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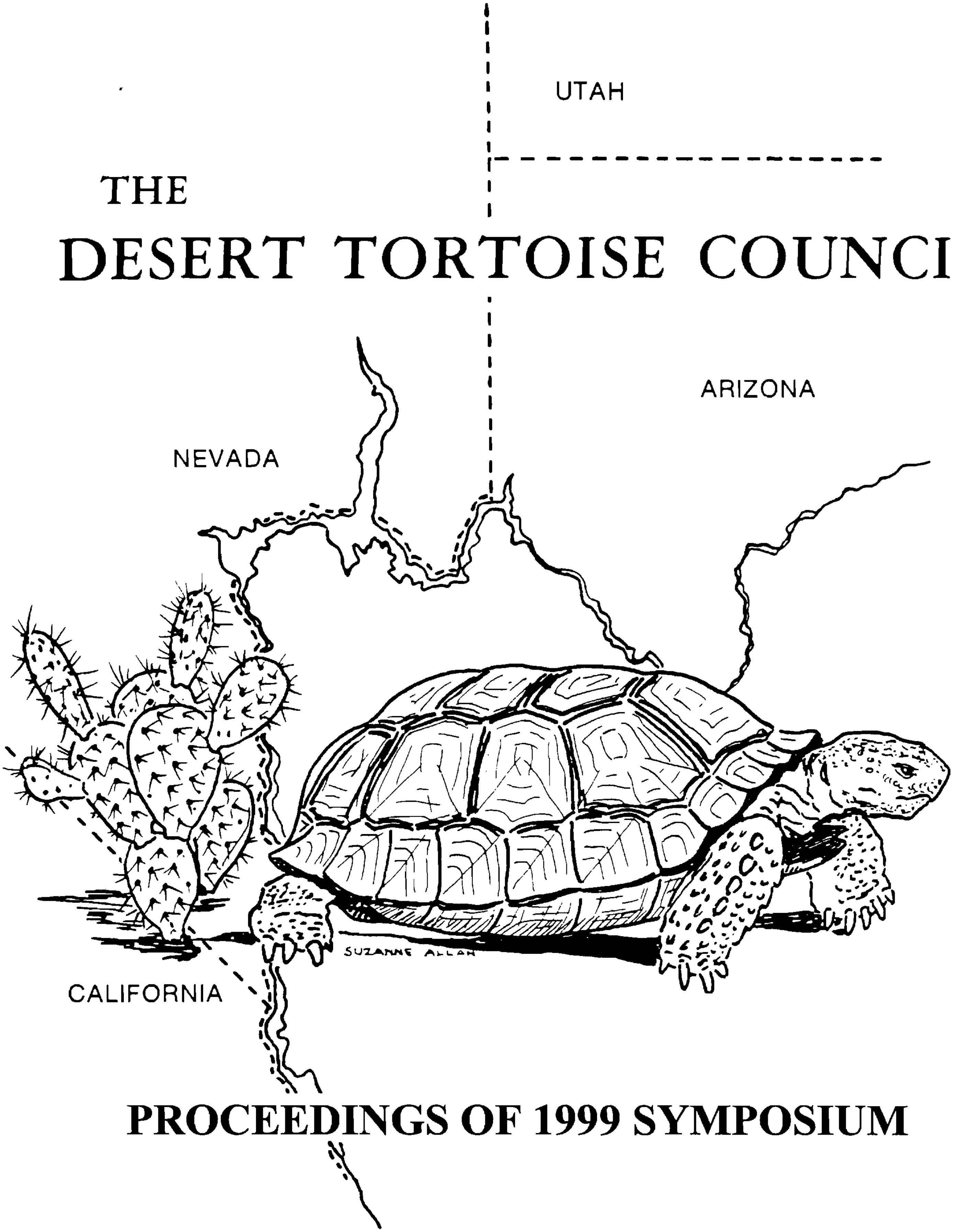

PROCEEDINGS OF 1999 SYMPOSIUM

DESERT TORTOISE COUNCIL
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Abstracts from the 1999 Symposium

Special Report

Ecology and Management of *Bromus tectorum* Communities

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Abstract—Cheatgrass (*Bromus tectorum*) is an exotic, self-invasive (establishes without direct human aid) annual that has invaded most plant communities in the Intermountain Area. It is now the dominant species on millions of hectares of formerly big sagebrush (*Artemisia tridentata*)/bunchgrass rangeland. Cheatgrass occurs, but usually is not the dominant annual grass, in the southern Great Basin and the warm deserts of the Southwest. Our purpose is to review several aspects of the ecology and management of cheatgrass, largely based upon the 40 plus years of experience our project has had with this annual grass.

Cheatgrass (*Bromus tectorum*) is an exotic, self invasive annual that has become a component or outright dominant of millions of hectares of temperate desert rangelands in the Intermountain Area. The late D. W. Billings (1990) considered cheatgrass to be the greatest cause of biotic impoverishment in the Intermountain Area. Cheatgrass is distributed throughout the western United States and adjacent Canada and Mexico. It occurs, but usually is not a dominant species in portions of the warm deserts of the southern Great Basin and the Southwest. It first became established in the Intermountain Area in disturbed portions of the big sagebrush (*Artemisia tridentata*)/bunchgrass zone (Stewart and Young, 1939; Yensen, 1981). Now the distribution of this invasive species extends into higher elevations in the adjacent pinyon (*Pinus* sp.)/ juniper (*Juniperus*) woodland zone and down into portions of the salt desert vegetation in the lower elevation basins of the Great Basin (Young and Tipton, 1990). Cheatgrass is a major agronomic weed in winter cereal grain production. Cheatgrass rarely occurs in the annual-dominated grasslands of the portion of California with a Mediterranean type climate, where other species of *Bromus* are among the dominant plants.

INTRODUCTION OF CHEATGRASS

Cheatgrass apparently originated in the temperate deserts of Central Asia (Young et al., 1972). It has spread to virtually all temperate desert or semi-desert environments in the world. It probably was first introduced into the western United States as an accidental contaminant of cereal grain seed (Mack, 1981). Its initial spread in agronomic agriculture probably corresponded with the period late in the 19th century when steam powered threshing machines or separators were moved, without proper cleaning, from farm to farm by custom operators.

Cheatgrass first appeared in big sagebrush environments as a ruderal species alongside dirt roads that were periodically graded and the road shoulders disturbed (Stewart and Hull, 1949). Cheatgrass became a *self invasive* species. This change for an occasional ruderal species to a landscape wide, self invasive species must have been due to widespread changes in the environment, adaptive changes in the weed itself, or a combination of both. In a series of papers Daubenmire (e. g. 1940) clearly showed that cheatgrass is capable of invading big sagebrush/bluebunch wheatgrass (*Pseudoroegneria spicata*) communities that were in high ecological condition and apparently never grazed by domestic livestock. Under such conditions, the invasion of cheatgrass is of little immediate ecological consequences other than to provide a seed source in the advent the community suffers catastrophic disturbance. By the time cheatgrass was well distributed in the big sagebrush zone, there were very few areas in high ecological condition. Much of the perennial grass portion of the native plant communities had been severely depressed, if not outright destroyed, by improperly timed, annually repeated, excessive grazing of domestic livestock (Young and Sparks, 1985)

It is very important to differentiate between potential to invade and rate of invasion of cheatgrass in native vegetation. Cheatgrass probably had the potential, in terms of basic ecological amplitude that governs competitiveness among species, to eventually invade all the communities where it currently exists. The accelerated rate that it invaded these communities and the ecological consequences of this invasion are largely a product of the excessive grazing that occurred on the ranges. A common misconception is that removal of domestic livestock grazing immediately results in a disappearance of cheatgrass and return to dominance by native perennial plant species. Depending on the ecological potential and seral status of the site where domestic livestock grazing is terminated, cheatgrass dominance may decrease, remain the same, or increase, but the invasive species is usually a permanent, irreversible component of the community (Tausch et al., 1993). Cheatgrass introduction and establishment often results in the community crossing an ecological threshold that can not be reversed.

Seed and Seedbed Ecology

As an annual, cheatgrass has to establish seedlings every year, and in turn produce seeds. Cheatgrass plants are capable of producing a prolific number of seeds per plant. The seeds (caryopses) are usually highly viable and nondormant (Young et al., 1969). Cheatgrass seeds that do not find a safe site for germination in field seedbeds, acquire a dormancy that can last for several years. Seed dormancy is broken by enrichment of the germination substrate with gibberellin or nitrate or a combination of both (Young and Evans, 1975). Because rangeland sites are not tilled, the seedbanks for cheatgrass are largely located in the litter on the soil surface.

In annual invasive species, there is a great ecological advantage in being able to germinate simultaneously with the first effective moisture event in the fall or early spring. The risk with such a simultaneous germination strategy is that inadequate future precipitation will result in the loss of the population before seed production and renewal of the seedbank can occur. Acquired seed dormancy assures a seedbank exists for cheatgrass, even through periods of prolonged drought.

Cheatgrass is seldom the dominant on sites where the seedbed has been reduced to absolutely bare soil. The cheatgrass caryopses require burial, favorable concave micro-topography, or litter cover for safe site for germination (Evans and Young, 1970). Other invasive, exotic species such as Russian thistle (*Salsola targus*) or tumble mustard (*Sisymbrium altissimum*) that dominate bare seedbeds have inherent germination strategies or seed coat additives such as mucilage to permit germination on bare seedbeds (Young et al., 1970). Once these plants of the lower level secondary successional stages have conditioned the harshness of bare seedbeds, cheatgrass plants can become established (Piemeisel, 1938).

Truncated Succession

The host of invasive annual species that have invaded the ranges of the Intermountain Area, have nearly completely changed secondary succession over large areas (Young et al., 1987). More importantly, cheatgrass has *truncated* succession so that it remains a continual dominant on many sites without progression back to dominance by native perennial species (Piemeisel, 1938). How is this truncation of succession accomplished? As previously mentioned, cheatgrass builds large seedbanks that insure continued presence on the site even if one, two, or more annual seed crops are failures. The most important aspects of the ecology of cheatgrass that allows it to truncate succession are moisture and wildfire relations.

Moisture Relations

Moisture is the most significant factor in seedling competition. Moisture stress for even relatively brief periods in the spring may mean death for perennial seedlings (Evans et al., 1970). Plant growth in temperate desert environments is hampered by the bulk of precipitation occurring during the coldest winter months when temperatures are usually too cold for growth. In portions of the range of cheatgrass in western North America rains are frequently early enough in the fall to condition germination before cold temperatures. In the more arid portions of the Great Basin, germination in about 4 out of 5 years must wait until early spring (Young et al., 1987). The key for perennial seedling establishment is for the seedling to attain sufficient growth during the cold fall or spring to be able to survive the summer drought (Harris, 1967). When cheatgrass seedlings germinate in the fall, aerial growth is confined to a flat rosette of leaves, but root growth extends to a considerable depth in the profile by spring. By out competing perennial seedlings for moisture, cheatgrass effectively closes sites to recruitment of perennial seedlings (Robertson and Pearce, 1945).

The amount of nitrate available in the seedbed may be critical in governing competition for moisture between cheatgrass and perennial grass seedlings. Cheatgrass thrives on nitrogen enrichment (Young et al., 1997).

Wildfire Relations

In comparison to the native herbaceous vegetation in most temperate desert plant communities, the introduction of cheatgrass increases the chance of ignition and the rate of spread of wildfires (Pickford, 1932). It also lengthens the season for wildfires from mid-August to September to mid-June to September (Young and Evans, 1978). The landscape characterizing species of *Artemisia* do not sprout from the crown or roots once the aerial portion of the community is destroyed by burning. This results in a transitory dominance of cheatgrass and the native root sprouting shrubs. If wildfires occur often enough, the root sprouting subdominant shrubs, often species of *Chrysothamnus*, will be lost from the community and cheatgrass will become the landscape characterizing species (Stewart and Hull, 1949).

Big sagebrush plants produce a huge number of achenes annually on a fairly consistent basis for much of their life span (Young et al., 1991). The very small seeds (achenes) of big sagebrush have a deciduous pappus so their dispersal is limited to about a meter from established plants (Young and Evans, 1989). Characteristically, it is 10 to 15 years after a wildfire before big sagebrush returns to dominance of the site. If wildfires are of sufficient size and repeated often enough, large areas of former big sagebrush/bunchgrass communities can become nearly devoid of big sagebrush with little evidence of shrub re-establishment. The Dumphy Hills in northeastern Nevada are an example of such an environment. Such large-scale conversions have been very detrimental for mule deer populations and have been the subject of large-scale restoration projects.

The controlling factor in the wildfire initiated dynamics of cheatgrass populations is the resident density of perennial grasses. If sufficient perennial grasses are present, they will be the transitory dominant after wildfires (Farve, 1942). For a modal big sagebrush community in the 30 to 35 cm precipitation zone, the density of perennial grasses to dampen the dynamics of cheatgrass is about 1 per m^2. The rule of thumb for use in the field is to be able to step from perennial grass to perennial grass. The maximum density of perennial grasses for the same environmental zone is about 10 plants per m^2 and is seldom achieved in natural communities, but is considered a fully stocked stand in artificial seedings. This density would nearly eliminate the occurrence of cheatgrass.

Wildfires result in much more than mere physical consumption of plants. Combustion products of wildland vegetation serve as germination cues and can increase the germination and growth of native grasses of sagebrush communities (Blank and Young, 1998). Fire effects on mature sagebrush/bunchgrass communities are spatially heterogeneous. This reflects differences in fire intensity between the sagebrush subcanopy and the light fuel load in interspaces among canopies (Blank et al., 1994). The combustibility and fine fuels of cheatgrass dominated sites promulgates rapid fire movement. Lethal heat penetration into the soil is minimal, preserving viable cheatgrass seeds for rapid establishment the season after the fire. Cheatgrass is so plastic phenotypically that a population of 1 plant per 0.1 m^2 after a wildfire can produce as many seeds as a pre-fire population of 1,000 plants per m^2 (Young et al., 1969).

Granivores

Granivorous desert animals utilize cheatgrass seeds extensively. Cheatgrass seeds are often an important dietary item for various taxa of granivorous birds, including many passerines, horned larks (*Eremophila alpestris*), and native and introduced game birds, such as mourning doves (*Zenaida macroura*) and chukar partridges (*Alectoris graeca*), respectively. Various species of seed harvester ants (*Veromessor* and *Pogonomyrmex*) harvest and store large quantities of cheatgrass seeds, as do granivorous desert rodents, such as species in the family Heteromyidae. However, despite the large numbers of seeds consumed by these animals, it seems that seed predation seldom, if ever, limits the expression or density of cheatgrass plants. In years of prolific seed production, the shear quantity of seeds in the environment probably overwhelms animal consumers. When seed abundance is relatively low, enough cheatgrass seeds escape predation to produce a low density of plants, which can subsequently produce copious quantities of seeds for the next generation of cheatgrass. Heteromyid rodents tend to prefer certain native plant seeds to cheatgrass (McAdoo et al., 1983; Kelrick et al., 1986), but the generally ubiquitous availability of cheatgrass seeds, both spatially and temporally, ensures that cheatgrass remains an important dietary constituent.

While few empirical data exist regarding effects of native granivores on cheatgrass populations, it seems more likely that these animals may enhance, rather than reduce, the expression of cheatgrass. Brown and Heske (1990) suggest that selective predation on large-seeded plants and soil disturbance through foraging activities of kangaroo rats (*Dipodomys* sp.) may account for changes in southern desert plant communities that have been noted with experimental removal of these animals. Considering the high levels of seed predation by kangaroo rats and other heteromyids on cheatgrass seeds, which are relatively large compared to most native herbaceous plant seeds, it seems unlikely that discrimination by these animals against cheatgrass and in favor of native seeds could enhance the expression of cheatgrass. However, given the affinity of cheatgrass for disturbed substrates, it is quite possible that soil disturbance by granivorous rodents, which can be extensive on at least a microsite level, could facilitate cheatgrass invasion. Perhaps this partially accounts for the apparent invasion of cheatgrass into some of the relict areas that have not been disturbed by anthropogenic factors, such as livestock grazing.

While both herteromyids and harvester ants cache large quantities of seeds, only the former cache seeds in scatterhoards as well as larderhoards. Larderhoarding in desert granivores involves caching of seeds in a centrally located burrow (rodent) or underground colony (ants). Seeds stored in this manner seldom establish seedlings both because they are managed by animals to prevent germination and because they are generally buried too deeply in the soil to allow germinated seedlings to reach the soil surface. Scatterhoarding, however, involves placement of a cluster of seeds (usually numbering several tens to hundreds of seeds) in a shallow pit excavated in the soil and backfilling these pits to prevent detection of the underlying seeds by competing granivores. In addition to heteromyids, several species of ground squirrels and chipmunks (Family Sciuridae) and various other rodents are known to scatterhoard seeds. Depending on a number of variables, varying numbers of these scatterhoards may remain unrecovered by the cache-making animals for consumption. In such cases, seeds within these caches, which may be placed at an optimal depth to allow germination and seedling establishment, may be primary sources of seedling recruitment for certain native range plants (Vander Wall, 1994; Longland, 1994). Even though cheatgrass seedlings can often be found emerging in clumps from scatterhoards made by heteromyids, this is probably not an important avenue of seedling recruitment for cheatgrass populations. In contrast to native seeds, there can be no evolutionary connections between introduced weeds and dispersal by native granivores. Consequently, cheatgrass seedlings generally exhibit stunted growth and produce seeds at a very small size under the competition induced by high density clumps emerging from rodent scatterhoards. These seeds are seldom viable. By contrast, seedlings of Indian ricegrass (*Achnatherum hymenoides*), a native perennial grass that frequently emerges from heteromyid scatterhoards, survive and mature quite well in these clumped conditions (McMurray et al., 1997). Perhaps it should not be surprising that virtually all invasive annual weeds on desert rangelands have a seed morphology that permits efficient dispersal by some means other than granivores. Cheatgrass, for example, has seed appendages that facilitate dispersal by wind or adhesion to animals.

Grazing Management

Cheatgrass is the most important forage species in the diet of domestic large herbivores in the Great Basin. This was demonstrated by Fleming et al., (1942) more than a half century ago. For much of this century public land management agencies refused to recognize cheatgrass as a component of the forage base because it was an exotic species. Cheatgrass has many drawbacks as a forage species. It has a very short green feed period (Stewart and Young, 1939). Year to year variations in forage production are much more extreme than for perennial species (Young et al., 1987). The mature seeds have awns that are injurious to grazing animals. Perhaps, the greatest drawback to depending on cheatgrass as a forage source is the increase in wildfires associated with this grass. Not only are dry feed reserves lost in fires, the grazing regulations for public land management agencies require 2 years of rest from grazing after wildfires. If a portion of a pasture burns, usually the entire pasture is rested for 2 years. In 1985 in the vicinity of Winnemucca, Nevada, about 250,000 hectares of rangeland burnt in wildfires. The impact of the lost forage and 2 years of required rest on the local agricultural economy was severe. The ranching community bitterly complained that the 2 years of required rest from grazing was resulting in the accumulation of huge fuel loads of cheatgrass herbage and did not produce any positive results toward restoration of native perennial species.

Early in the 20th century, scientists such as Arthur Sampson worked out the basic reaction of native perennial grasses to grazing by concentrations of domestic livestock (Sampson, 1914). If grazed by excessive numbers of livestock every spring, perennial grasses will never reproduce or restore carbohydrate reserves. Each repeated year of this type of grazing reduces the vigor of the perennials and gradually they disappear. Sampson's answer to this problem was to defer grazing until after seeds ripen. This solves the problem, but reduces the carrying capacity to about one fifth of season-long grazing. Sampson pointed out that deferred grazing was better than complete rest because it prevented the accumulations of excessive fuel loads and it helped incorporate seeds in seedbeds.

In an attempt to increase carrying capacity and still enhance degraded sagebrush / bunchgrass ranges, the rest-rotation system of grazing was developed (Hormay, 1956). With this system the range is divided into three pasture units. One pasture is grazed early, the next pasture is grazed after seeds ripen, and the third pasture is rested the entire growing season. The next year the rested pasture is grazed early, the deferred pasture is rested and the early grazed pasture grazed after seeds ripen. Superficially, this rest-rotation systems sounds like a very desirable method. Unless a large reduction in the numbers of animals permitted to use the range is instigated, the pasture grazed early receives three times the numbers of animals it would have received under season-long grazing. When you increase the number of animals on a unit of area, animal selectivity for forage species is reduced. This can have good and bad effects on the forage resource.

In the 1960s, the major public land management agencies adopted rest-rotation grazing for virtually all of the rangelands they administer. What have been the results of this action? Evaluations are largely anecdotal because comprehensive ecosystem based, scientific evaluations are largely incomplete or completely lacking. In the northwestern portion of the Great Basin, the results have been both spectacular successes and dismal failures.

At higher elevations, the results have been the restoration of perennial grasslands where wildfires result in perpetuation of perennial grass dominance with minimum expression of successional dynamics by cheatgrass. At lower elevations there has been a conversion from big sagebrush / cheatgrass to nearly pure cheatgrass dominance. This conversion has occurred over millions of hectares of rangeland. There is considerable evidence that cheatgrass was biologically suppressed on many sagebrush ranges up until the 1950s by excessive grazing of domestic livestock (Emmerich et al., 1992). It is hard to imagine how intensely the public rangelands, other than those administered by the USDA, Forest Service, were grazed in the Great Basin before the passage of the Taylor Grazing Act and the subsequent establishment of the Grazing Service. By 1942 the impact of governmental regulation of grazing was being felt and the numbers of animals on the range reduced (Brennen and Fleming, 1942).

Why the large disparity in results of grazing management? Basic differences in site potential and seral status existed when the grazing management systems were instigated. The higher elevation areas receive more precipitation than lower elevation sites. Generally, many more native perennial grasses were left in the partially degraded higher elevation plant communities. Grazing systems designed to favor perennial grasses have little chance for success if there is no seed source for perennials over vast areas of cheatgrass dominance.

The deferred and rest portions of rest-rotation grazing systems fostered high fuel loads on many degraded ranges that insured destructive wildfires would occur, and 2 years of rest from grazing after the wildfires occurred recreated the fuel bombs. The native shrubs were the losers in this scenario. Grazing systems designed to favor perennial grasses will not function if there are virtually no perennial grasses to favor. No one should want to manage for cheatgrass dominance, but we should develop logical science based management systems for ranges where cheatgrass is now and will remain the dominant.

One ray of hope for breaking this cycle is to change to a winter grazing system. Not every ranch has the optimal environmental infrastructure to make this system work. If such a system is feasible, it involves grazing lower elevation ranges during the seasons when the perennial grasses are dormant. In order to accomplish this there has to be an alternative forage source during the summer months. Some operators have turned to grazing native hay meadows during the summer and obtaining conserved fodder as required for wintering cattle from another source such as purchases or development of upland irrigated fields (Emmerich et al., 1993). Cheatgrass is a primary forage species in these systems. There is minimal carry over of herbaceous fuel to the next season. To implement such systems, a very good knowledge of the range soils and plant communities as well as innovative ideas in total ranch management are required (Tipton, 1994).

Restoration of Cheatgrass Infested Rangelands

In order to biologically suppress cheatgrass you need to establish a perennial grass (Hull, 1944). It requires a perennial grass that has sufficient overlap in ecological potential (use of similar inputs for growth at the same period of time) to suppress the dynamics of the exotic, self-invasive annual grass. Historically, the problem has been the lack of a native perennial grass with the inherent competitiveness to compete with cheatgrass at the seedling level. Plant breeders have not been able to locate the variability for this competiveness within the gene pool for such species as bluebunch wheatgrass. This led to the widespread use of exotic perennial grasses such as crested wheatgrass (*Agropyron desertorum*). If a "native" cultivar of perennial grass is going to be developed to biologically suppress cheatgrass, apparently it is going to have to be through hybridization and selection. Because of the genomic makeup of the grass tribe in which bluebunch wheatgrass occurs, any hybridization would probably be with an exotic species. If this cultivar is to establish in cheatgrass infested communities without weed control, it must be a self-invasive species. If you release such a perennial grass to suppress cheatgrass, you are introducing another self-invasive species. Crested wheatgrass is not a self-invasive species over the vast majority of the sites where it will grow. Perhaps, this is because it lacks a mid to long range dispersal mechanism. Crested wheatgrass is a self-perpetuating species once established. Everyone of these points is controversial and should receive scientific examination and discussion because they are central to conservation biology in the Great Basin. If you are interested in developing a perspective on this tangled web, a good starting place is *Taxonomy of the Crested Wheatgrasses* (Dewey, 1986).

