1				1									
Sand Hollow	NV														1					1									
Mormon Mesa	NV														1					1									
Trout Canyon	NV												1					1											
Eldorado Valley	NV																			1									
LMNRA																													
Tassi	NV																					0							
Road 152	NV																				0					0			
Road 149	NV																				0								
Road 60	NV																				0			0					
Road 58	NV																				0		0						0
Road 42	NV																						0				0		
River Mountains	NV																				1		0	1				1	
Pinto Valley	NV																				0								
Overton	NV																					1				1			
Lake Las Vegas	NV																					0							
Grapevine	NV																	1	1	1	0		0	0	0	0			
Government Wash	NV																					0							
Dupont Mine	NV																				0								
Cottonwood	NV																	1	1	1	0	0	0	0	0	0			
Cat Claw	NV																						0						
Bitter Springs	NV																					0	0						0
Pakoon Basin	AZ																0												
Virgin Slope	AZ																	1					1						0
BDS Exclosure	AZ														0							1					0		
Littlefield	AZ												0						0					1				1	
City Creek	UT													1						1									
Woodbury-Hardy	UT						0					1						1						1					
Beaver Dam Slope	UT																1												

Data on population densities on permanent study plots were assembled from numerous sources (Table 4.3). Data from these plots have limits to their value for scientific assessment of status and trends for several reasons. For example, the plots are not random samples of desert tortoise habitat, so extrapolations from them cannot be made. The plots were not sited to address specific hypotheses about management actions so it is not clear to what the contained tortoises are responding. The plots were not censused in the same years, and the timing of measuring the plots makes comparisons among plots of limited value. Detectability of tortoises was never measured which further limits temporal comparisons of status and trends. In spite of the inadequacies of these data, and with some caveats, they can be used to estimate the status and trends of desert tortoise populations with appropriate caution. When the Recovery Plan was assembled, information regarding the status of desert tortoise populations largely depended upon analyses of tortoise densities from permanent study plots. While these data showed that populations experienced significant declines in the western extent of the listed range (i.e., California, see USFWS 1994, Page 4, Fig. 1), no trend in adult densities for the eastern portion was discernable at that time (see USFWS 1994, Appendix C, Page C9, Fig. C4). Interpretations of analyses of data from permanent study plots have been controversial (Corn 1994, Bury and Corn 1995), and new sampling methods were advocated. Permanent study plots continued to be sampled in the years following the publication of the Recovery Plan, and many continue to be sampled. However, many of the study plots in Nevada, and Utah were not sampled beyond ~ 1996, as new methods of density estimation were implemented. Thus, the status of tortoise populations in California, as measured by data taken from study plots, is more current than that from Nevada or Utah. Nevertheless, data beyond those relied upon by the Recovery Team in 1994 are available and are analyzed herein, and those analyses show similar patterns in trends of desert tortoise densities to those published in the 1994 Plan.

Table 4.3 Citations for sources of data used in permanent study plot analyses

Advantage Environmental Consulting. undated (1992)
Bashor, A.N. undated (1991)
Berry, K.H. 1989
Berry, K.H. 1990
Berry. K.H. 1992
Berry. K.H. 1995
Berry, K.H. 1996
Berry, K.H. 1999
Berry, K.H., L.L. Nicholson, S. Juarez, and A.P. Woodman. 1986
Berry, K.H., T. Shields, and C. Knowles. In prep.
Duck, T.A., and E. Schipper. undated (1989)
Duck, T.A., and J.R. Snider. undated (1988)
EnviroPlus Consulting. 1995
EnviroPlus Consulting. 1994
Foreman, L. (pers. comm.)
Fridell, R.A. 1995
Fridell, R.A., and J.A. Shelby. 1996
Fridell, R.A., and M.P. Coffeen. undated (1993)
Fridell, R.A., J.R. Snider, K.M. Comella, and L.D. Lentsch. 1995
Fridell, R.A., M.P. Coffeen, and R. Radant. 1995
Goodlett, G., and P. Woodman 2003
Goodlett, G., M. Walker, and P. Woodman. 1997
Goodlett, G., P. Woodman, M. Walker, and S. Hart. 1996
Haley, R., and M. Boyles (pers. comm.)
K. Berry (pers. comm.)
K. Phillips (pers. comm.)
Longshore, K.M. 2003
Medica, P.A. 1992
Minden, R.L., and S.M. Keller. 1981
Nickolai, J.L., and R.A. Fridell. 1998
P. Medica (pers. comm.)
Rourke, J.W., C. Hillier, J. Merriam, and T.A. Duck. undated (1993)
Turner, F.B., and K.H. Berry. 1985
USFWS, Ventura Office Annual Permit Reports
Woodman, P. 1997

4.2.2 Trends Range-wide (East and West)

Permanent study plots that have been sampled for an extended period, from which data were used in the original Recovery Plan, and can be divided into those in the eastern and western part of the desert tortoise range (Table 4.4), as was done in the original Recovery Plan. When the 1994 Recovery Plan was written, there were documented population declines in the Western Mojave and this downward trend appears unabated (Fig. 4.6). In addition, there is now a guarded concern for populations in the East Mojave (in California), particularly due to a single recent data point at the Goffs site (Fig. 4.6). This concern has highlighted the need for more data to assess the importance of data points that could either be outliers or could be indicators of new trends. In these areas, desert tortoises appear to be affected by various combinations of threats or the cumulative effects of many threats.

Table 4.4 Study plots from which data were used to assess trends in population size in the original Recovery Plan.

Eastern	***Western***
Chemehuevi Valley	Desert Tortoise Natural Area (Interior)
Chuckwalla Bench	Desert Tortoise Natural Area (Visitors Center)
Chuckwalla Valley	Fremont Valley
Ivanpah Valley	Fremont Peak
Upper Ward Valley	Johnson Valley
Christmas Tree	Kramer Mountains
Coyote Springs	Lucerne Valley
Gold Butte	Stoddard Valley
Piute Valley	
Sheep Mountain	
Trout Mountain	

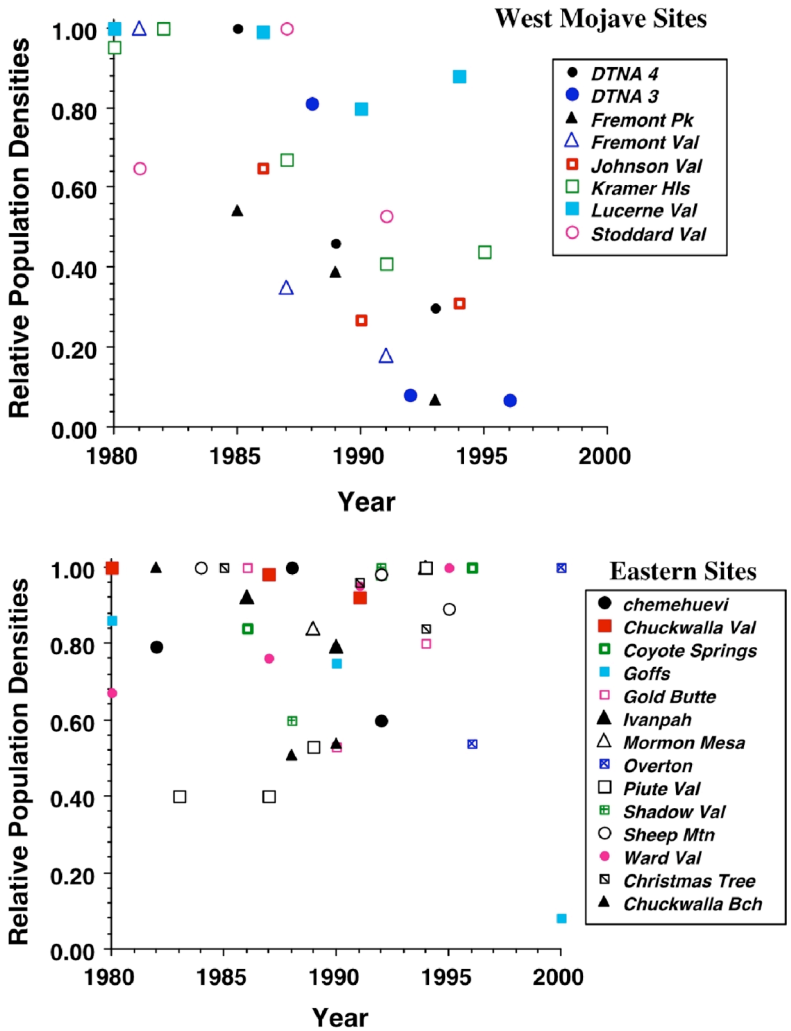

Fig. 4.6 Trends in relative population densities for desert tortoises in the eastern and western permanent study plot sites.

4.2.3 Trend Analyses by Recovery Unit

The DTRPAC analyzed for trends in tortoise population densities at a finer spatial scale than just the eastern and western portions of the listed range (as was done in the Recovery Plan). It is important to recognize that analyzing permanent study plots individually is largely meaningless except to learn about processes only on the plot (generally not valuable for conservation planning). Thus, analyzing permanent study plots cannot give insight into population trends occurring within larger management areas (Manly 1992, MacDonald and Erickson 1994, Underwood 1997) unless the plots are randomly placed within the area for which generalization is needed. Nevertheless, for our analyses, study plots were treated as though they were random samples of regions. Because the permanent study plots actually were not randomly placed (Berry 1984), this somewhat limits the extent to which it is

possible to generalize from analyses (Manly 1992). Regardless of the limitations to analyses from these plots (the only data available), the data from the plots were analyzed in a way that reduced bias as much as possible. The geographic areas that we examined included the Recovery Units specified in the original Recovery Plan (Fig. 4.7), and the Distinct Population Segments (Fig. 4.14) suggested by the DTRPAC (see Section 3). For each Recovery Unit and DPS, we constructed a weighted general linear model with one continuous and one categorical variable (results below). Estimates of the population densities of adult tortoises (carapace lengths > 208 mm) were the response variable, and time (years) and the study plot were predictor variables. The model was weighted by the inverse of the half-width of the upper confidence limit relative to the magnitude of the density estimate. This weighting caused more precise density estimates to have greater influence on the model than those with poor precision. Repeated measures analysis of variance was also considered for these analyses, however the data from study plots were collected in different years and for differing numbers of years, which made this type of analysis untenable. The graphs of adult tortoise density for each Recovery Unit and Distinct Population Segment given below are bivariate plots of the raw density estimates and their confidence limits and not the results of analyses on the data.

Some of the Recovery Units, or proposed Distinct Population Segments, did not have sufficient study plots within them to permit analysis, or had too few study plots to provide enough power to produce conclusive analyses. For example, the Upper Virgin River recovery unit and proposed DPS contained only one plot (City Creek), for which we had density estimates for only 1988 and 1994. Thus, no analyses were conducted for this Recovery Unit/DPS. In addition, the Eastern Colorado Recovery Unit and the Northern Colorado Recovery Unit each contained only two plots, and results for analyses from this small sample lack power and ability to generalize. The Western Mojave Recovery Unit contained the same set of permanent study plots as the proposed Western Mojave Distinct Population Segment, and therefore new analyses were not necessary for the DPS.

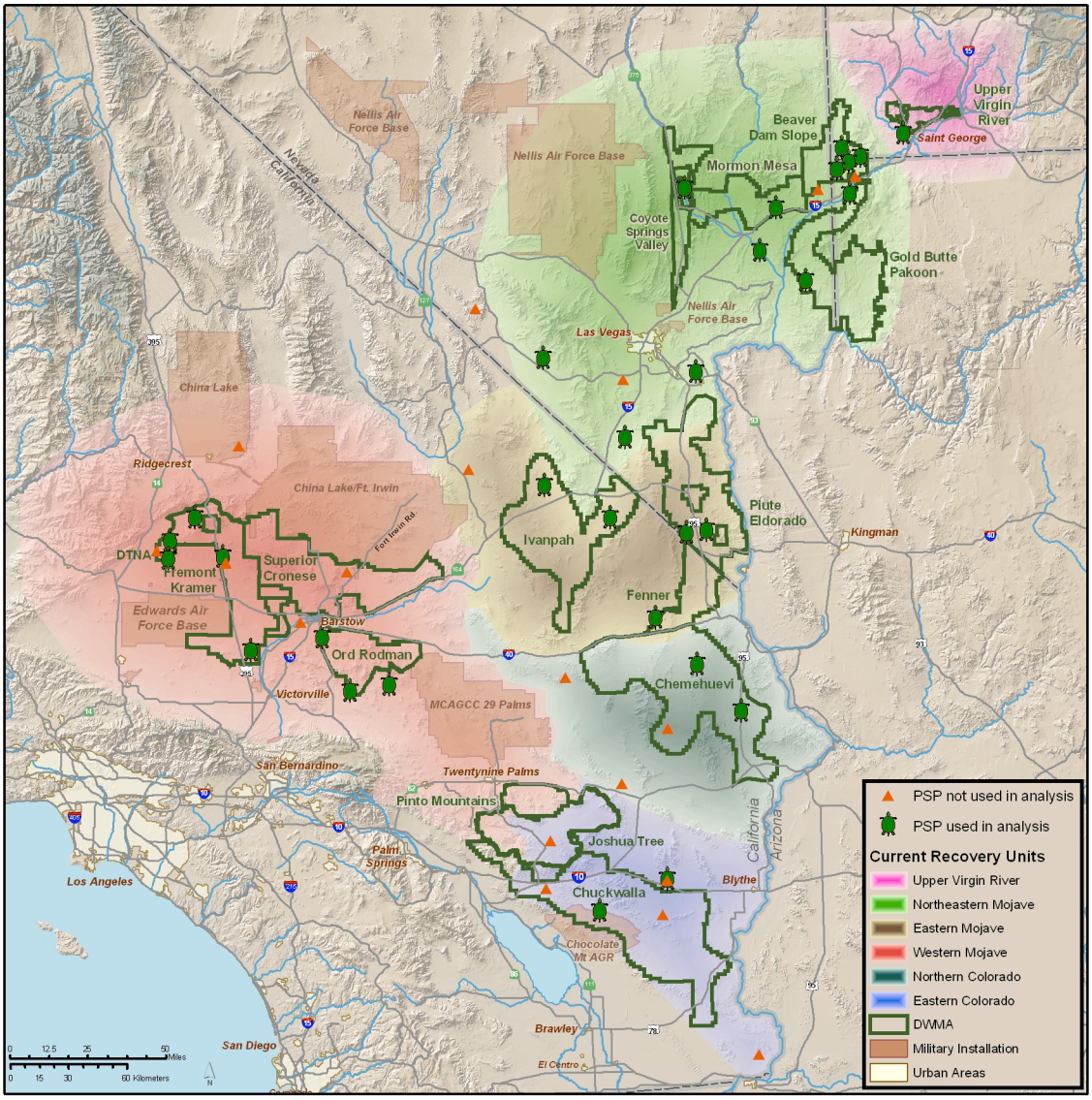

Fig. 4.7 Active (green tortoise symbols) and discontinued (orange triangles) permanent study plots grouped within the 1994 Recovery Units.

Upper Virgin River Recovery Unit (and DPS)

There was only one PSP represented in the Upper Virgin River recovery unit (City Creek; Fig. 4.7), and therefore no analysis was generated for this recovery unit. The density estimates for this site are given in Fig. 4.8.

The Upper Virgin River DPS contains the same permanent study plot (City Creek) as the recovery unit (Fig. 4.7). No analysis was conducted for this DPS and Recovery Unit.

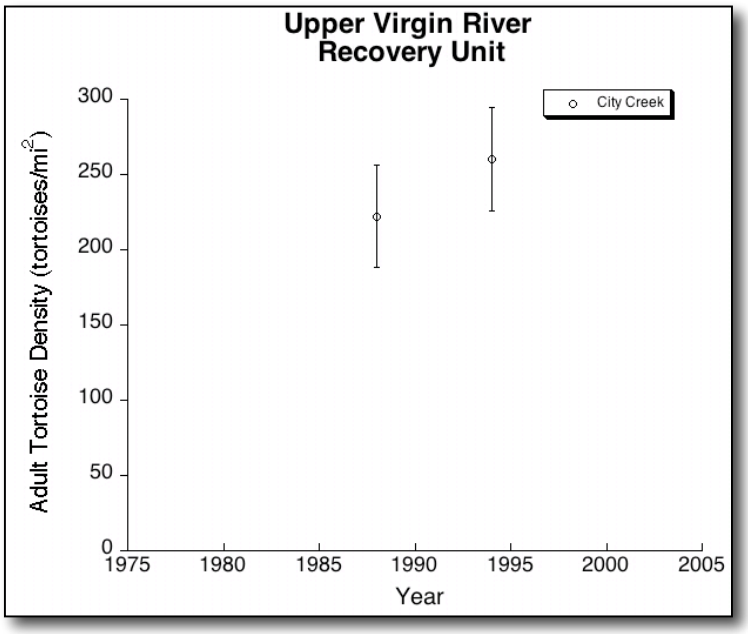

Fig. 4.8 Plot of adult densities over time for the City Creek permanent study plot located within the Upper Virgin River Recovery Unit. Error bars are 95% confidence intervals for the density estimate.

Northeastern Mojave Recovery Unit

The Northeastern Mojave Recovery Unit contained the Beaver Dam Slope (exclosure), Beaver Dam Slope, Coyote Springs, Gold Butte, Littlefield, Mormon Mesa, Overton, River Mountain, Sheep Mountain, Trout Canyon, Virgin Slope, and Woodbury Hardy permanent study plots (Fig. 4.7).

The overall analysis was significant ($F_{12,14} = 8.1$, $P = 0.0002$), which was entirely due to the effect of site ($F_{11,14} = 8.7$, $P = 0.0002$). There was no significant statistical trend in adult density over time ($F_{1,14} = 0.008$, $P = 0.93$; Fig 4.9).

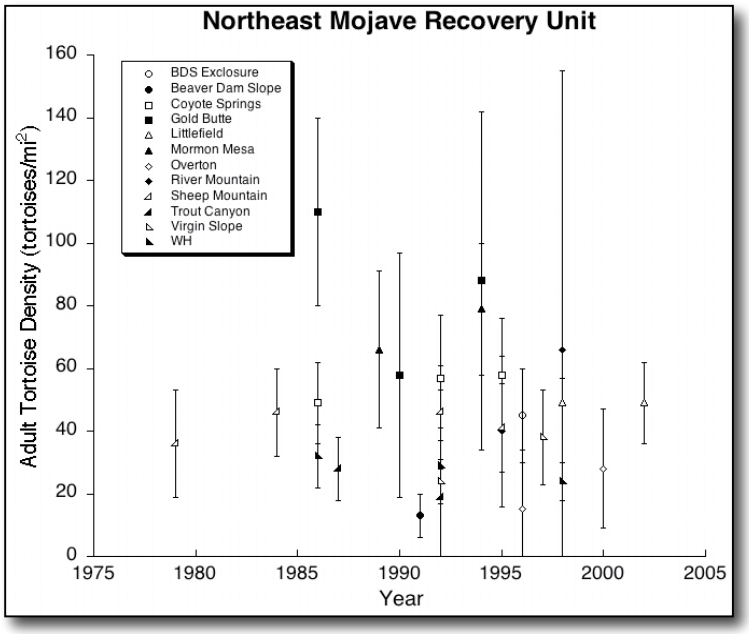

Fig. 4.9 Plot of adult densities over time for the study plots located within the Northeastern Mojave Recovery Unit. Error bars are 95% confidence intervals for the density estimate.

Eastern Mojave Recovery Unit

The Eastern Mojave Recovery Unit contains the Christmas Tree, Goffs, Ivanpah, Shadow Valley, and Piute Valley permanent study plots (Fig. 4.7).

The overall analysis for the Eastern Mojave Recovery Unit was significant ($F_{5,11} = 10.3$, $P = 0.0007$). This result was entirely due to the significance of the site effect ($F_{4,11} = 11.7$, $P = 0.0006$). There was no significant effect of year in the model, indicating that there was no trend in adult density estimates over time ($F_{1,11} = 0.2$, $P = 0.65$; Fig. 4.10).

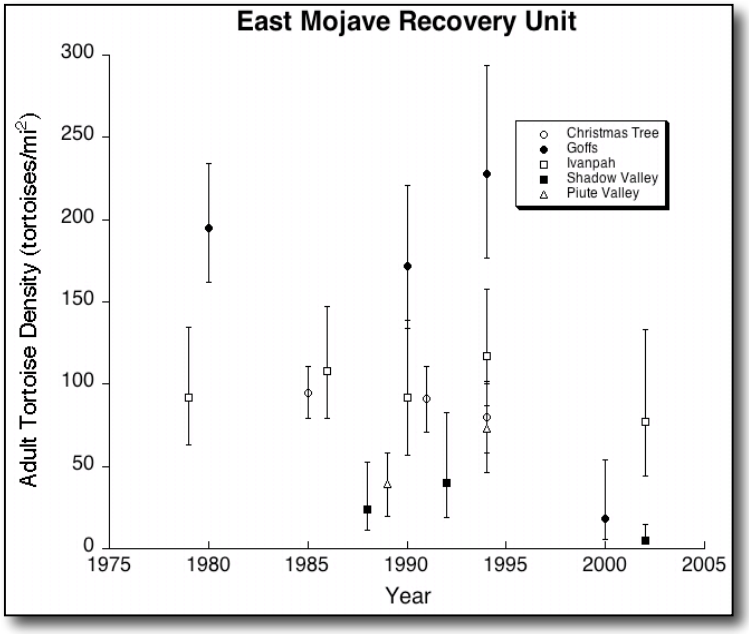

Fig. 4.10 Plot of adult densities over time for the study plots located within the Eastern Mojave Recovery Unit. Error bars are 95% confidence intervals for the density estimate.

Northern Colorado Recovery Unit

The Northern Colorado Recovery Unit contained two permanent study plots, Chemehuevi and Ward Valley (Fig. 4.7). This limits how generalizable the results from this analysis can be and again highlights one of the weaknesses of using data from permanent study plots to discern long-term trends for management areas.

The overall model for the Northern Colorado Recovery Unit was significant ($F_{2,7} = 23.29$, $P = 0.0008$), and the effect of site was significant ($F_{1,7} = 39.6$, $P = 0.0004$). There was no significant effect of year, indicating no statistical trend of adult tortoise density over time ($F_{1,7} = 1.3$, $P = 0.3$; Fig. 4.11).

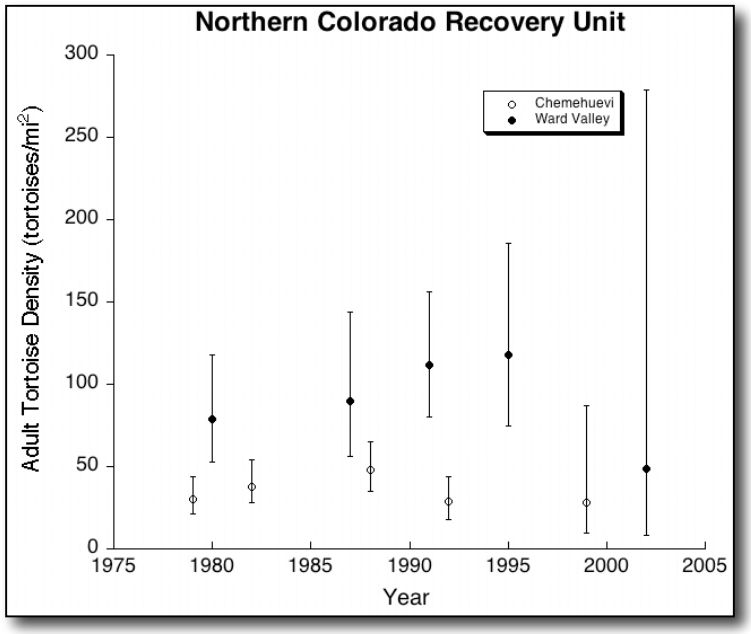

Fig 4.11 Plot of adult densities over time for the PSPs located within the Northern Colorado Recovery Unit. Error bars are 95% confidence intervals for the density estimate.

Eastern Colorado Recovery Unit

The Eastern Colorado Recovery Unit contained two permanent study plots, Chuckwalla Bench and Chuckwalla Valley (Fig. 4.7). As in the Northern Colorado Recovery Unit analysis, this limits how generalizable the results from this analysis can be and highlights one of the weaknesses of using data from permanent study plots to discern long-term trends for management areas, whether they are Recovery Units or Distinct Population Segments.

The overall model for the Eastern Colorado Recovery Unit was significant ($F_{2,6}$ = 21.0, P = 0.002), with significant effects of both site ($F_{1,6}$ = 19.18, P = 0.005) and year ($F_{1,6}$ = 20.24, P = 0.004; Fig. 4.12). This indicated that there was a statistical decline in adult densities over time, which appears to be due to the effect of Chuckwalla Bench.

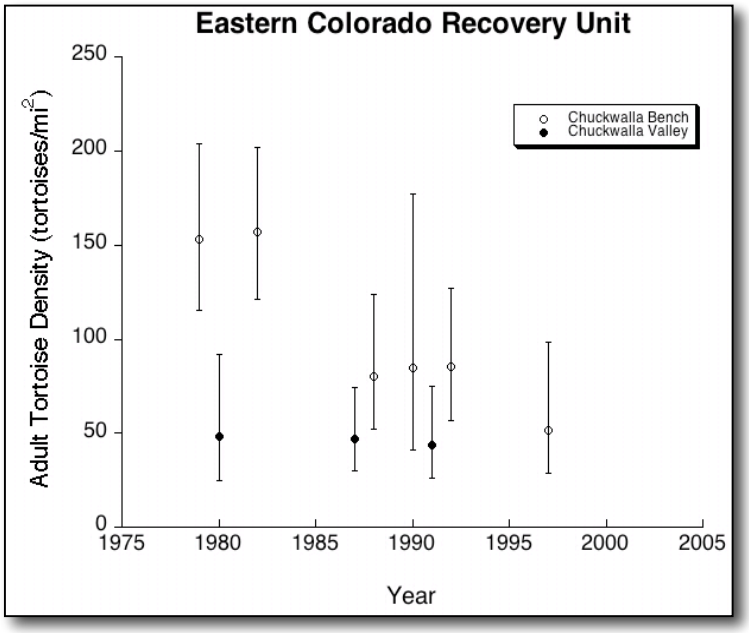

Fig. 4.12 Plot of adult densities over time for the PSPs located within the Eastern Colorado Recovery Unit. Error bars are 95% confidence intervals for the density estimate.

Western Mojave Recovery Unit (and DPS)

The Western Mojave Recovery Unit included the DTNA Interior, DTNA Interpretive Center, Fremont Peak, Fremont Valley, Johnson Valley, Kramer Hills, Lucerne Valley, and Stoddard Valley Permanent Study Plots (Fig. 4.7).

The overall analysis was significant ($F_{8,25} = 7.2$, $P < 0.0001$), and the year effect yielded a significantly negative trend in adult density estimates over time ($F_{1,25} = 20.52$, $P = 0.0001$ (Fig. 4.13). There was also a significant contribution of site to the model ($F_{7,25} = 4.46$, $P = 0.003$). This analysis indicates that, taken together, tortoise densities on the permanent study plots located within the Western Mojave Recovery Unit are declining, as was suggested in the Recovery Plan (Recovery Plan, Appendix C, page C10, Figure C5). This pattern suggests that recovery actions implemented since the Plan have not resulted in the reversal of this declining trend.

The study plots included in the proposed Western Mojave Distinct Population Segment (Fig. 4.14) are the same as those in the Western Mojave Recovery Unit (Fig. 4.7).

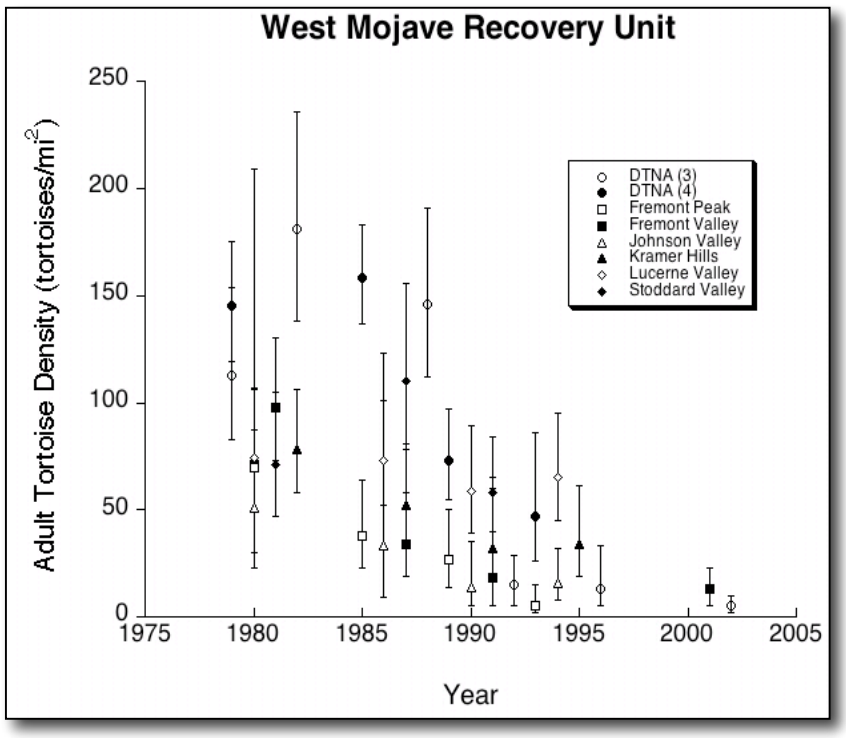

Fig. 4.13 Plot of adult densities over time for the permanent study plots located within the Western Mojave Recovery Unit. Error bars are 95% confidence intervals for the density estimate.

4.2.4 Trend Analyses by Distinct Population Segment

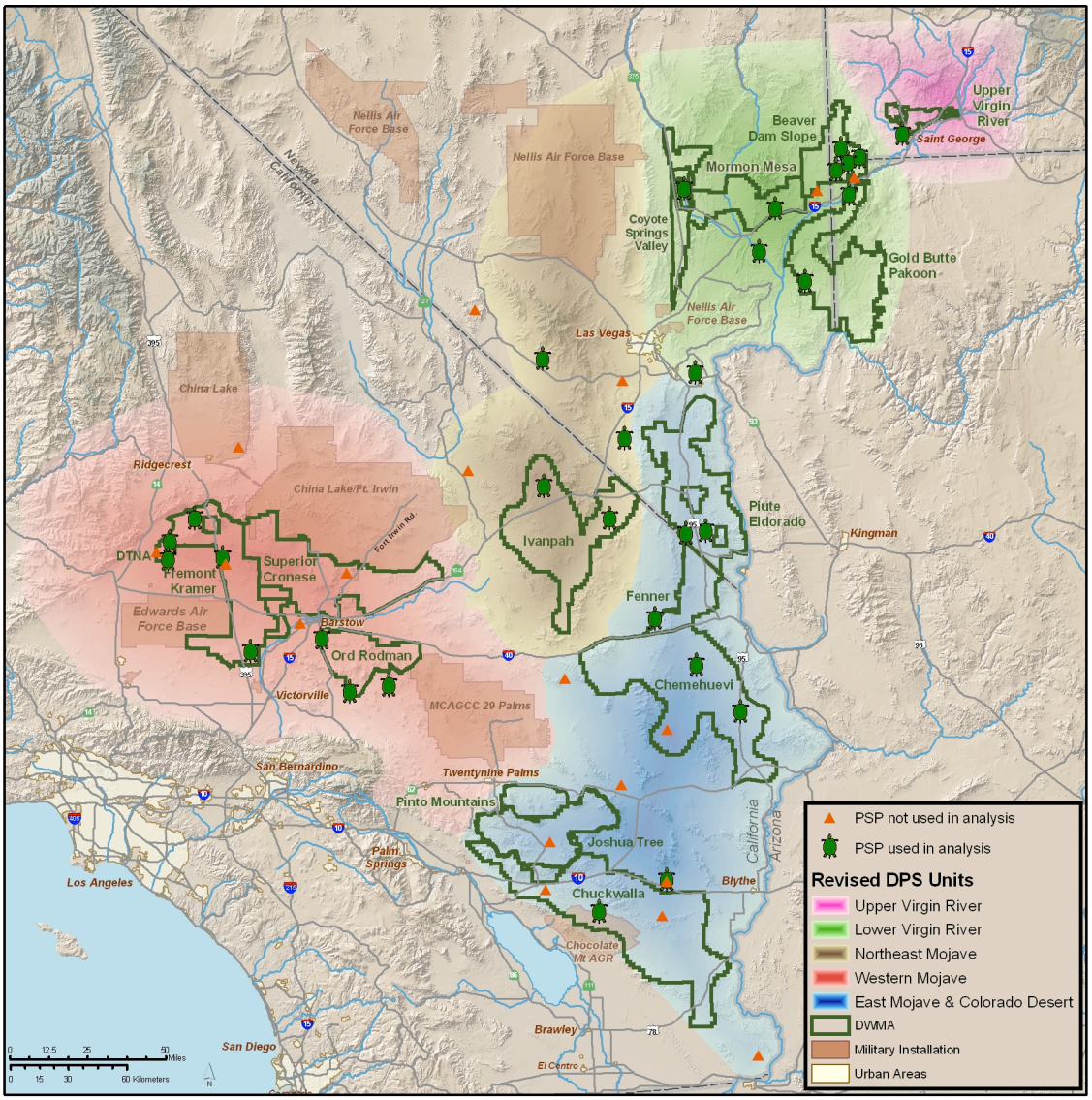

Fig. 4.14 Active (green tortoise symbols) and discontinued (orange triangles) study plots grouped by Distinct Population Segment.

Lower Virgin River DPS

The Lower Virgin River Distinct Population Segment contains the Beaver Dam Slope (Exclosure), Beaver Dam Slope, Coyote Springs, Gold Butte, Littlefield, Mormon Mesa, Overton, River Mountain, Virgin Slope, and Woodbury Hardy permanent study plots (Fig. 4.14).

The overall analysis was not significant ($F_{5,6} = 3.7$, $P = 0.07$). Indicating that there was no effect of site, and importantly there was no significant trend in adult tortoise density over time ($F_{1,6} = 0.29$, $P = 0.61$; Fig. 4.15).

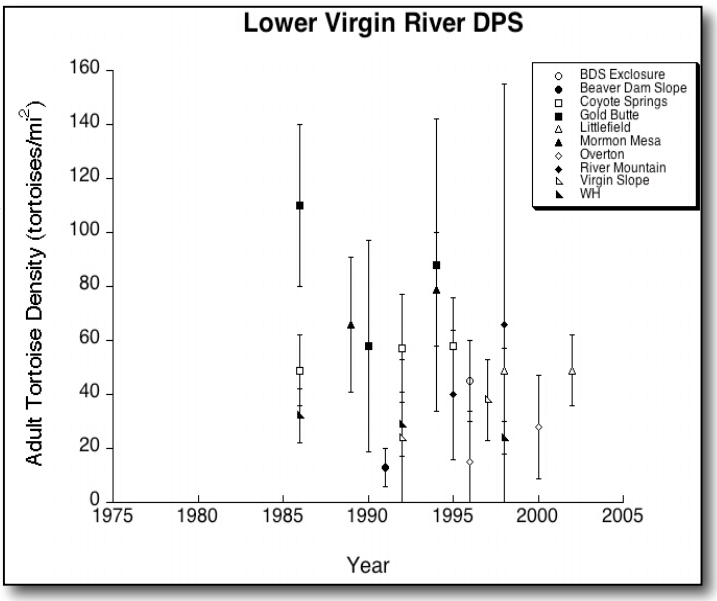

Fig. 4.15 Plot of adult densities over time for the Lower Virgin River Distinct Population Segment. Error bars are 95% confidence intervals for the density estimate.

Eastern Mojave and Colorado DPS

The Eastern Mojave and Colorado DPS contains the Chemehuevi, Christmas Tree, Chuckwalla Bench, Chuckwalla Valley, Goffs, Piute Valley, Ward Valley permanent study plots (Fig. 4.14).

The overall analysis was significant ($F_{7,20} = 11.89$, $P < 0.0001$), which was entirely due to the effect of site ($F_{6,20} = 13.46$, $P < 0.0001$). There was no significant trend in density estimates over time ($F_{1,20} = 2.22$, $P = 0.15$; Fig 4.16).

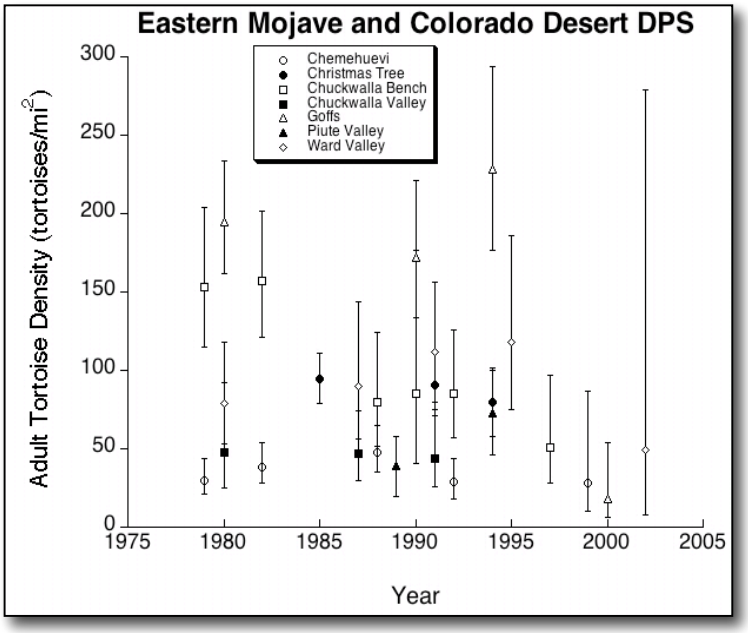

Fig. 4.16 Plot of adult densities over time for the Eastern Mojave and Colorado Distinct Population Segment. Error bars are 95% confidence intervals for the density estimate.

Northeastern Mojave DPS

The Northeastern Mojave Distinct Population Segment contains the Ivanpah, Shadow Valley, Sheep Mountain, and Trout Canyon permanent study plots (Fig. 4.14).

The overall analysis was significant ($F_{4,9} = 26.52$, $P < 0.0001$), which was entirely due to the effect of site ($F_{3,9} = 35.35$, $P < 0.0001$). There was no trend in adult densities as a function of time ($F_{1,9} = 0.06$, $P = 0.82$; Fig. 4.17).

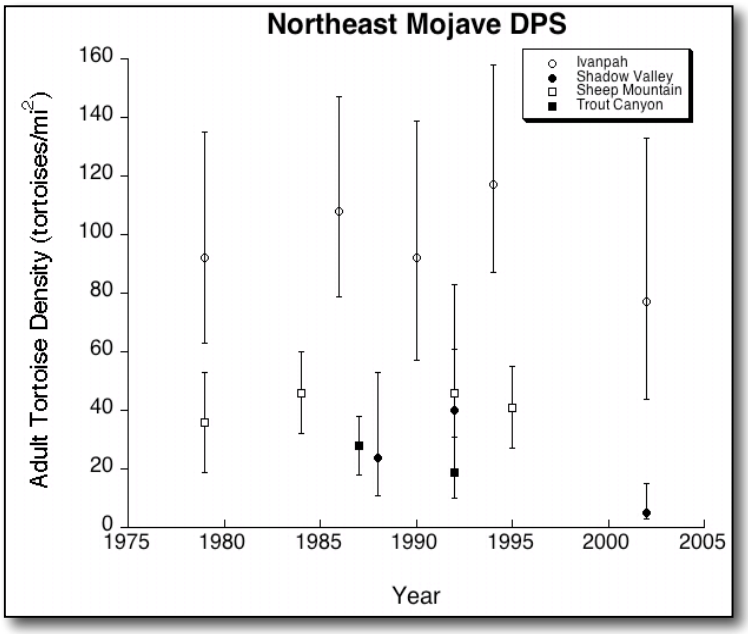

Fig. 4.17 Plot of adult densities over time for the Northeastern Mojave Distinct Population Segment. Error bars are 95% confidence intervals for the density estimate.

4.2.5 Summary of Trend Analyses

From the trend analyses a few key conclusions can be drawn. First, the downward trend in adult tortoise densities in the Western Mojave clearly dominates the analyses, whether considered by dividing the listed range into eastern and western sections (Fig 4.6), or analyzed at the level of the Recovery Unit/DPS (Fig 4.14). There were several Recovery Units that contained too few permanent study plots to allow meaningful analyses and some that could not be analyzed. This speaks to the inadequacy of the historical placement of the permanent study plots in light of the current needs of range-wide monitoring. One caveat to the weighting procedure should be pointed out, however. Low point estimates with high variance are often obtained when few animals are captured or recaptured, so real tortoise declines may have had little effect on some models. For example, in the Northeastern Mojave Recovery Unit (or Lower Virgin River DPS) plot surveys on the Beaver Dam Slope Exclosure in 2000 and the Virgin Slope in 2003 produced too few live tortoises to even produce a population estimate that could be included in the analyses presented here.

This, combined with the fact that many more carcasses were found than in prior surveys, suggests that recent declines have occurred on those plots.
Second, the variation in density estimates using study plots does not appear to be less than the variation from line distance sampling. Thus, it is unlikely that plot analyses would have sufficient power to detect the subtle trends that are assumed to be associated with recovery of desert tortoise populations (see Monitoring section).

Finally, the resolution of the analyses that can be conducted with data from permanent study plots is currently limited due to the relatively few plots established, the lack of random placement of existing plots, and the fact that plots were not established to test hypotheses concerning recovery. Newer research and monitoring using spatial analyses requires the more extensive transect sampling promoted by USFWS since 2001. However, a robust monitoring program requires exploring novel analyses, particularly those that can be conducted with existing data (or with little modification of current monitoring methods). New methods could become increasingly important as new hypotheses-driven research and monitoring is required for recovery.

4.3 Spatial Analyses

We conducted several GIS and spatial analyses to explore spatial variation within tortoise populations at different scales on the landscape and in different management units. Spatial analyses were based upon transect data generated for distance sampling and for surveys for total corrected sign (TCS), (see tortoise transect history below). The analyses that we conducted provide both qualitative and quantitative conclusions about the spatial nature of tortoises relative to carcasses, and of the relative presence and absence (viz., failure to detect) of tortoises in DWMAs.

Specific analyses included:

1) An **Observation Rates** analysis, which compared distance sampling transects in which live tortoises were observed relative to the number of transects in which only carcasses were observed.

2) A **Presence/Failure to detect** analysis to examine the recent spatial distribution of the presence of live tortoises and carcasses using transect data from surveys of total corrected sign (TCS).

3) Two **Conditional Probability of Live Encounter** analyses consisting of two approaches with the same goal. These analyses were used to estimate the probability that an observation was a living tortoise as a function of location within the Western Mojave DPS using Line Distance Sampling (LDS) data from 2001.

4) **Kernel analyses**, which are quantitative analyses in which the distributions of live tortoises and carcasses were smoothed to qualitatively search for areas where distributions of live tortoises and carcasses do not overlap. These non-overlapping areas may indicate areas that have experienced recent die offs or expansions of populations.

5) **Nearest Neighbor Clustering**, which is a quantitative search for statistical clusters of live animals and carcasses. Analyses included searching the degree of overlap (or separation) of these clusters.

Each of these analyses carries unique limitations concerning the extent to which transect data can be used. For example, Nearest Neighbor Hierarchical Clustering requires that the data be spatially random or regularly distributed. Thus, cluster analysis was restricted to using only LDS data from 2001. Table 4.5 lists data used in our spatial analyses.

These analyses are neither intended to be an exhaustive exploration of all spatial analysis techniques suitable for TCS and LDS data, nor are they an exhaustive attempt to analyze all possible data and/or regions. Instead, our objective is to investigate alternative, and primarily novel, spatial analysis techniques that should be explored further by the subsequent recovery team. There are very likely more types of spatial analyses that could be explored and perhaps better spatial analyses that are more appropriate given the different sources of data that we had available. If a future recovery team is formed, we recommend that all of the data available to them, and future monitoring efforts be explored to the fullest extent possible, as the detection of trends alone (given current sampling precision, see Section 6) seems at this time untenable.

Table 4.5 Summary of data, year, and region used for each analysis. TCS = total corrected sign surveys; LDS = line distance sampling.

Analysis	Transect Data	Years	Region
Presence/Failure to Detect	TCS, LDS	All years	West Mojave
Observation Rates	LDS	2001-2003	Range-wide (excluding Upper Virgin River)
Kernel	LDS	2001	Range-wide
Cluster	LDS	2001	West Mojave
Conditional Probability of Being Alive: Re-sampling	LDS	2001	West Mojave
Conditional Probability of Being Alive: Logistics Regression	LDS	2001	West Mojave

4.3.1 History of Desert Tortoise Transects

Total Corrected Sign Transects

There have been several transect methods used to estimate the relative presence of tortoises, especially in the Western Mojave. Prior to, and later in support of, the draft West Mojave Plan (BLM et al. 2003), many transects were surveyed with the goal of measuring tortoise sign. These data typically are referred to as total corrected sign (TCS). Historically, estimates of relative tortoise density have been estimated from the “corrected” sign of tortoises. This correction was based upon comparison of sign counts from areas of unknown density and areas with both sign counts and estimated density.