If you are not interested in suppressing cheatgrass by planting another self-invasive species, then you will have to practice some form of weed control. The central issue is competition for moisture for seedling growth. Minimal tillage with a disk harrow is very effective in suppressing cheatgrass, but only after cheatgrass seeds have germinated. Obviously only a tiny fraction of the area infested with cheatgrass in the Great Basin is suitable for the application of tillage treatments. Herbicidal weed control can be used to either create a fallow for one season before planting revegetation species, or by using a contact herbicide that is deactivated when it touches the mineral soil surface (Evans, et al., 1967 and 1969). Herbicides must be registered by the Environmental Protection Agency for the site and use where they are applied.

Seeds need to be placed in the seedbed at the correct depth and receive proper coverage for their individual germination requirements. This is best done through the process of drilling with an appropriate implement (Young and McKenzie, 1982). The number of safe site for germination that are created in the seedbed are going to control the species composition and initial density of the seedling stand obtained in revegetation attempts.

The Ultimate Cheatgrass Problem

We have stressed that cheatgrass invasion can bring wildfires that eventually wipe out the woody component of sagebrush communities and subsequent competition for moisture closes these communities to the establishment of perennial seedlings. The ultimate environment problem with cheatgrass dominance is that annual communities are subject to invasion by other invasive annual weeds that are even worse pests. Examples are the annual grass medusahead (*Taeniatherum caput-meduase* subsp. *asperum*), which has replaced cheatgrass in portions of the Great Basin. Members of the genus *Centaurea* may also be the future invaders of cheatgrass communities. Some of these invasive weeds are just more competitive than cheatgrass and some, such as the toxic bur buttercup (*Ranunculus testiculatus*), have such radical phenology they largely escape competition from cheatgrass while growing on the same site (Young et al., 1992).

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Variability in Phenology and Production of Desert Ephemerals: Implications for Predicting Resource Availability for Desert Tortoises

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Abstract—Among the food resources most important to desert tortoises are the desert ephemeral species (seasonal "annuals"), which germinate and grow following seasonal rains. The productivity of these species is highly variable from year to year. Understanding the causes of this variability is an important part of predicting availability of these plants as resources for desert tortoises and other herbivores. In order to explore how various plant and environmental factors interact to control plant productivity in deserts, we have developed a mechanistic model of phenology and growth of desert ephemerals. This model is incorporated into a patch-level ecosystem model — Patch Arid Land Simulator (PALS), which simulates a variety of desert ecosystem processes, including: evapotranspiration and soil water distribution, decomposition of litter and soil nutrient availability, as well as phenological/physiological responses of other desert plant life forms (shrubs, subshrubs, grasses, and forbs).

In this study, we carried out a series of simulations to determine the potential variability in seasonal productivity of desert ephemerals in response to long-term variability in rainfall at three desert sites using long-term rainfall records from these sites. Model results show that variation of productivity of ephemerals was very high for all seasonal guilds of ephemerals at all three desert locations. This variability is due to year to year changes in the distribution of rainfall that results in different phenological responses of ephemeral plants. Productivity may be limited not only by drought, but also in cases where rainfall events occur outside the period of normal seed germination or growth, or where single rains are smaller than the threshold necessary to induce germination. Productivity is maximized when rainfall events are sequenced so as to stimulate maximum germination and growth. Other factors that could further increase variability in ephemeral productivity, such as competition from other plant functional types and soil nutrient levels, were held constant in this study, so as to isolate variability solely related to rainfall. Variability in plant productivity differed somewhat among desert sites, with greatest variability associated with sites that had greatest variability in seasonal components of rainfall. Using a mechanistic model such as PALS may prove useful in helping to evaluate how changes in the tortoises' habitat (such as introduction of alien species, nitrogen deposition, and resource removal by competing herbivores) might impact future resource availability for desert tortoises.

Plant productivity in deserts is extremely variable between seasons and between years (Noy-Meir 1973; Hadley and Szarek 1981; Ludwig 1987). Much of this variation in productivity is associated with productivity of ephemeral (annual) species, which germinate, grow, and complete their life cycle within a period several months or less (Beatley 1969; Halvorson and Patten 1975; Turner and Randall 1989; Guo and Brown 1997). These desert ephermerals are among the most important food resources for desert tortoises (Coombs 1977; Minden 1980; Luckenbach 1982). Thus, understanding and predicting growth and survival of desert tortoise populations depends to a large extent on predicting availability of these food resources. Because water is such an important limiting factor in the desert, it might be expected that productivity of desert plants would be strongly related to the amount of rainfall (e.g., Noy-Meir 1973, Walter 1971). However, Beatley (1969) found that productivity of ephemeral species in the Mojave desert was not readily predicted from rainfall. LeHouérou, et al. (1988) compiled productivity data from desert regions throughout the world and concluded that productivity was not strongly related to rainfall and that, in fact, productivity was much more variable than rainfall. Thus, predicting productivity of desert ephemerals will depend upon developing a greater understanding of how various environmental and internal plant factors interact to affect their germination, establishment, growth, and seed production. To explore some of these factors and interactions, we have developed a mechanistic model of phenology and growth of desert ephermerals. This model is designed to be integrated into an ecosystem, patch-scale model — Patch Arid Lands Simulator (PALS) — which provides important linkages between the ephemeral plant community and the various other aspects of the desert ecosystem that they interact with. In this paper, we briefly describe the desert ephemeral model and use it to predict responses of desert ephemerals to long-term variability in rainfall. These results show that production of desert ephemerals is indeed extremely variable, suggesting that desert tortoises must be adapted to this long-term variability in order to have achieved long-term survival.

Model Description

Ephemeral Phenology and Growth. While there is a great diversity of ephemeral species in North American deserts (Shreve 1942), the species can be reasonably grouped into a few guilds with similar phenologies and functional responses (Went 1948, 1949; Beatley 1974; Mulroy and Rundel 1977; Kemp 1983). We consider three guilds of ephemerals in our model: 1) winter ephemerals that germinate in autumn or winter and flower in winter or spring (Went 1948; Beatley 1969; Mulroy and Rundel 1977); 2) spring ephemerals that germinate in winter or spring and flower anytime from late spring to late summer (Davidson et al. 1985); and 3) summer ephemerals that germinate and flower in summer (Went 1948; Mulroy and Rundel 1977). While there are variations within a guild in the phenology of individual species or in species composition from year to year, the vast majority of biomass produced by desert ephemerals tends to be temporally concentrated within one of the above seasonal groups as these are the periods of most reliable moisture.

Simulation of phenological responses of guilds to various environmental cues is based on the conceptual model of Beatley (1974) for Mojave desert ephemerals, with some modifications to account for variations in phenology observed in the Sonoran (e.g., Halvorson and Patten 1975) and Chihuahuan (e.g., Kemp 1983; Davidson, et al. 1985) deserts. A simple schematic diagram of the model is shown in Figure 1. Seed germination is controlled by temperature and moisture cues (Beatley 1974; Freas and Kemp 1983; Baskin et al. 1993). Temperature requirements for germination of each guild are such that they basically constrain germination to the appropriate season. A threshold amount of rainfall is necessary to induce germination in desert ephemerals (Tevis 1958; Beatley 1974; Freas and Kemp 1983). As part of our model verification, we investigated rainfall requirements for germination and found a threshold of 15 mm most closely matched field germination events. Rainfall on consecutive days was summed into a single event and considered to induce germination of a single cohort of seedlings. The size of the cohort of seedlings germinated was a function of the rainfall amount (Freas and Kemp 1983), and any rain within a week of a germinating rain was considered to enhance the size of the established cohort rather than produce a new one.

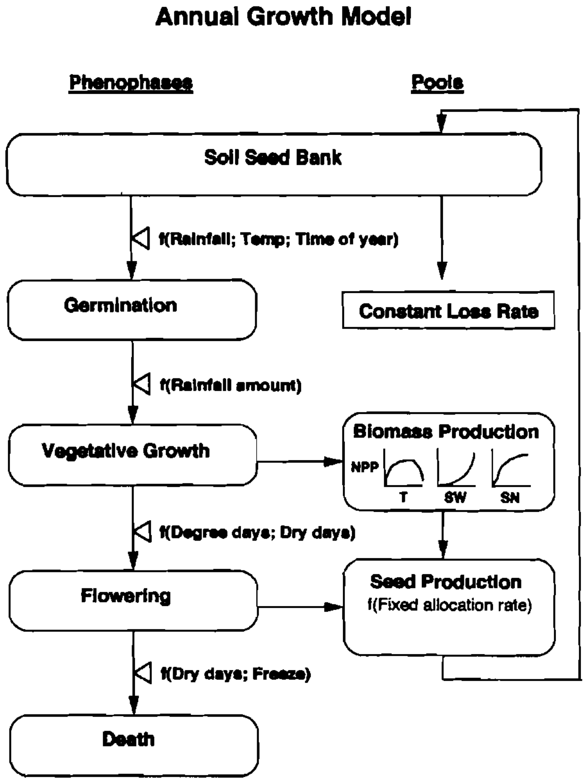

Fig. 1. Flow chart showing key steps in the simulation of phenological phases and growth of ephemeral guilds.

Growth of ephemerals was modeled as a simple function of whole plant daily relative growth rate during the vegetative phase. Maximum relative rates (RGR_{max}) were assumed to be 0.07 d^{-1} for winter and spring ephemerals and 0.09 d^{-1} for summer ephemerals. These values are consistent with rates of growth achieved under optimal field conditions by winter and spring ephemerals (C_3 species) and summer ephemerals (primarily C_4 species), respectively (Mulroy and Rundel 1977; Ehleringer 1983; Forseth and Ehleringer 1983; Werk et al. 1983). The actual (realized) daily growth (RGR) of each ephemeral guild (i) was its RGR_{max} multiplied by a simple scalar function of temperature, and soil water and soil nitrogen availability:

$$RGR_i = RGR_{max,i} \bullet f(T)_i \bullet f(SW)_i \bullet f(SN)_i$$

where f(T)i, $f(SW)_i$, and $f(SN)_i$ are scalar functions (varying from 0 to 1) that account for the effects of air temperature, soil water content (0–40 cm), and soil nitrogen (0–40 cm), respectively, on growth rates of each guild. The functional responses and parameters for each of the scalar functions were based on observed physiological responses for desert ephemerals from each of the three guilds (Ehleringer 1983; Forseth and Ehleringer 1983; Werk et al. 1983)

Time of flowering of desert ephemerals was determined using a simple degree-day formula as for agronomic annual species (Wang 1960). Bachelet et al. (1988) determined degree-days (sum of daily mean T > 5 °C) required for flowering for ephemeral species in the Chihuahuan desert as follows: 650 degree-days for winter ephemerals and spring ephemerals, and 1150 degree days for summer ephemerals. In addition, 200 of the degree-days for winter ephemerals were required to be accumulated after January 1, since early autumn germinating ephemerals would reach the flowering threshold prematurely.

Annual species, by definition, die following seed maturation. However, for desert ephemerals, moisture and, in the case of summer ephemerals, freezing temperatures, may restrict the period of growth. In fact, lack of moisture may result in death prior to completion of seed set (Tevis 1958; Beatley 1967; Loria and Noy-Meir 1979/80; Pake and Venable 1995). Death resulting from long-term soil drying was accounted for in the model by subtracting dry-degree-days from the accumulated degree-days when the highest soil water potential in the 0–40 cm layers dropped below -1.5 MPa. If the total degree-days dropped to 0, then the cohort was considered dead. Frost-kill of summer ephemerals was assumed to occur if the minimum air temperature dropped below -2 °C. In the event that soil moisture or temperature did not bring about the termination of a cohort, the seed maturation and death was assumed to occur at the typical end of the growing season: June 1 for winter ephemerals and December 1 for spring and summer ephemerals (consistent with field observations from Chihuahuan, Sonoran, and Mojave deserts).

PALS-FT model. The desert ephemeral model is integrated into a larger model, the Patch Arid Lands Simulator (PALS), which is designed to simulate various ecosystem processes (evapotranspiration, soil water distribution, soil organic matter decomposition, and nitrogen availability) in addition to the growth and biomass of a variety of plant functional types co-occurring in a small patch (1–10 m^2) of desert landscape. The value of using an integrated model such as this for predicting growth and reproductive success of ephemeral species is that their growth and reproductive success depends not only upon the direct effects of their immediate environment, but also upon a multitude of indirect effects brought about by other species that are utilizing and competing for the same resources (and thereby continually modifying the environment of the ephemerals). For this model exercise, however, many factors were held constant, so as to minimize their impacts upon year to year variability of ephemeral productivity, and thus isolate that portion of variability due strictly to rainfall and resulting soil water availability. Thus, the principal ecosystem and environmental factors that were allowed to vary were those associated with evapotranspiration and soil water distribution (see Kemp et al. 1997 for details of PALS soil water model). We assumed a constant level of soil nitrogen of 5 mg kg^{-1}. This value is consistent with values reported for soils in North American deserts (Skujins 1981; Stein and Ludwig 1979), and is consistent with the conclusion that nitrogen mineralization is rapid when moisture is available (Crawford and Gosz 1982). Productivity of other functional types was not simulated; rather we assumed that there was a fixed seasonal progression of cover of four of the most important functional types that co-occur with desert ephemerals: evergreen shrubs (e.g., *Larrea tridentata;* peak cover =5%), subshrubs (e.g., *Gutierrezia sarothrae, Ambrosia dumosa,* peak cover =5%), C_4 grasses (e.g., *Bouteloua* spp., *Hilaria rigida,* peak cover = 5%), and perennial forbs (peak cover = 2.5%). The only impact of these species upon desert ephemeral productivity (within the context of the present model) was via their impact upon soil water availability resulting from transpiration and effects upon the soil energy budget.

Model Verification and Simulations. Values for most parameters in the model were initially determined from literature values as described above. The model was then used to predict cover of desert ephemeral guilds for the Jornada Basin in the northern Chihuahuan desert. At this site, cover of all plant species along a 2.7 km transect was recorded seasonally for a 3-year period, as part of the data collected for the Jornada Long-term Ecological Research program (Wierenga et al. 1987; Cornelius et al. 1993). Abiotic data, including daily temperature and rainfall were also recorded at the site, and these data were used as driving variables in the model. Based on comparisons of simulated ephemeral plant cover with observed cover data, some parameter values in the model were adjusted via trial and error to achieve the least error between predicted and observed values of ephemeral plant cover.

Long-term simulations of ephemeral productivity were carried out using daily rainfall data from Las Vegas, Nevada (representative of the Mojave desert), from Tucson, Arizona (representative of the Sonoran desert), and from Las Cruces, NM (representative of the Chihuahuan desert). Other daily weather variables that were needed, including maximum and minimum temperatures and humidity, were simulated using a simple weather generator model parameterized for each site (Richardson 1981). The soils were assumed to be coarse-textured loamy sands for all simulations.

Results and Discussion

The predicted productivity for both winter and

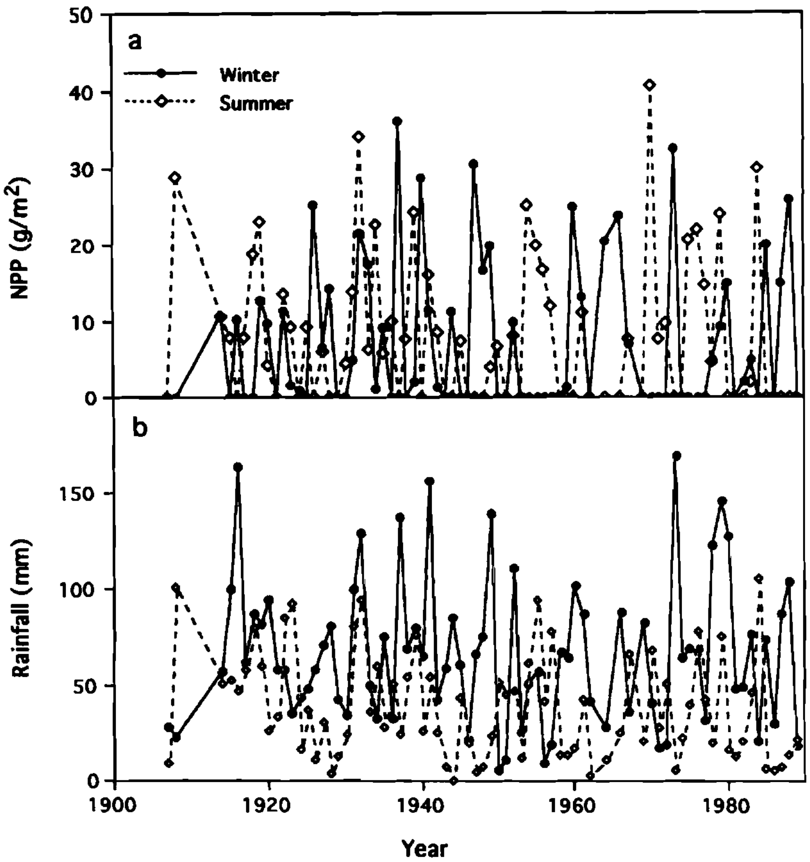

Fig. 2. a) Simulated peak biomass (Net Primary Productivity; g / m^{-2}) for the winter and summer ephemeral guilds predicted for the period of 1900 to 1990 using rainfall records from Las Vegas, Nevada; b) total winter (October-March) and summer (June-September) season rainfall from Las Vegas.

summer season ephemeral species in the Mojave desert is shown in Figure 2, along with the winter and summer season rainfall for Las Vegas, Nevada. (Predicted productivity of spring ephemerals was consistently very low in the Mojave desert simulations, and is not presented.) The relationship between simulated productivity and rainfall for winter season ephemerals is shown in Figure 3. Actual productivity data for winter ephemerals collected from several locations in the eastern Mojave desert over the period from 1964 to 1976 is shown for comparison in Figure 3 (Beatley 1969; Turner and Randall 1989). These data points are means of ephemeral productivity from several samples (sites) within a particular desert plant community. Much greater variation would be revealed for a given rainfall amount if we were to plot productivity from individual sites (see Beatley 1969). However, this additional variation is largely due to factors that produce spatial variation in productivity of desert ephemerals, such as shrub cover (Muller 1953; Halvorson and Patten 1975), soil nutrients (Ludwig 1866: Gutierrez and Whitford 1987), runoff and run-on (Ludwig 1986), and seed dispersal and seed patchiness (Nelson and Chew 1977; Reichman 1984). The average data values shown in Figure 3 are representative primarily of the temporal component of variation due specifically to variation in winter season rainfall, and are thus most consistent with our model formulation, which assumes an "average" desert landscape patch. Both model predictions and productivity data reveal that although there is a positive relationship between rainfall and ephemeral productivity, there is considerable variability in productivity for a given rainfall amount (that is, there are very different productivities in different years having similar total seasonal rainfall). The predicted variation in productivity for the other seasonal ephemeral guilds within the Mojave desert, as well as for ephemerals from the other deserts was similarly high. The coefficients of variation for the 100 years of simulated production of seasonal guilds of ephemerals within each of the deserts is shown in Table 1.

The results of these long-term simulations indicate the kind of year-to-year variability that may be expected with regard to productivity of ephemeral species within habitats of the desert tortoise. Most relevant to the distribution and food requirements of the desert tortoise are the simulations of winter season ephemeral productivity for the Mojave and Sonoran deserts (Patterson 1976; Luckenbach 1982). The results of long-term predictions for the Mojave desert indicate that there are many years with little or no productivity of ephemerals (see Figure 2 & 3). These instances resulted from several different conditions: a) complete winter drought, b) lack of a single large rain sufficient to induce germination, c) a dry period following germination of sufficient duration to kill the establishing plants, and d) rainfall occurring at a period when it could not be used efficiently by the ephemeral species (e.g., too cold, too hot). We did not analyze the fraction of the time that a specific one of the above conditions was the cause of failed ephemeral productivity, although such an analysis would be useful in determining availability of alternative food re-

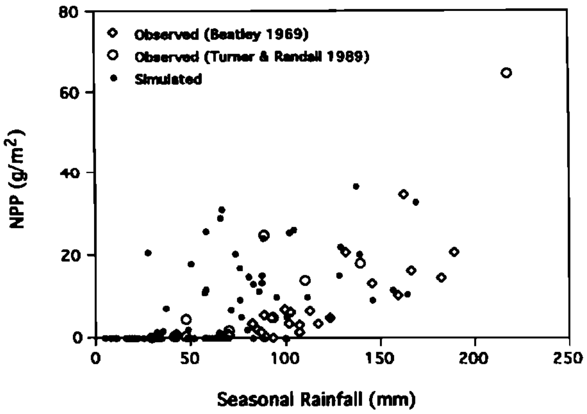

Fig. 3. Relationship between predicted peak biomass (NPP; g/m^{-2}) of winter season ephemeral species and the actual seasonal rainfall amounts for the period (1900-1990). Also plotted are observed winter ephemeral peak biomass from studies in the east central Mojave desert over the period from 1964 to 1976 (data from Beatley 1969; Turner & Randall 1989).

sources (see below). We can, however, estimate from Figure 3 that, except in rare cases, productivity of winter ephemerals requires more than 50 mm of total seasonal rainfall (a conclusion also reached by Beatley 1974), and only marginal productivity can be expected with 50 to 75 mm of winter rainfall. Examination of long-term rainfall records from Las Vegas indicate that 42% of all winters have less than 50 mm of rainfall and 66% of all winters have less than 75 mm. Thus, a reasonable estimate of "failure" of winter ephemeral production at a given location in the Mojave desert is about 1 out of 2 years.

When winter ephemerals fail to appear, availability of compensatory food supplies may be important for survival of desert tortoises. One alternative food would be other plant species that might be present in spring, such as forbs, grasses, subshrubs, and cacti (Woodbury and Hardy 1948; Berry 1978; Turner et al. 1984). In those years where lack of ephemeral productivity is caused by widespread drought (< 25 mm of rain), it is reasonable to assume that productivity of new leaf tissue in other functional types would also be relatively low (Beatley 1974). Thus, other herbaceous plant material probably does not offer reliable nutrition in dry winters (although young cacti and cacti fruits could be a potentially important alternative food in areas where sufficiently plentiful; Turner et al. 1984). In cases where low or lack of ephemeral productivity results from poor timing of rainfall or intermittent drought killing seedlings, the shrubs and perennial forbs may bear significant leaf material for tortoise consumption in spring and early summer (Berry 1978). In the case of very dry winters (total failure of herbaceous production), a possible compensatory food could be ephemerals and other herbaceous material produced in the following summer (Woodbury and Hardy 1948; Luckenbach 1982). From the results of the long-term simulations for the Mojave desert (Figure 2), it appears that in about half of the years in which winters had little or no production of ephemerals, there was a significant production of summer ephemerals. However, the extent to which summer production may compensate for lack of winter production is questionable, as summer ephemeral species may have less duration and less nutrition than winter ephemerals (Mulroy and Rundel 1977); also, our model probably overestimates summer ephemeral production in the Mojave desert because it was developed and verified for the northern Chihuahuan desert, which contains a much greater suite of summer ephemeral species.