Transect surveys for TCS transects were conducted in 1998, 1999, and 2001 by the Bureau of Land Management West Mojave Planning team in support of development of the draft West Mojave Plan (WMP) habitat conservation plan and the California Desert Conservation Area Plan amendment (BLM et al.2003). The transect method was developed by Berry and Nicholson (1984) to determine relative tortoise densities. However, the West Mojave Plan planning team restricted the use of the data for various reasons to depict relative "patterns of occurrence" for tortoises (BLM et al. 2003). The transects are typically walked in the Autumn, to allow for greater amounts of tortoise sign (i.e., scat and burrows) to accumulate during the activity season. In addition to observations of scat and burrows, observations of live tortoises and carcasses were also recorded.

For the purposes of analyses conducted herein only the raw sign data were used. In other words, data were not "corrected", and no density estimates were derived from the data.

Distance Sampling Transects

In February 1995 during a workshop on tortoise monitoring in Reno, Nevada (sponsored by the Biological Resources Research Center at the University of Nevada, Reno), tortoise biologists, statisticians, and monitoring experts reviewed previous methods used to monitor tortoise populations and possible methods to use in the future. At this workshop, the method of "Distance Sampling" (Buckland et al. 1993) was introduced as a way to mitigate the problems of the permanent study plots. At a second meeting in Laughlin, Nevada, in October 1998, the Management Oversight Group (MOG) proclaimed Distance Sampling to be the method that would be used on public lands for estimating density of desert tortoise populations. In June 1999, the MOG endorsed the use of Distance Sampling using program "Distance" as the method to be employed in range-wide sampling of desert tortoise populations. However, the appropriateness of the technique for sampling desert tortoises (especially in areas with low population densities) was, and remains, contentious (see Section 6).

In January 2001 a monitoring workshop was held in Las Vegas, Nevada, to explain the sampling techniques that would be used in 2001 to conduct the first years effort of Line Distance Sampling range wide. This meeting was attended both by agency and contractor personnel. A handbook was prepared by the Desert Tortoise Coordinator and provided in March 2001 to serve as the manual for conducting the distance sampling in 2001. In March of 2001, two training workshops were conducted. Approximately 40 people attended each of the two four-day workshops. These training workshops provided practice for conducting the Distance Sampling technique by using styrofoam tortoise models (styrotorts) placed in natural habitats near Jean, Nevada. This technique had been used as part of an earlier demonstration workshop conducted in October 1998 (Anderson et. al. 2001). Finally, the tortoise transects were sampled range-wide beginning in 2001 by Chambers Group; Kiva Biological Consultants; the Mojave National Preserve; the University of Nevada, Reno; and the Utah Division of Wildlife Resources.

The Utah Department of Wildlife Resources instituted a monitoring program similar to that of the rest of the listed range of tortoises (using transects to monitor tortoises and the distance technique to estimate densities of tortoise populations) at the Red Cliffs Desert Reserve within the Upper Virgin River Recovery Unit (McLuckie et al. 2002). A pilot study was initiated in 1997, and reserve-wide monitoring was initiated in 1998.

For most of the listed range (excluding the Upper Virgin River Recovery Unit) LDS transects (Buckland et al. 2001) were conducted for the years 2001-2003 by the USFWS in support of the range-wide sampling of tortoises within DWMAs. Transects were conducted in the spring, corresponding to periods of high tortoise activity. Data from these transects can be used to calculate density estimates at several scales (e.g., for each DWMA or Recovery Unit; Anderson et al. 2001). Transects for 2001 were randomly selected from a 400m grid within each DWMA with the following exclusions: areas greater than 4,200 ft in elevation, slopes ≥30%, permanent water bodies, playas, major roads, private land, and restricted areas within military reservations.

Density estimates for the 2001 distance sampling for the West Mojave indicate approximate densities of 7.3 tortoises/km^2 (95% CI = 5 – 10) for the Fremont-Kramer DWMA and 9.6 tortoises/km2 (95% CI = 7 – 13) for the Ord-Rodman DWMA (Medica pers. comm.). These numbers are relatively comparable to those given for permanent study plots near the same two DWMAs (DTNA Interior for 2002 = 2 tortoises/km^2 (95% CI = 1-4), Fremont Valley for 2001 = 5 tortoises/km^2 (95% CI = 2-9) (Berry pers. comm.). However, the sampling design for monitoring for most of the range (excluding the Upper Virgin River Recovery Unit) using transects was flawed in such a way that samples from subsequent years (2002 and 2003) cannot be considered representative of the DWMAs as a whole. Therefore, density estimates for 2002 and 2003 were not part of our analyses. The "flaws" in data collected in 2002 and 2003 reflect weaknesses in the system of constructively adapting monitoring each year to increase efficacy. In particular, several processes contributed to problems in 2002 and 2003. The lack of certainty in year-to-year funding of range wide monitoring contributed to an atmosphere of last-minute adjustments to monitoring methods. Adjustments to field techniques often emphasized logistics instead of needs for solid scientific design and statistical validity. Only as part of the DTRPAC process did we learn that adjustments in monitoring methods to improve logistics actually nullify the statistical validity of spatial analyses from those data. This experience reveals the pressing need for a consistent, high-level, scientific advisory capability as part of range wide monitoring overseen by USFWS.

The data provided by distance sampling transects sampled in 2001 and the TCS transects from other years provide a capacious source of information for spatial analyses. For example, we found that the spatial data from both the relative sign and distance sampling transects could be used to understand better the information regarding the declining density estimates of tortoises as provided by the permanent study plots, especially in the West Mojave.

4.3.2 Observation Rates

(distance sampling transects; range-wide, excluding Upper Virgin River; 2001-2003).

The objective of this analysis was to ascertain the percentage of transects in which live tortoises were observed in comparison to the number of transects on which only carcasses were observed. Spatial randomness was not required for this analysis, so the data from distance sampling transects for 2001 through 2003 were used (Table 4.6). Although data from corrected sign transects also contain observations of live and dead tortoises, the difference in sampling period relative to distance sampling transects (Autumn for sign transects and spring for distance sampling transects) disproportionately biases against live observations compared to those observed on the distance sampling transects, which could skew the live/carcass ratios. For this reason we limited our analysis to LDS data only.

The percentage of transects with observations of live tortoises and those with observations of carcasses are presented in Table 4.6. Note that high/low percentages should not be confused with high/low numbers of live tortoises or carcasses. For example, 29% of the transects in Fremont-Kramer in 2001-2003 had live tortoises and 67% of transects had carcasses (Table 4.6).

We also calculated the ratio of carcasses to live tortoises for the same areas (Table 4.6, Fig. 4.18). A low ratio (i.e. close to 1) does not mean that there are a low number of carcasses; it instead means that there were approximately equal numbers of carcasses and live tortoises. There was a continuum of ratios ranging from 1.08 for the Pinto to 3.67 for Fenner (Table 4.6).

Table 4.6 Percentages of live animals and dead animals found on LDS transects. The third column is the ratio of the percent of dead animals encountered to the percent of live animals encountered.

DWMA	% Live	%Dead	Ratio Dead/Live
Beaver Dam Slope	5	6	1.25
Chemehuevi	41	70	1.71
Chuckwalla	24	46	1.94
Chocolate Mountains	45	68	1.51
DTNA	41	59	1.51
Fenner	20	74	3.67
Gold Butte	8	15	1.88
Fremont-Kramer	29	67	2.29
Ivanpah	16	46	2.87
Joshua Tree	23	33	1.40
Mormon Mesa	21	34	1.58
Ord-Rodman	46	56	1.22
Pinto Mountains	32	34	1.08
Piute-Eldorado	15	48	3.23
Superior-Cronese	29	46	1.60

The transects revealed patterns of discrepancy between observations of live tortoises and observations of carcasses. This analysis is based upon the premise that tortoise populations with equal numbers of live animals and carcasses are in a better state than those with disproportionately larger carcass numbers. It is worth noting that carcasses are purposely removed from active permanent study plots in California. In this case, the small analysis area and presence of two active study plots at the DTNA (one sampled in 1997 and 2002 and the other in 2002 only) could contribute to the low ratio of carcasses to live tortoises.

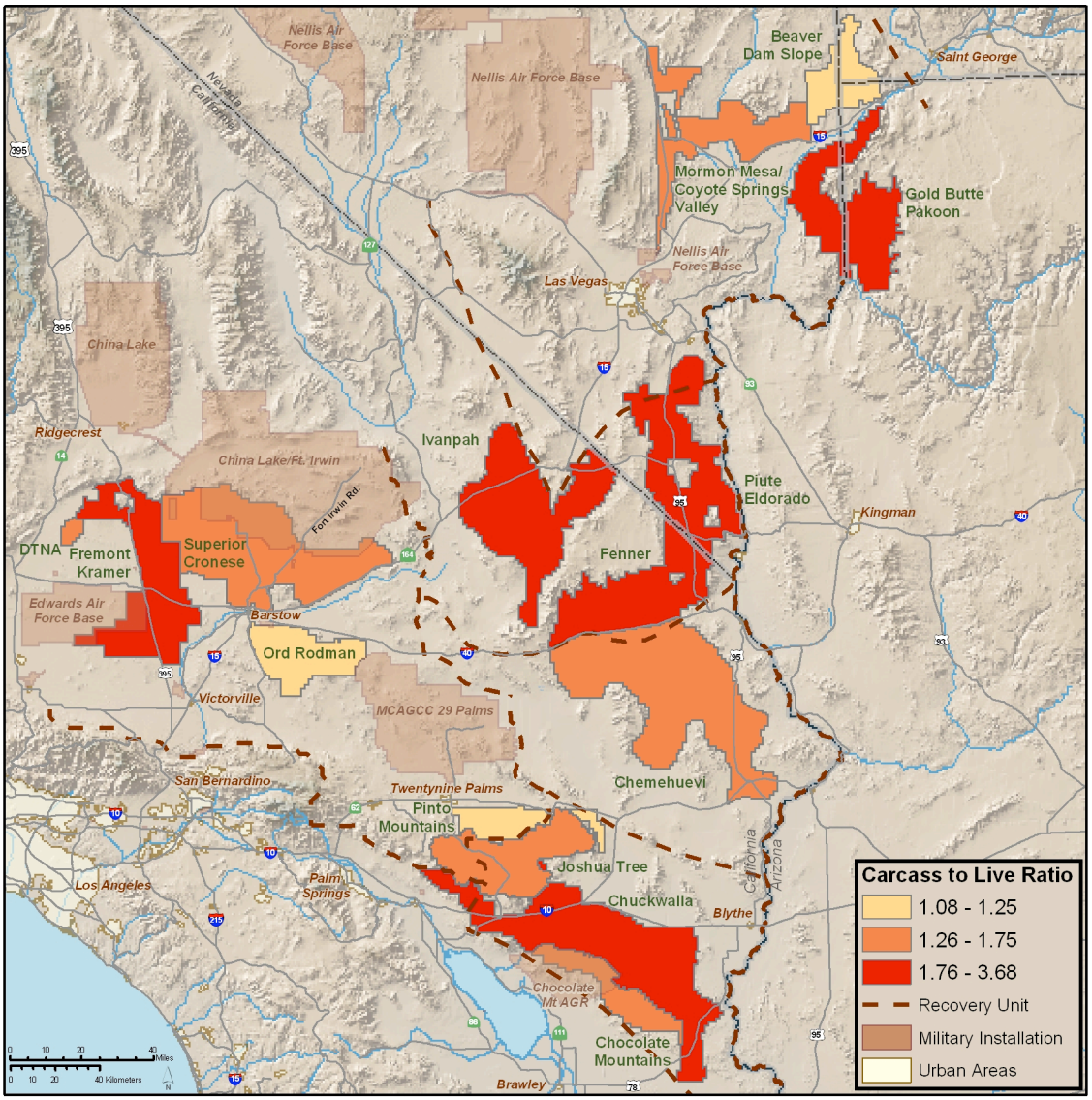

Fig. 4.18 The ratio of carcasses to live tortoises for DWMAs.

4.3.3 Presence/Failure to Detect

(total corrected sign and distance sampling transects, Western Mojave, all years).

This analysis graphically assesses the recent spatial distribution of live tortoises and carcasses, but is not a statistical analysis of this distribution. Although burrows have been shown to be significantly correlated with live tortoises (BLM et al. 2003), we restricted our analysis of presence or "failure to detect" tortoises on transects with observations of live tortoises or scat. We used the presence of scat as an indication of live tortoises in a given area when live tortoises were not actually observed. This method assumes that where there is scat, there must have been a tortoise (recognizing that scat can be moved by wind, water, or other animals) within a relatively short time frame (assuming scat degradation rates of 1-2 yrs).

This analysis was restricted to the Western Mojave for two reasons. First, the DTRPAC had access to spatially referenced distance sampling data for the West Mojave, but not for other areas. Second, though the DTRPAC had access to distance sampling data throughout the entire listed range of the desert tortoise, an analysis of distance transects alone would not have been comparable to the combined transect data for the West Mojave due to the disparity in their sampling periods.

All transects were assigned to one square mile analysis grids. Each grid cell was assigned a different color based on the composition of the observations of tortoises, scat, and carcasses found within the grids (Fig. 4.19).

The presence/"failure to detect" analysis illustrates patterns of 1) tortoise or scat presence, 2) tortoise or scat and carcass presence, 3) carcasses only, and 4) failure to detect either tortoises or scat or carcasses. Areas containing tortoises included the DTNA, the southern portions of Fremont-Kramer, south and east Superior-Cronese, and most areas of Ord-Rodman (Fig. 4.19). Large sections of Superior-Cronese have not been recently sampled (as near as we can determine). It is likely that many of these areas have been sampled by other research and/or compliance projects, however data from these areas were not available for analysis by the committee. Maintenance of a master desert tortoise location database would enhance the ability to track areas of tortoise and carcass occurrence.

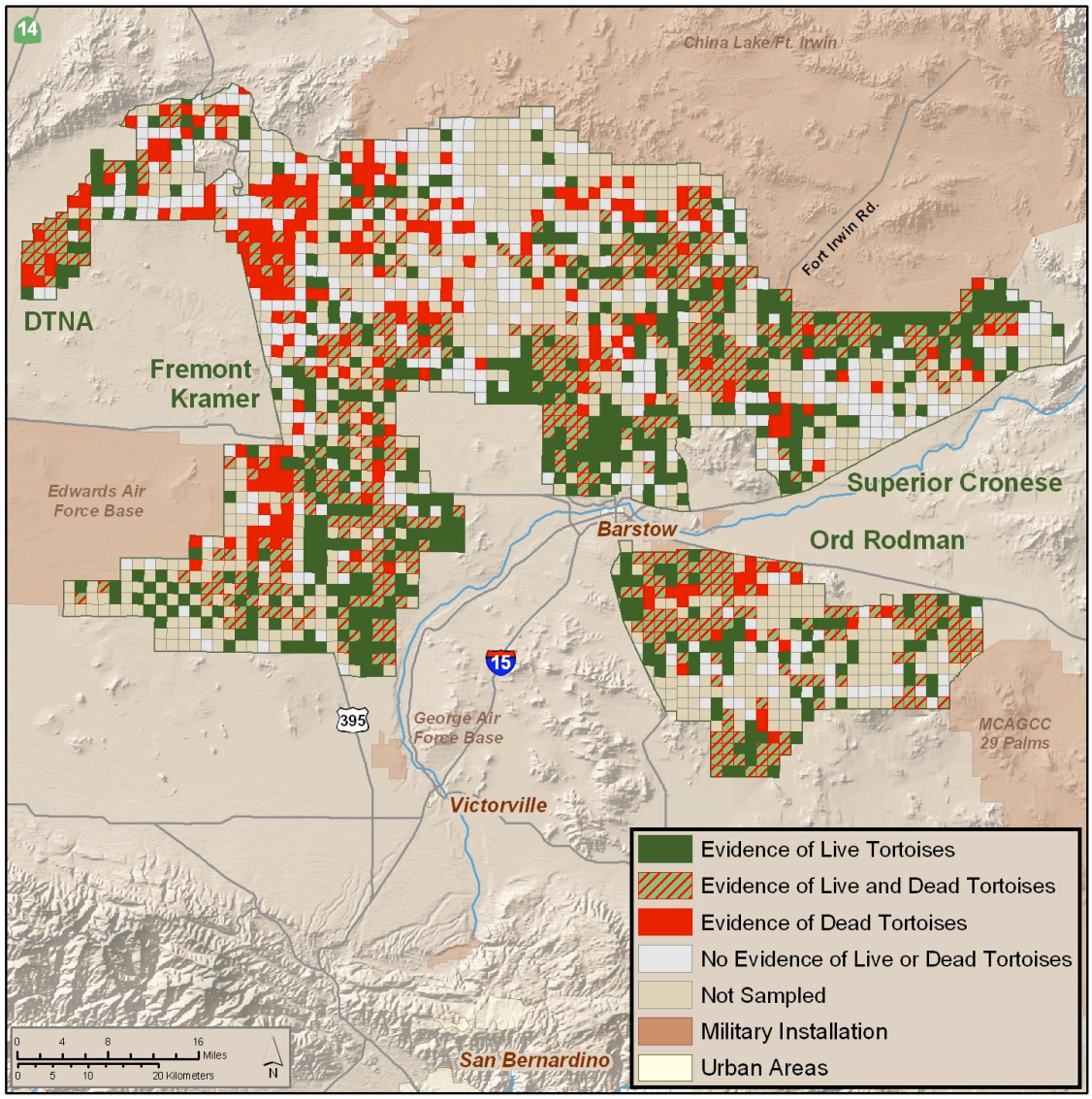

Fig. 4.19 Presence/"Failure to Detect" tortoises and carcasses for combined distance sampling (2001-2003) and total corrected sign (1998, 1999, and 2001) transects. Dark green areas are those in which a tortoise and/or scat were present. Light green areas are those in which a tortoise and/or scat and carcasses were present. Red areas indicate only carcasses were present. White areas indicate no tortoises, scat, or carcasses were found. Light tan areas indicate no distance sampling or total corrected sign transects were conducted.

4.3.4 Conditional Probability of Live Encounter

(distance sampling transects, Western Mojave, 2001).

Resampling

For this analysis the Western Mojave was divided into a grid consisting of 18 cells. Using the 2001 LDS data, the proportion of tortoises that were alive (i.e., live tortoises/[live + dead tortoises]) was then calculated for each cell. A test statistic was then derived for each cell, which consisted of the observed proportion of tortoises that were alive in each cell minus the proportion calculated from all cells combined (0.284).

The test statistics for each of the 18 cells (Table 4.7) were tested for significance using a randomization method. To produce a randomized set of data the 609 transects were randomly reallocated to the 18 cells. This was done 10,000 times. The p-value for the statistic from the ith cell was then the proportion of times that the randomized sets of data gave a value as far or further from zero than the observed test statistic. In addition, a 19th statistic was calculated, which consisted of the maximum of the absolute values of the statistics for the individual cells. This was then used to calculate an overall test of differences between the cells and for all of the data.

As shown in Table 4.7, there are significant results for cells 6, 7, 12, and 16, and for the maximum statistic. There is also a nearly significant result for cell 15. It is more compelling to view the data graphically. Distinct areas, as defined by groupings of points with the same color with lower (red) or higher probabilities (green) of live encounters are clearly identifiable in Fig. 4.20.

Table 4.7 Observed ratios of live to dead tortoises. The P values indicate bins of transects in which the ratios were different from that expected at random. The sign of the observed value indicates the direction of the difference.

Bin	Observed Value	P-value	Bin	Observed Value	P-value
1	0.08	0.45	10	0.09	0.09
2	-0.13	0.24	11	0.01	0.85
3	0.10	0.47	12	-0.14	0.04
4	0.06	0.30	13	-0.06	0.56
5	0.10	0.47	14	0.05	0.43
6	-0.28	0.002	15	-0.21	0.07
7	0.29	0.008	16	0.52	0.001
8	0.03	0.75	17	0.05	0.54
9	0.05	0.54	18	0.22	0.09
			Max	0.52	0.004

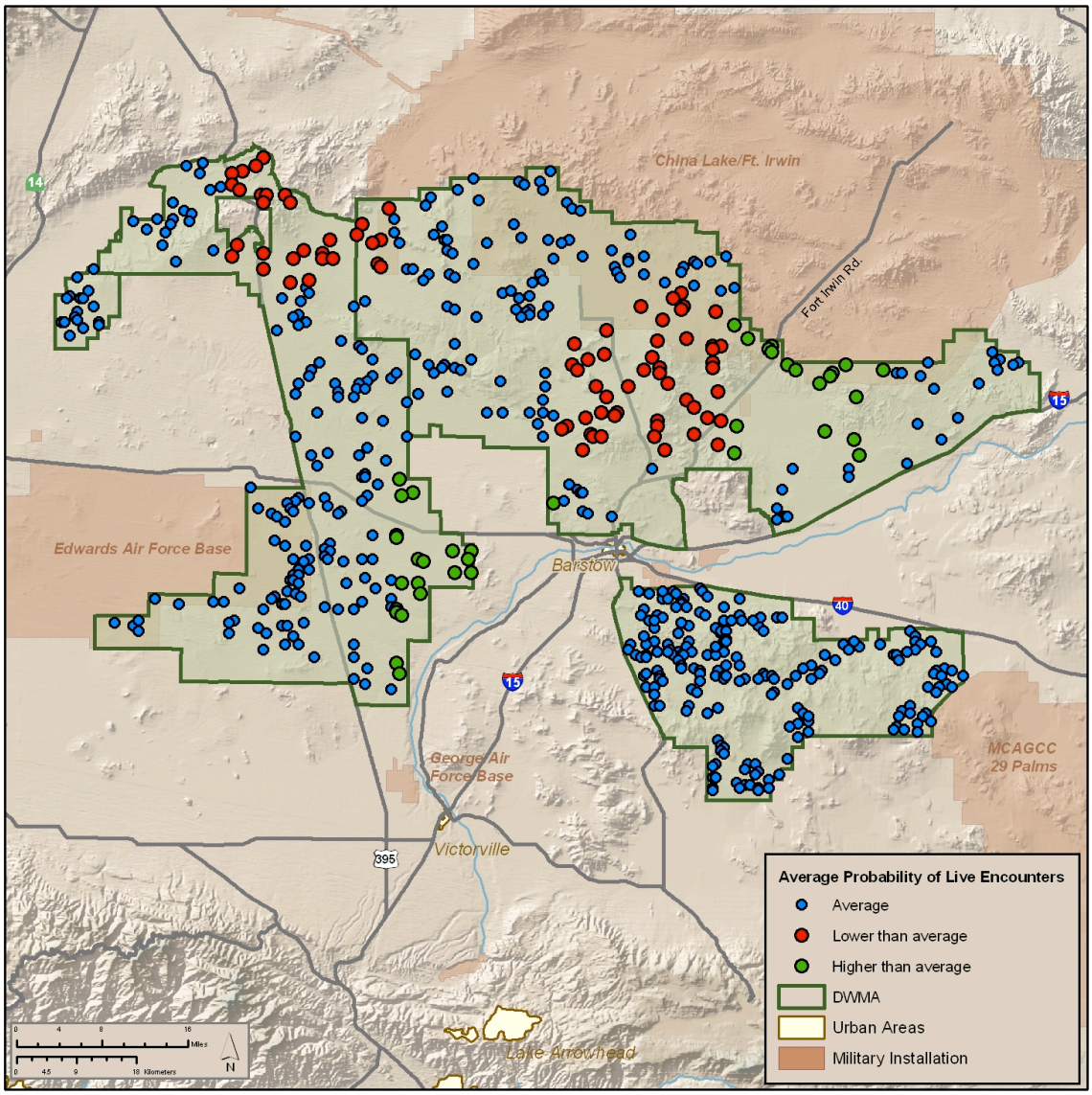

Fig. 4.20 Results from the resampling analysis - Areas depicted in red are points in bins 6 and 12, which had lower than average probabilities of live encounters; green points are bins 7 and 16, which had higher proportions of live animals. Points in all other bins are blue in color.

Logistic Regression

Another analysis was possible based upon logistic regression. The regression calculates the probability of a tortoise being live at a distance E km east and N km north from easting 414493 and northing 3825771 and is given by

$$P(E,N) = \exp(\beta_0 + \beta_1 E + \beta_2 N + \beta_3 E.N + \beta_4 E^2 + \beta_5 N^2)/\{1 + \exp(\beta_0 + \beta_1 E + \beta_2 N + \beta_3 E.N + \beta_4 E^2 + \beta_5 N^2)\}.$$

Data for this analysis were restricted to transects on which both live and/or dead tortoises were observed. Each of these transects then provided one observation on the number of

tortoises that were live in a sample of *n* tortoises. It is possible that higher order polynomial terms are needed in the equation to describe better the spatial changes in the probability of a tortoise being live. This was not investigated.

The following analysis of deviance shows that the model accounts for a significant amount of the variation in the data (Tables 4.8 and 4.9). The mean deviance is much larger than one, indicating that part of the variation in the data is not properly accounted for. This confirms that it would be worth investigating adding higher order polynomial terms into the equation. A kriging surface mapping the conditional probability of being alive in 2001 are presented in Fig. 4.21.

This analysis asks the question, if a tortoise is found on a transect, what is the probability that it is a live tortoise? The region in the northern portion of the Fremont-Kramer DWMA and the northwestern portion of the Superior-Cronese DWMA had noticeably lower probabilities of encountering a live tortoise relative to other portions of the DWMAs.

Table 4.8 Statistical table for the logistic regression analysis.

	df	Mean deviance	Deviance	Deviance ratio	Approx chi pr.
Regression	5	47.8	9.56	9.56	<.001
Residual	300	820.5	2.74		
Total	305	868.3	2.85		

Table 4.9 The estimated coefficients for the logistic regression model.

	Estimate	s.e.	t(*)	t pr.
Constant	1.966	0.63300	3.11	0.002
E	-0.02214	0.00506	-4.37	<.001
N	-0.02654	0.00979	-2.71	0.007
EN	0.0000791	0.0000251	3.15	0.002
E2	0.0000480	0.0000133	3.61	<.001
N2	0.0000348	0.0000427	0.82	0.414

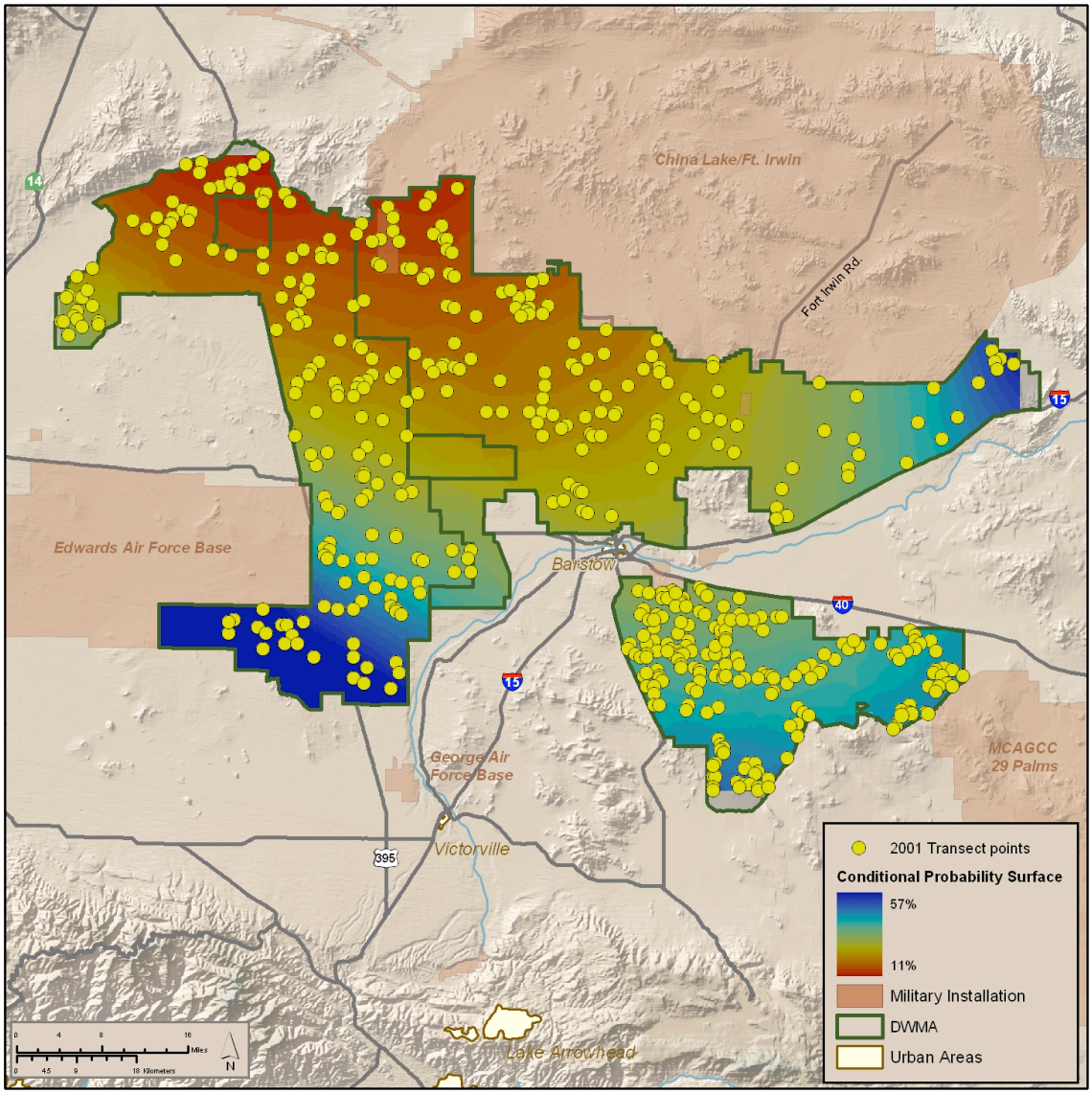

Fig. 4.21 Results from the logistic regression analysis. Cooler colors indicate higher probabilities of encountering a live tortoise, and warmer colors indicate a lower probability.

4.3.5 Kernel Analyses

(distance sampling transects, range-wide, 2001).

The analyses presented above are useful for comparisons among DWMAs, but do not indicate *where* within an individual DWMA one would be more likely to find live tortoises. The kernel, cluster, and conditional probability of being-alive analyses presented below however, do indicate *where* within a DWMA one would expect to find live tortoises. This type of within-DWMA spatial analysis requires that the sample transects be significantly spatially random or regularly distributed. As such (for reasons given above), only the 2001 LDS data were used.

This analysis used adaptive kernels (frequently used for home range analyses) to smooth the distributions of the observations of live tortoises and carcasses on the distance sampling transects to look for lack of overlap in regions of these two smoothed distributions. Data were separated into groups of adjacent DWMAs that had similar numbers of transects per area. Observations from these groups were separated into two datasets, one for live observations and one for carcass observations. Kernel analyses were conducted for both the live tortoises and carcasses for each of the groupings. The kernels were created using the Animal Movement Extension (v 2.04b, Hooge and Eichenlaub 2001) for ArcView 3.2 (ESRI, Redlands, CA). The smoothing factor (H) was reduced to a value below that of the default to constrain the kernels to areas that were close to the boundaries of the sampled areas. These smoothing factors were taken to be the same for the carcass and live kernels for each area. Separate kernel analyses were conducted for the following areas which are generally denoted by the DWMAs included therein: 1) Upper Virgin River (Fig. 4.22); 2) Beaver Dam Slope/Mormon Mesa/Gold Butte-Pakoon (Fig. 4.23); 3) Coyote Springs (Fig. 4.24); 4) Piute-Eldorado Valley (Fig. 4.25); 5) Chuckwalla (Fig. 4.26); 6) Joshua Tree/Pinto Mountain (Fig. 4.27); 7) Chemehuevi (Fig. 4.28); 8) Ivanpah (Fig 4.29); and Fremont-Kramer/Superior-Cronese, and Ord-Rodman (Fig. 4.30).

The kernel analyses revealed several areas in which the kernel estimations for live tortoises and carcasses did not overlap. The pattern of non-overlapping kernels that is of greatest concern are those in which there were large areas where the kernels encompassed carcasses but not live animals. These regions represent areas within DWMAs where there were likely recent die-offs or declines in tortoise populations. This pattern occurred in half of the areas for which kernel analyses were conducted (Figures 4.24, 4.25, 4.29, 4.30). It should be noted that a few of these areas had relatively few transects (Fig. 4.25, 4.29), and that the data underlying all of these results come from only one year of sampling (2001).

Kernel analyses for the Upper Virgin River (Fig. 4.22), Chemehuevi (Fig. 4.28), Joshua Tree/Pinto Mountain (Fig. 4.27), and Chuckwalla (Fig. 4.26) DWMAs had distributions of live and dead animals that were more like what we expect to occur in “normal” tortoise populations, in that carcasses occurred in the same areas as live animals and not in extensive areas absent of live animals.

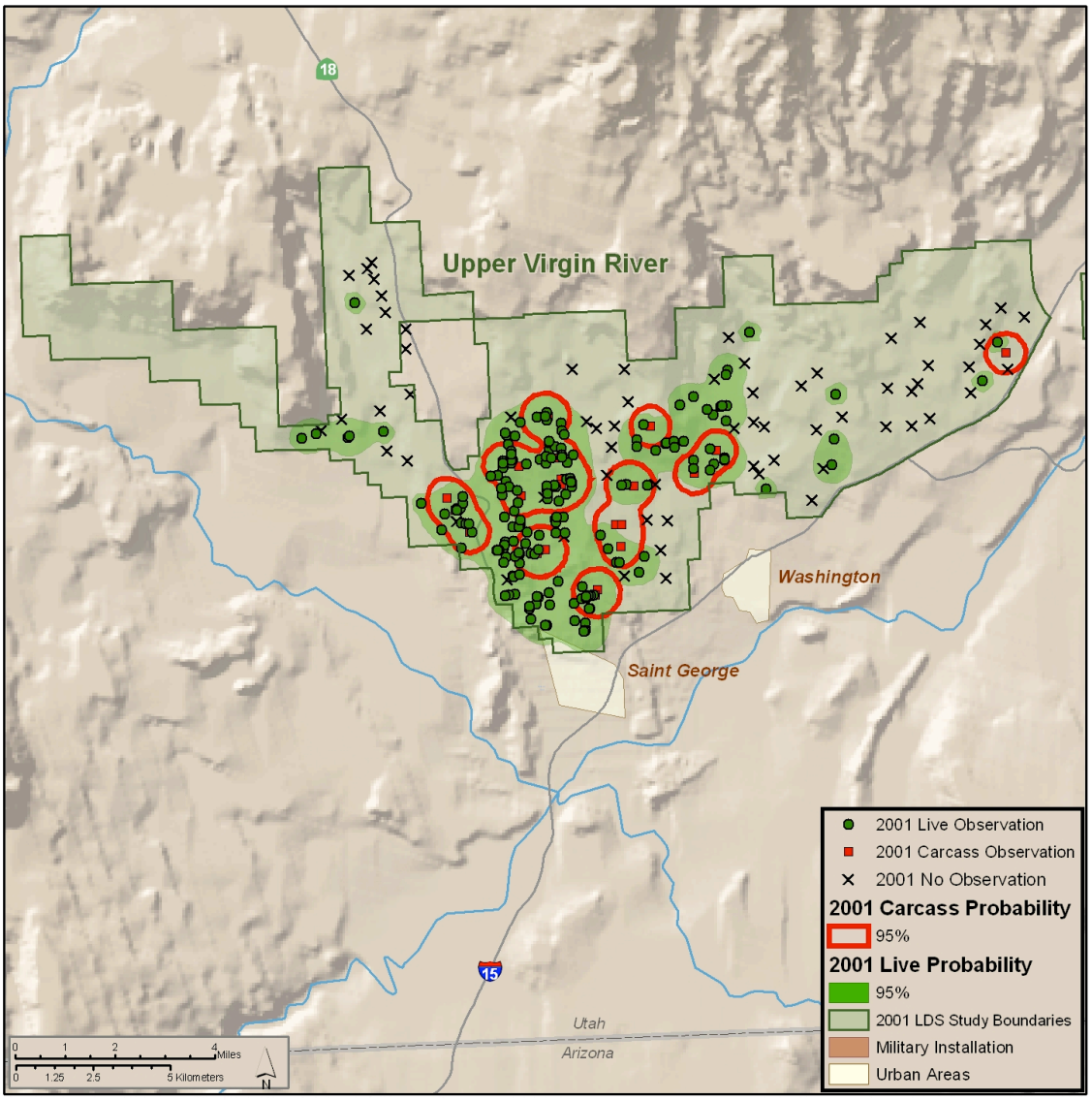

Fig. 4.22 Kernel analysis for the Upper Virgin River DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

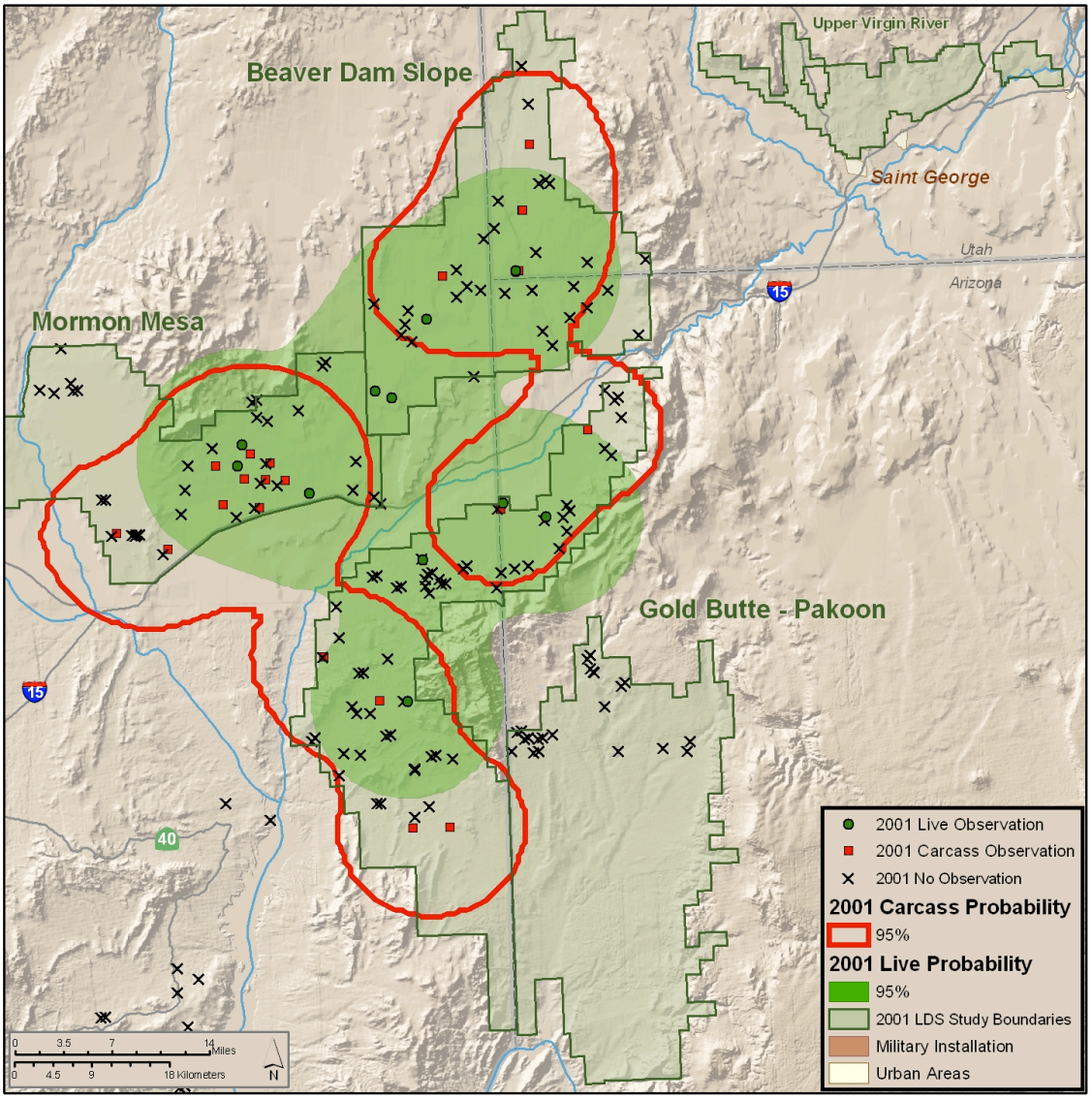

Fig. 4.23 Kernel analysis for the Beaver Dam Slope / Mormon Mesa / Gold Butte-Pakoon DWMAs. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

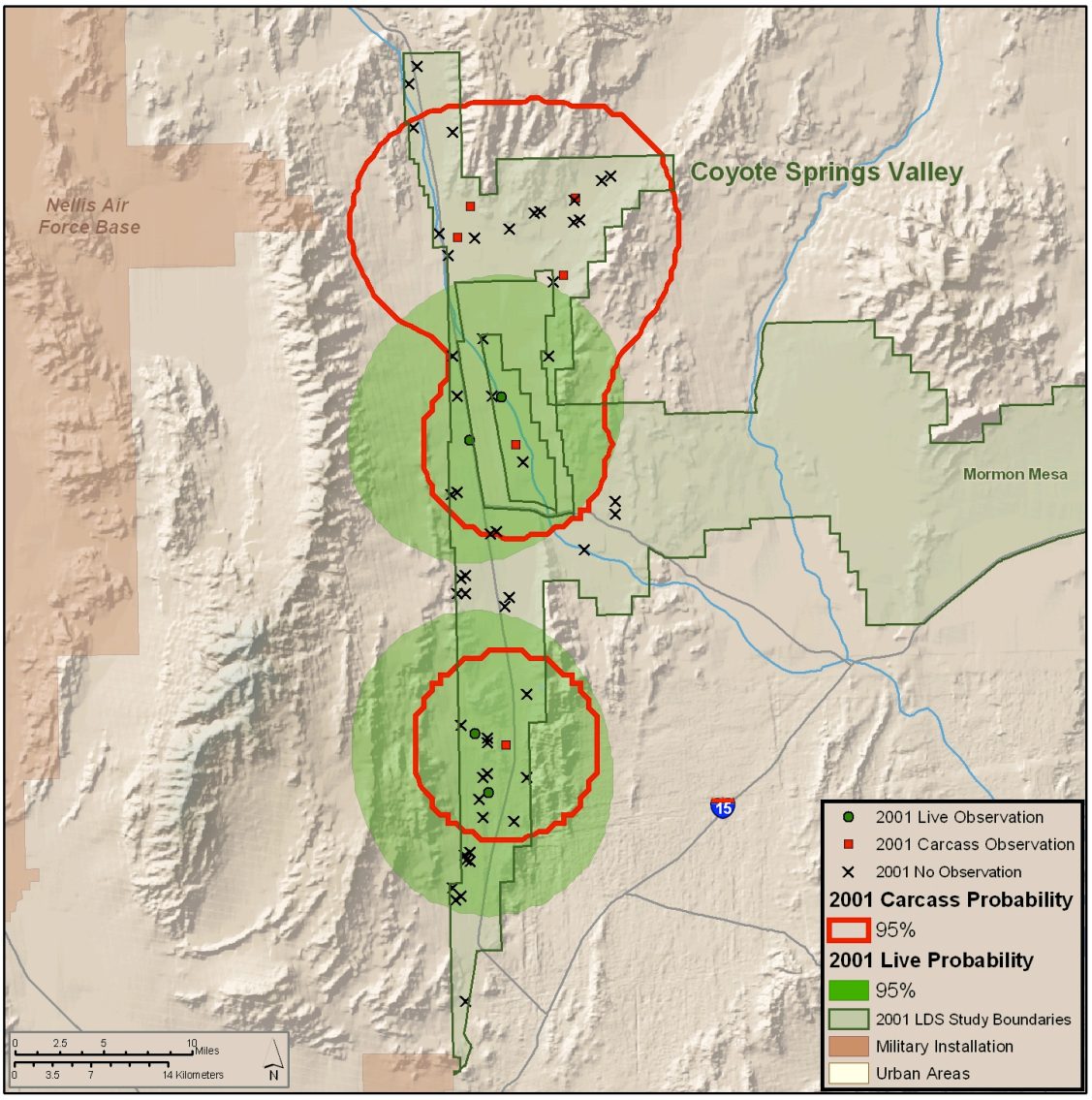

Fig. 4.24 Kernel analysis for the Coyote Springs Valley DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