These model predictions, as well as productivity data from a number of North American desert sites, indicate that the amount of herbaceous vegetation (ephemerals) varies greatly from year to year in tortoise habitats. Determining how this variability affects desert tortoise populations will be important for predicting survivorship of desert tortoises and viability of their populations. The model results suggest that the use of short-term data sets may not be indicative of the true amount of variability that can be expected over a greater time period (decades or longer). Habitat management plans based upon such short term data may not fully account for conditions that may be encountered by tortoises and other competing wildlife resources (or livestock) over long-term periods. Fur-

Table 1. Simulated long-term means and coefficient of variation (CV) of seasonal rainfall and productivity (NPP) of ephemerals at 3 desert sites.

	Winter Season				Summer Season			
	Mean Rain (mm)	CV	Mean NPP (g/m^2)	CV	Mean Rain (mm)	CV	Mean NPP (g/m^2)	CV
Mojave Desert	65	0.59	7.0	1.38	38	0.74	7.5	1.28
Sonoran Desert	122	0.52	9.7	0.95	132	0.42	11.0	0.84
Chihuahuan Desert	73	0.48	4.5	1.45	131	0.39	14.5	0.80

ther modeling studies such as this could be useful in evaluating how changes in the tortoises' habitat (such as introduction of alien species, nitrogen deposition, and resource removal by competing herbivores) might impact future resource availability for desert tortoises.

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Regional Desert Tortoise Monitoring in the Upper Virgin River Recovery Unit

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Abstract—Comprehensive and accurate desert tortoise density estimates are recognized as critical in both the Washington County Habitat Conservation and the Desert Tortoise (Mojave Population) Recovery Plan. Distance sampling monitoring was implemented within the Upper Virgin Recovery Unit, managed as the Red Cliffs Desert Reserve (Reserve), to gather baseline regional population densities of desert tortoises. In 1997, a pilot study was completed to standardize field techniques, to provide preliminary estimates of encounter rates and the detection probability, and to determine the field effort necessary to achieve precise regional density estimates within the Reserve. In the spring of 1998, 201.42 km (103 transects) of distance sampling was completed within Management Zone 3 of the Reserve.

One hundred and thirty-three adult and subadult tortoises (≥ 180 mm) were observed with an encounter rate of 0.66 tortoises per km (range = 0.49 to 0.88) throughout Zone 3 of the Reserve. Densities were estimated at 0.23 tortoises per hectare with a 95% confidence interval from 0.17 to 0.32 and a cv of 16.87%. Abundances were estimated at 2,361 tortoises per area sampled with a 95% confidence interval from 1,700 to 3,279 and a cv of 16.87 %. The precision level of measured estimates (i.e., P_w, g_o D, A) will be refined as additional years of monitoring data are collected.

Density estimates from this study are not comparable to previously reported estimates within the Reserve since previous efforts focused on small, unrepresentative areas. In 1999, distance sampling monitoring will be implemented within Management Zones 2, 3 and 5 of the Reserve. Baseline regional density and abundance estimates will be compared to future estimates to reveal regional trends within the Reserve.

On April 2, 1990, the Mojave desert tortoise population was listed as threatened under the Endangered Species Act of 1973, as amended. Declines of Mojave populations rangewide are associated with habitat degradation, disease, predation, and human-related mortality (USFWS 1990). The Desert Tortoise (Mojave Population) Recovery Plan identifies the Upper Virgin River population as one of six distinct recovery units (USFWS 1994). Due to its proximity to urban growth and considerably smaller size than other recovery units, it is classified as having a high degree of threat (USFWS 1994).

In an effort to resolve conflicts between urban development and desert tortoise conservation, the habitat conservation planning process was initiated in Washington County, Utah, in 1991. In February 1996, Washington County completed a Habitat Conservation Plan (HCP) and received an incidental take permit for 1,169 tortoises, 12,264 acres of desert tortoise habitat, and 31,282 acres of potential habitat. The HCP offers measures to minimize and mitigate take by establishing the 61,202 acre Red Cliffs Desert Reserve (Reserve; WCC 1995). The Reserve is divided into five Management Zones and includes 38,787 acres of Mojave desert tortoise habitat (WCC 1995).

Accurate regional desert tortoise density estimates are a critical component of both the Washington County HCP and the Recovery Plan (USFWS 1994, WCC 1995). The Desert Tortoise (Mojave Population) Recovery Plan recommends monitoring long term population trends within recovery units for at least 25 years, the equivalent of one tortoise generation, to determine population trends (USFWS 1994). The HCP requires the development and implementation of a long term desert tortoise monitoring program to determine regional population trends (WCC 1995).

To determine long term trends within the Reserve a reliable method of estimating regional tortoise densities is necessary. In the past, estimates of tortoise densities included two commonly used techniques, strip transects and mark-recapture monitoring plots. Strip transects, if calibrated with populations of known densities, allowed estimates of relative densities to be determined. However, since the relationship between sign and animals varies with environment, habitat, and physiological factors, population estimation techniques that infer population size indirectly from sign are not reliable for monitoring population trends. Intensive surveys of 2.59 km^2 (1.0 $mile^2$) monitoring plots provide detailed information on habitat condition, human uses, tortoise densities, and tortoise population demographics such as age-size class structure, sex ratios, and mortality. However, this information cannot be extrapolated beyond the boundaries of the 2.59 km^2 (1.0 m^2) monitoring plot. Neither strip transects nor mark-recapture monitoring plots are suitable for economical and reliable estimates of desert tortoise densities on a regional scale (USFWS 1994).

Variability in tortoise density requires a survey technique that is both robust to spatial variations in tortoise distribution and applicable to the entire Reserve. The Technical Advisory Committee of the Interstate Management Oversight Group (MOG-TAC) sought consensus on a method that was applicable range wide for monitoring densities and trends of Mojave tortoise populations. The Recovery Plan suggested the Zippin removal method as a simple and inexpensive method to assess tortoise densities (USFWS 1994). However, researchers agreed consistent and high capture probabilities, unobtainable in many areas, are required for precise and unbiased population estimates. After critically reviewing a variety of monitoring techniques (Burnham et al. 1980, Zippin 1956, Zippin 1958), the MOG-TAC recommended distance sampling (Buckland et al. 1994) for range wide Mojave desert tortoise monitoring.

Distance sampling is a method for estimating density of aggregated, random or clustered biological populations over large areas (Burnham et al. 1980, Buckland et al. 1994). The perpendicular distance from the line of observed objects enables one to create a detection function, a curve with detectability decreasing with increasing distance from the random line. Although a large proportion of the objects may go undetected, the theory allows accurate estimates of density to be made under several assumptions (Buckland et al. 1994). The three main assumptions essential for reliable density estimates include: 1) Objects on the random transect line are always detected, 2) Objects are detected at their initial location, prior to any movement in response to the observer, and 3) Perpendicular distances are measured accurately. Since tortoises spend a large percentage of time underground, the proportion of the population above ground must be estimated during monitoring in order to meet the first assumption and quantify the true probability of detection.

The Utah Division of Wildlife Resources has implemented distance sampling methodology within the Reserve to monitor tortoise densities. Zone 3 was initially sampled because it contains the most significant portion of tortoise habitat within the core of the Reserve. Future efforts will be concentrated in Management Zones 2, 3, and 5 within the Reserve (Fig. 1). At this time, Zones 1 and 4 will not be sampled. Management Zones 1 and 4 contain large, extended areas where tortoise sign has not been documented. Zone 1 of the Reserve includes the Kayenta Development, a low density housing development with a maximum overall density of one unit per acre. Zone 4 is the location for desert tortoise translocation studies associated with the HCP. The monitoring plan is intensively designed so that management efforts at the Reserve level, as well as for Management Zone 3, can be assessed.

In 1997, a pilot study was completed to standardize field techniques, to provide preliminary estimates of encounter rates and the detection probability, and to determine the field effort necessary to achieve dependable regional density estimates (McLuckie et al. 1998). Based on the 1997 results, goals for the 1998 distance sampling season included: 1) Collect quality field

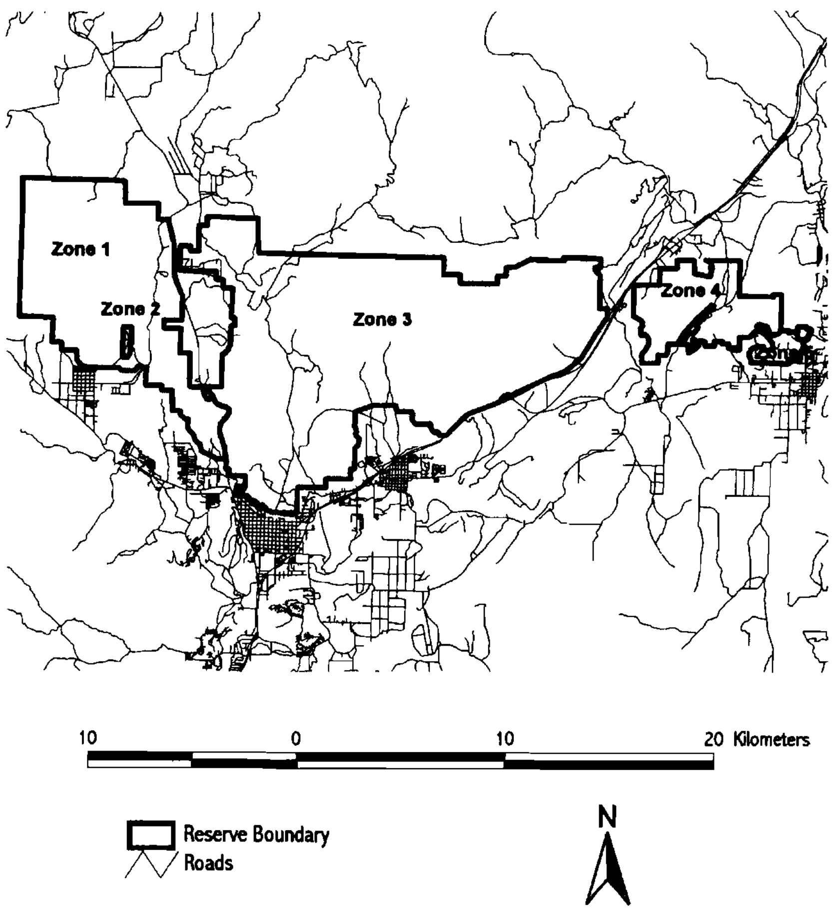


Fig. 1 Location of HCP Management Zones 1 through 5 within the Red Cliffs Desert Reserve, Washington County, Utah

data consistent with statistical assumptions, 2) Complete 200 km of distance sampling within Zone 3 of the Red Cliffs Desert Reserve and, 3) Obtain precise regional density estimates. All estimates presented in this document are preliminary. The precision level of measured estimates (i.e., P_w, g_0 D, A) will be refined as additional years of monitoring data are collected.

Study Area

The Red Cliffs Desert Reserve, within the Upper Virgin River Valley, Washington County, Utah, is located at the northeastern limits of the desert tortoise's geographic distribution. The Reserve is located in southwest Utah, east of the Beaver Dam Mountains and approximately 6 miles north of the Utah - Arizona border. It extends from the town of Ivins on the west to the city of Hurricane on the east.

Land ownership within the 61,202 acre Reserve is currently a patchwork of BLM (40.735 acres), School Trust (10,204 acres), private or municipal (5,644 acres), and state park lands (4,619 acres; Randy Massey, Bureau of Land Management, pers. comm.). Through the HCP process, private, municipal, and School Trust lands within the Red Cliffs Desert Reserve are being federally acquired in order to manage tortoises in perpetuity.

The Reserve is divided into five management zones, Zones 1 through 5 (Figure 1). Zone 3, approximately 38,541 acres, extends from Highway 18 on the west to Interstate 15 on the east. It contains the largest contiguous block of tortoise habitat within the Reserve, and includes some of the highest tortoise densities recorded in the Mojave Desert (Corn 1994, Fridell et al. 1995b, USFWS 1994). Zone 2, approximately 10,372 acres, includes Snow Canyon State Park and Paradise Canyon, areas with medium to high relative tortoise densities. Zone 5, approximately 766 acres, contains areas with moderate to high relative tortoise densities and is adjacent to the city of Hurricane.

Within the Reserve, desert tortoises occupy a mosaic of Navajo sandstone outcrops, rugged rocky canyons, and basalt capped ridges interspersed with sandy valleys. Tortoises utilize a combination of these habitats for winter and summer dens, egg laying, and foraging (Bury et al. 1994, Esque 1994). Tortoises commonly use basalt slopes, ridges of adjacent sandy valleys and hills interspersed with sandy areas for foraging (Esque 1994). Overwintering tortoises are found in caves, deep fissures, rocky overhangs, and deep sandy burrows in aeolian sand (Bury et al. 1994). Vegetation within the Reserve is diverse and includes representative species from the Mojave and Great Basin desertscrub biomes (Turner 1982a, Turner 1982b). Major vegetation types consist of a transitional mix of creosote bush scrub, sagebrush scrub, blackbrush scrub, and desert psammophyte (USFWS 1994). Predominant vegetation within these groups includes ephedra (*Ephedra nevadensis*), creosote bush (*Larrea tridentata*), blackbrush (*Coleogyne ramosissima*), snake weed (*Gutierrezia sarothrae*), sandsage (*Artemesia filifolia*), and big galleta (*Hilaria rigida*). Predominate annuals include filaree (*Erodium cicutarium*), woolly daisy (*Eriophyllum wallacei*), red brome (*Bromus rubens*), and cheatgrass (*Bromus tectorum*).

The Reserve is characterized by low humidity, low precipitation and a wide annual temperature range. From 1988 to 1994 the average annual temperature range was -11 °C in January to 43 °C in July (12 °F to 110 °F; UCC 1996). Average annual precipitation was 192 mm (7.5 in), with the majority of precipitation occurring from December to March (UCC 1996). Winter storms are typically widespread, with low intensity storms bringing moisture from the north Pacific. Summer thunder storms, which bring moist tropical air northward from the Gulf of California, are usually intense, local and of fairly short duration (UCC 1996).

Materials and Methods

Field Effort—A monitoring program with two independent teams of observers, one using line transect sampling (Team A) and the other using radio telemetry (Team B), was implemented to gather distance sampling data on tortoises within Zone 3 of the Reserve. Sampling methodology is described in Fridell et al. (1998) and is consistent with methods described in Anderson and Burnham (1996). Transects (n=103) were randomly located throughout Zone 3 by generating random coordinates (Fig. 2). These coordinates marked the northeast corner of 2 km square quadrats with 500 m sides. Because tortoises are rarely found at elevations above 1,400 m (Germano et al. 1994), only random transects below 1,200 m were sampled. In addition, areas with greater than 45% slopes were not sampled due to the danger of sampling these steep, rocky areas. Sampled areas within Zone 3 are identified in Figure 2.

The location of each corner of the transect was identified on the ground using GPS units and permanently marked with 10" nails. Nail heads were painted red with enamel exterior spray paint. Transect corners were labeled using double faced aluminum tags identifying the transect number and directional corner (NW, SW, NE, SE).

Each two km transect quadrat was surveyed by a two person crew. Using a compass to check directional alignment, a 50 m surveyor rope was placed along the transect line. Search efforts were concentrated within 30 m of the line, in 50 m increments, until the entire quadrat was completed. Tortoises were located by walking in a irregular, zig-zag path, on opposite sides of the line. Search time and observer speed varied with vegetation and topography. Prior to moving

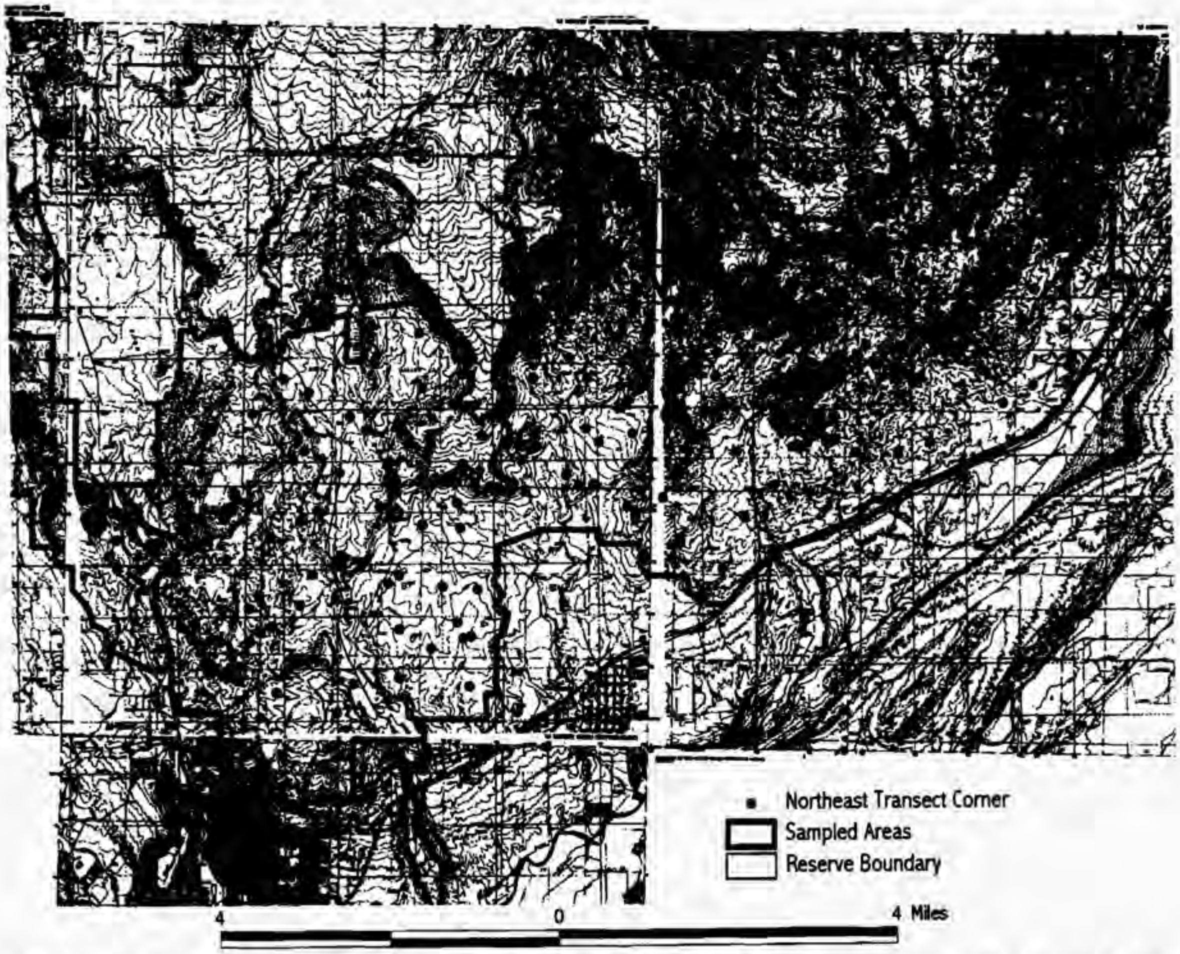


Fig. 2. Northeast corner of random transects within Zone 3 of the Red Cliffs Desert Reserve, Washington County, Utah.

the transect tape to the adjacent 50 m increment, one team member would confirm that all tortoises along the line were detected.

For each tortoise located, the perpendicular distance to the line was measured exactly using a 50 meter open reel fiberglass tape. For each tortoise encountered, distance along the transect line, UTM coordinates, and time detected were recorded. Standard tortoise carapace measurements were taken including median carapace length (MCL), width at third marginal (post M3), and width at seven and eight marginals (seam M7/M8). Sex, if above 180 mm, shelter type found in, if any, behavior, health observations, parasites, injuries, shell anomalies, and gular shape were noted on data sheets. Environmental variables including dominant vegetation, soil type, wind speed, cloud cover, and temperature at ground, and one meter above ground were also taken. Each tortoise was assigned a unique file number using the standard filing technique (Cagle 1939). The carapace of each tortoise was photographed for future reference. Once processing was completed, tortoises were released at the point of detection. MCL, sex, age, UTM coordinates, time since death and perpendicular distance from the transect line were recorded for each shell remain located. All shell remains were photographed. Data associated with shell remains (i.e., time since death, MCL, etc.) are presented in McLuckie and Fridell (1999).

The proportion of tortoises above ground was estimated by simultaneously tracking a subset of radioed tortoises. Thirty tortoises above 180 mm were fitted with radiotransmitters (Telonics Model 125) affixed above the forelimb with five minute gel epoxy. Transmitters were attached below the highest point of the carapace to reduce interference in shelters. Antennas were attached to costals or marginal scutes depending on the size of the tortoise. Masking tape was placed directly onto scute seams, to avoid epoxy soaking into scute seams.

Radioed tortoises were relocated using Telonics directional antenna and receiver (Model TR-2E). Fifteen radioed adult tortoises were used at each of two sites, Area 31 and Red Cliffs, located at the extreme west and east portions of Management Zone 3, Washington County, Utah. Above ground activity in both study areas was continually tracked during distance sampling monitoring to reveal potentially significant differences in tortoise surface activity.

Activity and GPS coordinates were noted for all radioed tortoises located. Above ground was defined as tortoises seen on the surface or in burrows with only the aid of mirrors (Anderson and Burnham 1996). Tortoises not visible and deep in burrows were not recorded by Team A and were also considered "below ground" by Team B. Vegetation association, time found, wind, soil temperature, and temperature 1 m above ground were also recorded.

Statistical Analysis—Means are presented in the format ± one standard error. The chi square test with the Yates Continuity Correction was employed using Instat Statistical Program to compare expected and observed sex ratio frequencies. The significance level was set at $\alpha = 0.05$.

A weighted mean for g_o was computed by using the following formula: mean of $g_o = \Sigma (N_j \bullet g_j) \div \Sigma N_j$ where N_j equals the total number of tortoise observations and g_j equals the number of locations above ground divided by N_j. Sampling variance for g_o was calculated using the following formula:

$$\text{var}(g_o) = \Sigma N_j (g_j - g_o)^2 \div [(\Sigma N_j)(n_T - 1)]$$

where n_T equals the number of radioed tortoises. Standard error was calculated by taking the square root of the variance.

Detailed distance sampling analysis is described in Anderson and Burnham (1996) and Buckland et al. (1994). Two density analyses were completed: 1) all reproductive animals, defined as adult and subadult tortoises ≥ 180 mm in carapace length, and 2) all animals encountered.

During the initial distance sampling data analysis, detection histograms were examined by plotting the number of tortoises observed within each perpendicular distance category. The perpendicular distance from the observed object to the transect line was used to determine the detection function, a curve with detectability decreasing with increasing distance from a random line. The perpendicular distances from the line, x_i, were used to estimate the specific shape of the probability function, $g(x)$, relating detection probability to distance from the transect. The detection function was estimated from the exact perpendicular distances ($x_1, x_2, x_3, \ldots, x_n$) generated during the survey. The unknown proportion of tortoises that were detected during the survey, P_a, was estimated from the distance data using the relationship, $P_a = \int_0^w g(x)dx\ (l/w)$. Program DISTANCE was employed to estimate the detection function from the distance data (i.e., $g(x)$), compute the integral, and provide an objective estimate of P_a and its standard error.

Four detection models were examined (uniform + cosine, uniform + polynomial, half-normal + hermite, and hazard + cosine) to determine the model that best fit the perpendicular distance data based on the minimum Akaike Information Criterion value. A detection probability plot was overlaid onto the histogram data to determine the data fit to the model. A chi-square test was used to determine how well the model fit the data for three categories based on increasingly smaller perpendicular distance categories. This test was used to compare the observed frequencies with the estimated expected frequencies under the model (Buckland et al. 1994).

Examination of the histograms revealed the existence of extreme observations or 'outliers'. Data was truncated when $g(x)$, probability of detection at perpendicular distance x, was 0.15. Outliers were deleted since extreme observations provide little information for estimating $f(0)$, the density function at $x = 0$, are difficult to model, and may increase the sampling variance of the density estimate (Buckland et al. 1994). In addition, truncation may reduce bias in the density estimate or improve precision, or both, by making the data easier to model (Buckland et al. 1994). A second analysis, including model selection and fit, was performed after determining the maximum perpendicular distance based on $g(x) = 0.15$.