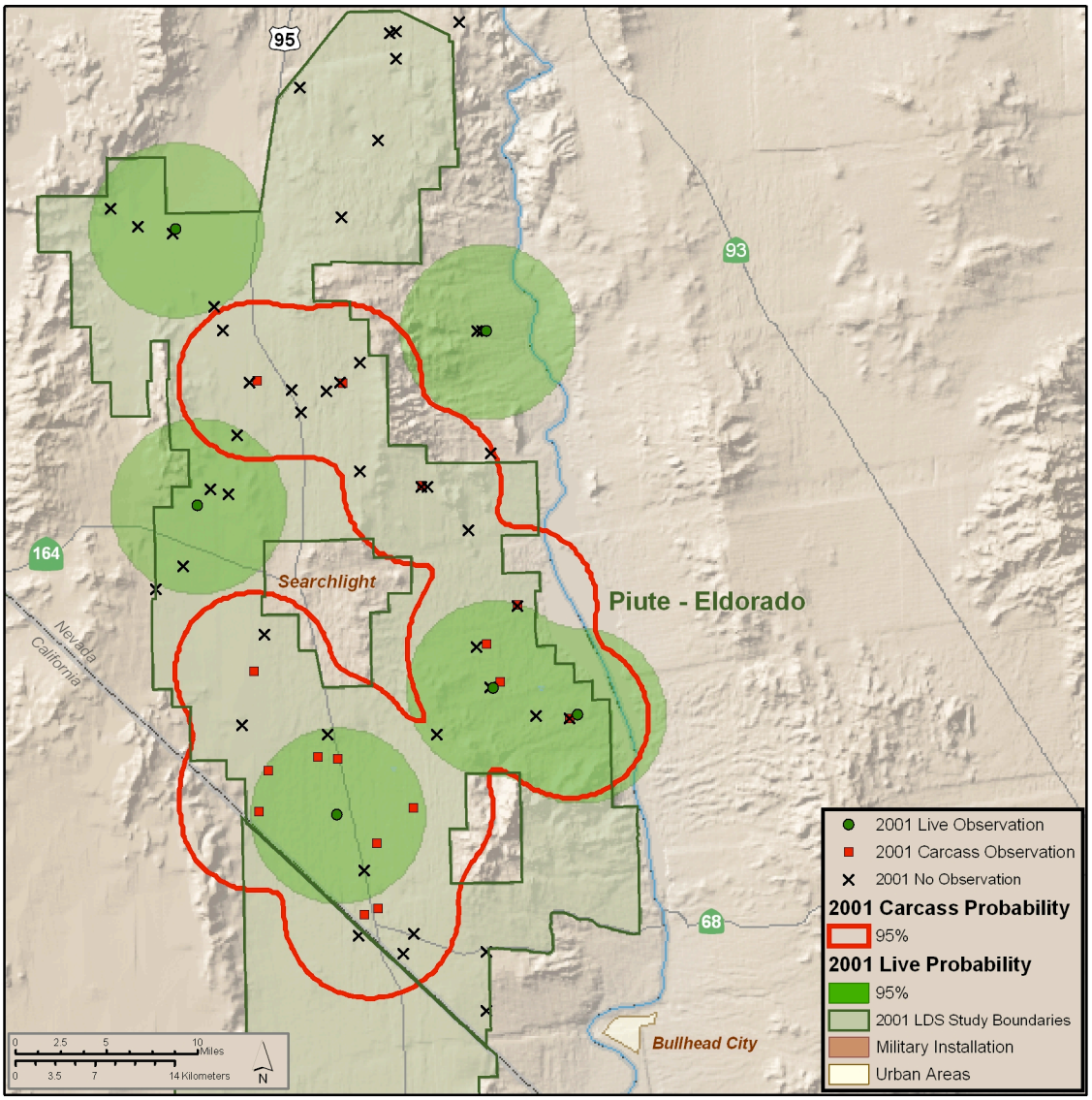

Fig. 4.25 Kernel analysis for the Piute-Eldorado Valley DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

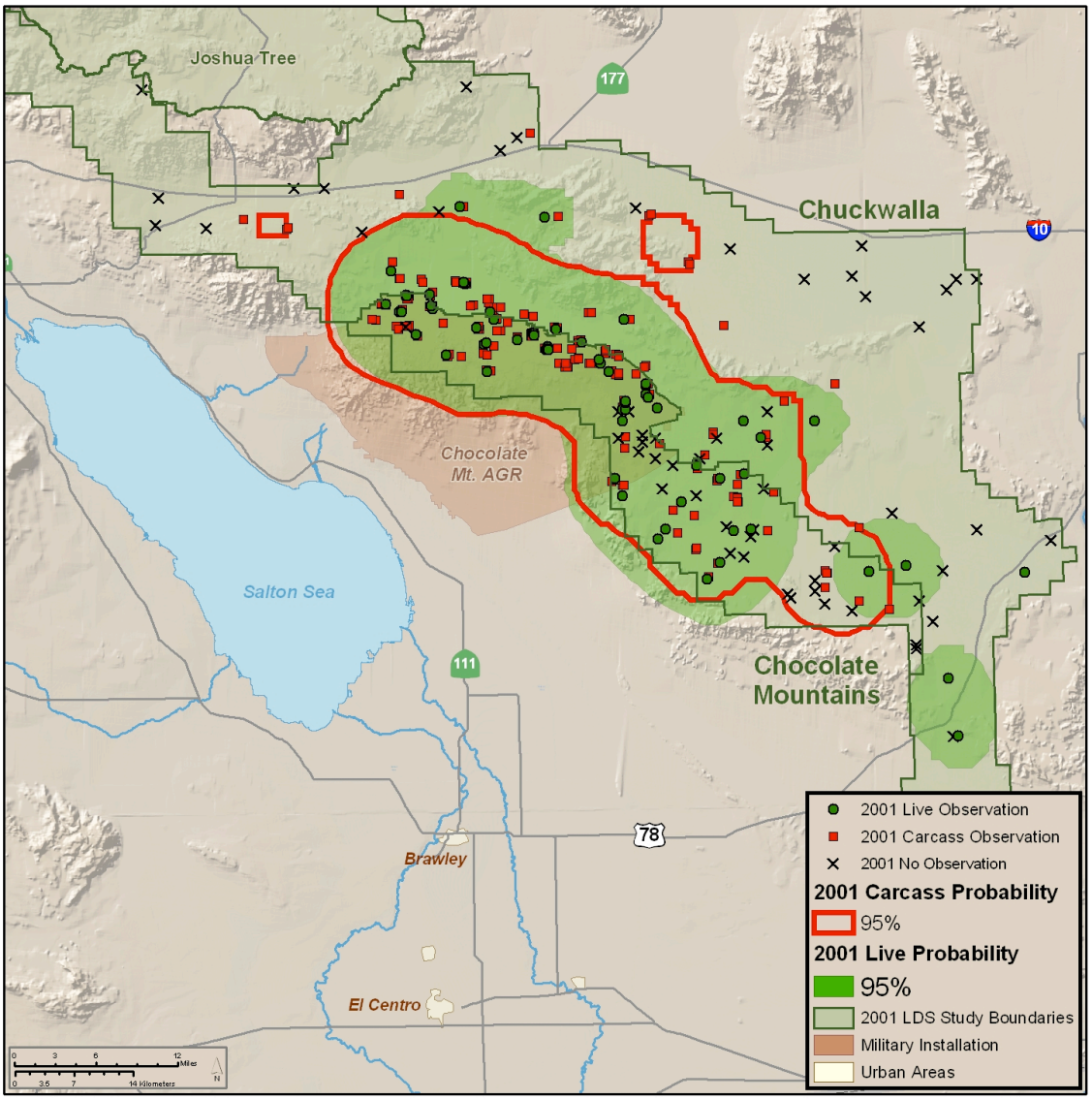

Fig. 4.26 Kernel analysis for the Chuckwalla DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

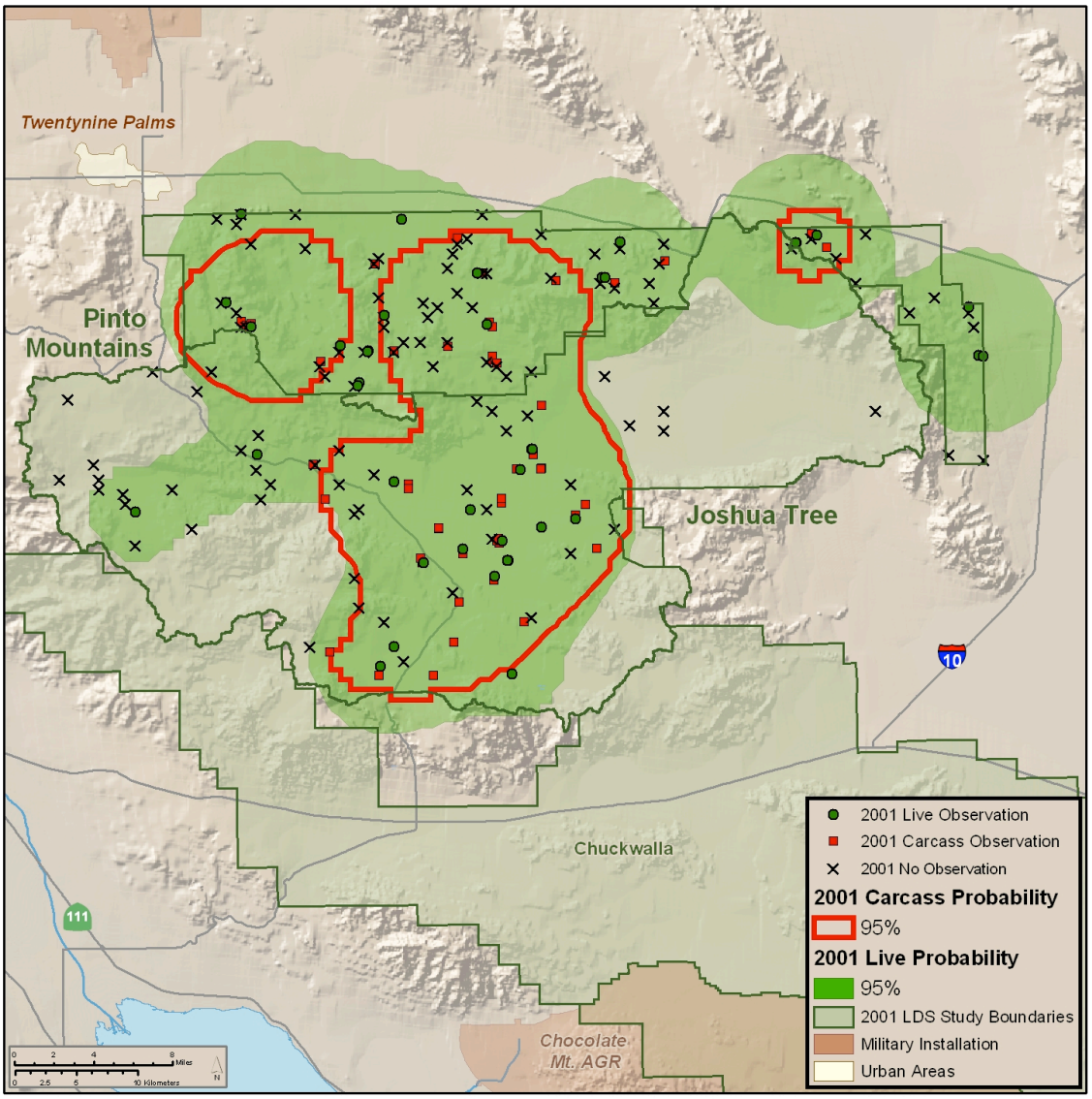

Fig. 4.27 Kernel analysis for the Pinto Mountain and Joshua Tree DWMAs. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

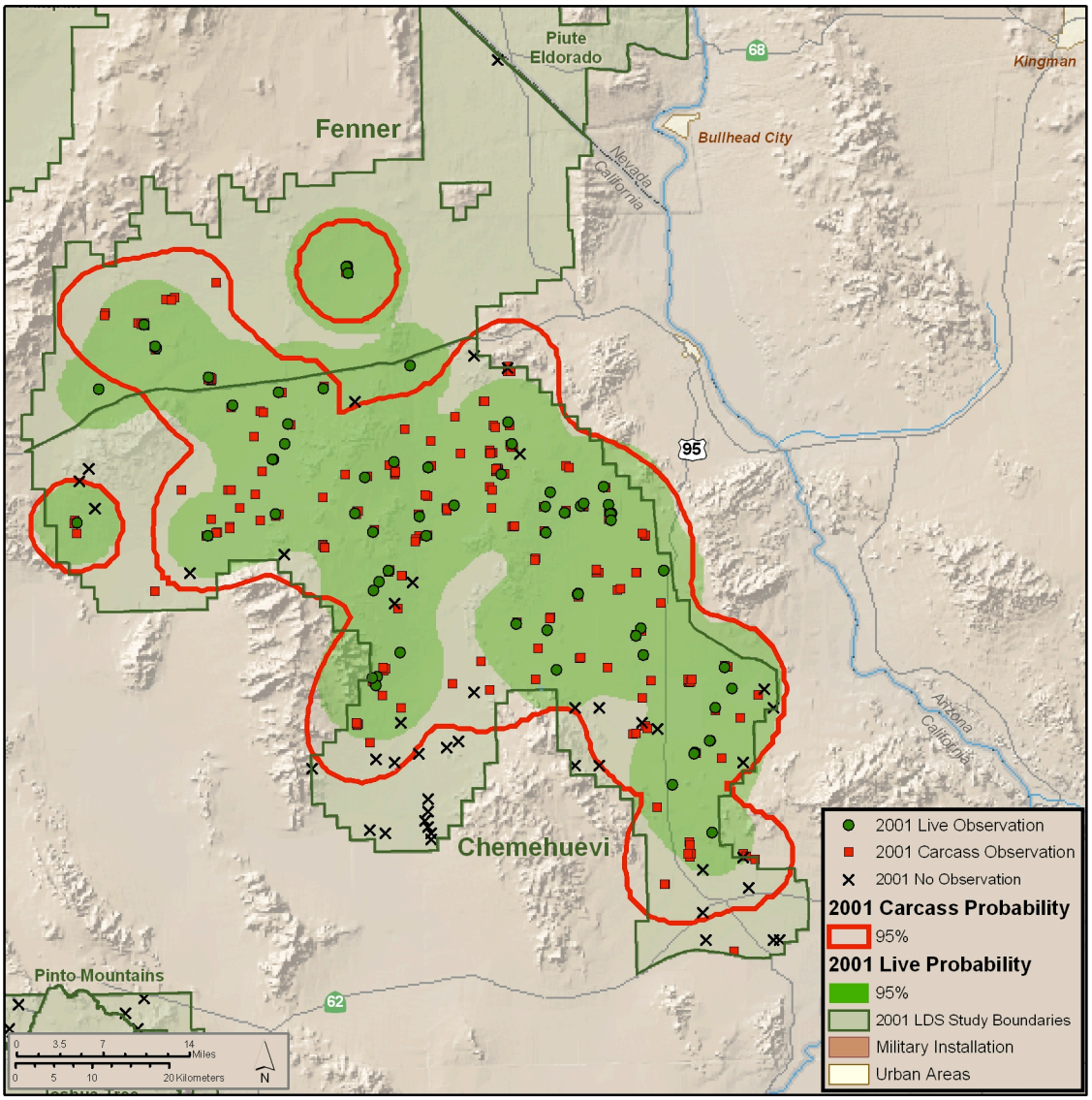

Fig. 4.28 Kernel analysis for the Chemehuevi DWMA The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

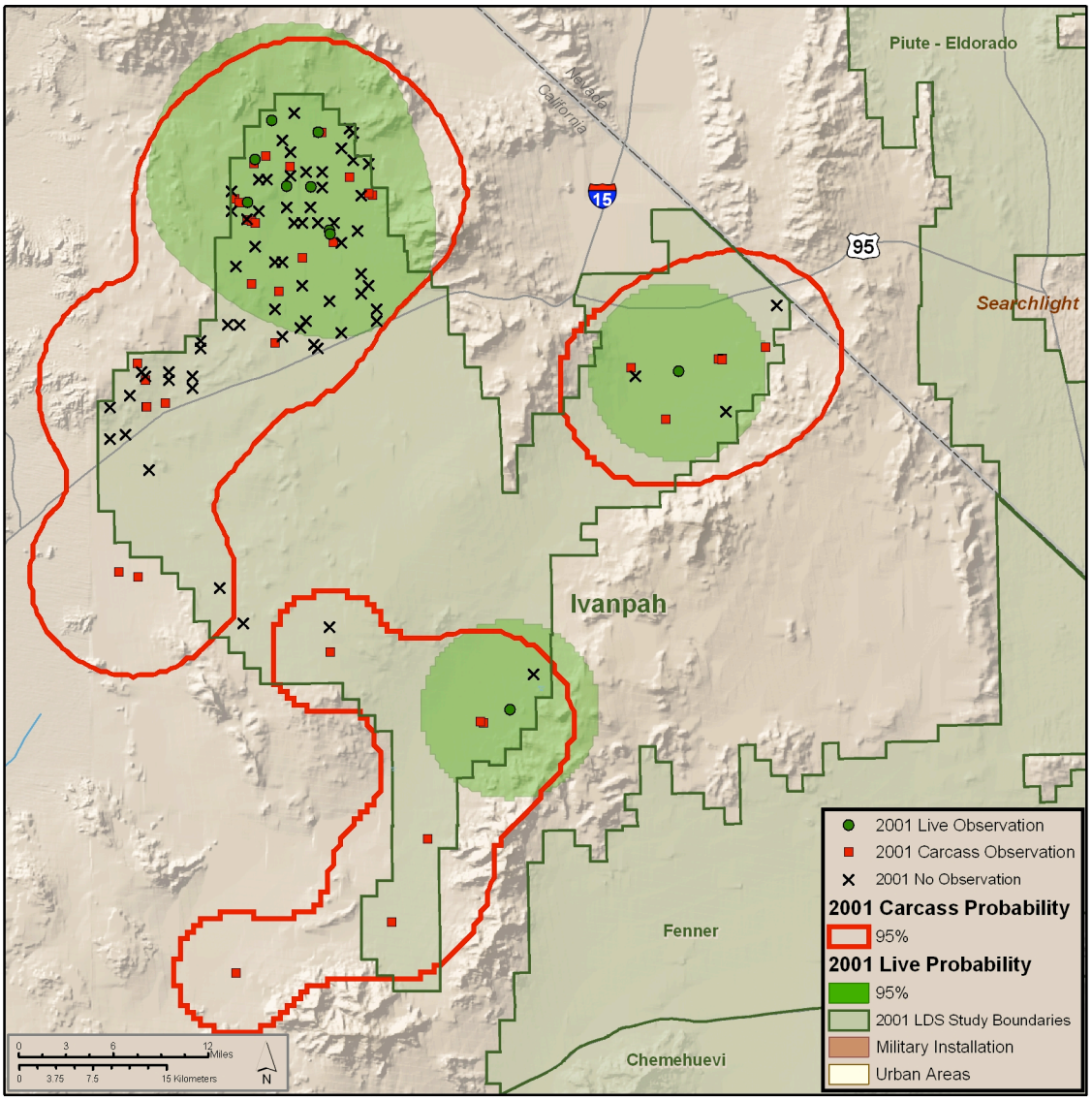

Fig. 4.29 Kernel analysis for the Ivanpah DWMA. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

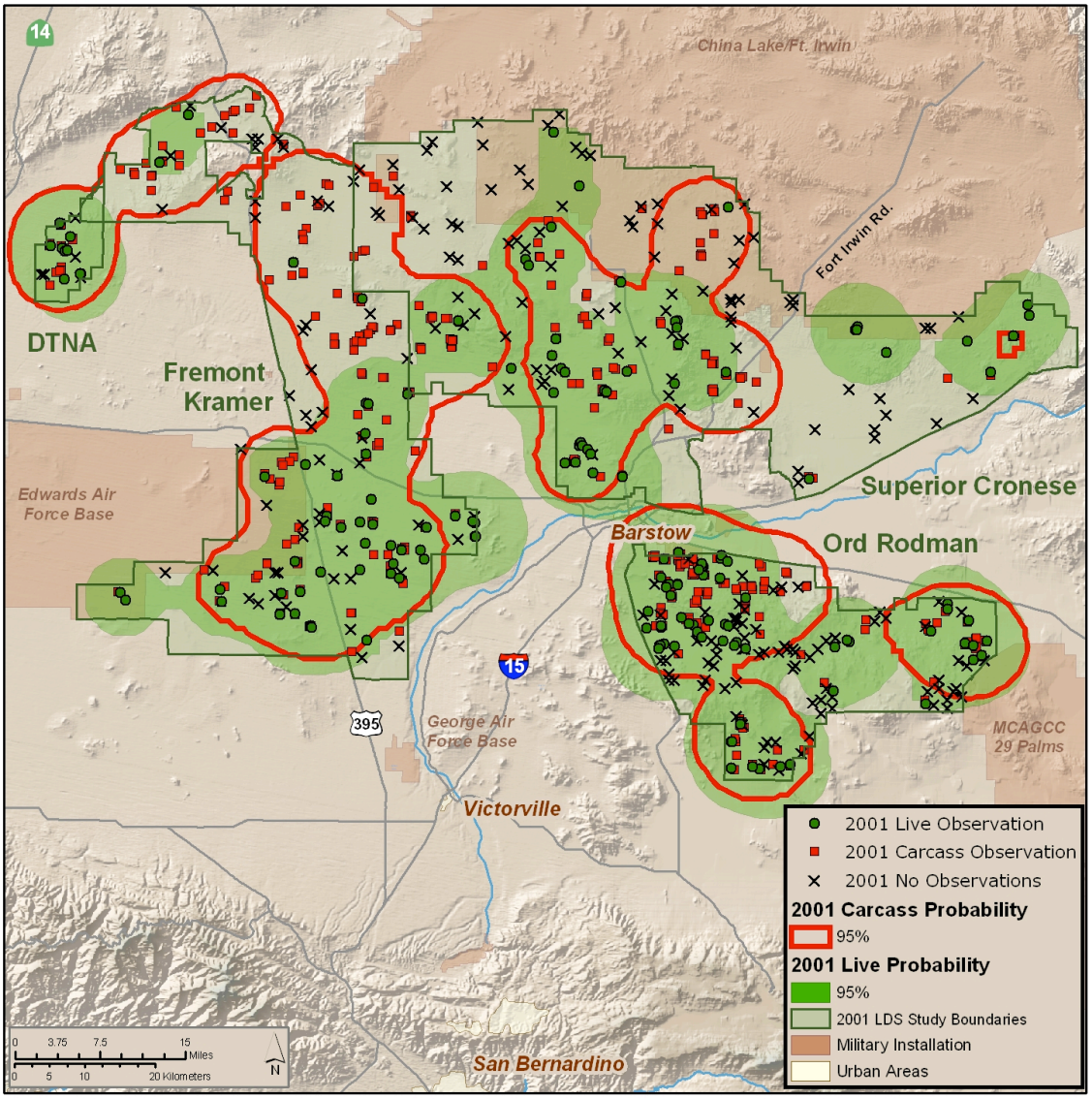

Fig. 4.30 Kernel analyses for Fremont-Kramer / Superior-Cronese, and Ord-Rodman DWMAs. The 95% kernel for live animals is indicated by the green polygon; the 95% kernel for carcasses is indicated by the red outlined polygon. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

4.3.6 Nearest Neighbor Clustering
(distance sampling transects, Western Mojave, 2001).

Nearest Neighbor Hierarchical Clustering analysis was used to identify clusters of live tortoises and carcasses within the Western Mojave. These analyses were performed using CrimeStat II (Levine 2002). Spatial randomness of distance sampling data (2001-2003) and total corrected sign data (1998, 1999, and 2001) was tested. The tests included analysis of each year, all years, and both. All analyses were using the ArcView extension Animal Movement (Hooge and Eichenlaub 2001). The results of these tests confirmed that distance sampling transects in 2001 were randomly distributed. However, all other years and all combinations of years and methods were statistically spatially clustered. Thus, only data from 2001 were analyzed. As with the kernel analyses, where one finds live animals one would expect to find carcasses at some level, although the draft West Mojave Plan (BLM et al. 2003, Appendix L) reported that carcass counts were not correlated with transect live tortoises counts. However, our analyses were conducted for presence and absence and not for densities. Where one finds carcasses and no live animals there is cause for concern, suggesting recent die-offs in these areas.