Encounter rates, population density and abundance estimates, and the corresponding coefficient of variation and 95% confidence interval were calculated using Program DISTANCE (Laake et al. 1994). Tortoise density (D) was estimated from standard line transect theory,

$$D = n/(2wL \bullet P_a \bullet g_o),$$

where n is the number of tortoise detected, P_a is the (average) proportion of the tortoises detected within a transect of width w, and g_o is the (average) proportion of tortoises that were detected "above ground" during the survey period. The variable D is an estimate of the average density during the time of the survey and includes those tortoises above and below ground. The total area sampled was determined by heads-up digitizing using ArcView GIS, Version 3.0. Abundance estimates were then calculated using the total area sampled and the estimated average density. Population abundance (N) is estimated by

$$N = A \bullet D \text{ with } var(N) = A^2 \bullet var(D).$$

The precision of density and abundance estimates are computed by program DISTANCE as standard errors,

Table 1. Size and sex structure of live desert tortoises encountered during distance sampling monitoring, April 18 to June 4, 1998, Red Cliffs Desert Reserve, Washington County, Utah. Three adult tortoises were not processed since they could not be removed from deep soil burrows.

Size Class	MCL Range (mm)	Number of Tortoises			Total Tortoises
		Male	Female	Unknown	
Juvenile 1	< 60	0	0	8	8
Juvenile 2	60-99	0	0	14	14
Immature 1	100-139	0	0	9	9
Immature 2	140-179	0	0	15	15
Subadult	180-207	5	5	1	11
Adult 1	208-239	12	28	0	40
Adult 2	≥ 240	55	27	0	82
Total		72	60	47	179

coefficients of variation and confidence intervals (Laake et al. 1994). Precision levels of measured estimates will be refined as additional data are collected. Variations associated with estimates P_a and g_0 will decrease by pooling multiple years of data, resulting in increased precision of density and abundance estimates.

Results

Distance Sampling Field Effort—Transect surveys were initiated on March 9, 1998. However, since the majority of radio telemetered adult tortoises (tortoises ≥ 180 mm) were not active until mid-April, surveys were reinitiated on April 18, 1998. A total of 201.42 km (103 transects) were surveyed from April 18 to June 4, 1998. Transect lengths ranged from 0.87 to 2 km. A range of six to eight kilometers were completed per day, depending on the number of survey teams and the topography surveyed. Approximately 3,920 work hours were expended on distance sampling monitoring over 70 field days.

Size Class Distribution and Sex Ratio—One hundred and eighty-five live tortoises were encountered during the sampling period. Although included in the density and abundance analysis, three adult tortoises were not processed since they could not be removed from deep soil burrows. Twenty-seven were recaptures of tortoises marked in previous studies; three tortoises were captured twice during the 1998 monitoring period.

Median carapace length of tortoises ranged from 45 to 310 mm (Table 1). All processed tortoises were categorized into size classes devised by Turner and Berry (1984). Tortoises encountered included eight Juvenile 1 (mean MCL = 53.38 ± 1.7 mm; range 45–59), 14 Juvenile 2 (mean MCL = 78.14 ± 3.2 mm; range 60–96), nine Immature 1 (mean MCL = 120.89 ± 3.4 mm; range 106–138), 15 Immature 2 (mean MCL = 163.33 ± 2.9 mm; range 148–179), 11 Subadult (mean MCL = 197.73 ± 2.0 mm; range 187–207), 40 Adult 1 (mean MCL = 226.12 ± 0.5 mm; range 212–239), and 82 Adult 2 (mean MCL = 264.62 ± 1.8 mm; range 241–310).

Sex could not be accurately determined for all tortoises less than 180 mm, for one subadult tortoise, and for all tortoises in deep burrows (Table 1). Observed sex ratio (72 males to 60 females) was not significantly different from an expected ratio of one to one ($X^2 = 0.38$; $P > 0.05$).

G_0 Estimate— From 10 to 15 radioed tortoises were relocated daily during distance sampling in Area 31 (Table 2) and Red Cliffs (Table 3) to estimate the number of tortoises above ground and, in turn, the probability of detection on the line. At Area 31, mean MCL of radioed desert tortoises was 233 ± 6.1 mm (range = 200 to 283 mm; n = 15). At Red Cliffs, mean MCL was 251 ± 7.0 mm (range 207 to 289; n = 15). Five males and ten females were radioed at each site. During the sampling period, the number of tortoises above ground at both the Red Cliffs and Area 31 sites, g_o, was 0.83 (n = 30; SE = 0.03).

Histogram of Detection and Detection Probability Plots—During the initial data analyses, detection histograms were examined using 18 distance categories of 2.50 meters for reproductive animals and 21 perpendicular distance categories of 2.14 meters for all tortoises encountered. A detection probability plot using the half-normal + hermite model of encountered tortoises was overlaid onto the histogram data to determine the data fit to the model (Fig. 3). For the two sets of data examined, reproductive and all animals encountered, the detection histograms revealed field data which followed the shape criterion outlined including detectability certain near the line, the presence of a "shoulder" of detection 4 to 5 meters from the line, and no evidence of heaping observations (Buckland et al. 1994; Fig. 3). Examination of the histograms revealed the existence of extreme observations or 'outliers' up to 45 m from the line. Examination of both detection function graphs (Fig. 3), suggested truncation at the perpendicular distance of 30 meters since $g(30)$ was 0.15.

Observations with a perpendicular distance exceeding 30 meters from the random transect line were

Table 2. Dates and above ground activity of radio telemetered desert tortoises in the Area 31 study area, Red Cliffs Desert Reserve, April 18 to June 4, 1998, Washington County, UT. Above or below ground activity is identified by the following: 1 = above ground, 0 = below ground, * = tortoise not located.

	April				May															June		Total Locations
	27	28	29	30	1	4	5	6	11	12	14	15	18	19	20	26	27	28	29	1	2	
Male																						
1035	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21
1036	0	0	0	0	0	0	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	21
1038	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	*	1	20
1039	1	*	*	1	1	*	*	*	1	1	1	1	1	1	1	1	1	1	1	*	*	14
1042	0	0	1	1	0	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	*	20
Female																						
856	1	1	1	1	*	*	*	1	1	1	1	1	0	1	1	1	1	1	1	*	1	17
1037	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	21
1040	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21
1041	1	1	1	1	*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
1043	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21
1044	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	21
1045	*	*	*	*	*	*	*	0	1	1	1	0	*	*	*	*	0	1	1	1	1	10
1046	*	*	*	*	*	*	*	1	1	1	1	1	1	1	1	1	1	1	1	0	1	14
1048	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21
1049	*	*	*	*	*	*	*	1	1	1	*	1	1	1	1	1	1	1	1	1	0	13
Total	12	11	11	12	10	10	10	14	15	15	14	15	14	14	14	14	15	15	15	12	13	275

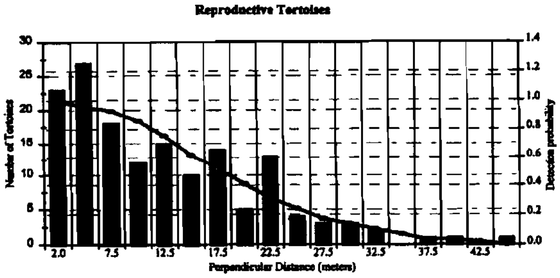
excluded from the final analysis for reproductive animals (n=5) and for all tortoises encountered (n=7). In both density estimates, the half-normal + hermite model was chosen based on the minimum Akaike Information Criterion value (Table 4). The chi-square test of the model for reproductive animals and all animals encountered demonstrated that the model fit the data for all test categories (Table 4).

Encounter Rates—One hundred and thirty-three reproductive tortoises were observed with an encounter rate of 0.66 tortoises per km (range = 0.49 to 0.88). Of the 103 transects completed, no reproductive tortoises were found on 54 transects and four or more reproductive tortoises were found on 12 transects. When tortoises of all size classes were included in the analysis, the encounter rate was 0.88 tortoises per km (range = 0.68 to 1.15).

Density and Abundance Estimates—The density of reproductive tortoises within Zone 3 of the Reserve was estimated at 0.23 tortoises per hectare with a 95% confidence interval from 0.17 to 0.32 and a cv(D) of 16.87 % (Table 5). The density of all animals encountered was estimated at 0.30 tortoises per hectare with a 95% confidence interval from 0.21 to 0.42 and a cv(D) of 17.65 % (Table 5). Of the three density

Table 3. Dates and above ground activity of radio telemetered desert tortoises in Red Cliffs study area, Red Cliffs Desert Reserve, April 18 to June 4, 1998, Washington County, Utah. Above or below ground activity is identified by the following: 1 = above ground, 0 = below ground, * = tortoise not located.

	April						May				June		Total Locations
	18	20	21	22	23	24	7	8	21	22	3	4	
Male													
406	1	1	1	1	1	1	1	1	1	1	1	0	12
414	0	1	1	1	1	1	0	*	1	0	0	0	11
481	0	1	1	0	1	1	1	1	1	1	1	1	11
1050	0	1	1	1	1	1	*	*	1	*	1	1	9
1053	0	1	0	1	1	0	1	1	1	1	0	0	12
Female													
407	0	1	1	1	1	1	1	1	1	1	0	0	12
408	*	1	1	1	*	1	1	0	1	1	1	1	10
412	0	1	1	1	1	1	*	*	1	1	1	1	10
417	1	1	1	1	1	1	0	0	1	1	1	0	12
1051	1	1	1	1	1	0	1	1	1	0	0	0	12
1052	*	1	0	1	0	0	0	1	1	1	0	1	11
1054	1	1	1	1	1	1	1	*	*	*	*	*	7
1055	1	1	1	1	1	1	*	*	1	1	1	1	10
1056	1	1	1	1	1	1	*	1	1	1	1	1	11
1057	0	1	1	1	0	1	0	0	0	1	*	*	10
Total	13	15	15	15	14	15	10	10	14	13	13	13	160



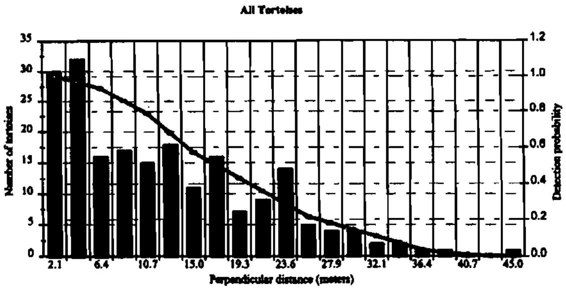


Fig. 3. Histogram of detections using perpendicular distances and detection probability plots for the half-normal + hermite model of encountered tortoises for reproductive tortoises (≥ 180 mm) and all tortoises encountered within the Red Cliffs Desert Reserve, Washington County, Utah, 1998.

variance components, detection probability, encounter rate and $g(0)$, encounter rate variance was highest in both the reproductive (n/km=77.8%) and all tortoises encountered analysis (n/km=59.3%).

The abundance of reproductive tortoises was estimated at 2,361 tortoises per area sampled (10,176 ha) within Zone 3 of the Reserve with a 95% confidence interval from 1,700 to 3,279 and a cv(D) of 16.87 % (Table 5). The abundance of all size classes of tortoises was estimated at 3,019 tortoises per area sampled with a 95% confidence interval from 2,142 to 4,256 and a cv(D) of 17.65 % (Table 5).

Discussion

In 1998, baseline density estimates were calculated for both reproductive tortoises (0.23 tortoises/ha) and all tortoises encountered (0.30 tortoises/ha) within Management Zone 3 of the Red Cliffs Desert Reserve, Washington County, Utah. These estimates are the first recorded regional density estimates of desert tortoises calculated with such an associated precision level and on such a scale (USFWS 1994). Previously reported density estimates within the Reserve are not comparable to density estimates from this 1998 distance sampling study due to limitations with the monitoring technique or unrepresentative areas sampled (Fridell et al. 1995a, Fridell et al. 1995b, McLuckie et al. 1998). Although population density estimates were obtained for the City Creek monitoring plot (Fridell et al. 1995a, Fridell et al. 1995b), these density estimates cannot be extrapolated beyond the boundaries of the 2.59 km^2 (1.0 m^2) study plot. McLuckie et al. (1998) reported density estimates for both the 1997 spring and fall sampling periods. Although a small, unrepresentative area within Zone 3 was sampled and the associated cv (D) was high, 1997 density estimates (Spring = 0.18 tortoises per ha; Fall = 0.25 tortoises per ha) were within the 95% confidence range of 1998 estimates (McLuckie et al. 1998). The regional density estimates obtained in 1998 have one of the highest associated precision level of any density estimate reported range wide for desert tortoises (USFWS 1994).

One of the major assumptions of distance sampling, complete detection of all tortoises on the line and a small distance away from the line, is likely violated with juveniles and immatures. Of the tortoises observed within Zone 3 of the Red Cliffs Desert Reserve, only 26 % had an MCL of ≤ 180 mm. The majority of tortoises encountered (74%) were subadult or adults. Juvenile and immature tortoises are more difficult to observe since they are small, secretive, and spend limited time above ground compared with adults (Diemer 1992, Wilson et al. 1994). Therefore, one of the assumptions of the technique, all tortoises found on the transect line, could be violated since juveniles

Table 4. Akaike Information Criterion values (AIC) and goodness of fit statistics for four detection models, uniform + cosine, uniform + polynomial, half-normal + hermite, and hazard + cosine fitted to the truncated desert tortoise distance sampling data, April 18 to June 4, 1998, Red Cliffs Desert Reserve, Washington County, Utah.

Model Analyses	AIC	Goodness of fit statistics			
		Number of Cells	X^2	DF	*P*
Reproductive tortoises:					
Uniform + cosine	957.52	8	6.46	6	0.37
Uniform + polynomial	959.62	12	13.12	10	0.22
Half-normal + hermite	957.22	18	9.70	16	0.88
Hazard + cosine	958.90				
All tortoises:					
Uniform + cosine	1297.74	9	11.49	7	0.12
Uniform + polynomial	1299.94	14	17.61	12	0.13
Half-normal + hermite	1297.29	21	30.21	19	0.05
Hazard + cosine	1298.53				

Table 5. Sample size of truncated data, encounter rate (number per km), density estimate (tortoise per ha), abundance estimate (total animals) and associated 95% confidence interval, and coefficient of variation of estimates for reproductive (≥ 180 mm) and all tortoises encountered from April 18 to June 4, 1998, Red Cliffs Desert Reserve, Washington County, Utah.

Analyses	Estimate	95% Confidence Interval	Coefficient of Variation (%)
Reproductive tortoises			
Sample size (n)	133		
Encounter rate (n / km)	0.66	0.49 to 0.88	
Density (n / ha)	0.23	0.17 to 0.32	16.87
Abundance (total animals)	2361	1700 to 3279	16.87
All tortoises			
Sample size (n)	178		
Encounter rate (n / km)	0.88	0.68 to 1.15	
Density (n / ha)	0.30	0.21 to 0.42	17.65
Abundance (total animals)	3019	2142 to 4256	17.65

and immatures are more likely missed along the random transect line. Including these animals likely introduces bias into the estimates (Buckland et al. 1994). In the future, we will focus on estimates of reproductive tortoises to determine density and abundance trends. Typically, the largest variance component in population surveys is the spatial variation in the number of tortoises detected, var(n) (Anderson and Burnham 1996). In this study, the encounter rate had the highest component of variance in both analyses, reproductive tortoises and all tortoises encountered, which is typical of population studies (Anderson and Burnham, pers. comm.). Post-stratification, stratification of the data after the data have been collected and examined, is a method which can reduce heterogeneity in the data while improving precision and reducing bias of estimates (Buckland et al. 1994). Stratification could be implemented by geographic region, soil type, vegetational communities, elevation, substrate, or relative densities. Future analyses will reveal the most appropriate stratification to reduce the variance associated with encounter rates.

Full scale sampling within Management Zones 2, 3 and 5 within the Red Cliffs Desert Reserve will allow detection and analysis of population trends. In 1999, two density estimates will be obtained; a density estimate throughout the Reserve and a density estimate within Management Zone 3. This will allow us to assess current management efforts at two levels: within Management Zone 3, an area with the largest contiguous population of desert tortoises, and Reserve wide.

Several demographic parameters including sex ratios, mortality, growth and health conditions were calculated as a byproduct of distance sampling. Consistent with previous desert tortoise population studies within the Reserve (Fridell et al. 1995a, Fridell et al. 1995b), sex ratios observed during distance sampling were not different from 1:1. Shell remain, mortality, growth, and health observation data is presented in McLuckie and Fridell (1999).

Due to the number of potential threats within the Reserve and its proximity to rapidly growing communities, it is critical that population density trends are monitored. These initial density estimates obtained through the distance sampling technique will be compared to future estimates to reveal regional density trends. As additional data are gathered, probability of detection, P_d, and above ground activity, g_0, can be pooled over monitoring years to refine previous density estimates. As pressures from human populations increase, active management will be essential to ensure the continued existence of tortoise populations within the Reserve.

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Maternal Behavior in Desert Tortoises (*Gopherus agassizii*) at Goffs, California*

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Abstract—The behavior of ten wild female tortoises was monitored during the spring and summer of 1986. One of the ten females rammed a human observer with the anterior region of her plastron (epiplastral ramming) on June 4th and August 1st. Each incident occurred a few days to two weeks after the female deposited a clutch of eggs. A fresh portion of tortoise eggshell was found near the female's burrow when the second incident occurred, so nest predation may have recently occurred and affected this female's behavior. The female may have been protecting her nests and such maternal behaviors are not commonly reported for chelonians. Nest protection by female desert tortoises may be a graded form of communication. Ramming may not be common for wild female tortoises, but much more study is needed to determine the consequences of such behavior.

Agonistic behavior between adult male desert tortoises is common in the wild. Male to male combat sometimes results in one male being turned onto its dorsum (Auffenberg 1977; see Berry 1986) which can be lethal if the tortoise cannot right itself. There are also reports of pugnacious behavior in hatchling tortoises (Miller 1932; Grant 1936; Booth 1958; Berry 1986), yet there is little evidence for agonistic or aggressive behavior in wild female tortoises. Barrett and Humphrey (1986) have observed female tortoises fighting with Gila monsters (*Heloderma suspectum*). These female tortoises also blocked burrow entrances and rested on top of their nests, preventing nest access by the *H. suspectum*. In light of the paucity of data of female tortoise aggression in the wild, I am reporting incidents of aggressive behavior by a wild female desert tortoise.

Materials and Methods

The behavior of ten female desert tortoises at Goffs, California was monitored from May to September 1986. Tortoises had been previously fitted with radio-transmitters to facilitate relocation (Turner and Berry 1984, 1985, and 1986; Turner et al. 1986). Radiographs of female tortoises provided information on reproductive status (i.e., gravid, non-gravid, and number of eggs) and approximate laying dates for egg clutches. Females may carry oviductal (shelled) eggs for approximately 22 days before laying them (Turner et al. 1986). Females were radiographed every two weeks until August when females stopped producing eggs. Midline carapace length (MCL, mm) and age class based upon scute wear (P. Hayden and K. Berry, personal communications) were recorded every two weeks.

* Originally presented at the 1987 Desert Tortoise Council Symposium

Results

Radiographic results indicated that all ten females produced at least one clutch of eggs in 1986, but only one female exhibited a ramming behavior, where she repeatedly rammed an observer with the anterior portion of her plastron (epiplastral ramming). The average age class and carapace length of the females was 4.4 (n = 10) and 201 mm (n = 9), respectively. The ramming female (#1067) was relatively small and young (MCL = 182 mm; plastron length = 173 mm and age class = 3) and exhibited epiplastral ramming on June 4 and August 1, 1986. Both incidents were similar and I will describe the details of the latter incident.

On August 1, 1986 at 1813 h (PST), I located tortoise 1067 using radiotelemetry equipment. When within 10 m of her burrow, I could see the entrance and I heard 1067 quickly moving to the burrow entrance from deep inside the burrow. Then, as I approached the burrow incrementally (one or two step increments), she incrementally moved out from her burrow, a few steps at a time. I knelt down on the ground when within two meters of her and she moved to within one meter of me. As I moved one step away, she began ramming my leg several times (five or more) with the anterior portion of her plastron. Her mouth was closed and her head withdrawn as she propelled herself, using all four legs, against my leg.

Up to this point, both incidents were essentially the same. On this occasion, however, she then began ramming my camera bag, pushing it one meter away before I could retrieve it. I placed her back into her burrow and walked ten meters back to my gear. As I turned to face the burrow, I saw her approaching me. She sniffed my backpack and began ramming my backpack. I returned her to the burrow and promptly left the area.

Other relevant information includes the data on the behavior and reproductive status of tortoise 1067. From May to August, I always located 1067 in the same burrow. Prior to her laying her first clutch of eggs, she did not exhibit this aggressive behavior. In September, she was in a different burrow and she no longer exhibited this behavior. The first display of epiplastral ramming occurred on June 4, a few days after she laid her first clutch of eggs. After she laid her second clutch of eggs in mid-June, she also rushed out to her burrow entrance when I approached within 10 m of her burrow. However, I did not move closer to her on this occasion, and she did not move from the entrance of the burrow.

The August ramming incident occurred a few weeks after she laid her second clutch of eggs and at this time I found a fresh piece of tortoise eggshell within two meters of her burrow. It was not determined whether a natural predator had destroyed the egg, and the burrow was not excavated in search of a nest.

On June 18, several days after laying a clutch of eggs, female 1072 (MCL = 194 mm; age class = 3) rushed to the entrance of her burrow (from within) when I approached the burrow. However, she remained in the entrance and did not exhibit epiplastral ramming. The burrow was not excavated in search of a nest.

Discussion

Noting epiplastral ramming by one female tortoise on two different occasions is anecdotal but may indicate the relative importance of epiplastral ramming to female desert tortoises. Only one of the ten females exhibited epiplastral ramming during 1986, so this behavior was not common at least for the females monitored in 1986. To this female tortoise however, this type of behavior may have helped her protect her eggs if predators approached the nest or burrow. Yet this behavior may have also been a large risk to her life and residual reproductive value (Fisher 1930; Williams 1966; and Pianka 1978). These conflicting interests make this behavior intriguing.

Many communication or signaling behaviors are graded in their intensity which is determined by motivation or drive (Alcock 1979; Manning 1979; Gould 1982). Nest defense by crocodilians is graded (Kushlan and Kushlan 1980) and in female alligators (*Alligator mississipiensis*), ranges from sitting on top of nests to protect the eggs to attacking and chasing predators away from nests. Nest defense behavior also has variation components which are modifiable and affected by the experience of individual alligators (Kushlan and Kushlan 1980). Perhaps sitting on nests and attacking potential egg predators (Barrett and Humphrey 1986; and my observations) are two grades of nest defense in desert tortoises. Both tortoises 1067 and 1072 blocked the entrance of their burrows at least temporarily, but whether this behavior was intended to protect nests is not known. It is also common for desert tortoises to turn sideways in the entrance of their burrows (Berry 1986; B. T. Henen, personal observations). This orientation causes a tighter fit of the tortoise within the burrow, making it more difficult to remove the tortoise from its burrow.

The maternal behavior may also be related to the females' age or experience. Females 1067 and 1072 were relatively young and small compared to the other females studied. Perhaps older tortoises have more experience with predators and would not make themselves susceptible to predation. However, the eggshell fragment outside the burrow of 1067 suggests she may have recently encountered an egg predator, potentially predisposing her to attack on subsequent visits. Encountering an egg predator might accentuate a female's response, potentially explaining the additional ramming of inanimate objects in the second incident. Conclusions should not be drawn however, until much more data is available from studies designed to evaluate the frequency, circumstances, benefits and costs (e.g., risks) of this behavior.