The Nearest Neighbor Hierarchical Spatial Clustering routine used by CrimeStat is a constant-distance clustering routine that groups points together on the basis of spatial proximity (Levine 2002). The threshold distance (i.e., the confidence interval around a random expected distance of a pair of points) was set to 0.95 (i.e., fewer then 95% of the pairs could be expected to be as close or closer by chance). Only pairs of points that are closer together than this threshold distance are grouped together as clusters. The minimum number of points required to create a cluster was set to 5. The size of the ellipse around the cluster was set to one standard deviation, which would cover about 65% of the points.

The Cluster analysis revealed numerous patterns of statistically significant live and carcass clusters, and these clusters did not overlap in several areas. These include; central Fremont-Kramer, western Superior-Cronese, and numerous areas within the Western Mojave (Fig. 4.31).

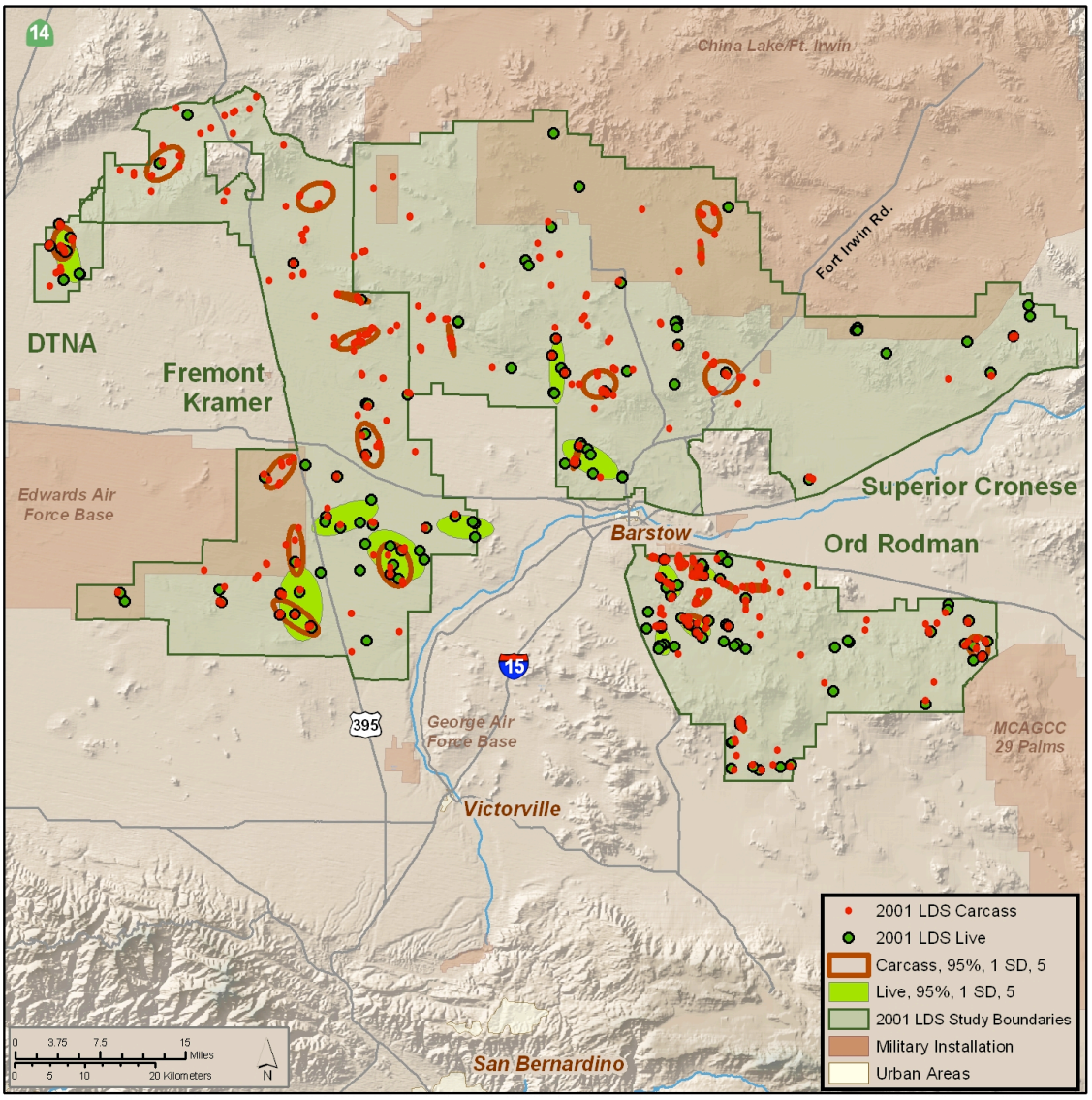

Fig. 4.31 Nearest Neighbour Hierarchical Cluster analysis for the Western Mojave. Green areas are clusters of living tortoises; red outlines are clusters of carcasses.

4.4 Implications of Population and Spatial Analyses

The spatial analyses provided in this report are examples of the kinds of analyses that should be considered by a possible future recovery team and by the science advisors to the USFWS. We recommend that similar analyses be conducted for the rest of the listed range. We also recommend analyses with additional years of data when suitable data become available. Time and data limitations have prevented the DTRPAC from completing all possible analyses for this report.

The Western Mojave (Recovery Unit/DPS) has experienced marked population declines over time (Fig 4.6). This was indicated in the original Recovery Plan and continues today. Spatial analyses of the West Mojave show areas with increased probabilities of encountering dead rather than live animals (Fig. 4.18, 4.19, 4.20, and 4.21), areas where kernel estimates for carcasses exist in the absence of live animals (Fig. 4.31), and extensive regions where there are clusters of carcasses where there are no clusters of live animals (Fig. 4.31). Collectively, these analyses point generally toward the same areas within the West Mojave, namely the northern portion of the Fremont-Kramer DWMA and the northwestern part of the Superior–Cronese DWMA. Together, these independent analyses, based on different combinations of data, all suggest the same conclusion. The management strategy and implementation of recommended management actions over the last decade in West Mojave Recovery Unit have not slowed the decline of tortoise populations, and tortoise numbers are plummeting. Indeed the Draft West Mojave Plan (WMP) points out problems within the same areas highlighted in our analysis. For example, despite historically high densities of tortoises (BLM et al. 2003, map 3-7) within some portions of the West Mojave Recovery Unit, analyses in the West Mojave Plan indicate recent die offs (BLM et al. 2003, map 3-12) and higher-than-average sign counts (BLM 2003, map 3-8) in the same regions as presented by our independent analyses of the data.

Data are not currently available (i.e., they either do not exist or are not easily accessible) with the same detail for most of the range of desert tortoises. Nevertheless, it is possible to compile and digitally catalog corrected sign data for other recovery units within the listed range, but not without considerable time and money. We had additional historical data for permanent study plots and recent data from distance sampling surveys for these regions, and they were similarly analyzed but not reported. Kernel analyses of DWMAs within other Recovery Units and Distinct Population Segments also show areas of non-overlapping carcass and live animal distributions (e.g., Fig. 4.24, 4.25, 4.29 and 4.30) and this signals reason for concern for these areas. Ivanpah (Fig. 4.29) and Piute–Eldorado Valley (Fig. 4.25) contained study plots that were analyzed in the East Mojave Recovery Unit analysis (Fig. 4.6). While there was no overall statistical trend in adult density over time, the 2000 survey at Goffs and the 2002 survey at Shadow Valley indicate low densities of adult tortoises relative to earlier years. Unfortunately there are no data in the latter years for all five study plots within this recovery unit, and therefore, while there is no statistical trend in adult densities, we cannot conclude that tortoises have not experienced recent declines in this area. The probability of finding a carcass on a distance sampling transect was considerably higher for Ivanpah, Chemehuevi, Fenner, and Piute-Eldorado

which make up the Eastern Mojave Recovery Unit and portions of the Northeastern Mojave and Eastern Mojave/Colorado Desert DPSs (Table 4.6).

The kernel analysis for the Piute-Eldorado Valley (Fig 4.25) indicated large areas where there were carcasses, but no live animals were found. For this entire area in 2001, there were 166 km of transects walked, and a total of six live and 15 dead tortoises were found, resulting in a live encounter rate of 0.04 tortoises per km for this area. This encounter rate was among the lowest for that year for any of the areas sampled in the listed range. Analyses of the study plots for the Eastern Mojave Recovery Unit (Fig. 4.6) and the East Mojave and Colorado DPS (Fig. 4.16) do not indicate significantly declining densities of adult tortoises prior to 1997. The kernel analysis for the Ivanpah DWMA also indicates large areas where only carcasses were found and smaller areas where live animals occurred (Fig. 4.29). Analyses of the study plots for the Lower Virgin River DPS (Fig. 4.19) and the Eastern Mojave Recovery Unit (Fig. 4.6) do not indicate significant declines in adult density over time (although note the apparent declines on the Beaver Dam Slope Exclosure and Virgin Slope plots noted in Section 4.2.5).

The Coyote Springs Valley DWMA is included in the Lower Virgin River DPS plot analysis. While the kernel analysis for this region showed areas where the distributions of carcasses and living tortoises do not overlap (Fig. 4.24), densities of adult tortoises for the region do not show a statistical trend over time (Fig. 4.6). Thus, while there may be a local die-off occurring in the northern portion of this DWMA, this does not appear to influence the overall trend in the region as interpreted by study plot data. However, as stated above, the data for permanent study plots for this region were discontinued after 1996. Thus, if there have been recent declines in numbers, they are not reflected in our analyses of study plots. Nevertheless, we did not see large regions of non-overlapping carcass and live tortoise kernels in the regions adjacent to the Coyote Springs Valley DWMA (Fig. 4.24). The probability of finding either a live tortoise or a carcass was relatively very low for Beaver Dam Slope and Gold-Butte Pakoon and moderately low for Mormon Mesa/Coyote Springs Valley (Table 4.6) all within the Lower Virgin River DPS.

The Eastern Colorado Recovery Unit contained only two study plots, and analyses of adult densities over time indicate that there may be declines in this area (Fig. 4.12). From inspection of the density data, it appears that this is likely due to declines in adult density for the Chuckwalla Bench plot, but not the other plot (Fig. 4.12). The kernel analysis of this area shows that the distributions of the living tortoises and carcasses overlap for most of the region sampled by LDS (Fig. 4.26). The Chuckwalla Bench study plot is outside of the distance sampling study area, and this creates a problem in evaluating what may be occurring in that area of the DWMA. However, the few transects walked in that portion of the DWMA yielded no observations of live or dead tortoises. This illustrates our concern for drawing conclusions from areas represented by too few study plots and leaves us with guarded concern for this region. The percentage of transects with live animals was relatively high for most DWMAs within the Eastern Colorado Recovery Unit (Table 4.6). In addition, the ratio of carcasses to live animals was low within this recovery unit relative to others (Fig 4.18).

Desert tortoise populations defy definition in terms of population dynamics even after 30 years of data from a wide variety of studies. In particular, the existing paradigm and the original Recovery Plan treated desert tortoise population dynamics and planned for recovery as individual populations. However, the temporal dynamics revealed in existing data and theory, and the clear indication that populations of tortoises respond remarkably slowly, suggest that this original paradigm needs re-evaluation. Specifically, it is not known if desert tortoises have evolved to exist in single large populations or in metapopulations. The prescriptions for recovery in the Plan were for individual populations and assumed that preserving large blocks of habitat and managing threats in that habitat would be principally all that would be necessary to recover the species. However, that original paradigm, and the prescriptions made within that paradigm, may be wrong and dangerously misleading and ineffective. Consider, for example, that existing data have revealed population crashes occurring asynchronously across the range. There are reports that some populations, which have crashed previously, have subsequently increased in population density. Additionally, everywhere where populations have been dense, those populations have crashed. This suggests that density-dependent mortality occurs in desert tortoise populations, and that population dynamics may be asynchronous.

These characteristics indicate that tortoises may exist in a classic metapopulation (Hanski, 1999, Levins and Culver 1971, Levins et al. 1984), and this should portend profoundly different prescriptions for recovery. In particular, if desert tortoises have historically existed in metapopulations, then connections among habitat patches are a necessary part of conservation prescriptions. Additionally, habitat suitable for tortoises, but without tortoises, should be regarded as equally necessary for recovery. Assessing the state of a metapopulation (including the long-term persistence of the species) will be entirely different and needs to be the subject of future research and consultation. Long-term persistence cannot be determined from tortoise density or tortoise numbers alone, but assessment must include the complexities of metapopulation dynamics and the habitat characteristics that promote metapopulation dynamics (habitat connectivity through inefficient corridors (i.e., partial connectivity), asynchrony of subpopulation dynamics, several separate habitat patches, and others). Some of the characteristics of proper metapopulation function may already have been obviated by proliferation of highways, and habitat fragmentation due to satellite urbanization. Thus, management may require artificially facilitating metapopulation processes such as movement among patches. Insofar as having the correct paradigm is central to recovery success, this is a critical area requiring attention by science consultants to the USFWS.

Plot and Spatial Analysis Recommendations

1. There were several recovery units and proposed DPSs that contained too few permanent study plots to be analyzed either with any power, or at all. If study plot sampling is to continue, it would be better if there were enough study plots to represent the different scales of management areas. As a study plot is in itself only a sample, and not representative of an entire area, it would be beneficial to have several plots within each area upon which future analyses are to be conducted, for example a DPS, or even for DWMAs within DPSs.

2. If permanent study plots are to be continued (see, for example, recommendations in Section 3), then there should be some agreement among the surveying agencies to share the data for the greater good of the tortoise species. Permanent study plots played a key role in this committee's interpretation of the current status of tortoise populations, but it is possible that some of the conclusions reached as a result of our analyses could be different had additional years of data been available. However, the trend from the Western Mojave is a solid conclusion that cannot be disputed.

3. We found the exploration of new analyses, especially those that can be conducted with existing data or with little modification of current monitoring methods, to be extremely valuable toward understanding the status of tortoise populations and the inadequacies of current monitoring. These types of analyses should be part of any future reporting on status and trends of desert tortoise to the MOG, DMG, and/or Congress. These kinds of analyses should be prepared by a body like the recommended Desert Tortoise Recovery Office discussed in Section 7.3 of this report, so that regular advice can provide a means towards improved monitoring.

4. The paradigms of population/metapopulation dynamics need to be re-evaluated. This may require explicit experimental research to dissect the driving ecosystem processes important to long-term persistence of desert tortoise populations or metapopulations.

4.5 Status and Trends of Habitat and Environmental Setting for Tortoise Populations

An efficacious monitoring program should be multidimensional, including monitoring of populations, monitoring the extent and condition of habitat, and monitoring threats to tortoises. Monitoring habitats and threats has not previously been part of the protocols for monitoring the desert tortoise, so analyses of past efforts is not possible. However, it is possible retrospectively to provide examples of how such analyses can be conducted. We present the examples below as “case studies.”

4.5.1 Road Case Study

Habitat monitoring considers variables related to the physical environment of the desert tortoise. These variables can include natural processes, such as climate and weather, and anthropogenic threats, such as presence of roads, livestock grazing, urbanization, etc. In this case study, we explore the temporal distribution of routes (i.e., roads) inventoried between the mid 1980s and 2001 and the co-occurrence of above average vehicle impact areas with higher density TCS and die-off regions as presented by the West Mojave Plan (BLM et al. 2003).

Roads are conduits by which humans come into contact with tortoises. Hence, understanding the relationship between the presence of roads and tortoise population dynamics may be important to formulating desert tortoise recovery strategies. The original Recovery Plan recommended: 1) prohibiting vehicles from driving off roads; 2) restricting proliferation of new roads; 3) closing vehicle access to all but designated routes; and 4) implementing emergency closures of unpaved roads and routes as needed to reduce human access and disturbances in areas where human-caused mortality may have caused negative population trends. The plan also specifically highlighted the need to halt unauthorized ORV use in the Fremont-Kramer DWMA (USFWS 1994, Table 4.3).

The comparisons made in this case study use the best data available to the DTRPAC. However, we are aware that both road and tortoise data are imperfect, thus we identify possible scenarios resulting from these imperfections and geographic regions within the Western Mojave that yield contradictory relationships between the presence of roads and tortoise sign.

The following data were used in this case study: 1985-87 (Fig. 4.32) and 2001 routes (Fig. 4.33) provided by the BLM. Above average vehicle impact areas, areas identified as higher then average sign counts, and areas with recent die-offs (Fig 4.34) were taken from the West Mojave Plan. In the following section, *inventory* and any of its variants, is used to represent routes (i.e., roads) without dealing with official designation (i.e., open, closed, undetermined, etc.). Different methods were used by the BLM to inventory routes between 1985-87 and 2001. In particular, Global Positioning System (GPS) and Geographic Information Systems (GIS) were used for locating and mapping roads in 2001 but not in 1985-87. Thus, the 2001 inventory is likely to be more detailed and more accurate than the initial 1985-87 inventory. Despite this discrepancy, the data used for this case study represent the best available data, data for which management and policy decisions have been made, and data for which management and policy decisions are being made currently (e.g., WMP and West Mojave Route Designation).

The 2001 inventory of roads (Fig. 4.33) indicates that a higher density of roads currently exists within DWMAs in the West Mojave than was documented in 1985-87 and also that more roads are currently documented than were documented in 1985-87 (Fig. 4.34). One explanation for the increase in road density in the Western Mojave is that the number of roads increased during this period. Based on the increased human population in the western Mojave during this time, an actual increase in roads is a plausible and likely explanation for the increase in inventoried roads. This is especially likely considering the popularity of vehicle-based recreation in the desert leading to the legal and illegal creation of single and two-track routes. However, an important alternative explanation exists. It is plausible and likely that at least some of the recently mapped roads are historic rather than newly created, especially considering the effectiveness of GPS-based mapping and increased survey effort in recent years. This alternative hypothesis is important because arithmetically it is possible that the rate of discovery of established roads (better technology and greater effort) exceeded the rate of road closures (management action) and resulted in more apparent roads. It is possible that the question of recent road creation could be resolved by analyzing consistently collected data such as satellite and aerial surveys that documented the presence

or absence of roads in the Western Mojave from 1987-2001.The DTRPAC encourages management agencies to consider performing this analysis.

The tortoise population dynamics information for the western Mojave also has caveats. In particular, the "higher density TCS areas" may have used burrow counts as well as sightings of live tortoises and tortoise scats. Hence, it is possible that higher than average TCS may be inflated relative to other surveys techniques. This is an example of the difficulties that arise when data are inconsistently collected, named, and reported.

The number of inventoried routes increased significantly between 1985-87 and 2001 (Fig. 4.32 and 4.33). The spatial location of open routes between 1985-87 and 2001 has changed significantly (Fig 4.35 and 4.36). The red lines in Fig. 4.35 represent 2001 officially designated open routes that were not similarly designated as such in 1985-87. In some cases these routes may have existed in 1985-87 but failed to be inventoried, or if inventoried they were not designated as open. The blue lines in Fig. 4.36 represent 1985-87 officially designated open routes that were not officially designated as open in 2001. In some cases these routes may no longer exist, they exist but were not inventoried in 2001, or they may still exist but were not officially designated as open in 2001.

We identified 6 regions within the western Mojave roads case study that each indicate a different potential relationship between roads, higher then average TCS densities, and tortoise die-off regions (Fig. 4.34). We identify tortoise die-off regions within and outside vehicle use areas (Fig. 4.34, regions A and B, respectively); higher then average TCS densities within and outside of vehicular areas (Fig 4.34, regions C and D, respectively); areas simultaneously with high die-off, high TCS, and vehicle use (Fig. 4.34, region E); and areas with simultaneous high die-off, high TCS, and no vehicle use (Fig. 4.34, region F). A superficial explanation for these results is that vehicle use is unrelated to higher than average density TCS and/or die-off regions. This interpretation is incongruous with other indications that tortoise mortality is linked to human encounters via roads and would require a reinterpretation of other studies. Alternatively, there are many kinds of vehicle use and some uses are relatively innocuous to tortoises whereas other uses are deleterious. It is also possible that the data in this comparison lack sufficient resolution to detect the real and complex relationships between TCS, carcasses, roads, and vehicle use.

Road Case-Study Recommendations

1. Management agencies should compare historic satellite and aerial surveys to better document changes in road density.

2. Despite ambiguities in the current case study, a similar approach could be employed using rigorously collected data to reveal real and important relationships between tortoise population dynamics and presence of roads or other aspects of, or impacts to, desert tortoise habitat.