Birds, mammals, crocodilians, amphibians and fish exhibit maternal behavior or parental care (McIlhenny 1935, Kushlan 1973, Pooley and Gans 1976, Alcock 1979, Manning 1979, Bustard 1980, Gould 1982, and many others, see Ferguson 1985). By understanding the frequency and circumstances of parental care or maternal behavior in chelonians, we may achieve a better understanding of the evolution of parental care and maternal behavior in vertebrates. Understanding the significance of such behavior in tortoises may also facilitate management of desert tortoise populations.

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Facilitation and interference between annuals and shrubs in the Mojave Desert: An association out of balance?

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Coexisting species are likely to have both negative and positive effects on each other, and the resultant of both types of interactions may contribute to long-term interspecific dynamics and species coexistence (Callaway, 1995; Callaway and Walker, 1997). Using the close association of annual plants with a desert shrub (*Ambrosia dumosa*) in the northern Mojave Desert of California (Fremont Valley, Kern County) as a test system, we identified and quantified negative and positive effects of annuals on shrubs and shrubs on annuals. A separation of negative and positive effects was achieved using an experimental design which included reciprocal removals of neighbors and simulations of physical effects of neighbors on water availability using artificial structures (for a detailed description of the experimental approach and its evaluation see Holzapfel and Mahall, 1999).

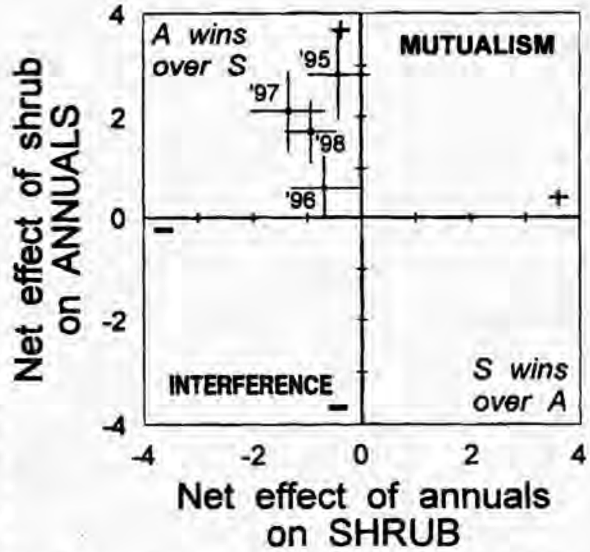

Fig.1. Interaction biplot for the association of the desert shrub *Ambrosia dumosa* and annual plants. The net outcome of the interaction of shrubs and annuals is shown based on above-ground biomass production of shrubs and annuals (see Holzapfel and Mahall 1999). Annuals "win" over shrubs in all four years, they behave like shrub parasites.

Assessments of performance of shrubs and annuals showed that neighboring shrubs and annuals compete for resources but also facilitate each other. Even though positive and negative effects were acting simultaneously, the relative importance of positive and negative effects shifted during the growing season. Annual plants benefited from the presence of shrubs to the largest extent early in the growing season, while the negative effect of annuals on shrubs declined as senescence of the annuals ensued later in the season (Holzapfel and Mahall, 1999). Positive and negative effects among associated plant species are likely to vary among seasons. Therefore the outcomes of interactions will change among years, and neighbors may be favored or depressed to varying extents in different years, thereby influencing long-term coexistence. The investigation of a shrub-annual association over four consecutive years indeed showed that bidirectional positive and negative effects between shrubs and annuals varied strongly from year to year (Holzapfel and Mahall, unpubl. data). Since these opposing effects also varied independently among years, the magnitude of resulting net effects changed in time as well. Based on theoretical considerations it has been predicted that positive net interactions (facilitation) will be more prominent in years of low resource availability (e.g., years with low rainfall). Negative net interactions (interference) are expected to be of greater importance in years with high resource availability. Such a predicted trend was not found for the effects of shrubs on annuals. Shrubs facilitated annuals to the largest extent in intermediate years. In extremely wet and extremely dry years positive net effects were comparatively smaller. The effect of annuals on shrubs followed the prediction more closely: annuals interfered with shrubs increasingly from dry to wet years. Overall, annuals benefited from shrubs most of the time and annuals always had negative effects on shrubs. Fig. 1 shows this for biomass production of shrubs and annuals. The net effect of annuals on the shrub is plotted in this graph against the net effect of shrubs on annuals. Theoretically, this biplot displays four distinct quarters: First, a quarter where both shrubs and annuals are effected positively (mutualism), second, a quarter where both are effected negatively (interference) and two additional quarters where either one is benefiting and the other is effected negatively. Fig. 1 demonstrates that annuals always benefited in the association while shrubs always lost, as the results of each of the four years fall within one quarter. Therefore annuals can be considered as "shrub parasites". It remains to be tested whether this disproportion in the interaction is caused by recent changes in the annual plant community due to invasion by non-native plants. Today, non-native plants contribute the largest part to the biomass within the investigated annual plant community. The proportion of aliens in the annual community in association with shrubs is especially high in wet years (around 80 %, see Fig. 2). Aliens were less predominant in years with lower precipitation (1996 and 1997). Such year-to-year changes are found mainly for annuals in close association with shrubs. The proportion of aliens in the annual community in open areas changed much less in dry and intermediate years (Fig. 2). In the wettest season (1997/98), however, very high proportion of alien annuals were found in intershrub areas as well.

Human impact is known to be disruptive to many ecosystems and to interactions between coevolved species (Goudie, 1986). The introduction of exotic plants to North America has had large impacts on the composition of the local vegetation (Baker, 1986). Californian plant communities in particular have been altered by alien plant invasion (Mooney et al., 1986). This disruptive impact has been strongest in Mediterranean-climate grasslands and savannas, but the proportion of alien plants increased rapidly also in the desert regions in the Southwest U.S. (Mack, 1981; D'Antonio and Vitousek, 1992; Brooks, 1995; Kemp and Brooks, 1998). Many of these exotic invaders originated in the Mediterranean Basin and SW Asia (Jackson, 1985), where even disturbed plant communities typically are not invaded as much as communities in the New World (Dafni and Heller 1982; Holzapfel et al., 1992). We hypothesize that altered species composition in the New World due to invasion by alien plants has altered the strength of reciprocal positive and negative interactions between plant species. Although there have been numerous studies of the competitive effects of exotics plants on natives, there appear to be no investigations of the effects of exotic plants on complex combinations of interactions in natural communities. We found evidence that the annual plant community competes with shrubs. Whether this can lead to a replacement of shrubs with annual plants is not fully understood to date. However, there is some indication that shrubs decline under the pressure of invasive plants, especially annual grasses (Ewing and Dobrowolski, 1992; Freeman and Emlen, 1995). Long-term changes in the interaction of shrubs with annuals need to be monitored in order to assess and predict possible changes in desert shrub communities.

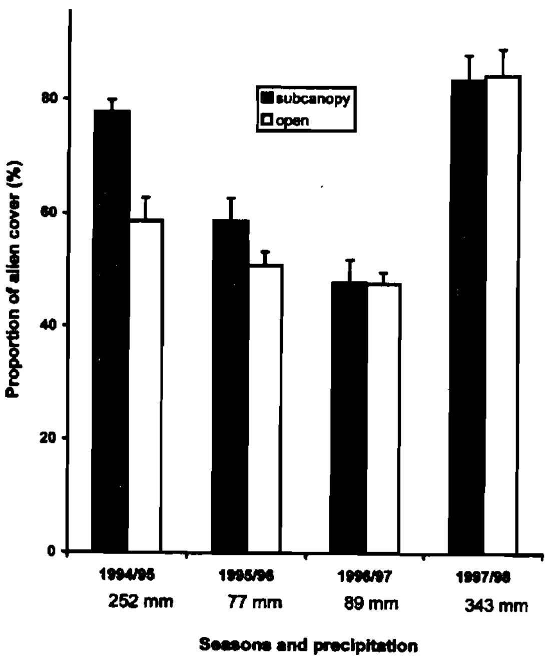

Fig. 2. Proportion of alien plants in the annual community in four different years. Shown is the proportion of alien cover in percent of the total cover of the annual community (+ 1 SE). Annual communities under the northern side of the shrub *Ambrosia dumosa* (subcanopy) and in intershrub areas (open) are separated. The amounts of precipitation represent the sum of the given growth seasons (September to August).

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Desert Tortoise Translocation: The effects of pre-release water availability

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We evaluated the use of translocation to augment populations of the threatened Mojave desert tortoise (*Gopherus agassizii*) with tortoises that had been in captivity. The success of translocating desert tortoises potentially may be affected by many elements involved in the translocation process. We tested the importance of discontinuing daily supplements of water to which tortoises had become accustomed while in captivity. The absence of supplemental water more closely mimicked the infrequent and stochastic desert rainfall that translocated tortoises would normally encounter in natural Mojave Desert habitat.

The tortoises used as experimental subjects were among those living at the Desert Tortoise Conservation Center (DTCC) in Las Vegas, Nevada. While in captivity, these tortoises received daily supplements of water from a sprinkler system until they entered hibernacula in the winter of 1996-1997. Before activation of the sprinkler system in the spring of 1997 and before many tortoises had emerged from hibernacula, experimental subjects were selected and placed in experimental pens. One-half of the tortoises to be translocated did not receive supplemental water while in experimental pens. The remaining tortoises continued to receive the daily water supplement that was part of the protocol for captive tortoises at the DTCC. Both groups of tortoises were given the opportunity to drink prior to their release into experimental pens and at the translocation site. Translocations took place at the Large Scale Translocation Study (LSTS) site near Jean, Nevada. Twenty-eight tortoises with radio transmitters were released in April through May 1997 until temperatures became too hot to release additional tortoises. Six females, eight males, and 1 juvenile that had been supplemented with water were released, while seven females, five males, and 1 juvenile that had not been supplemented with water were released. The tortoises were radio-tracked through late fall 1998.

Following their release, tortoises lost body mass during a period of drought in the spring and summer of 1997. After rainfall in late July, tortoises gained body mass. Male and female tortoises did not differ in their changes in body mass ($F_{3,18} = 0.365$, $P = 0.7789$), so the data for both sexes were pooled. Changes in body mass did not differ between groups that did or did not have access to supplemental water prior to release ($F_{1,20} = 0.166$, $P = 0.6879$). When compared by number of days since release, groups of males and females with and without supplemental water did not have different changes in body mass across all days ($F_{3,18} = 0.295$, $P = 0.829$).

Males that had been supplemented with water prior to release traveled farther on average during their first season (straight-line distance from release site: 3273 m SD = 1774) than did unsupplemented males (straight-line distance from release site: 612 m SD = 418) ($F_{2,12} = 5.86$, $P = 0.0168$). There were no differences in distances traveled by groups of supplemented and unsupplemented tortoises of the two sexes during their second season (May through September 1998) at the LSTS site (mean straight-line distance from hibernacula: 275 m 95% CI $\pm$ 29) ($F_{1,15} = 0.053$, $P = 0.8209$). Home ranges were not calculated for the first season after release because the movement patterns of tortoises were inappropriate for the calculations according to the definition of home range. During the second season after their release, tortoises had home range sizes typical of wild tortoises from nearby sites. The mean home range size of male tortoises was 25.5 ha (SD = 0.151) and of female tortoises was 8.9 ha (SD = 0.019).

All mortality occurred within the first season after release. There were no significant differences among sexes (Fisher's Exact P = 0.1602), water treatments (Fisher's Exact P = 0.6546), or the sex by water treatment groups (Chi Squared P = 0.2059) in mortality rates. The mortality rate of 21.4% in 1997 was not different from the mortality rates of translocated or resident wild tortoises in a nearby valley. Half of the carcasses at the LSTS site had signs of predation or scavenging.

High fidelity to the area of release may be achieved if tortoises in holding facilities are kept on a water regimen similar to that found in nature. Distant movements following translocation may be problematic at small translocation sites or when goals include increased density in particular portions of the translocation site. The circumstances of each translocation program should be evaluated to determine the relevance of potential long-distance movements. Even when translocated during a period of drought, tortoises with and without supplemental water in the weeks prior to release did well following translocation. These data suggest that translocation of desert tortoises can be an efficacious conservation tactic.

Reproduction in Sonoran Desert Tortoises: 1998 Progress Report

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Murray et al. (1996) and Klug and Averill-Murray (1999) summarized reproductive output of desert tortoises (*Gopherus agassizii*) in 1993 and 1997, respectively, from a population in the Sonoran Desert, Arizona. This paper presents reproductive output results from the same population in 1998 and summarizes results to date. Our study site is located near Sugarloaf Mountain on the Tonto National Forest, 48 km northeast of Mesa, Maricopa County, Arizona. Elevations at Sugarloaf range from 549-853 m with steep, rocky slopes divided by many arroyos. Boulders up to 4-m diameter occur on many slopes. Vegetation at the site is classified in the paloverde-mixed cacti series in the Arizona Upland Subdivision of the Sonoran Desert (Turner and Brown, 1982).

In 1998 we monitored 22 female tortoises (184-288 mm straight midline carapace length [MCL]) weekly using radiotelemetry (see Klug and Averill-Murray, 1999, for telemetry details). Primary radiographic sampling occurred on a bi-weekly basis (approximately half the tortoises each week) between 21 May and 6 August 1998. We used an HF-80 (MinXray Inc., Northbrook, IL) portable X-ray machine powered by a gasoline generator. X-ray exposure times ranged from 0.12 to 0.24 sec depending on tortoise size (MCL). If we could detect eggs by palpation after we had confirmed clutch size on a previous radiograph, that tortoise was not radiographed during its normal rotation; this procedure allowed us to minimize handling, cumulative radiographic exposure, and stress to individual tortoises. Oviposition date for each gravid tortoise was estimated as the midpoint between the date eggs were last recorded and the date eggs were confirmed to have been laid. All means are reported ±1 SD. We recorded rainfall each week from a raingauge on site.

We also randomly sampled tortoises from our telemetered population in the spring and fall to determine whether tortoises developed shelled eggs outside the primary period during which reproduction has been observed to date in the Sonoran Desert. In the spring, we randomly sampled 10 tortoises on 1 April and 16 tortoises on 1 May. On 7 May, we radiographed 4 of the 6 tortoises not sampled plus 1 which was sampled on 1 May. In the fall, we radiographed random samples of tortoises on 14 August, 3 September, and 6 October (n = 11 on each date). We calculated the minimum overall probability that we would detect eggs in both the spring and fall based on our samples of negative radiographs, if any female in the telemetered population actually had eggs. We limited this analysis to our 18 telemetered tortoises ≥220 mm MCL; tortoises below this size have not been observed to reproduce at this site. To date, the smallest tortoise in the Sonoran Desert found to lay eggs was 220 mm MCL (Murray et al. 1996; Wirt and Holm, 1997). First, we determined the maximum probability of each sample containing no gravid females, given at least 1 of the total number (18) are gravid, based on the hypergeometric distribution:

$$P(0) = [(qn)!*(n-k)!] / [n!*(qn-k)!],$$

where q is the proportion of tortoises without eggs, n is the size of the telemetered population, and k is the size of the random sample. The overall power of detecting a gravid female in a seasonal sample of tortoises is then 1 minus the product of each sample's P(0) within that season.

The 1 April radiography sample revealed no gravid tortoises, but 1 tortoise (#77) was found with a single egg on 1 May. The 7 May sample resulted in no additional gravid females. Tortoise #77 is the first tortoise in the Sonoran Desert found to be gravid in the spring. It is possible, especially since she only had a single egg, that tortoise #77 retained this egg from the previous year (J. Jarchow, pers. comm., 1998; J. Johnson, pers. comm., 1998); unfortunately, this tortoise was not telemetered during the 1997 reproductive season. Two pieces of evidence suggest that this clutch was retained from 1997, rather than produced (relatively) early in

1998. First, 1997 was an abnormally dry year, during which most females did not reproduce and those that did had small clutch sizes (Klug and Averill-Murray, 1999). Most tortoises did reproduce in 1998, and mean clutch size increased (see below); tortoise #77's clutch of 1 egg does not fit this pattern. Second, tortoise #77's behavior differed significantly from other females that reproduced. Prior to oviposition, from her initial capture on 21 October 1997 to 5 June 1998, tortoise #77 occupied an area of 3.03 ha (measured with a minimum convex polygon), spanning 348 m. Between 11 June and 13 July, she moved north to a canyon 1.2 km from her previous activity area. She moved about this canyon through 3 September before returning to her original activity area on 11 September. All other post-gravid tortoises that we have observed have either remained at the nest site for several weeks following oviposition or have at least remained within their normal activity areas. Therefore, we exclude tortoise #77 from analyses in the remainder of this paper.

The smallest tortoise to lay eggs in 1998 was 229 mm MCL (Table 1). Excluding tortoise #77, 12 of 17 adult tortoises (71%) laid eggs (Table 1). Clutch size ranged from 4 to 7 eggs (0 = 5.4 ± 1.16), but we found a 238-mm, untelemetered tortoise with 9 eggs on 26 June, increasing mean clutch size to 5.7 (±1.49). No tortoise laid more than one clutch. We first detected eggs by radiography on 4-5 June, and oviposition occurred between 2 July and 6 August (0 = 13 July ± 9 days; Table 1). Oviposition occurred near the onset of the summer monsoon rains, which began with 28.7 mm during the first week of July after a period of about 3 months with no measurable rainfall.

Excluding tortoise #77, we radiographed 8 tortoises ≥220 mm on 1 April and 15 on 1 May. Radiographs of 2 samples of these sizes from a telemetered population of 17 tortoises result in a 94% probability of detecting eggs, if any tortoise (other than #77) was gravid. Our August, September, and October samples each consisted of 10 radiographs, and all were negative. The probability of detecting eggs in the fall was 91%, if any tortoise was gravid (n = 18). Similar calculations indicate that we had a 95% chance of detecting gravid tortoises in 2 samples (k=9 on 16 September, k=8 on 21 October) in fall 1997 (n = 11). Regardless of whether tortoise #77's spring clutch was held over from the previous year, the overwhelming majority of tortoises did not reproduce in the spring. Likewise, tortoises at Sugarloaf did not produce clutches after the summer laying season. Our sample sizes were certainly sufficient to detect egg production outside the summer laying season.

In 1993, 8 of 10 telemetered tortoises laid eggs at Sugarloaf, with a mean clutch size of 5.7 eggs (±2.43;

Table 1. Egg production of desert tortoises at Sugarloaf Mountain, Arizona, 1998. MCL is straight midline carapace length.

Tort. #	MCL (mm)	Date Telemetered	Eggs last detected on	Eggs laid by	Estimated Oviposition Date	Clutch size
56	171	21 Oct 97	—	—	—	0
73	181	25 Mar 98	—	—	—	0
61	186	23 Aug 96	—	—	—	0
55	209	9 Aug 96	—	—	—	0
66	229	18 Mar 98	10 Jul	16 Jul	13 Jul	7
63	233	13 Mar 97	—	—	—	0
81	233	25 Mar 98	10 Jul	24 Jul	17 Jul	7
77	233	21 Oct 97	5 Jun	19 Jun	12 Jun	1
51	235	8 Aug 96	—	—	—	0
80	235	19 Nov 97	1 Jul	10 Jul	5 Jul	4
67	238	16 Sep 97	1 Jul	10 Jul	5 Jul	5
58	240	9 Aug 96	—	—	—	0
65	242	20 Mar 97	9 Jul	17 Jul	13 Jul	5
1	246	3 Jul 96	9 Jul	17 Jul	13 Jul	4
25	246	13 Apr 96	16 Jul	Jul 24	20 Jul	6
14	250	17 Apr 98	—	—	—	0
46	252	11 Jul 96	17 Jul	24 Jul	21 Jul	4
17	253	30 Dec 97	1 Jul	10 Jul	5 Jul	5
29	254	20 Sep 96	1 Jul	10 Jul	5 Jul	5
57	254	9 Aug 96	—	—	—	0
3	270	13 Apr 96	2 Jul	9 Jul	5 Jul	6
68	287	10 Jun 97	31 Jul	6 Aug	3 Aug	7

Table 2. Reproductive output of desert tortoises at Sugarloaf Mountain, Arizona, 1993 and 1997-98. The rainfall column includes cumulative rainfall from July through April preceding the current reproductive season. Mean July-April rainfall at Stewart Mountain = 31.5 cm (±12.37, n = 51 years). Standard deviations are reported with means.

Reproduction year (n ≥ 220 mm MCL)	10-mo preceding rainfall (cm)	Mean Estimated Oviposition Date	% Gravid	Clutch size Range	Clutch size Mean
1993 (10)	67.9	27 Jun (14 d)	80	3 – 9	5.7 (2.43)
1997 (12)	18.9	1 Jul (7 d)	33	2 – 5	3.8 (1.26)
1998 (17)	41.0	13 Jul (9 d)	71	4 – 7	5.7 (1.49)
1999 (16)	22.9	???	??	???	???

Murray et al., 1996). In 1997, only 4 of 12 telemetered tortoises laid eggs, with a mean clutch size of 3.8 eggs (—1.26; Klug and Averill-Murray, 1999). Mean estimated oviposition occurred on 27 June 1993 (±14 days) and 1 July 1999 (±7 days). Annual differences in clutch frequency and mean clutch size appear to be related to rainfall. Cumulative rainfall from the summer through winter and spring 10 months prior to ovulation in 1993 (July-April, with ovulation occurring as early as late May; Klug and Averill-Murray, 1999) was greater than twice the average at Stewart Mountain (Table 2), about 13 km south of Sugarloaf (from National Oceanic & Atmospheric Administration data). The 1997 reproduction season was preceded by dramatically below average rainfall, and 1998 was preceded by somewhat above average rainfall (Table 2).

Summer monsoon rainfall in 1992 and winter rainfall in 1992-93 were both higher than the average at Stewart Mountain. Wet conditions provided abundant summer and spring forage prior to the 1993 reproductive season, when most females laid eggs. In contrast, summer rainfall in 1996 and the following winter were both below average. Therefore, tortoises had little fresh forage during the year prior to the 1997 reproductive season, and few tortoises laid eggs. Summer monsoon rainfall in 1997 was late (<1 mm rain in July) and below average, while 1997-98 winter rainfall was above average. Abundant spring forage may have provided the final nutritional boost needed for reproduction.

Mean oviposition date was not correlated with July-April rainfall (Table 2). Oviposition occurred about 2 weeks later, on average, after an average year of rain (1998) compared to following a drought (1997). However, earliest mean oviposition followed the wettest year of the study (1993).

Finally, in 1997 and 1998, we attempted to find as many nests as possible and monitor them to determine their outcome. We have only found nests laid inside burrow entrances. Of 4 nests laid in 1997, 3 appeared to have been destroyed by predators; 1 (which was never confirmed) had an unknown outcome. Of the 12 nests laid in 1998, we confirmed 4 inside burrows and suspected 2 others based on the females' occupation of the same burrows for several weeks after ovipositing; we were unable to find the remaining 6 nests. Of the 4 confirmed nests, 2 appeared to have been destroyed by predators, and 2 appeared to have successfully hatched. We observed 2 hatchlings in 1 of these nests between 15 and 29 October 1998. The last hatchling (43.5mm MCL and 16g) was observed leaving the nest on 29 October.

We are continuing to collect reproductive output data from Sugarloaf in 1999. In addition to the radiographic study, we plan to collect data on female tortoises' seasonal reproductive cycles using ultrasonography (*cf.* Rostal et al., 1994). These additional data will help develop a more clear understanding of seasonal reproductive cycles in Sonoran Desert tortoises.

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Status of the Washington County Habitat Conservation Plan—March, 1999

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My presentation today will deal with the WCHCP's implementation and a little of its background and development.

Introduction

Here in Washington County, annual growth over the last 20 years has averaged 6.2 percent. In 1980, there were about 26,000 residents in the county. Today, that number stands at 80,000. While growth last year was only 3%, the county's population is still increasing at an impressive rate. The county's extraordinarily warm year-round climate provides many Utahns with an escape from harsh winters. Aside from a booming retirement destination, Washington County represents a biologically unique transition zone where the northeastern finger of the Mojave Desert meets the southern edge of the Great Basin. Desert tortoises in the Upper Virgin River Recovery Unit thrive in concentrations higher than anywhere else across their range — as many as 350 tortoises per square mile.

Rapid growth and declining habitat of the threatened desert tortoise resulted in a serious conflict between the FWS and local home building and development interests in Washington County. As undeveloped land surrounding St. George and other towns in Washington County was graded and improved, a large number of new developments were violating the ESA's section 9 prohibition against harming or harassing (i.e, take) Mojave desert tortoises.

Endangered Species Act Section 10: An Answer

In 1982, Congress passed several amendments to the ESA which authorized the United States Fish and Wildlife Service to issue permits authorizing non-federal entities to Take a federally protected species if (1) such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity (ESA, Sec.10(a)(1)(B)), (2) the applicant submits a conservation plan which outlines, "the impact which will likely result from such taking;...what steps the applicant will take to minimize and mitigate such impacts, and the funding that will be available to implement such steps...[and] what alternative actions to such taking the applicant considered and the reasons why such alternatives are not being utilized," (ESA Sec. 10(a)(2)(A)), and (3) the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild.

In February, 1996, roughly five years after the idea of applying for a county-wide incidental take permit was seriously undertaken by the Washington County Commission, the FWS issued Washington County a 20-year incidental take permit and approved its associated Habitat Conservation Plan. Plan development funds came from sources as diverse as Congress, the state of Utah, local cities and towns, the Bureau of Land Management, and the FWS. It has, at least in the short term, alleviated the protection vs. development dilemma facing the county.

The Washington County Habitat Conservation Plan

The WCHCP permits the majority of private landowners in Washington County to develop their property supporting tortoises without the threat of an ESA Section 9 violation and subsequent prosecution. Before development in tortoise habitat can legally take place, Washington County is responsible to clear the site of tortoises, up to 1,169 of them on 12,264 acres over the twenty-year life of the plan to the best of its ability. This loss expected over the 20-year permit's life represents 15% of the estimated 7,883 tortoises in the RU and 22% of the 55,947 acres of tortoise habitat in the Recovery Unit. Taken animals are tested for antibodies to upper respiratory tract disease. Tortoises testing positive for the disease are sent to a university veterinarian at CSU for use in health studies. Healthy animals are kept in Washington County's tortoise holding facility to be released at one of three experimental translocation sites in the County.

In return for regulatory assurity when building within tortoise habitat, the county assesses a fee of $250 per acre developed plus 0.2 percent of the estimated cost of construction. This money funds administration and management of the WCHCP. The primary mitigation measure in the WCHCP is establishment of a 61,000 acre reserve, of which 38,787 acres is desert tortoise habitat (the remainder of which supports several other endangered or threatened species, or is important to maintain a contiguous character of the reserve). Establishment of the reserve will ensure that the most valuable tortoise habitat (i.e., habitat containing the highest density) is preserved. Eighty-seven percent of high-density and 80% of medium-density tortoise habitat in Washington County is included within the reserve. Most of the Take area will be in low-density tortoise habitat.

When the plan was approved, roughly 42,000 acres within the reserve were already owned by the BLM or Snow Canyon State Park, both of whom are committed to tortoise conservation and form part of the reserve. The remaining 18,600 acres were owned by various private landowners and the Utah School and Institutional Trust Lands Administration. The BLM is conducting voluntary land exchanges to trade BLM lands outside the reserve for acreage within the reserve currently owned by private entities and USITLA. The WCHCP calls for the entire reserve to be eventually owned by the BLM and Utah State Parks and managed jointly by the BLM, State Parks, and Washington County. Private landowners whose property falls within the reserve who do not wish to sell their property will not be forced to do so, but will not be protected under the county's permit from ESA Section 9 prosecution if they harm or harass desert tortoises.

Washington County must manage this reserve for the long-term benefit of the tortoise and its other native inhabitants. The following actions have been accomplished during the three years since the plan was approved.

Benefits for the Mojave Desert Tortoise Establishment of Long-Term Contiguous Habitat Reserve

Desert tortoises reap many benefits from issuance of the incidental take permit and acceptance of the accompanying WCHCP. First and foremost, the establishment of a contiguous reserve for the tortoise is indisputably the most important mitigation measure. If more extensive development had continued within what is now the reserve, tortoise populations would be more fragmented and would most likely succumb to eventual extinction.

Conservation Accomplishments to Date

- Washington County has spent $150,000 to acquire and retire about 2,000 grazing AUMs within the reserve. State Parks and USFWS have acquired several hundred additional AUMs, some of which were not even slated for acquisition under the HCP. Right now, over 99% of all grazing permits within the reserve's tortoise habitat have been retired. Grazing is a non-issue here in the Upper Virgin River RU.
- Washington County has funded a full-time BLM law enforcement officer whose sole responsibility is protection of the reserve. BLM has outlawed off-road vehicle use except on designated roads and trails, which are few. This is being enforced, and the number and frequency of violations has dropped significantly as people learn that no motorized off-road recreation is permitted in the reserve.
- The county employs a full-time WCHCP administrator and biologist who coordinate and carry out activities vital to accomplishing conservation measures on the ground.
- Washington County annually funds seasonal technicians with the Utah Division of Wildlife Resources who monitor tortoise populations within the reserve.
- Over 12 miles of fencing have been built by Washington County, UDOT, the Nature Conservancy, Ivins City, and St. George to exclude tortoises from roads or other hazards and to keep people from dumping, vandalism, or ORV riding in sensitive areas.
- Several ORV trails which permitted habitat degradation have been closed.
- Thanks to BLM, Utah State Parks, and Washington County, approximately 3,300 acres of desert tortoise habitat have been acquired within the reserve via purchase, exchange, and donation. Total land value of acreage acquired is $25 million. Some property not previously designated for acquisition has been acquired by BLM to improve configuration of the reserve. To date, the Bureau has been allocated $7 million from Land and Water Conservation Funds for acquisition of private lands within the reserve, and the State of Utah has been awarded $1.75M from ESA section 6 funds for the same purpose.
- Development of a nature education center focusing on sensitive reserve species is forthcoming.
- UDWR has written a multi-species plan for other wildlife which summarizes current knowledge and contains strategies for monitoring various sensitive species throughout the County.
- Washington County has provided class lectures to over 1,600 people at schools and other groups on tortoises and other wildlife. As a result of this and other efforts, public perception is changing in favor of supporting the reserve. Compared to three years ago, public support is significantly higher.
- A translocation experiment has begun which has provided us with valuable information regarding which habitats tortoises prefer, how far they will travel, and other information.
- The BLM is withdrawing the entire reserve from mineral development in their Resource Management Plan. Vegetation harvest, ORV uses, camping, and other uses in the reserve are strictly limited. Utility development is discouraged within the reserve. Where no other practical alternative is possible, strict criteria must be followed during placement and rehabilitation is required after it.

Benefits for Washington County and Developers Development Continues with "No Surprises"

Since issuance of the permit, 800 acres of tortoise habitat have been legally cleared and developed. One hundred and twelve tortoises have been taken and processed by Washington County. The county has cleared all take areas, and development in Washington County is booming. The tortoise issue has largely fallen by the wayside for most Washington County residents. In most residents' eyes, the issue was resolved when the FWS issued Washington County its Incidental Take Permit.

The county and developers are guaranteed that they may continue to legally develop tortoise habitat outside the reserve through March 15, 2015 as long as they implement the terms of the HCP. This is due to a "No Surprises" policy adopted by the FWS:

> [I]f unforeseen circumstances occur during the life of an HCP, the FWS...will not require additional lands, additional funds, or additional restrictions on lands or other natural resources released for development or use, from any permittee, who in good faith, is adequately implementing or has implemented an approved HCP (U.S. Fish and Wildlife Service 1996).

In other words, the county and developers are certain that no further resources can be extracted from them as long as they abide by the current HCP's stipulations regardless of what monitoring results reveal.

Areas of Concern: Public Use Plan

Representatives from various outdoor recreation groups along with representatives from BLM, the UDWR and the County are developing a public use plan for the many recreationists who want to enjoy the reserve's unique beauty and outstanding recreational opportunities. On the one hand, FWS views establishment and management of the reserve as mitigation for take elsewhere, and therefore no further compromises are appropriate. On the other hand, we know that some low levels of controlled and specifically placed recreation will not significantly impact tortoises, and local public support is valuable in defending the reserve from potential threats. This local ownership sentiment is unquantifiable but not insignificant. It has benefits such as local recreationists reporting violations in their reserve and having extra eyes in the reserve looking for potential problem areas.

Translocation Agreement

The original translocation agreement, signed in 1997 by BLM, UDNR, USFWS, Washington County, and six livestock permittees in the translocation area, only permitted the tortoises to wander within one square mile of translocation areas. Tortoises released last spring have wandered many miles. Consequently, negotiations are under way to see if signatories will be amenable to agreeing to an amendment which would allow the tortoises to wander further.

Land Acquisition Costs

The BLM has done an outstanding job in acquiring reserve property as quickly as administratively possible. However, the Bureau is limited in its acquisitions by a cash shortage, and has been unable to acquire needed acreage quickly enough to avert the threat of development. With skyrocketing land values in the County, acquisition of the remaining 15,300 acres could require 30-40 years. Current value of the land is roughly $125 million (about $35 million for private, and about $90 million for USITLA land). Spread out over 30 years, the value will only increase. Washington County has appealed to the Department of Interior for a complete buy out of all remaining inholders.

Edge Effect

One insidious threat to the long-term well-being of the desert tortoise in the Upper Virgin River RU is the edge effect. Because this is the smallest tortoise RU, it has a very high perimeter to area ratio. Its proximity to significant population centers and human associated impacts, including artificially high numbers of tortoise predators both wild and feral, will have an as yet undetermined but certainly significant impact on the reserve and its tortoises. This will be an issue to deal with at some future point once imminent issues like habitat acquisition and habitat degradation are sufficiently addressed.

Conclusion

The Washington County Habitat Conservation Plan constituted a necessary compromise between private property rights and conservation. Realistically, the problem could not have been addressed by any other means than an HCP. That human development will continue to boom in Washington County is now assured, as is the right of most private property owners to develop their land. Landowners with private holdings within the reserve boundaries are being offered fair market value for their land as money or exchange parcels become available.

We believe that, despite fewer tortoises and acres of tortoise habitat, the population of tortoises in the Upper Virgin River Recovery Unit is better protected today that it was without the plan. Reduced forage competition, contiguous reserve design, habitat acquisition, fencing, education, and law enforcement are making a difference. With adequate vigilance and regulation, we believe these influences will outweigh negative impacts sustained from habitat loss and degradation, and that the tortoise will survive in the Upper Virgin River RU.

ABSTRACTS FROM THE 1999 SYMPOSIUM

Attributes of Desert Tortoise Populations within Selected Areas at the National Training Center, Fort Irwin, California

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Between 1996 and 1998, we established 20 plots within the National Training Center (NTC), Fort Irwin, in San Bernardino County, California. Research objectives were site- or region-specific and included: (1) characterization of demographic attributes of tortoises, (2) assessment of health and presence of mycoplasmosis and shell diseases, (3) evaluation of location for suitability for translocated tortoises, and (4) assessment of potential for critical habitat. The health and demographic attributes of populations differed by site and region, and depended on such factors as geographic location and history of human use. Two of the 20 plots (2.25 km^2 each) are within the Superior-Cronese critical habitat on the north Alvord Slope and have been protected from military vehicle use by a fence since 1994. Densities range from 6 to 17 tortoises/km^2. Subadult and adult tortoises on both plots experienced higher annual death rates (>5%) between 1993 and 1997 than reported for stable populations. Significantly fewer live tortoises were found near the fence and the military training area than in less disturbed areas away from the fence. We tested 17 of the 44 tortoises captured for *Mycoplasma agassizii* and *M.* nov. sp., the pathogens responsible for upper respiratory tract disease (URTD). None of the tortoises tested positive for the pathogen. In previous years, Jacobson et al. (1996) reported tortoises with positive ELISA tests (12.5%, N = 32) from the North Alvord Slope.

Three of the 20 plots are in military training areas (Tiefort Mountains, Eastgate 1 and Eastgate 2). The Tiefort Mountains plot (4.6 km^2 in size), the site for which we have the most complete population data, has a density of 28 tortoises/km^2 and experienced an annual death rate of 1.9% for subadult and adult tortoises between 1992 and 1997. Tortoises at the Tiefort and Eastgate sites were tested for mycoplasma using the ELISA test, polymerase chain reaction technique, and cultures. The 81 sets of samples were negative.

The 15 plots (1 km^2 each) at the Goldstone Deep Space Communications Center were in areas protected from military training exercises. Densities were low, estimated at 1-5 tortoises/km^2 overall. A total of 17 live tortoises and 135 shell-skeletal remains were found on the plots. Approximately 80 of the 135 shell-skeletal remains represent tortoises that died between 1994 and 1998. Of 9 tortoises tested for mycoplasmosis, 2 (22%) were positive with the ELISA test. Shell disease was common in the tortoises at Goldstone and the NTC.

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A Look at the Reproductive Ecology of the Desert Tortoise at the Marine Corps Air Ground Combat Center, 29 Palms, California

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In late May 1998, we began the first field season of a two year investigation into the reproductive ecology of a wild population of desert tortoises at the Marine Corps Air Ground Combat Center, 29 Palms, California. We monitored the reproductive status of 19 adult female tortoises using radiographic analysis. Two females did not produce eggs, 15 produced one clutch and two produced two clutches. Mean clutch size was 5.2 eggs (n=17) and ranged from 3-9 eggs. Using thread trailing devices attached to the carapace of gravid females, we located 17 of the 19 nests laid. Two nests were laid under creosote bushes, one was within a pallet and 15 were associated with burrows. Eight of seventeen nests (47%) were depredated. Kit foxes were implicated by circumstantial evidence in most predation events. Seventy-seven percent of the eggs in surviving nests emerged successfully from the nest chamber. Incubation time ranged between 74 and 88 days, though one abnormally pigmented individual emerged after 106 days. Hatchlings were measured and a sub-sample was monitored with radiotransmitters for survivorship and movement patterns. Only one of 11 hatchling tortoises was predated prior to October 22, when all transmitters were removed. These data give a preliminary look at the nest site selection of gravid females and survivorship of nests, eggs and hatchling desert tortoises in a robust Mojave Desert population.

Exotic Plant Species in Desert Tortoise Habitat

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Exotic plants comprise a relatively small proportion of the Mojave Desert flora, but a few species dominate many plant communities and have negatively affected or threaten to affect ecosystem integrity. The most studied exotic plant species in the Mojave Desert is the riparian perennial, *Tamarix* spp. Riparian habitats comprise less than 3% of the entire region, and the remaining upland area is often dominated by exotic annuals. Exotic annuals can comprise 66-97% of the total annual plant biomass, and are present at approximately 50% of all wildland sites. Because annuals are currently the most common exotic plants in the Mojave Desert, we will focus on the ecology and management of exotic annuals in this paper.

Widespread and common exotics include four species that are dominant in plant communities throughout the Mojave Desert. *Bromus madritensis* ssp. *rubens* [*Bromus rubens*] is recognized as a potential wildland pest, but relatively little is known about its ecology. It is considered an invasive weed in its Mediterranean home range and appears to be limited in dominance primarily by rainfall and soil nitrogen in the Mojave Desert. *Bromus tectorum* has ecological effects that are well documented in the Great Basin Desert, but not in the Mojave Desert. Distribution of *Bromus tectorum* is generally confined to elevations above 5,000 feet, yet encroachment into and dominance at lower elevations has been observed throughout the Mojave Desert. *Schismus* spp (*S. arabicus* and *S. barbatus*) is recognized as a potential wildland pest but very little is known about its ecology in North America. It is not invasive in its home range, but it is well adapted for arid conditions and is not limited by low water and nutrient levels in the Mojave Desert. *Erodium cicutarium* is widespread and has been shown to outcompete native plants in the Mojave and Sonoran Deserts.

Locally common exotic annuals include seven species that are dominant in plant communities in certain regions or habitats. *Brassica tournefortii* became dominant in cis-montane southern California during the 1980's. It is currently spreading north and east along roads into the Mojave Desert, but since 1995 it has been observed spreading away from roads into wildland areas. *Hirschfeldia incana* [*Brassica geniculata*], *Descurania sophia, Sisymbrium irio, Sisymbrium altissimum*, and *Salsola* spp., are often locally abundant along roadsides, livestock watering sites, and off-highway vehicle staging areas. *Bromus trinii* appears to be ecologically similar to other brome grasses, and where it is abundant, it can fuel the spread of fires and may compete with native plants. Other exotic annuals are either very limited in their distributions or are confined to urban or agricultural areas.

Exotic annuals may affect ecosystem integrity by competing with native plants, altering soil characteristics, and/or promoting wildfires. Increased levels of atmospheric CO_2 and nitrogen may promote the dominance of exotic annual species in the Mojave Desert. Management of exotic plants must begin by preventing invasions. Once they become established, the dominance of exotic annuals may be minimized with biological agents, application of herbicides, manual removal, or protection of habitat from human disturbances.

We identify several research areas important to the control and management of exotic annuals in the Mojave Desert: 1) determine the distributions of exotic species and consolidate this information on a public domain database; 2) identify environmental variables that facilitate the invasion and dominance of alien species; 3) identify physiological and ecological characteristics of exotic annual species that promote their invasiveness; 4) prioritize the most vulnerable habitats to receive immediate protection from exotic plant invasion and prioritize the exotics of greatest concern based on their invasive attributes; and 5) control exotic species and restore degraded habitats using well-designed and replicated experiments.

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Effects of Exotic Grasses via Wildfire on Desert Tortoises and their Habitat

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One of the most significant effects of plant invasions worldwide is the alteration of natural fire regimes. In most cases invasions lead to increased frequency of fire, especially invasions of exotic grasses. The effects of increased fire frequency can be dramatic in regions where fires are historically rare. Estimates of historical intervals between fires in the Mojave Desert range from 30 to > 100 years. The invasion of exotic grasses has shortened this interval to an average of 5 years in some areas, resulting in significant changes in plant communities and in threats to the desert tortoise (*Gopherus agassizii*).

Annual exotic grasses have been shown to cause type-conversion of native desertscrub to exotic annual grasslands in the Great Basin and Mojave deserts. Dead stems of the exotics red brome (*Bromus madritensis* subsp. *rubens*), cheatgrass (*Bromus tectorum*) and the Mediterranean grass (*Schismus arabicus* and *S. barbatus*) remain rooted and upright into the summer fire season and over successive years, whereas those of most native forbs crumble soon after they senesce. These exotic annual grasses often cover the desert landscape resulting in continuous and persistent fine fuels that facilitate the spread of fire in an otherwise fire-resistant landscape. Frequency and cover of exotic annual grasses can increase within 3 to 5 years after fires, thus increasing the continuity and amount of fine fuels that promote additional fires. This grass / fire cycle reduces fire return intervals and significantly threatens desert tortoise populations and ecosystem integrity.

Perennial exotic grasses can also promote fires. One such species is buffelgrass (*Pennisetum ciliare*) which was introduced as a forage species to Sonora, Mexico. Thousands of hectares of Sonoran Desert have been converted to buffelgrass stands for livestock. In stands where buffelgrass is cultivated for livestock, fire is sometimes used as a management tool to the keep stands vigorous. Since this plant has naturalized, additional large expanses of desert and thornscrub habitat have been converted to buffelgrass that burn occasionally. This perennial grass has moved northward from Mexico and into the Sonoran Desert of Arizona mostly along roadways. In Arizona, several urban parks have been invaded by buffelgrass and there has been habitat degradation due to fires at these locations. Buffelgrass was only recently discovered in Arizona wildlands and although fires that result from buffelgrass stands appear to be imminent, to date they have not been recorded in great numbers. The potential exists for buffelgrass to invade other desert regions such as the Mojave and Colorado deserts, and studies are planned to evaluate their potential geographic range.

Fires affect desert tortoises directly by killing them with lethal heat or low oxygen levels, and indirectly by altering their habitats. Fires in general appear to be detrimental to the desert tortoise and its habitats. Management of fire in the Mojave and Sonoran deserts should focus on preventing invasions of new exotic grasses, minimizing the dominance of exotic grasses already present, reducing the number of human-caused fires, and suppression of fires when they occur.

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Development of a Qualitative Field Diagnostic Test for Specific Anti-Mycoplasma Antibodies in Blood of Tortoises. I. Rationale and Significance

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Chronic upper respiratory tract disease (URTD) of tortoises is a syndrome of nasal and ocular discharge, conjunctivitis, and palpebral edema. Inflammation accompanies degeneration of upper respiratory tract epithelium. Appetite and social interactions may be disrupted by olfactory lesions or occlusion of the respiratory tract with mucus, reducing fitness of severely affected individuals. Stress from chronic immune stimulation can become debilitating, and the disease is probably a predisposing factor to secondary illnesses. The URTD of *Gopherus agassizii* is thought to have contributed to population declines over parts of the species' natural ranges during the past two decades. *Mycoplasma agassizii* was shown by experimental infection studies of *G. agassizii* and *G. polyphemus* to be an etiologic agent of URTD. Seropositive status is a significant risk factor for transmitting URTD. Serological monitoring therefore may be valuable for epidemiology of natural populations, and for management decision-making to minimize the risk of spread of mycoplasmosis. However, quantitative ELISA is limited by sample handling requirements and by turnaround time which requires tortoise quarantine before decision-making. A qualitative field test for specific antibodies against mycoplasma could provide an alternative test without the need for sample refrigeration and shipping, and also provide nearly instant information for management decision-making.

The Search for Sources of Potential Toxicants in Desert Tortoises: Results of a Pilot Project Incorporating Surficial Materials and Plants from Three Areas in Southeastern California

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Diseases are known contributors to rapid declines in desert tortoise (*Gopherus agassizii*) populations in some parts of the southeastern California deserts. Elevated levels of potential toxicants (e.g., Cd, Cr, Hg, Ni, Pb) have been found in some ill, dying, and recently dead tortoises (Jacobson et al. 1991, Homer et al., unpublished data) and may have exacerbated poor health. The sources of the potential toxicants have not previously been investigated. For this pilot project, we evaluated levels of chemical elements in soils where tortoises live and in common forage plants, including forbs, grasses, and herbaceous perennial species. We collected 46 plant samples, representing 22 different species, and 107 surficial samples (rock, soil, and active wash sediment). The plants and surficial materials were collected from one of three localities: (1) a traverse between the Rand mining district (Randsburg, Red Mountain, and Johannesburg) and the Desert Tortoise Research Natural Area in eastern Kern County, to identify effects of mining; (2) selected areas within the Goldstone Deep Space Area at Fort Irwin, San Bernardino County, to identify effects of past military activities and a natural playa lake environment; and (3) the Chuckwalla Bench and Salt Creek area, Riverside County, to identify effects of an old railroad used to transport iron ore and other lithologically-related factors.

We analyzed the dried plant material for 35 elements (Ag, As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, Hg, Ir, K, La, Lu, Mo, Na, Nd, Ni, Rb, Sb, Sc, Se, Sm, Sr, Ta, Tb, Th, U, W, Yb, and Zn) using neutron-activation analysis. For comparative purposes, we also collected samples of surficial materials and analyzed them for 41 elements (Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cu, Eu, Fe, Ga, Hg, Ho, K, La, Li, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Sb, Sc, Sr, Ta, Th, Ti, U, V, Y, Yb and Zn) using a total-acid digestion, inductively-coupled plasma spectrometric technique. From these data, 17 elements (As, Ba, Ca, Ce, Co, Cr, Fe, K, La, Mo, Na, Sb, Sc, Sr, Th, Yb, and Zn) yielded mostly detectable concentrations in both plants and soils. We compared element concentrations in plants (on an ash-equivalent basis) with those of the substrate soil collected near each individual plant sample. We found elevated concentrations of Ca, K, and Zn in all plants, and similar enrichments of As, Co, Mo, and Sr in most species. With the exception of arsenic, all seven elements are biologically active in plants. Other elements, such as Cr, Ni, and Se, are also enriched, but only in a few plants.