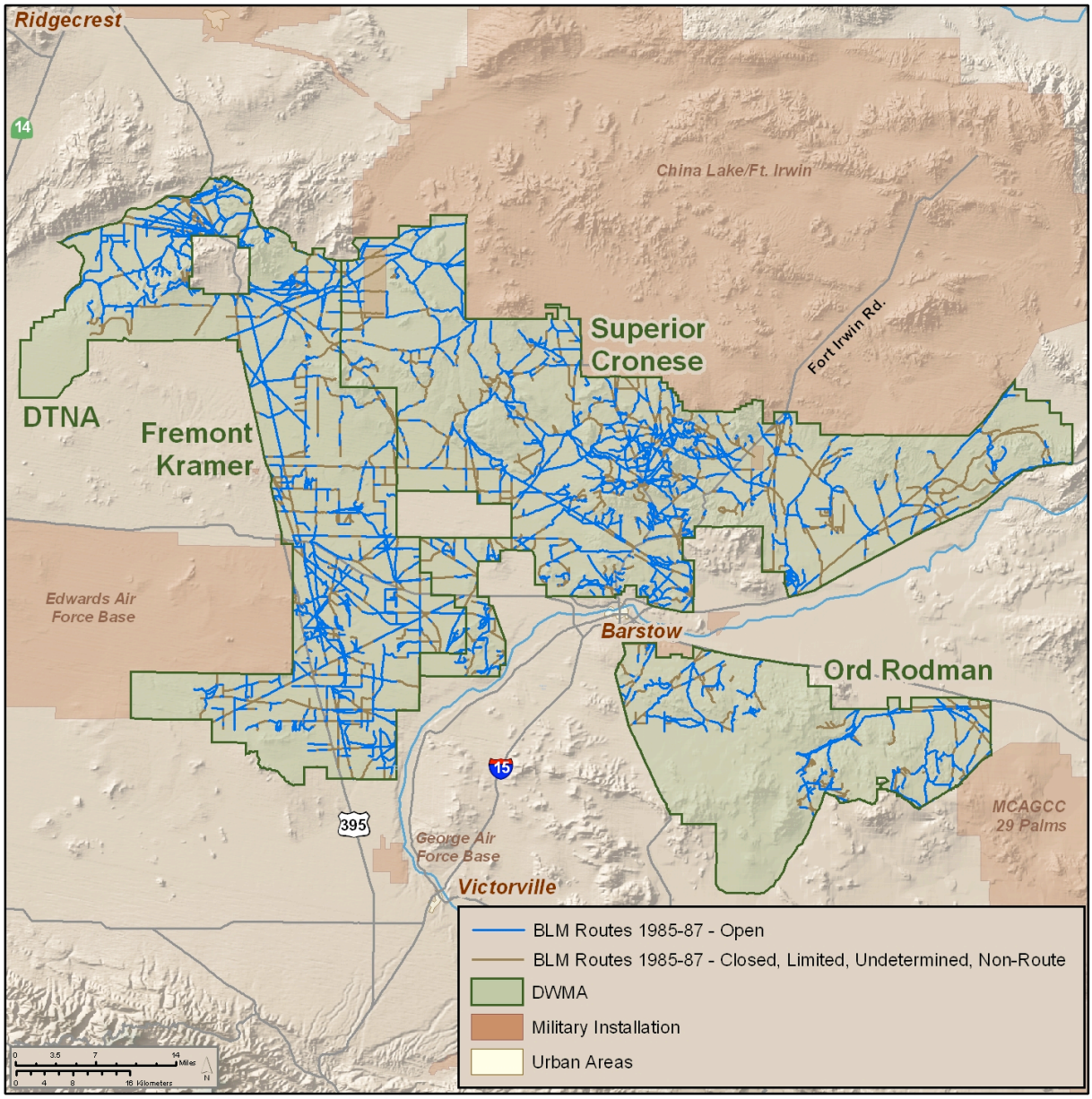

Fig. 4.32 Routes in the Western Mojave DWMAs in 1985-87. Blue routes were designated as open, brown as either closed, limited, undetermined, or non-route. Large roadless areas such as southwest Ord-Rodman, and the most southwestern portion of Fremont-Kramer were not without roads in 1985-87, but were instead not inventoried. On the other hand, the DTNA was designated by the BLM as an Area of Critical Environmental Concern and fenced in the late 1970's, thus creating a roadless area.

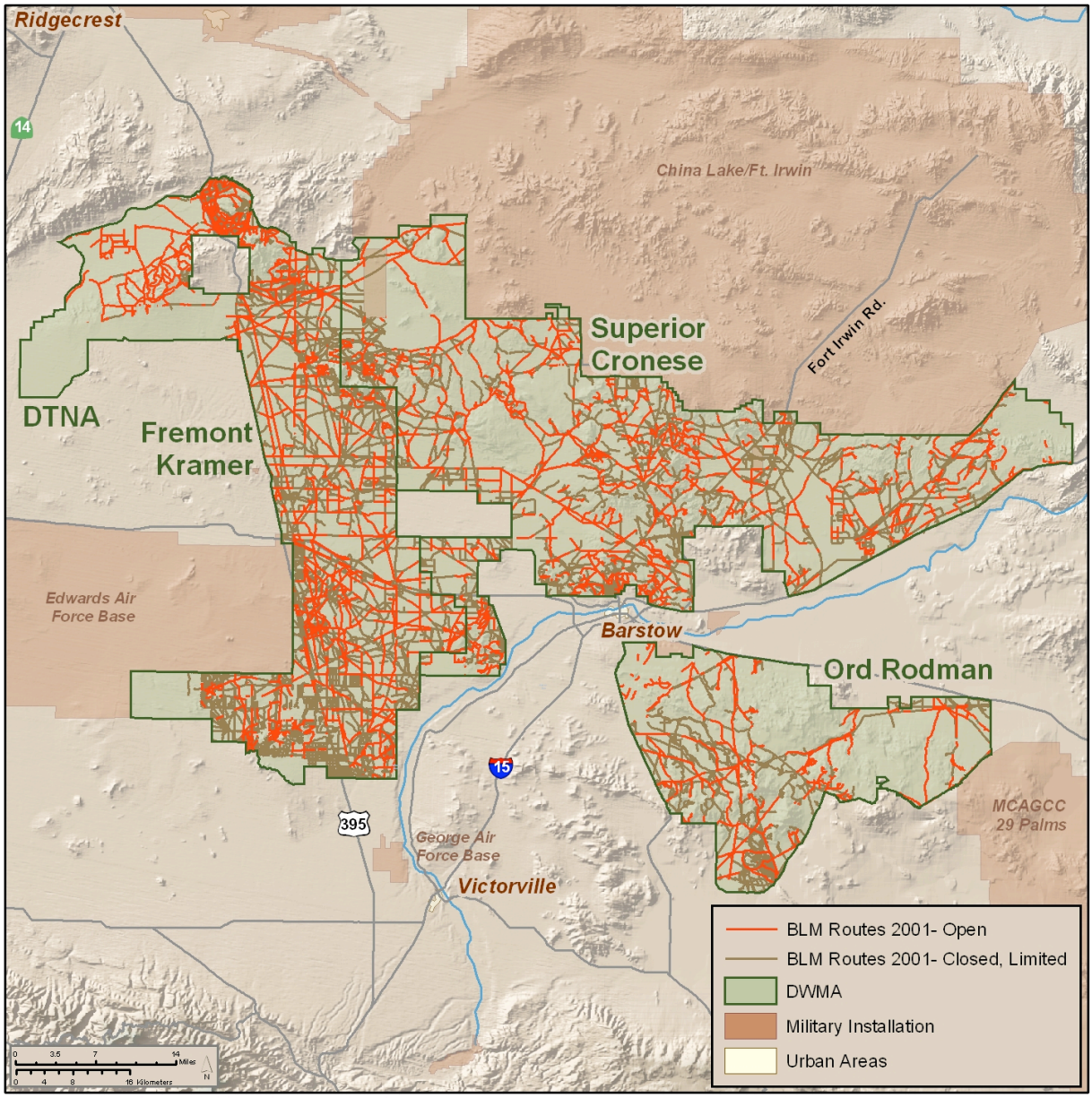

Fig. 4.33 Routes in the Western Mojave DWMAs in 2001. Orange routes were designated as open, brown as either closed, limited, or non-BLM owned routes. The most southwestern portion of Fremont-Kramer remains un-inventoried as does portions of northern Fremont-Kramer, excluding the DTNA.

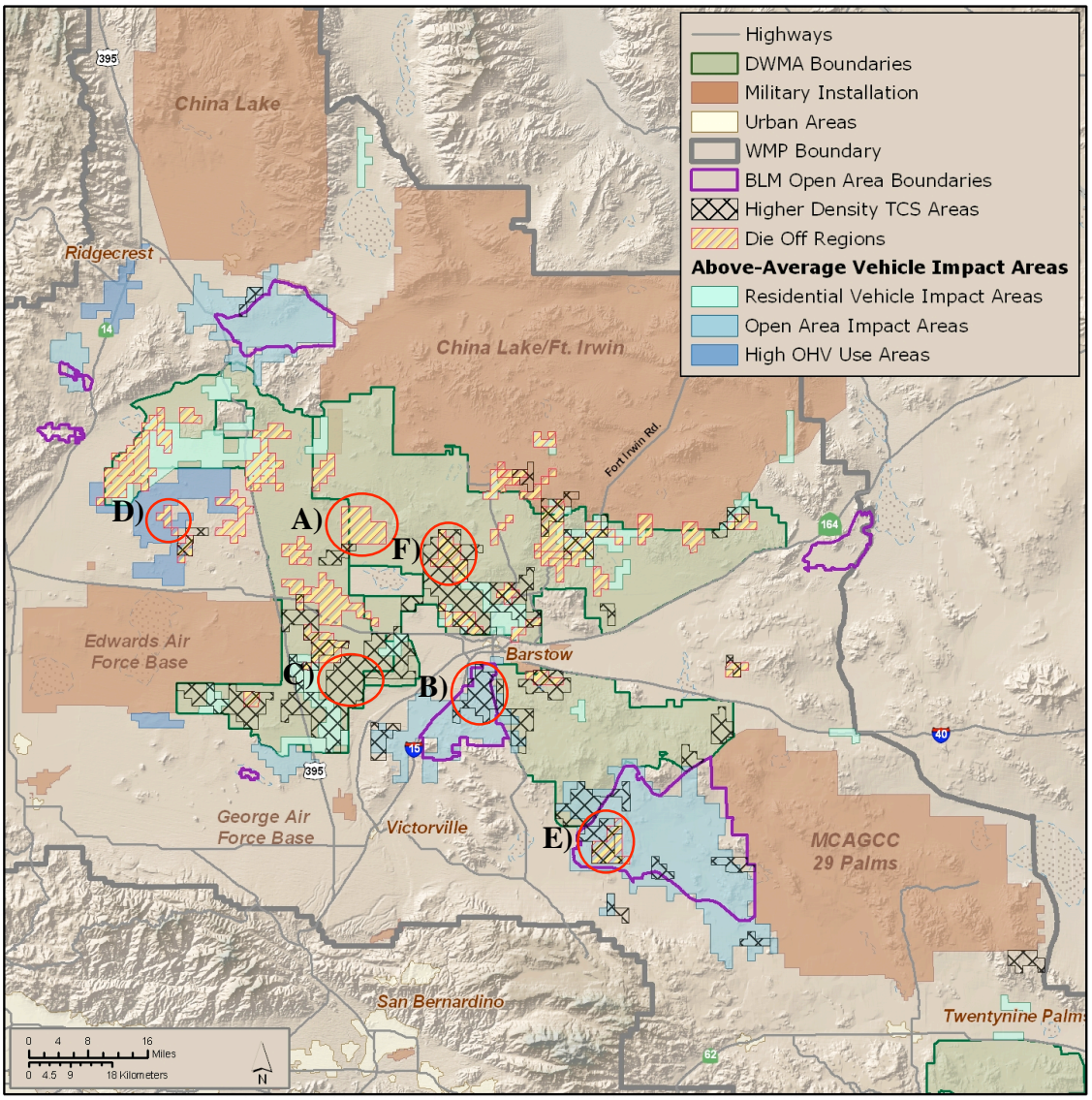

Fig. 4.34 Distribution of above average vehicle based impacts areas, higher then average TCS and recent die-off regions as reported by the West Mojave Plan (BLM et al 2003). Letters are explained in the text.

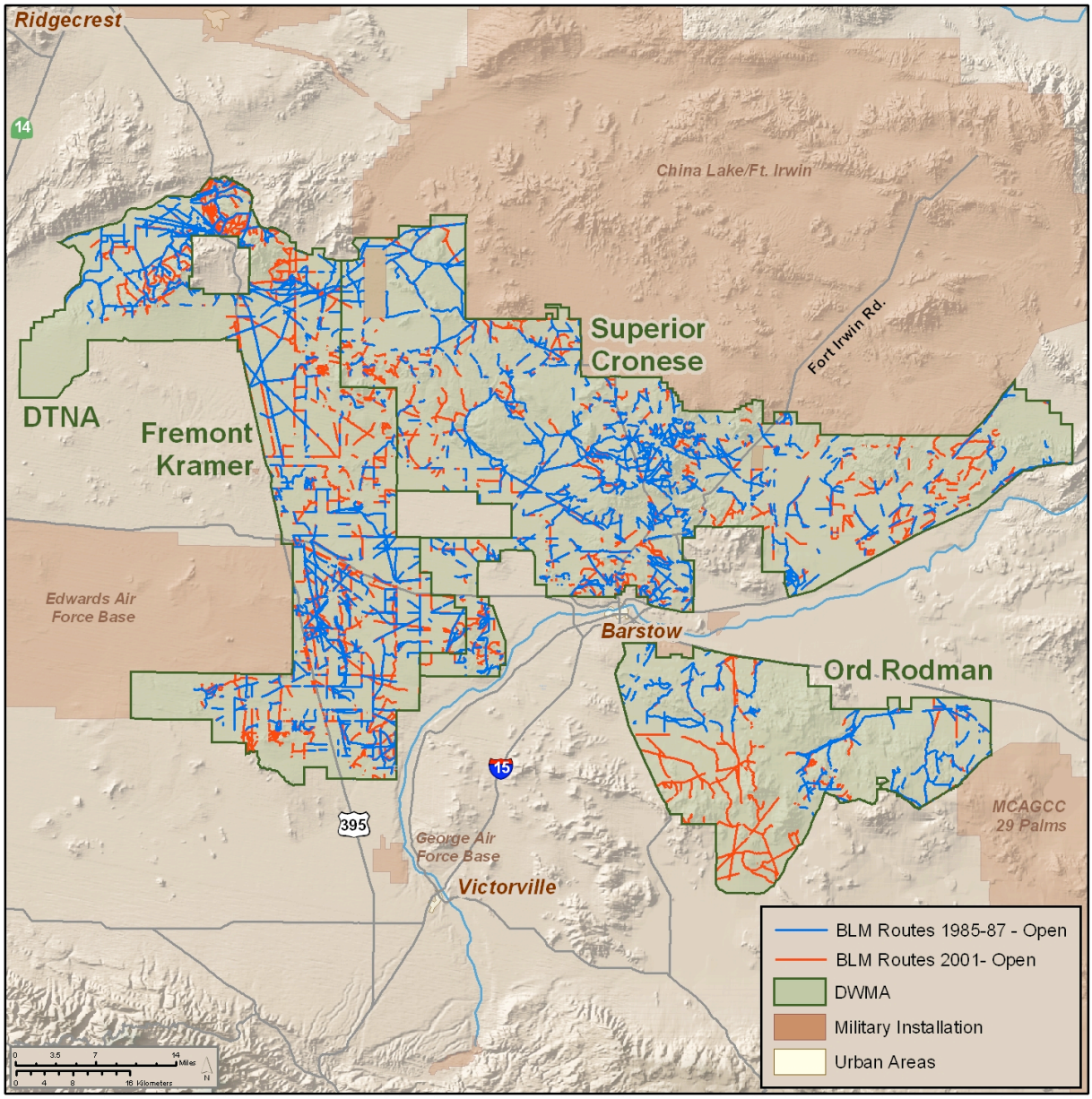

Fig. 4.35 Comparison of 1985-87 and 2001 designated open BLM routes. The red routes represent 2001 routes not formally designated as open in 1985-87. The lack of designation as open in 1985-87 could be a result of the fact that the route was inventoried in 1985-87 but not designated as open, not inventoried in 1985-87 but existing, or not existing in 1985-87.

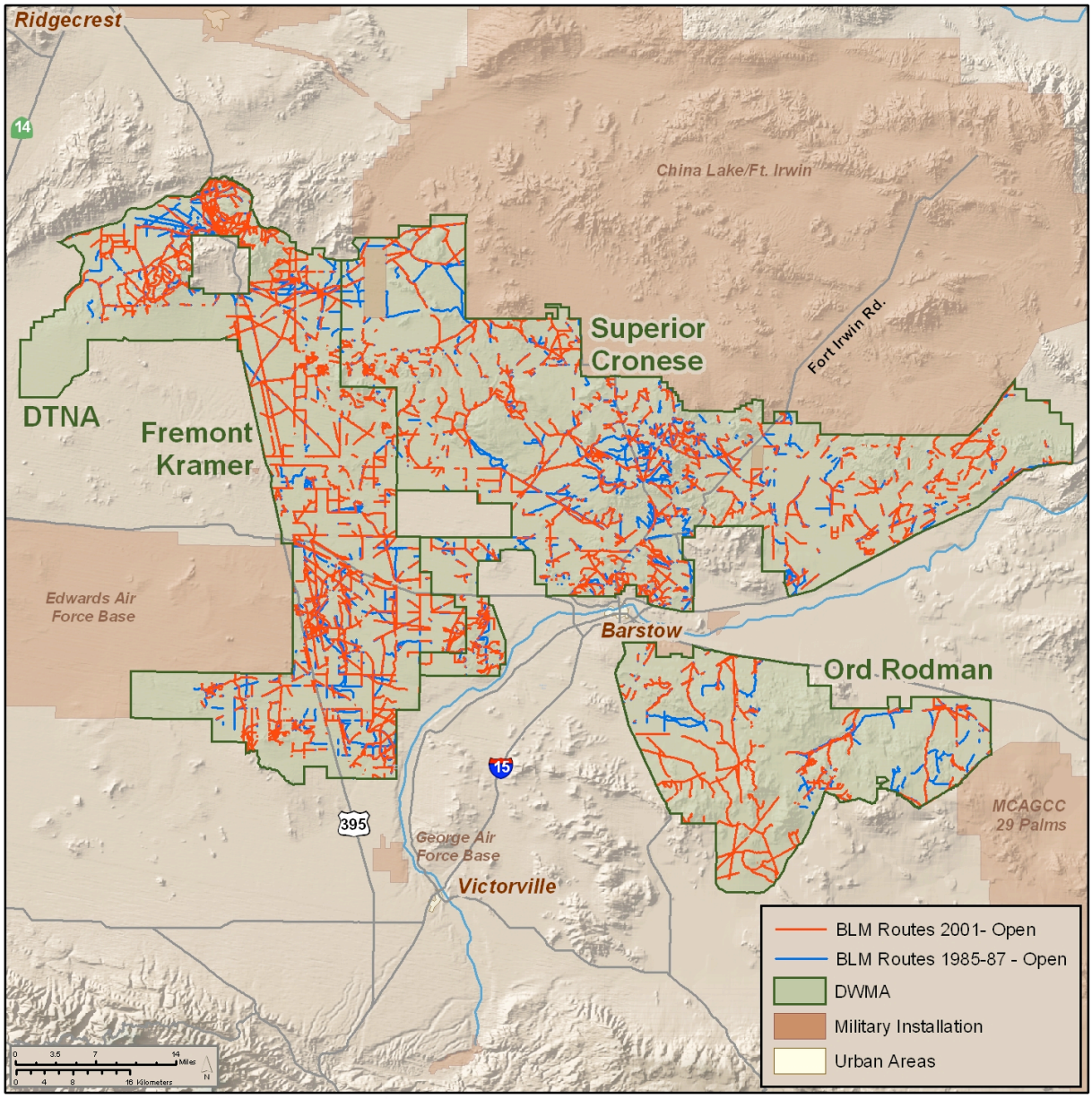

Fig. 4.36 Comparison of 2001 and 1985-87 designated open BLM routes. The blue routes represent 1985-87 routes not formally designated as open in 2001. The lack of designation as open in 2001 could be the result of the fact that the route was inventoried in 2001 but not designated as open, not inventoried in 2001 but existing, or not existing in 2001.

4.5.2 Patterns of Precipitation Case Study

It is important to assess the natural variation in the physical environment as well as the anthropogenically-altered environments. Drought has been hypothesized potentially to cause population declines in desert tortoise populations. To assess the extent to which there have been trends in precipitation, we obtained data on precipitation from all known weather stations in the Mojave. These data were parsed into cumulative rain that would affect production of spring annual plants (precipitation within November to April) and rain resulting from summer monsoonal thundershowers (precipitation within May to October). These data were assembled for three locations in the Mojave (Table 4.10) and averages for each region and for each season were plotted in Fig. 4.37. Clearly, the regions have different patterns of rainfall, as the West Mojave has almost all of its rainfall in the winter season. Also, clearly, there is no long-term trend in rainfall amounts or in patterns of drought duration. The variability of precipitation from year-to-year is very large, and the only apparent conclusion one can draw from the data is that the amount of precipitation and the occurrence of drought are not especially predictable measures for any place in the Mojave. Thus, the absence of a clear pattern suggests that precipitation alone (i.e., not in concert with other stressors) cannot account for downward trends in population sizes in the Mojave.

Table 4.10 Weather stations in the Mojave Desert used in analysis of precipitation (Fig. 4.37).

Northeast-Sonoran	East Group	West Group
BEAVER DAM	BOULDER CITY	ADELANTO
BULLHEAD CITY	DESERT NATL WL RANGE	APPLE VALLEY
BUNKERVILLE	DUNN SIDING	BARSTOW
CALLVILLE BAY	KYLE CANYON RANGER STN	CANTIL
DAVIS DAM	LAS VEGAS MCCARRAN INTL AP	CHINA LAKE NAF
ECHO BAY	MITCHELL CAVERNS	EL MIRAGE
KINGMAN	MOUNTAIN PASS	HESPERIA
LAKE HAVASU	NORTH LAS VEGAS	INYOKERN
LAUGHLIN	RED ROCK CANYON ST PK	LUCERNE VALLEY 1 WSW
LITTLEFIELD 1 NE	SEARCHLIGHT	MOJAVE
LOGANDALE	SUNRISE MANOR LAS VEGAS	RANDSBURG
LYTLE RANCH	SHOSHONE	TRONA
MESQUITE		VICTORVILLE PUMP PLANT
NEEDLES		
OVERTON		
PARKER RESERVOIR		
PIERCE FERRY 17 SSW		
ST GEORGE		
TEMPLE BAR		
TRUXTON CANYON		
VALLEY OF FIRE ST PK		
WIKIEUP		
WILLOW BEACH		
YUCCA 1 NNE		

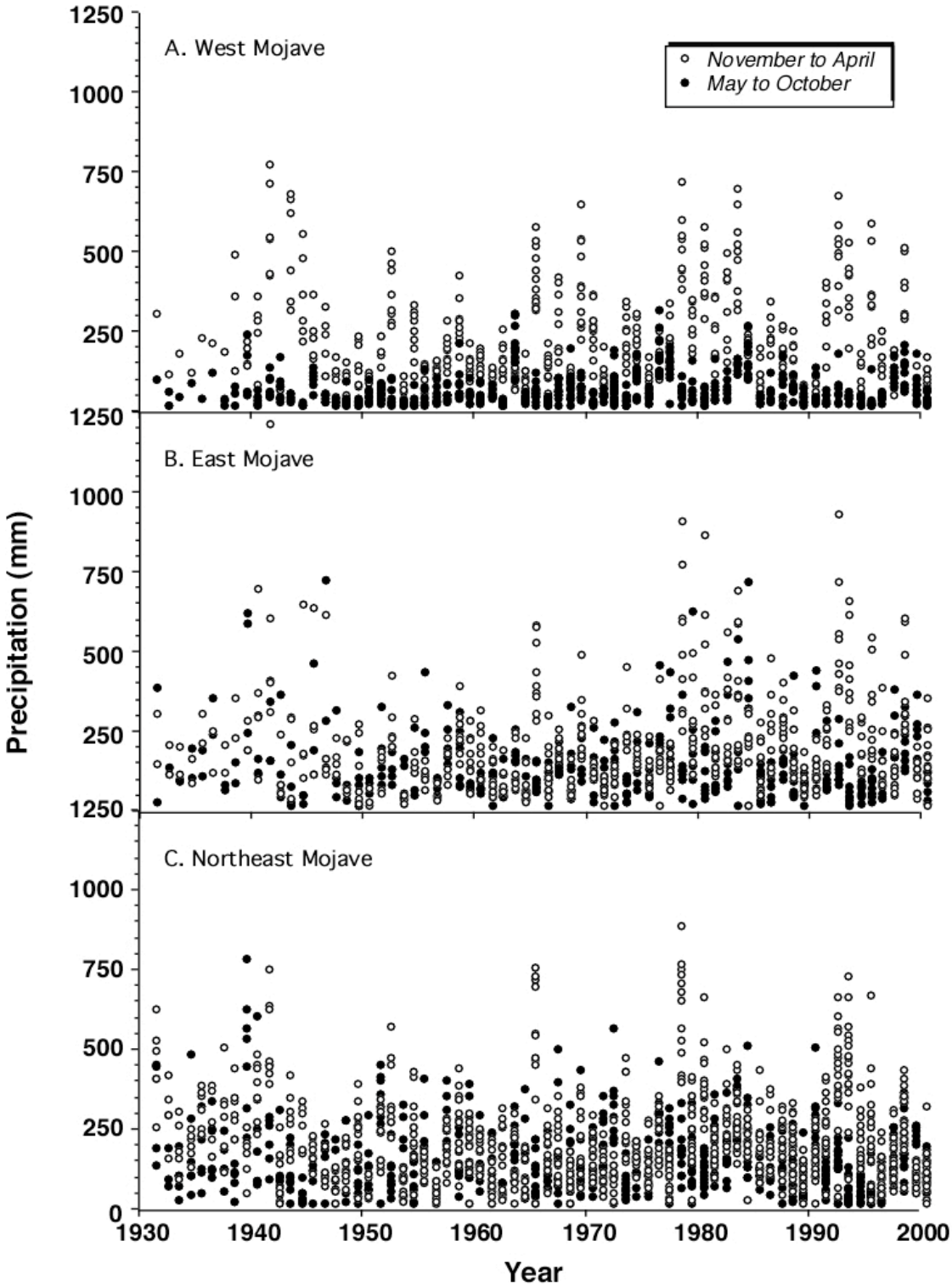

Fig. 4.37 Seasonal rainfall in the Mojave Desert, 1930-2000.