Of the elements studied in the pilot project, the most interesting are probably arsenic and molybdenum, potentially toxic elements. Consumption of large quantities of arsenic- and / or molybdenum-rich plants by tortoises theoretically could affect their health. We have no information as to the extent of arsenic-rich plants region-wide but our data suggest that this element only occurs in anomalous concentrations in scattered localities and only in some species. Arsenic anomalies were found in all three study areas, with the highest concentrations in the vicinity of the area of past and present gold mining around Johannesburg, where arsenic is a known component of the gold ores. The anomaly related to that mineralization extends southward from the mined area for about 6.4 km. Other anomalous concentrations of arsenic are probably related to normal but relatively elevated concentrations of this element in rocks of the region. In contrast to arsenic, the distributions of anomalies for elements such as lanthanum, an element that is not biologically important, are solely related to rock chemistry.

Goldstone Lake represents a specialized local chemical environment. A sample of the lake-bed material contained weakly anomalous concentrations of As, Ca, Cd, Co, Cr, Cu, Li, Mo, Ni, Sb, Sc, Sr, V, and Zn. Plants growing in the area surrounding the lake bottom are generally salt tolerant. One species found there, *Stanleya pinnata,* contained an unusually high concentration of selenium, another biologically active element that can be toxic to animals. Selenium was not found in any of the tortoise forage plants, however.

When compared to their soil substrates, most of the 22 different plant species that we analyzed show weak enrichments for a number of elements. Some of these enrichments reflect differences in substrate chemistry and some reflect the biochemical differences between plant species. For example, the samples of native perennial grass and alien annual grass were enriched in Ca, K, Mo, Sr, Zn, whereas some samples of alien annual grass also contained As, Co, and Cr. The forbs *Stylocline micropoides* and *Plantago ovata* were enriched with more than 12 elements. The impact of any of these elements acting singly or together on the health of desert tortoise populations is not yet clear. To test hypotheses concerning the potential toxicants, more surficial and plant samples need to be collected both locally and regionally, particularly from sampling control sites where tortoises are healthy and show few signs of disease. The ongoing research on potential toxicants identified in tortoise scute and bone from ill and control tortoises also needs to be integrated with our plant and surficial material data.

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Status of the Northern & Eastern Colorado Desert Coordinated Management Plan

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One of three large plans in progress that address the recovery of the desert tortoise in the California Desert, the Northern & Eastern Colorado Desert Coordinated Management Plan (Plan) focuses on the Northern and Eastern Colorado Desert Recovery Units and a small portion of the Joshua Tree Recovery Unit. The planning area, 5.5 million acres in size, lies mostly in the Sonoran Desert Ecoregion. It is bounded by I-40 (North), the Colorado River (east), the Imperial Sand Dunes and Coachella Canal (south), and the West Mojave Plan (west). The planning area does not contain urbanizing areas which characterize the West Mojave Plan. The major cooperating agencies are the Bureau of Land Management (lead), Joshua Tree National Park, U. S. Marine Corps Air Station in Yuma for the Chocolate Mountains Aerial Gunnery Range, U. S. Fish & Wildlife Service, and California Department of Fish & Game (provides the lead wildlife biologist). Additional cooperators to the Plan include other federal, state, and local agencies as well as many interest groups. The Plan is ecosystem management in scope. Plan decisions will amend or augment existing land use plans of the cooperating federal agencies for the tortoise and other species and habitats and may be of use by other agencies and companies with interests in the planning area.

Work and accomplishments during the last year:

Plan Concept. Issued in June, this was essentially a single alternative proposal that amounted to a "trial balloon" for cooperators' consideration. Comments were generally negatively critical, running the gamut from "not restrictive enough" for tortoise recovery to "too restrictive." Comments focused on labeling and size of proposed DWMAs (ACECs of roughly 1,000,000 acres each) and on proposed restrictions on non-permitted driving in washes in recovery areas. From comments received we developed additional data and analyses to help better relate sensitivities and use levels.

Science Panel Review. On November 12, we held a science panel review for the cooperators of work in progress, including data and methods. It was led by Dr. Mike Allen, Director of the new Center for Conservation Biology at the University of California at Riverside. The event increased the level of confidence among cooperators in science basis and improved plan direction . The Panel provided findings and recommendations on four topics: data quality and analysis, ecosystem approach, conservation principles, and monitoring/research strategy (given probable future funding limitations). At the conclusion of the panel the cooperators voiced the feeling that we were essentially ready to begin developing the plan. (A copy of the panel report was available at the symposium).

Building the Plan. We are developing plan alternatives at this time. Each alternative will:

- Resolve six scoping issues
- Provide a spectrum of possibilities
- Be practical and implementable
- Show clear management direction
- Be an interdisciplinary approach

We anticipate having at least three alternatives, although there may be as many as four or five. No action alternative consists of "Current Management" which is current policy and regulation. Each alternative will depart from Current Management with increasing focus on desert tortoise recovery and species habitats.

Schedule. Major scheduled milestones for remaining work on the Plan are:

- August, 1999 - Develop and review administrative draft plan/EIS
- September 1999-Issue draft plan/EIS for 90 day public review; public meetings
- May 2000-Issue proposed plan/FEIS
- July 2000-Sign Record of Decision

Interactions Between Nitrogen and Exotic Species with Implications for Habitat Restoration

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Restoration efforts have focused on returning structure by planting an appropriate species composition on a site. The assumption is that ecosystem functioning will subsequently be returned to that resembling the undisturbed habitats. Increasingly, however, anthropogenic activity changes not only community composition but also broad-scale ecosystem functioning through direct soil disturbance coupled with indirect human activities. Two perturbations, exotic species invasions and nitrogen deposition, pose a serious problem for restoring native communities because they alter ecosystem functioning. The resulting pattern in the western Mojave is a shift in species from a shrub-dominated ecosystem to one dominated by exotic annual grasses and forbs. We postulate that this shift reflects a "third axis" of the teeter-totter model between grassland and shrubland communities.

Schlesinger and colleagues proposed that cattle grazing destroyed the grasses thereby resulting in nutrient loss. Under low nutrients, shrubs invaded forming "islands of fertility" and inhibited native perennial grasses from re-establishing. Currently, the composition of the west Mojave is predominantly shrubs that are widely dispersed. Many native interspace annuals are N fixers or N scavengers. Today's perturbations are different than those a century ago. Nitrogen deposition from automobiles and agriculture into the Mojave shrublands is increasing the available surface nutrients, particularly N. In addition, the increasing incidence of roads provides corridors for the invasion of exotic annuals that are largely nitrophilous.

Based on observations, we know that these shifts change the saprobic and mycorrhizal composition. We hypothesize that manipulation of these below ground community components could facilitate restoration by manipulating ecosystem functioning. This will require new approaches. Some useful restoration approaches may include manipulating the carbon to nitrogen ratio with recalcitrant mulches and spatial manipulations of water and mycorrhizal fungal inoculum. Since most desert plants are adapted to low soil nitrogen, additions of recalcitrant mulches can be used to immobilize soil nitrogen, making it unavailable for weedy species while shifting competitive advantages toward natives. Competition between shrubs and exotics can be further minimized by planting seedlings with deep (10 cm) inoculum and by using irrigation techniques such as deep pipe watering. Based on our survey data, native annual forbs should be more successfully restored if few or no mycorrhizae are present at the soil surface. Ultimately, restoration techniques like these, that take advantage of ecosystem functioning may be the only "smart bombs" we have in our restoration arsenal that will overcome disturbance under altered environmental conditions.

Home Range and Movements of Hillside Residing Desert Tortoises in the Western Mojave Desert

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Tortoises were tracked during the 1997 and 1998 field seasons at two hillside sites within the Western Mojave Recovery Unit: The Barstow Marine Corps Logistical Base Rifle Range (Barstow) and The Marine Corps Air Ground Combat Center Lava Range (Lava). All fixes at each site were combined to estimate a search area, allowing for estimation of density in tortoises/ mi^2 (Barstow = 60.8 - 76.5, Lava = 14.1 - 17.7). Home range size was not correlated with tortoise density.

Fixes within each year were used to calculate home range size, overlap, and interfix distances. Barstow minimum convex polygon (MCP) home ranges (n=19) were significantly larger ($\underline{P}< 0.001$) in 1998 (8.46 ha ± 5.22) than in 1997 (3.62 ha ± 3.12). No difference was found between males (n=10) and females (n=9) at Barstow in either year. Lava MCP ranges (n=5) were larger in 1998 (21.59 ha ± 36.24) than in 1997 (8.39 ha ± 10.95), but not significantly so. The larger 1998 ranges overlapped a large portion of the range used by the same animal in 1997 at both Barstow (83.3% ± 16.07) and Lava (81.9% ± 18.43), but the 1997 ranges included only a small portion of the same animal's 1998 range (Barstow: 38.1 ha ± 25.4; Lava: 46.24 ha ± 21.01).

Barstow mean interfix distances were significantly larger ($\underline{P}<0.001$) in 1998 (117.5 ha ± 39.6) than in 1997 (72.2 ha ± 38.8); however, distances in maximum inter-fix distances (1998 = 360.5 ha ± 114.8; 1997 = 288.4 ha ± 149.5) were marginally significant ($\underline{P} = 0.052$). Lava mean and maximum interfix distances for 1998 (262.8 ha ± 234.0; 897.2 ha ± 379.4) were not significantly different from those for 1997 (160.5 ha ± 120.5; 469.8 ha ± 332.6).

Invasive Species: A Longstanding Environmental Problem, A New Environmental Issue

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Available estimates indicate that more than 6,000 nonindigenous plants, animals, and microorganisms, introduced intentionally or inadvertently by humans, have established free-living populations in U.S. ecosystems. Although most do not cause significant harm, the risks to native communities, ecosystem services, the economy and human health, are increasing as an increasing number of established invaders emerge from obscurity and the rapid globalization of travel and trade continues to increase the pathways for introduction of additional organisms. Because of its large variety of life zones and predominant role in global commerce, the U.S. is especially vulnerable to invasions by species from biologically rich countries newly opened to expanded trade, such as China, Russia and South Africa, which have life zones similar to those in the U.S.

In recent years, well publicized invaders, such as the Asian longhorn beetle, Asian swamp eel, the brown tree snake, the zebra mussel, and purple loosestrife, have focused public attention on this emerging environmental issue. During the 1990's, increasing public concerns and demands for action have fostered development of new organizations and initiatives to address the threats at scales from local to global.

More than 20 Federal agencies have responsibilities relating to the prevention, detection, monitoring, and control of invasive species. Federal programs have traditionally focused on particular invaders, especially those posing significant risk to U.S. agriculture or other economic sectors. However, efforts are expanding to develop more effective and consistent policies, strengthen cooperation and public participation, assess risks and develop reliable information and management tools. The White House has recently issued an Executive Order to improve the coordination of these efforts. The order calls for the establishment of an interagency council which will develop a coordinated national strategy for addressing threats from all types of invasive organisms. Efforts are underway to develop a national invasive species information system that facilitates "one stop shopping" on the Internet.

Complementing the growing Federal role are the efforts of more than a dozen states to establish their own invasive species councils, and the organization of scores of local partnerships to address the effects of invasive weeds. At the international level, invasive species are an important focus of attention under the Convention on Biological Diversity, and international organizations such as the World Conservation Union and the International Council of Scientific Unions, increasingly involved in developing plans to address the problem.

Reproductive Output of Female Central Asian Tortoises (*Testudo horsfieldi*)

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Concerns about the demise of wild Central Asian tortoises (*Testudo horsfieldi*) have prompted studies of *T. horsfieldi* demographics and resource requirements in the Kyzylkum Desert (Bukhara Ecocentre, Uzbekistan). For part of these studies, we x-rayed 14 female *T. horsfieldi* (midline carapace length: 150 to 174 mm) weekly, from May 1 to June 14, 1998, to measure their reproductive output. The apparently high clutch sizes and clutch frequencies that we measured (up to 5 eggs and 3 clutches, respectively) may have been due to the high plant productivity in Spring 1998, but little is known about the reproductive output of wild *T. horsfieldi*. The average (± SD, range) clutch frequency and annual egg production (AEP, eggs produced per female) equaled 2.29 (± 0.47, 2 to 3) and 5.79 (± 1.63, 3 to 9 eggs), respectively. As for *Gopherus agassizii*, AEP was correlated to female size (midline carapace length: $r^2 = 0.414$; body mass: $r^2 = 0.650$), potentially influencing the impacts of poaching and conservation efforts. Also, female nutrient reserves and the ability to acquire nutrients for egg production may be size dependent. Measuring reproductive output, body condition and spring forage under a variety of conditions will help determine the relative importance of nutrient reserves and spring forage conditions to the reproductive output of *T. horsfieldi*. Field metabolism and water flux measurements made in conjunction with our x-ray analyses will help in assessing the importance of female reproductive output to the overall nutrient requirements of female *T. horsfieldi*.

Characterization of Proteins Extracted from Shell Scutes of California Desert Tortoises, *Gopherus agassizii*

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In the course of our studies on the pathogenesis of cutaneous dyskeratosis, the numbers, sizes and relative concentrations of shell scute proteins from tortoises with cutaneous dyskeratosis were compared to shell scute proteins of ill and healthy tortoises with normal appearing shells. Gel electrophoresis of extracted scute protein samples on 10% Tris-Tricin-SDS polyacrylamide gels revealed nine distinct protein bands, ranging from approximately 7 to 73 kilodaltons (KD) with the major protein component of about 14 KD molecular weight. This major protein component comprised up to 75% of the scute protein. Two-dimensional electrophoretic analysis of the 14 KD major protein component revealed three proteins, and amino acid composition analysis of the 14 KD proteins revealed an amino acid composition similar to that of chicken beta keratins. Moreover, immunoblot analysis revealed reactivity of several proteins, including the 14 KD major protein component, with antisera specific for chicken and alligator β-keratins.

This study showed no statistically significant differences ($\underline{P} < 0.05$) in the relative concentration of scute proteins within each of the nine electrophoretic bands when comparing tortoises with cutaneous dyskeratosis to healthy tortoises. However, there were significant differences in the concentrations of the major 14 KD protein and of a low molecular weight protein found in normal appearing shells of ill tortoises relative to healthy tortoises. This suggests that systematic disease, such as mycoplasmosis, may affect composition of scute keratin proteins in desert tortoises. The exact cause of cutaneous dyskeratosis in desert tortoises remains to be elucidated. It may be that less concentrated scute protein components, such as matrix-associated proteins, or other components such as lipids or inorganic substances, play an important role in the disease. Also, a larger sample size may be required to detect differences in the relative concentrations of scute proteins found in tortoises with cutaneous dyskeratosis compared to healthy desert tortoises. Further studies, employing immunoblot analyses of scute proteins, are being conducted.

Mechanisms of Coexistence Among Desert Annual Plants: Implications for Biodiversity and Ecosystem Dynamics

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I report results from ongoing field studies designed to measure the relative importance of a variety of mechanisms of coexistence to the persistence of a group of roughly 40 winter annual plant species at an Arizona field site. The species and genera that make up the local flora at this site are common across the Sonoran and Mojave deserts. I will discuss briefly the importance of animals, both large grazers and smaller granivores, to plant diversity and species composition, but will focus especially on the roles of weather and of spatial variation in soils or other habitat factors.

Desert annual plants produce seeds that are dormant for at least a season before potentially germinating. Longevity of seeds in the seed bank varies considerably among species and each species germinates in response to specific weather conditions, especially temperature and amount of rainfall. Germination patterns vary among species and cause different annual plant species to grow and reproduce during different years. This temporal separation of plant growth makes an important contribution to the persistence of many species of annuals. Thus, the contributions of desert annuals as food for desert tortoises can be expected to vary from year to year. The fluctuations in species composition that are commonly observed reflect an important mechanism by which the diversity of the annual plant flora is maintained. Short-term changes in weather patterns, as well as longer term directional changes in weather as are predicted from human-caused climate change can be expected to alter the abundance and species composition of desert annuals.

In addition to among-year separation of plant growth and reproduction, annual plant species also show some separation in growth phenology within a year. This additional source of temporal separation of growth contributes significantly to the coexistence of annuals, but is about an order of magnitude less important than are the differences that occur among years, caused by annual variation in weather. The diversity of spatial habitats that are present in a desert also affect the abundance and species composition of annual plants, but we do not have comparable precise measurements of their relative importance yet.

Herpesvirus Infection by Tortoises

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Stomatitis / pharyngitis, with or without rhinitis, is a significant health problem of tortoises. The first report involved a 6 year old cachectic desert tortoise, *Gopherus agassizii*, which was in captivity since hatching. The tortoise was found to have a pharyngeal abscess which upon histologic examination had intranuclear inclusions in the superficial epithelial cells of the palatine mucosa (Harper et al. 1982). Electron microscopy demonstrated various developmental stages of a virus morphologically compatible with members of the family Herpetoviridae. In a second report, a 60-year-old captive desert tortoise with caseous necrosis of the oral cavity, choanae, trachea, and lungs, had intranuclear inclusions within epithelial cells at those sites, syncytial giant cells, and bacterial granulomas (Pettan-Brewer et al. 1996). By electron microscopy, herpesvirus-like particles were found within the inclusions.

Of 2,200 recently imported Argentine tortoises (*Geochelone chilensis*), 1,200 died over a 3 month period; red-footed tortoises (*Geochelone carbonaria*) imported with the Argentine tortoises and housed together remained clinically healthy (Jacobson et al. 1985). At necropsy, necrosis of the oral mucosa with accumulations of necrotic cellular debris around the glottis, the roof of the oral cavity, and internal nares was seen. By light microscopy, desquamated degenerating epithelial cells contained eosinophilic intranuclear inclusions. Electron microscopy, demonstrated inclusions to consist of viral particles containing an electron-dense core. Particles consistent with herpesvirus were seen enveloping from cell membranes and mature enveloped particles measuring approximately 125 nm were seen in the cytoplasm.

There are several reports of herpesvirus infection in Mediterranean tortoises (*Testudo graeca* and *T. hermanni*). Of 13 Greek tortoises (*T. graeca*) from two private colonies, herpes-like particles were detected by electron microscopy in two animals with stomatitis (Cooper et al. 1988). Initially, while swabs taken from the oral lesions resulted in the isolation of a variety of microorganisms, treatment with a number of systemic and local antibiotics had no effect on the course of the disease. Eventually, viral particles consistent with herpesvirus were demonstrated by electron microscopy within bronchial and palatine mucosal epithelium. In 16 Hermann's tortoises and 8 Greek tortoises with necrotizing glossitis/stomatitis, intranuclear inclusions were found in epithelial cells in the tongue, trachea, bronchi, alveolae, endothelial cells of capillaries of the gomeruli and within neurons and glial cells in the medulla oblongata and diencephalon (Muller et al. 1990). Electron microscopic examination of the liver and trachea demonstrated hexagonal nucleocapsids in the nuclei of hepatocytes and epithelial cells of the trachea. Enveloped virions in the cytoplasm were 110-120 nm and were morphologically consistent with herpesvirus. The authors considered imported tortoises to be latent carrier of this virus. Stress and parasitism may have contributed to the clinical manifestation of the virus in the imported tortoises. By electron microscopy, herpes-like particles have also been seen in the intestinal contents of a Hermann's tortoise, several of which had caseous material in the upper digestive tract, hepatomegaly, and enteritis (Biermann et al. 1995).

There are multiple isolates of herpesvirus from Mediterranean tortoises with stomatitis/pharyngitis. Herpesvirus has been isolated in cell culture from brain, lung/trachea, and liver from two Hermann's tortoises and a Russian tortoise (*T. horsfieldii*) (Biermann and Blahak 1994) and from spleen, liver and brain of seven Hermann's tortoise and one Russian tortoise (Kabisch and Frost 1994). A serum neutralization test was used to determine exposure of tortoises to herpesvirus and in one study, 42.5% of Greek tortoises and 18.5 % of Hermann's tortoises were seropositive (Frost and Schmidt 1997).

While serum neutralization is often considered the gold standard when measuring an animal's antibody response to a viral pathogen, it has limited utility because of certain practical problems since 9 to 10 days are required to determine the titer of a potentially exposed tortoise. Therefore we initiated studies designed to develop a more rapid and practical assay that would have wide application in private, zoological, rehabilitation, and breeding programs designed for releasing captive tortoises to the wild. Mediterranean tortoise immunoglobulin has been purified in the Core Hybridoma Laboratory, ICBR, University of Florida and mouse monoclonal and polyclonal antibodies have been produced against this immunoglobulin. With this reagent we will develop an immunoperoxidase and ELISA based approach to determining exposure to this virus(es).

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Growth Patterns of the Desert Tortoise in an East Mojave Population

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Growth was monitored on 127 tortoises in an eastern Mojave Desert population from 1988 to 1995. Nearly all annual growth occurred between early April and mid-June. Smaller tortoises had larger growth rates. Between 125 and 184 mm in carapace length, the mean growth rate was 10.80 mm ± 0.660. For immature tortoises, mean growth in the best years was 14.7 mm, but only 3.6 during a drought; for adults, growth was negligible during drought. Above 184 mm, growth rates decreased in a more or less linear fashion until tortoises reached approximately 235 mm (males) or 208 mm (females), at which point growth was less than 2 mm per year. For females, this growth cessation point was coincident with increased reproductive output. Both among and within gender, the larger size that a tortoise obtains, the greater its growth rate at some point. There was no significant difference in growth between immature males and females, but adult males experienced significantly higher growth rates than adult females, following a growth spurt at supposed sexual maturity. Drought negatively affected growth in all groups. Age was predicted from size using von Bertalanffy growth curves.

West Mojave Plan: Status Report

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Formulation of the 9.2 million-acre West Mojave Plan of southern California was recently strengthened when Bureau of Land Management staff (Alden Sievers and Wes Chambers, among others) were joined by a team leader (Bill Haigh), two biologists (Ed LaRue and Larry LaPré), geographical information systems specialist (Matt Daniels and Ann Davis, with assistance from Tom Smudka and Cheryl Hickam), government liaison (Chuck Bell), support staff (Emily Cohen and Dita Mann), and a USGS-Biological Resources Division biologist (Bill Boarman), collectively referred to as the "Team." During 1998, the Team:

- Contracted approximately 30 species experts to complete life history profiles, including threats analyses and known occurrences for 96 rare plant and animal species being considered by the plan;

- Completed a Current Management Situation document weighing in at about 600 pages;

- Met with U.S. Fish and Wildlife Service and California Department of Fish and Game to develop a reserve design for the area and management prescriptions to resolve threats affecting the desert tortoise, Mohave ground squirrel, and other species;

- Surveyed approximately 850 square miles of the planning area to estimate distribution and density patterns of desert tortoise populations and quantify observable human disturbances;

- Acquired 1990 tortoise survey data sets from Department of Defense (Edwards Air Force Base, China Lake, Fort Irwin, and Twentynine Palms) and USGS-BRD (Dr. Kristin Berry) that, combined with the 1998 survey results, cover approximately 3,000 square miles of the planning area;

- Met with 15 Steering Committee members, environmental managers of the five military bases (collectively referred to as the "PACIDERM"), most of the 28 jurisdictions involved, and ± 50 Supergroup members to ensure public involvement in the planning process.

At this time, a biological evaluation is 95% complete, a preliminary conservation strategy has been formulated, and we will soon initiate public consensus building and produce a plan by the end of 1999.

Do The Physiological Strategies of Desert Annuals Influence Their Nutrient Composition and Hence Their Value to Desert Tortoises?