Patterns of Precipitation Case Study Recommendations

This type of analysis should be conducted for other specific threats to desert tortoise populations, as well as ecological variables that may also influence tortoise population status (e.g., rainfall, Fig. 4.37). Such analyses will provide managers and scientists with a comprehensive database of the current environmental setting under which tortoise recovery is taking place and will provide the basis for future hypothesis-based monitoring of tortoise populations relative to threat mitigation and environmental change.

4.5.3 Disease Case Study

Because disease has been such a prevalent issue throughout the range of the desert tortoise, it seems appropriate to consider it in some depth here, as an aspect of the status of the species' environmental setting. The Recovery Plan mentions two diseases specifically, shell dyskeratosis (section I.B.3) and upper respiratory tract disease (sections I.B.3 and II.D.3.b.1, appendix D.IV.C). Other potentially important diseases not mentioned specifically include herpesvirus (THV) (Pettan-Brewer et al. 1996), iridovirus (Westhouse et al. 1996), and fungus (Homer et al. 1998, Rose et al. 2001) infections. Diseases in general are mentioned or implied for topics such as sources of mortality (USFWS 1994, Section II.D.b.2) and translocation (USFWS 1994, Appendix B.6).

Shell dyskeratosis is not uncommon in both the desert tortoise and the gopher tortoise. The disease may be related to nutrient deficiency or to toxins (Jacobson et al. 1994, Homer et al. 1998, Christopher et al. 2003; E.R. Jacobson, pers. comm.). A direct connection between shell dyskeratosis and population decline in tortoises has not been established. A correlation between the presence of shell dyskeratosis and a die-off of individuals has been reported for a site in California (Berry 1997), yet numerous other threats (Boarmann 2002) are also present at that site. In addition, no correlation exists between frequency of shell dyskeratosis and population declines in the Sonoran Desert (Arizona Game and Fish Department, unpublished data).

Little was known about the relationship of *Mycoplasma* to tortoise disease when the Recovery Plan was developed. Likewise, the potential relevance to the desert tortoise of studies of *Mycoplasma* in the gopher tortoise was little appreciated when the Recovery Plan was developed. Upper respiratory tract disease (URTD) now is confirmed to be the result of infection by *Mycoplasma agassizii* in both the desert tortoise and gopher tortoise (Brown et al. 1994, 1996). Furthermore, another, closely related, species of *Mycoplasma*, *M. cheloniae*, has been isolated from tortoises, and two more species of mycoplasma are known from tortoises, but not as yet isolated (Brown et al. 2002; M.B. Brown, pers. comm.). Important studies of respiratory mycoplasmal infection in tortoises published since 1994 include Jacobson et al. (1995), Berry (1997), Epperson (1997), Lederle et al. (1997), McLaughlin (1997), Schumacher et al. (1997, 1999), Smith et al. (1998), Brown et al. (1999), and Diemer-Berish et al. (2000). A direct cause/effect relationship between respiratory mycoplasmal infection and population decline in tortoises has not been established, although a provocative correlation between the presence of URTD and die-offs

of individuals of both the desert tortoise and the gopher tortoise has been documented at some locations (Jacobson et al. 1995, Berry 1997, Rabatsky and Blihovde 2002, Seigel et al. 2003; K.H. Berry, pers. comm.; J.E. Diemer-Berish, pers. comm.).

Mycoplasma agassizii is easily transmitted horizontally by direct contact between host individuals (McLaughlin 1997, Brown et al. 2002). Although other Mycoplasma are known to be transmitted vertically from host mother to offspring and via fomite, such modes of transmission have not been demonstrated for *M. agassizii* (Brown et al. 2002). Because *M. agassizii* is so easily transmitted horizontally, isolating infected individuals is an appropriate means to control spread. Isolation of infected individuals is only a part of the general strategy for control of an infectious disease, which should include diagnosis, quarantine, culling or segregation, physical separation, sentinels, and long-term monitoring (M.B. Brown, pers. comm.). How much time, effort, and funds are put into implementing this strategy for a particular disease depends, in large part, on the perceived risk to the host: the greater the perceived risk, the larger the commitment. For example, although the viruses that can cause another upper respiratory tract infection, the "common cold" in humans, are extremely contagious, virtually no control strategy for the pathogens has been implemented, because the perceived risk is low, despite the fact that individuals sometimes develop secondary infections and occasionally succumb to the – largely indirect – effects of the viruses. Assessing risk is particularly difficult in situations, such as those surrounding both the desert tortoise and the gopher tortoise, in which many of the relevant facts that bear on the assessment simply are uncertain or unknown. We return to assessing risk later.

What is known and what is not known?

A great deal has been learned about the relationship of *Mycoplasma* to tortoise disease, mostly since the Recovery Plan was developed. It is certain (Brown et al. 2002) that:

- *Mycoplasma agassizii* (strains PS6 and 723) is a cause of URTD
- The pathology of mycoplasmosis involves hyperplastic and dysplastic lesions of the upper respiratory tract
- Clinical signs of URTD vary in onset, duration, and severity
- Mycoplasmosis has a chronic phase and may be clinically silent (subclinical) in adult tortoises
- Infection with *M. agassizii* elicits specific antibody responses that can be detected by ELISA
- The current ELISA may not be able to detect exposure of all tortoises to mycoplasmas other than *M. agassizii*, although some cross-reactions do occur
- The antibody responses to *M. agassizii* are detectable by ELISA beginning eight weeks after experimental infection
- Under experimental conditions, gopher tortoises become ill quicker after repeated exposure to *M. agassizii*

- Colonization of the upper respiratory tract with *M. agassizii* may be detected by culture and PCR, but assay sensitivity is not as high as the ELISA
- Mycoplasmosis is a horizontally transmissible disease

Note, first, that the important information that we know with certainty relates entirely to individual tortoises and not to populations. We return to current understanding at the level of the population later. Secondly, important uncertainties and unknowns remain even at the level of individual tortoises. For example, it is probable, but not clearly established (Brown et al. 2002) that:

- Pathogenic and nonpathogenic tortoise mycoplasmas exist
- There is variation among strains of *Mycoplasma agassizii* in their ability to cause URTD
- Other species of *Mycoplasma* (such as *M. cheloniae*) also can cause URTD
- Specific antibodies against *M. agassizii* may not confer protective immunity
- *Mycoplasma* may be transmitted by some forms of indirect contact
- *Mycoplasma* may not persist in burrows of infected tortoises

Many of the uncertainties and unknowns **at the level of individual tortoises** warrant increased attention (Brown et al. 2002; M.B. Brown, pers. comm.; E.R. Jacobsen, pers. comm.). In particular, more information is needed about: vertical transmission of tortoise pathogens (on-going studies are examining vertical transmission of both *M. agassizii* and THV), tortoise immunobiology (need information on reagents and functional assays, normal versus abnormal values, and the cellular immune system), tortoise pathophysiology and hemosiderosis, modes of transmission of tortoise pathogens other than *M. agassizii*, and relative importance of tortoise pathogens (need information on the virulence of species and strains).

Although accruing information about the effects of URTD and other diseases on individuals is an important undertaking, sound management decisions about species recovery require accruing information about the effects of diseases on populations. Unfortunately, virtually nothing still is known about the demographic consequences, either direct or indirect, of URTD. It is suspected that respiratory mycoplasmal infection can affect desert tortoise and gopher tortoise life history traits (survival, fecundity, migration) directly and, therefore, affect population dynamics directly (Brown et al. 2002; M.B. Brown, pers. comm.), but establishing such a connection, if it indeed does exist, requires a more concerted effort than has been made to date. This cause-and-effect relationship has two linkages: Disease → Individual → Population. A suitable research plan, therefore, would need to be designed first to establish that disease affects the life history traits of individuals, and second, to establish that the changes in life history traits of individuals cumulatively affect population dynamics. Although some tortoises with respiratory mycoplasmal infection clearly have died with what appear to be abnormal deaths (Jacobson et al. 1995, Berry 1997, Rabatsky and Blihovde 2002, Seigel et al. 2003; K.H. Berry, pers.

comm.; J.E. Diemer-Berish, pers. comm.), other tortoises with the infection have lived what appear to be normal lives for extended periods (e.g., at sites at which seropositive individuals occur, yet at which no substantial declines in population size can be documented; McCoy et al. in review). Unfortunately, the nature of the research to date has been such that cases of the absence of population decline, in the face of respiratory mycoplasmal infection or of subsequent recovery from URTD, have not been well reported. Neither have the fates of random samples of ill – defined broadly – and healthy individuals from the same populations been mapped, as far as we can tell. The connection between the disease and survival of individuals, therefore, remains inferential, and whether or not disease is an important source of mortality (section II.D.3.b.2) remains largely unknown. Declines in the fecundity of tortoises with acute respiratory mycoplasmal infection have occurred, but the best available evidence indicates that they eventually recover (Schumacher et al. 1999; D.C. Rostal, pers. comm.). The connection between the disease and fecundity of individuals, therefore, remains problematic. No studies to date have explored the potential connection between disease and migration of individuals. Tortoises with respiratory mycoplasmal infection may display abnormal physiological responses, such as increased water loss, or behavioral responses, such as reduction in appetite, reluctance to leave burrows, and irregular basking and burrowing, however, which could influence movement patterns (Brown et al. 2002; M.B. Brown, pers. comm.; E.R. Jacobson, pers. comm.).

It seems clear that the dearth of information on the linkage between disease and life history traits of individuals would reduce the linkage between changes in life history traits of individuals brought about by disease and resulting population dynamics largely to speculation. The best-published attempt to relate tortoise demography to disease was by Berry (1997). She presented convincing evidence that desert tortoise population densities had declined substantially at two sites (but see the discussion of permanent study plots and measurement of population densities presented elsewhere). Some individuals at one of the sites were seropositive and/or clinically ill with URTD, and some individuals at the other site exhibited varying degrees of shell dyskeratosis. She concluded (p. 94) that "between 1988 and 1992 the declines of adults [at the site with seropositive and/or clinically ill individuals] are clearly attributable to URTD caused by *M. agassizii*." She is more reserved in her conclusion about the second case (p. 95): "the population decline appears to be linked to the appearance of shell lesions on the tortoises." The evidence that she presents for the cause-and-effect relationship between tortoise population decline and disease in the first case is: (1) prior to 1988, before the appearance of acute URTD, few individuals ever were observed with overt signs of illness or in a dying state; (2) individuals displaying clinical signs of URTD were distributed throughout the site and in adjacent areas; and (3) of 27 individuals in a health profile research program, fitted with radio transmitters, 6 died and 11 disappeared between 1989 and 1992. We suggest that this evidence supports a more conservative conclusion, one that is nearer the conclusion that Berry (1997) reached for the other site: the population decline appears to be linked to the appearance of URTD in the tortoises. Note that this conclusion still is immensely important and demonstrates that, at present, disease threats deserve consideration on par with other threats.

Risk from disease threats

It appears that URTD is a complex, multi-factorial disease, interacting in some circumstances with other stressors to affect tortoises (Brown et al. 2002; M.B. Brown, pers. comm.). Hypothesized factors contributing to mycoplasmal transmission and URTD disease severity include different critical thresholds of exposure among tortoise populations; difference in virulence among microbial species and strains; prior exposure, which probably limits the ability to control disease severity; variable clinical expression, both temporally and spatially; differences in sex ratios, age structures, and behaviors among tortoise populations; exacerbating factors, such as drought; and tortoise nutritional status (M.B. Brown, pers. comm.).

At present, the accumulating evidence about URTD is a mass of seeming contradictions. No data indicate that URTD is moving through Mojave Desert tortoise populations in a wavelike pattern typical of mycoplasmal spread (E.R. Jacobson, pers. comm.); yet, failure to identify the pattern may have resulted from inadequate serological sample sizes, inadequate spread of sampling effort throughout the range of the desert tortoise, or other, similar, problems (E.R. Jacobson, pers. comm.; see Diemer-Berish et al. 2000, McCoy and Mushinsky in review). Tortoises in the genus *Gopherus* may have maintained a long-term coexistence with the pathogens causing URTD (E.R. Jacobsen, pers. comm.; McCoy and Mushinsky in review); yet, in some places, such as Ft. Irwin, tortoises seem to have been isolated from at least *Mycoplasma agassizii* (E.R. Jacobson pers. comm.; see McCoy and Mushinsky in review), and, in many ways, respiratory mycoplasmal infection in tortoises resembles a new interaction between host and pathogen (D. Thawley, pers. comm.). In general, respiratory mycoplasmal infections have high morbidity but low mortality (Brown et al. 2002); yet, in some places, severe population declines have been hypothesized to be linked to URTD caused by *M. agassizii* (e.g., Berry 1997).

These seeming contradictions reinforce the emerging picture of URTD as a complex, multi-factorial disease. First, as we have seen, demonstrating the two important cause-and-effect relationships Disease → Individual → Population is not easy, and the difficulty is compounded by inadequate sample sizes and inadequate experimental design. Second, the potential effects of URTD, either for individuals or for populations, are inextricably intertwined with potential effects by numerous other threats, and teasing out individual effects, when several factors co-vary, is a difficult analytic problem. Third, changing ecological conditions, whether connected with human activities (e.g., habitat degeneration, McCoy et al. in review) or not (e.g., malnutrition, Jacobson 1994, Oftedahl et al. 2002); drought, Berry et al. 2002), may stress individuals and result in more severe clinical expression of URTD (Brown et al. 2002). Fourth, mycoplasmal infections often are density dependent (e.g., Hochachka and Dhont 2000), and URTD is seen mostly in relatively dense populations (M.B. Brown, pers. comm.), suggesting that some threshold density of tortoises may need to be reached before the infection becomes severe. Fifth, even if the mycoplasmal species responsible for URTD have maintained a long-term relationship with tortoises in the genus *Gopherus*, the pathogens appear to evolve rapidly into novel strains (Brown et al. 2002), suggesting that demographically important pathogenic relationship may occur at the sub-specific level.

The complexity of the disease threat facing the desert tortoise, coupled with the uncertainty surrounding many of the key issues, and the fact that the tortoise is faced with many other threats, suggests that a conservative approach toward disease as a threat be adopted at this time. Although the evidence suggests that disease, especially URTD, could be an important force shaping the demography of desert tortoise populations, the evidence neither demonstrates that disease is a potent force, nor that it is the most important force, nor that it acts independently of others forces. A more balanced, adaptive, and focused approach to dealing with URTD is appropriate at this time, perhaps one modeled on the recommendations of McCoy and Mushinsky (in review) for dealing with the disease in the gopher tortoise. Such a balanced approach would take into account the risks, and associated costs, involved not only of transmitting *Mycoplasma agassizii* among tortoise populations, but also of transmitting it within populations or to other species. It would deal with the management practice of translocation and of dooming demographically valuable individuals to euthanasia simply because they are suspected of harboring the pathogen. It would deal with underestimating the importance of other pathogens (such as herpesvirus, THV) and of diverting attention and resources away from managing, acquiring, and restoring habitat. For example, if *Mycoplasma agassizii* has a long-term relationship with its tortoise host, then addressing the risks involving habitat loss, fragmentation, and degeneration is crucial for permitting recovery from URTD. Die-offs are likely to have occurred historically, and populations have obviously recovered. Under current conditions, large populations in good habitat likely could recover again, but small populations or populations in poorly managed habitat may be in serious danger of extinction. A more adaptive approach would take into account the evolution of knowledge about *M. agassizii* and URTD. Advances in knowledge may necessitate reevaluation of the risks facing the tortoise. For example, if strains of *M. agassizii* are variable in virulence, as evidence now suggests (Brown et al. 2002), then careful isolation of high-virulence strains on the one hand, and relaxation of the moratorium on translocation of the low-virulence strains on the other hand, may be warranted and wise. A more focused approach would take into account the ultimate goals of any actions taken against URTD. Different goals may dictate different weightings of the risks facing the gopher tortoise. For example, if the ultimate goal is for populations to be self-sustaining in the face of environmental pressures, including disease, then actions requiring persistent veterinary intervention may counter indicated and dangerous.

The complexity of the disease threat facing the desert tortoise, coupled with the uncertainty surrounding many of the key issues and the fact that the tortoise is faced with many other threats, suggests that the disease threat will not be understood without bringing to bear all of the tools of modern epidemiology, particularly ecological epidemiology. Classical epidemiology primarily is concerned with the statistical relationship between disease agents, both infectious and non-infectious, while ecological epidemiology is concerned with the ecological interactions between populations of hosts and parasites (Swinton 1999). Epidemiologists are aware of the importance of the sociodemographic (classical epidemiology) or the ecological (ecological epidemiology) setting influencing the course that a disease takes in a population, and they are equipped with the statistical tools

necessary to deal with diseases resulting from a variety of confounded and interdependent factors and to establish causal chains.

Disease Case-Study Recommendations

An immediate need exists to develop scientifically-based recommendations for management of healthy and ill -- defined broadly – wild tortoises so as to minimize the risk to both individuals and populations of uninfected tortoises (Brown et al. 2002), and by extension, risks both to individuals and populations of infected tortoises. The focus here is on the two recovery actions recommended in the Recovery Plan most relevant to disease threats in light of this need (see below). These two recommendations still are sound, but suffer from almost complete lack of implementation in the past decade. Here we also list additional recovery actions, which should be seen as simple extensions of the original actions based on new knowledge available today.

a. *Initiate epidemiological studies of URTD and other diseases (section II.D.3.b.1)*

- Refocus the general approach to research on disease, treating it as part of a network of threats to tortoise populations, which, because of negative and positive feedback loops to other threats, cannot be addressed effectively without reference to the threats network (see section 5.1.1).
- Develop multi-disciplinary, long-term research agendas to understand the network of threats (a possible model, developed for studying URTD in the gopher tortoise, is in Section 7.3).
- Develop tools to study disease which are not so expensive that they preclude needed resources to research the interactive effects of disease with other threats.
- Develop more knowledge about the ecogeography of genetics of disease and hosts as a way to develop recommendations for translocation programs cognizant of the potential harm that can come from lack of information about mismatches between virulence of genetic strains of pathogens with different strains of host.
- Include epidemiologists and population biologists in developing the research agendas.

b. *Research sources of mortality, and their representation of the total mortality, including human, natural predation, diminishment of required resources, etc. (section II.D.3.b.2)*

- Add health assessments to the information gathered in ecological studies and monitoring, perhaps using an existing protocol (Berry and Christopher 2001).
- Develop clear standards for determining whether individuals in a population are healthy or not and whether they have been stressed or not.
- Continue current serological surveys for *M. agassizii*, adding screening for THV. Develop surveys for other *Mycoplasma* species as assays become available.

- Continue necropsies (the sample currently includes 74 individuals according to E.R. Jacobson). Develop a rationale for these necropsies in relation to the potential for information from them to affect new knowledge and management.
- Continue developing, improving, and extending diagnostic tests. This includes developing less expensive and more field-portable testing.
- Continue developing stress tests that are applicable to wild tortoises (e.g., adrenocorticotropin hormone (ACTH), phytohemagglutinen (PHA), and sheep red blood cell (SRBC) challenge experiments, to examine adrenal gland response, T-cell response, and B-cell response, respectively; P. Kahn, pers. comm.).
- Inform researchers about both the qualities and the shortcomings of diagnostic tests (see Brown et al. 2002); for example, clinical signs of URTD may be non-specific or specific host responses to agents other than mycoplasmas; seropositive (ELISA) individuals may display no overt clinical signs of URTD; and that ELISA alone often is not sufficient, largely because they indicate only past exposure and not necessarily current infection.
- Inform researchers about the value of different diagnostic tests in addressing different goals (see Brown et al. 2002); for example, different tests are appropriate for health assessment of an individual tortoise, for a population survey, for long term population monitoring, and for investigation of a mortality event.
- Ensure that all important information is made accessible to researchers.
- Ensure that the expedient course of killing seropositive, but otherwise healthy, individuals is kept to a minimum.

A caveat to these recommendations is in order. Many modern epidemiologists do not think that epidemiology itself should be concerned with the delivery of services or with implementation of policy (e.g., Savitz et al. 1999). Regardless of whether or not one agrees with this viewpoint – which reflects a similar viewpoint common in conservation biology – it points to a separation between the scientifically-based accumulation of knowledge and the ultimate use of knowledge. The recommendations made here are for improving the science surrounding disease as a threat for the desert tortoise and may not necessarily provide an easy transition to management strategies. Designing management strategies for a complex disease threat, particularly one in which the factors contributing to the complexity may themselves be threats – which is an unusual situation – is a daunting task; however, the response to this daunting task must not be to ignore the complexity in the name of expediency.