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The scarcity and unpredictability of precipitation presents a challenge to all desert plants. Perennial plants such as shrubs and cacti cope with soils in which moisture is seasonally very low, but winter annuals are conventionally considered drought avoiders that complete reproduction while soil moisture remains high. This physiological strategy includes: 1) seeds germinate only after heavy rains, 2) photosynthetic and growth rates are very high, 3) the stomata (surface pores) remain open during the day to maximize CO_2 influx, 4) transpirational water loss is consequently high, 5) photosynthetic enzyme levels are high, and 6) the capacity for osmotic adjustment to low soil water is limited (Smith et al. 1997). True drought avoiders are unable to tolerate low soil moisture. Species shown to fit this pattern include an evening primrose (*Camissonia claviformis*) and a lupine (*Lupinus arizonicus*).

The combination of high photosynthesis, high water use and limited osmotic adjustment is associated with plants that are high in water and protein but low in potassium concentration. Plants of four species of desert evening primroses (*Camissonia* spp.) contained 78-84% water, 10-18% protein (on a dry matter basis, DMB) and 80-180 mmol/L potassium when in flower or immature fruit. Similarly, seven species of desert lupines (*Lupinus* spp.) contained 80-86% water, 18-24% protein (DMB), and 70-150 mmol/L potassium. Such species appear to be of high nutritional value for desert tortoises, having calculated Potassium Excretion Potential (PEP) indices of about 3-5.

However, other annual species are more tolerant of low soil moisture. Low tissue water potentials (<-3.0 MPa) in some annuals and in herbaceous perennials reflect adaptation to drying soils and may indicate greater water use efficiency and reduced photosynthetic rates. Not surprisingly many of these plants had lower water (<75%) and protein (<12% DMB) and higher potassium (>300 mmol/L) concentrations as soils dried, so that PEP indices were very low (<1) or negative.

It is likely that tortoises rely disproportionately on annuals with high photosynthetic rates that require relatively high soil moisture. In drier years such plants may not be present, and available plants, having adjusted to low soil moisture, have low nutritional value (PEP).

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Interrelationships Between Annual Plants and Desert Rodents

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The herbaceous plant species that desert tortoises eat are embedded in a complex web of interactions with other plants and with animals. Animals affect the reproductive success, survival, and population densities of plants in a variety of ways. Pollinators facilitate seed production; seed dispersers enhance the probability seeds will successfully germinate and grow; herbivores reduce plant survival and reproductive success; granivores kill seeds; and some animals physically disturb the soil, creating favorable or unfavorable microsites in the process.

In the Mojave and Sonoran deserts, the interaction between plants and granivorous rodents is especially prominent. These deserts support an abundant and diverse fauna of rodents in the family Heteromyidae, which includes kangaroo rats and pocket mice. Heteromyid rodents are specialized granivores that often harvest 90% or more of preferred seeds before they have a chance to enter the soil seed bank. Heteromyid rodents affect desert plants in three basic ways. First, by eating seeds they reduce the density of seeds in the soil and hence reduce the population density of preferred plant species, which tend to have large seeds. This in turn releases small-seeded plant species from competition, precipitating changes in species composition of the entire plant community. Second, heteromyid rodents consume some green vegetation in addition to seeds, a behavior that could put them into direct competition with desert tortoises as well as reducing reproduction of preferred plants. The tendency of some kangaroo rat species to clip grass tillers may be responsible for observed increases in small-seeded grasses when kangaroo rats were experimentally excluded in the Chihuahuan Desert. Finally, heteromyid rodents may affect plants in positive ways via their seed-caching activities.

All heteromyids avidly harvest seeds well beyond their immediate food requirements and store the excess in caches located either in the burrow (these are called larderhoards), or in shallow pits dug into the soil surface (these are called scatterhoards). Although larderhoarded seeds probably have been buried too deeply to germinate successfully, scatterhoarded seeds have been, in effect, planted in a favorable microsite for germination. There is growing evidence that the primary route to successful establishment of some desert plants is via an unrecovered scatterhoard, that exotic invaders are not able to benefit from being scatterhoarded because they are intolerant of crowding, and that the net impact of heteromyid rodents on desert plants can vary temporally, being positive (mutualistic) when cache recovery rates are low and negative when cache recovery is virtually complete. Too little is understood at present about the interactions between granivorous rodents and desert plants to know whether the net impact of rodents on the food of desert tortoises is positive or negative. This impact is, however, likely to be important enough to warrant consideration as we devise management strategies for desert tortoise habitat.

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Habitat Reclamation at Yucca Mountain, Nevada

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The U.S. Department of Energy (DOE) is characterizing the suitability of Yucca Mountain in Nye County, Nevada as a potential monitored geologic repository for spent nuclear fuel and high-level radioactive waste. The DOE is committed to reclaiming lands disturbed by characterization activities and has initiated a habitat reclamation program. This program has included research investigations, interim reclamation (i.e., efforts to maintain topsoil viability prior to final reclamation), and final or permanent revegetation of disturbed sites. Reclamation feasibility studies were conducted from 1992 to 1997 and focused on several aspects of reclamation including establishment techniques by direct seeding and transplanting, water management techniques, and emergence success of several native plant species. Research also has included assessment of herbivory effects on shrub establishment, and use of soil amendments to increase establishment success. Promising techniques from these studies have been implemented during both interim and final reclamation. The selection of proper plant materials and reclamation techniques have been shown to play an important role in revegetation efforts at Yucca Mountain.

1998-1999 Status Report for the Desert Tortoise Council

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The Desert Tortoise Council (DTC) is an organization dedicated to assure the perpetual survival of viable populations of the desert tortoise within suitable areas of its historic range. Over the past two years, the DTC has worked to meet this goal through the objectives outlined in its charter. We have commented on management plans and environmental assessments. We have formed a coalition of organizations interested in protecting and managing tortoise habitat in the West Mojave to better represent tortoise interests in the development of the West Mojave Plan. The DTC has written letters supporting actions that benefit tortoises, such as for improved management of cattle grazing in critical habitat. We held a 1998 annual symposium, highlighting studies and management of tortoises and desert ecosystems. We are planning a Desert Tortoise Handling Workshop in October of 1999. We set up an internet web site that currently serves as a source of information about the DTC, and will soon have more symposium abstracts, more information about desert tortoises, and links to other similar organizations. We also publish and distribute proceedings of our annual Symposia, and will soon publish, Answering Questions About Desert Tortoises: A Guide For People Who Work With The Public, a questions and answers pamphlet about desert tortoises.

Most accomplishments have been possible through the efforts of the Board of Directors and many other volunteers. The DTC can improve its productivity and effectiveness if more members volunteer to help meet our objectives. We could provide information and formal comments on more environment assessments, analyses, and impact statements / reports if more members assisted with the review process. The 1999-2000 period promises to be more productive than 1998, because of web site development, the growing alliance with other environmental organizations, a Desert Tortoise Handling Workshop in October, our silver anniversary Symposium in 2000, and hopefully more involvement from our membership.

Ord Mountain Pilot Study: Recommendations for Route Designation by Desert Tortoise Council

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Executive Summary — Since 1995, the Desert Tortoise Council, as an Affected Interest and member of a Technical Review Team, has assisted the Bureau of Land Management with route designation in the Ord Mountain Off-Highway Vehicle Pilot Study Area. Lessons learned from this Pilot Study will be applied to route designation throughout the 8.6 million-acre West Mojave Coordinated Management Plan area.

Three management tools were used to derive the Desert Tortoise Council's recommended route network for the Pilot Study Area: data collected along routes in the Study Area during January and February 1997, the Bureau of Land Management's 1997 *Biological Resource Screening Components* document (Bureau of Land Management 1997), and the Bureau's maps depicting Biological Resource Overlays.

The Desert Tortoise Council's recommendations for route designation throughout the Mojave Desert consider the management prescriptions given in the Desert Tortoise (Mojave Population) Recovery Plan (U.S. Fish and Wildlife Service 1994b), the California Desert Conservation Area Plan (Bureau of Land Management 1980), and the 1982 Amendment to that Plan (Bureau of Land Management 1982).

Based on these materials and the threats analysis summarized in the *Federal Register* notice for the designation of tortoise Critical Habitat (U.S. Fish and Wildlife Service 1994a), the Desert Tortoise Council recommends that the following guidelines be used to designate routes in the Study Area and throughout the West Mojave Coordinated Management Plan area:

- The Desert Tortoise Council's preferred alternative for route designation in the Ord Mountain Study Area is the Bureau of Land Management's Emergency Route Network of 1996, with the addition of several roads and deletion of several other roads (see Map 2).
- The Bureau should consider closure of the following Route Types in Critical Habitat, Desert Wildlife Management Areas, and "core areas" identified in the West Mojave Coordinated Management Plan (see referenced page number for rationale for each recommendation):
    - Routes that did not exist prior to 1980.
    - Routes in most washes.
    - Routes in poor condition.
    - Routes that show evidence of natural revegetation.
    - Redundant routes in High Desert Tortoise Emphasis Zones.
    - Dead-end routes with no obvious through-destination.
    - "Non-essential" routes in topographically plain areas.
- Additionally, the Bureau should:
    - Consider Critical Habitat Units and DWMAs as the highest priority for route designation.
    - De-emphasize the Study Area and other Critical Habitat/DWMAs as prime off-highway vehicle recreation opportunities.
    - Consider the cumulative effect of route designation and other uses in the desert.
    - Complete field work to ground-proof any proposed network.
    - Use "Limited Route" designations where "Closed Route" designations are not feasible.
    - Ensure adequate law enforcement is available to enforce the network.
    - Pursue a Memorandum of Understanding with Catellus Land Development Company to facilitate an appropriate route network.

1.0. Introduction

1.1. Purpose of the Ord Mountain Pilot Study. The purpose of the Pilot Study is to designate routes within the Ord Mountain Pilot Study Area (Study Area) as either "Open" or "Closed," and to determine methods and guidelines that can be used to similarly designate routes in the larger, 8.6 million-acre West Mojave Coordinated Management Plan Area (WMCMP; see Glossary in Appendix A for terms, acronyms, and abbreviations used throughout this document). Since 1995, the Desert Tortoise Council (Council) has served on a Technical Review Team (TRT) to assist the U.S. Bureau of Land Management (Bureau) with this Pilot Study. This document, in part, provides the Bureau with data and the Council's recommendations to facilitate route designation and ensure compliance with applicable regulatory laws designed to protect the federally-listed, threatened desert tortoise (*Gopherus agassizii*).

1.2. Bureau of Land Management Route Inventory. Since 1995, the Bureau has completed a 100% inventory of roads and "road-like" areas (usually washes) within the Study Area. One Bureau estimate is that the 126,000-acre Study Area may have as many as 725 linear miles of designated and undesignated routes and roads (Brad Blomquist, pers. comm., 10 December 1996). Recent Bureau analysis has shown a 27% increase of routes in the area since 1980 (Brad Blomquist, pers. comm., 30 September 1997).

Members of conservation groups and recreation groups serving on the TRT and otherwise participating in the Pilot Study have agreed that the Bureau's census represents a 100% inventory of the roads and routes that occur within the Study Area. However, the inventory does not differentiate Route Types; three-foot wide motorcycle routes, 40-foot wide pipeline roads, six-foot wide, lightly-used truck routes, and washes with no obvious use all appear as thin, black lines on inventory maps. One purpose of the present study is to provide the Bureau with descriptive data for the Route Types that occur within the Study Area.

1.3. Federal Land Status Within Study Area. The U.S. Fish and Wildlife Service (Service) designated the entire Study Area as desert tortoise Critical Habitat in 1994 (U.S. Fish and Wildlife Service 1994a). As per the Desert Tortoise (Mojave Population) Recovery Plan (U.S. Fish and Wildlife Service 1994b), the area is also found within the proposed Ord-Rodman Desert Wildlife Management Area (DWMA), which is one of four DWMAs proposed for the West Mojave Recovery Unit.

Currently, the northern half of the Study Area is designated by the Bureau as a Class M (Moderate Use) Area and the southern half is designated as a Class L (Limited Use) Area (Bureau of Land Management 1980). The Class L designation "...protects sensitive, natural, scenic, ecological, and cultural resource values" that "...are managed to provide for generally lower-intensity, carefully controlled multiple use of resources, while ensuring that sensitive values are not significantly diminished." The Class M designation "...provides for a wide variety of present and future uses such as mining, livestock grazing, recreation, energy, and utility development" and is "...designed to conserve desert resources and to mitigate damage to those resources which permitted uses may cause." Within the West Mojave Desert, Class M Areas found within Critical Habitat will convert to Class L Areas with implementation of the WMCMP.

In 1996, the entire Study Area was affected by an emergency route closure, whereby certain routes (mostly labeled "OM," as in "OM-4") were designated as "Open" and all others were considered "Closed." This Pilot Study will result in a network of open and closed routes that will replace the current designations under the emergency closure and will facilitate route designation required by the California Desert Conservation Area Plan (Bureau of Land Management 1980) and its 1982 Amendment (Bureau of Land Management 1982).

1.4. Goals for Route Designation. The goals for route designation were identified 17 years ago in the California Desert Conservation Area Plan (Bureau of Land Management 1980) and formally amended in 1982 (Bureau of Land Management 1982). The goals identified in these two documents are as follows:

Route approval in Multiple Use Classes M and L will be based on:

Minimizing the damage to soil, watershed, vegetation, air or other resources and to prevent impairment of wilderness suitability.

Minimizing the harassment of wildlife or significant disruption of wildlife habitats. Special attention will be given to protect endangered or threatened species and their habitats.

Minimizing conflicts between off-road vehicle use and other existing or proposed recreational uses of the same or neighboring public lands, and to ensure the compatibility of such uses with existing conditions in populated areas, taking into account noise and other factors.

Vehicle routes to be considered for designation are those that are considered existing routes of travel. An existing route of travel is a route (roads, ways, trails and washes) established before approval of the CDCA Plan of 1980, with a minimum width of two feet, showing significant surface evidence of prior vehicle use or, for washes, history of prior use.

In all areas of limited vehicle use, special attention will be given to identifying conflict areas, zones of route proliferation, and specific sites or resources being damaged by vehicle use. The public will be involved in each step of this process. Appropriate actions will then be taken to reduce or eliminate the problem, depending on the multiple-use class and degree of control needed.

The Wildlife Element of the California Desert Conservation Area Plan provides for the following:

Some fish and wildlife resources requiring special management direction can be protected in Multiple Use Class L through the number and location of routes approved.

In general, where other land uses (...vehicle use, intense visitor use) are found to adversely affect officially listed and sensitive species or other significant wildlife resources, action will be taken to remove or reduce impacts.

The Motorized Vehicle Access Element of the California Desert Conservation Area Plan provides for the following:

Avoid or minimize damage or degradation of the natural, cultural, and aesthetic values of the desert.

Provide a reasonable network of "routes of travel" which meets the needs of desert users, including commercial users and BLM's "neighbors," the private land owners, and other public land managing agencies in the CDCA.

Reduce to the greatest possible degree conflicts among desert users.

Provide an element that is understandable, easy to follow, acceptable, and supported and encouraged by most desert users.

Implement and manage these programs efficiently, economically, and cooperatively.

Provide for "appropriate" use of off-road recreational vehicles as directed by FLMPA and in conformance with Executive Orders 11644 and 11989, and 43 CFR 8340.

1.5. Objectives of the Present Study. The Council's objectives for this study are:

- To provide the Bureau with descriptive data for the trails in the Study Area.
- To recommend a specific route network for the Study Area.
- To identify programmatic guidelines for designating routes in the WMCMP area.

2.0. Methods

2.1. Study Area Location. The Ord Mountain Study Area is located immediately north of Lucerne Valley, approximately 20 miles southeast of Barstow, in San Bernardino County, California. It is bounded to the north by a major transmission line, to the east by Camp Rock Road, to the south by Northside Road, and to the west by Highway 247. It encompasses East Ord Mountain, Ord Mountain, West Ord Mountain, and other smaller mountainous areas, such as Daggett Ridge; the eastern portions of Stoddard Valley and northern portions of Lucerne Valley also occur within the Study Area.

The Study Area has been designated by the Service as desert tortoise Critical Habitat (U.S. Fish and Wildlife Service 1994a) and is recommended as one of four DWMAs within the West Mojave Recovery Unit (U.S. Fish and Wildlife Service 1994b). As such, the Service has identified the entire area as essential to the survival and recovery of the desert tortoise.

Within the Study Area the Bureau has identified particularly important areas as "Desert Tortoise Emphasis Zones" or "DTEZs" (Bureau of Land Management 1997). These areas are considered high quality tortoise habitat "...in relation to these areas' potential habitat contribution to desert tortoise population recovery" (Bureau of Land Management 1997). The defining characteristics of High DTEZs are elevations less than 4,000 feet and slopes of less than 30 degrees, which the Bureau concluded "...support the bulk of tortoise numbers" within the Study Area.

The Bureau's Biological Resource Overlays (Overlays) identify two High DTEZs, which we refer to the "North" and "South DTEZs." The North DTEZ is characterized by the wide basin of eastern Stoddard Valley, the braided washes south and southeast of Daggett Ridge that comprise Lenwood Wash and others, and the areas northwest of Daggett Ridge. Daggett Wash is a major land feature that skirts the northeastern edge of Daggett Ridge. The Stoddard Valley Open Area occurs immediately west of this area. The South DTEZ is somewhat more homogenous, being comprised of the northern portions of Lucerne Valley. Mountainous areas bound it to the north and west, with Tyler Valley Road (OM30) forming the eastern boundary. The Cinnamon Hills area is encompassed by the South DTEZ. The Johnson Valley Open Area is east and northeast of this area.

Even though the Bureau has identified emphasis zones within the area, the importance of so-called, "Non Desert Tortoise Emphasis Zones" should not be underestimated; *the entire area* is considered Critical Habitat. Mark Hagan (pers. comm., 15 October 1997) indicated that preliminary results of on-going studies show that a comparable number of tortoises can occur in rocky, mountainous areas as in level areas, and that such areas could be essential to tortoise recovery. Genetic diversity that may characterize tortoises in such areas would be important to the recovery and viability of the tortoise population occurring throughout the region.

2.2. Field Studies. On 10 January 1997, the Council organized a group of biological consultants, desert field workers, and others to begin the arduous task of collecting data on the routes included in the Bureau's inventory. The group developed a standard data sheet (see Appendix B) to record the following information for each route segment: dominant perennial plants; substrate (rocky, sandy, wash substrate, or hard-packed dirt); descriptive data (width, use, type, and presence/absence of berms; indices for Straying and Concealment Potential); topography (plain, hill, or mountainous); and relative route condition (good, moderate, and poor).

During January and February of 1997, 15 people drove or walked approximately 208 linear miles of routes and washes within the Study Area, collecting data that characterize approximately 370 linear miles of the Bureau's inventory. Table 1 lists the survey areas, dates, and personnel involved in collecting route data.

2.3. Data Analysis. Data were organized according to "Survey Areas," A through I. Route segments were assessed and assigned a number; e.g., A1 through A15 ... I1 through I26, etc. Map 1 (Section 8.0.) depicts the route segments, assigned numbers, and "Route Type" that best describes each road, trail, or wash.

Data were included in five broad categories: Plant Community, Substrate, Descriptive Data, Topography, and Condition. Codes (e.g., BBU, ROC, WDT, etc.) and additional descriptions are included in Table B1 (see Appendix B). The following clarifications are provided to describe the types of data that were collected.

2.3.1. *Plant Community.* Applicable codes include "BBU" (blackbush scrub), "CRE" (creosote bush scrub), "WAS" (wash community), and "YUC" (Mohave yucca). These data represent general observations about the common or dominant perennial plants associated with a given route segment. "Plant community" determinations are not supported by scientific studies or measurements. Their main usefulness relates to indicating if wash-adapted or upland shrub species are most common. The following, non-

Table 1. Survey areas, dates, and personnel for data collected within the Study Area.

Survey Area	Survey Dates	Survey Personnel
Area A (north-central)	10 Jan. 1997	Ed LaRue (Biologist) Tom Egan (Biologist) Gilbert Goodlett (Biologist) Natasha Nelson (Biologist)
Area B (northwest)	10 Jan. 1997	Steve Hartman (Biologist) Doug Laye (Biologist) Dan Patterson (Biologist) Peter Woodman (Biologist)
Area B (northwest)	17 Jan. 1997	Ed LaRue (Biologist) Tom Egan (Biologist) Doug Laye (Biologist)
Area C (west-central)	10 Jan. 1997	Sharon Dougherty (Biologist) Glenn Goodlett (Biologist) Tracy Goodlett (Biologist)
Area D (southeast)	12 Jan. 1997	Ed LaRue (Biologist) Tom Egan (Biologist) Tim Dischler (Fireman)
Area E (north-central, south-central)	18, 19 Jan. 1997	Ed LaRue (Biologist) Georg Beyerle (Physicist)
Area F (east, southeast, central)	21, 22 Feb. 1997	Ed LaRue (Biologist) Bill Donnan (Technician)
Area G (northwest, north-central)	23 Feb. 1997	Ed LaRue (Biologist) Bill Wagner (Biologist)
Area H (Central, northeast)	24 Feb. 1997	Ed LaRue (Biologist) Bill Donnan (Technician)
Area I (west, southwest)	25 Feb. 1997	Ed LaRue (Biologist) Bill Donnan (Technician)

exclusive list of species are considered indicators of washes in the Study Area: desert willow (*Chilopsis linearis*), cat-claw acacia (*Acacia greggii*), desert almond (*Prunus fasciculata*), rabbitbrush (*Chrysothamnus nauseosus*), paperbag bush (*Salazaria mexicana*), etc.

In reviewing the study design and analyzing the data, Steve Hartman of the California Native Plant Society cautioned the Council in using the plant community data. He indicated that it is necessary to use scientifically acceptable methods to characterize the communities. As such, although general data were collected, we will not use these data to characterize plant communities in the Study Area. Hartman recommended that such studies be completed to better understand the distributions of communities and potential, cumulative impacts to them.

2.3.2. *Substrate.* Applicable codes include "ROC" (rocky), "SAN" (sandy), "WASH" (wash substrate), "WASH*" (note describing WASH substrates), and "HPD" (hard-packed dirt). These data best describe the prevalent substrate on a given route segment. A route that skirts a short rocky area and crosses several sandy washes, but is mostly compressed dirt, would be identified as "hard-packed dirt." "SAN" and "WAS" are not always redundant; whereas most washes in the Study Area are sandy, others, particularly in mountainous and hilly areas, may be mostly rocky or gravely; it is also possible that a route is sandy but not within a wash. As such, when field notes were recorded to describe "WASH" routes, the "WASH*" category is checked (see code descriptions in Appendix B or data in Appendix D).

2.3.3. *Descriptive Data.* Applicable codes include "WDT" (width), "SAMPLE LGN" (sample length), "ROUTE LGN" (route length), "USE" (route use), "TYP" (Route Type), "BERM" (bermed), "SP" (Straying Potential), and "CP" (Concealment Potential).

Route widths were estimated to the nearest foot. Widths are variable, particularly washes; in one area a wash may be 10 feet wide and the same wash, a quarter mile away, is 80 feet wide. So route width is the rough average of a given route segment.

Sample length is the distance along the trail for which data were collected. The length was determined in the field by either truck odometer or calibrated pacing.

Route length was determined in the office using calipers and the Bureau's inventory. For example, the surveyor may have collected data along 500 feet of a wash (Sample Length) that is a half mile long; the Route Length would be one-half mile. Caliper measurements of sinuous routes on aerial photographs or maps provide only a rough estimate of route length.

Use is a relative estimate of vehicle occurrence on a given route, based on tracks, soil compaction, and other observations. Where "USE = 0," no use was observed. For point of reference, nearly all of the routes that are currently designated as "Open" were identified as "USE = 3," for heavy use. One may argue that all of the washes have been used by vehicles and that the tracks had been washed away just prior to our collecting data. However, there were no major rain storms in the area prior to the present study. If notes were recorded to further describe route use, the "USE*" column is marked with a 1 in Appendix D.

Route Type data were collected for five categories: 1 = single-track truck route; 2 = two-track truck route (two ruts with vegetation growing in between); 3 = a route that is smaller than a truck but larger than a motorcycle (usually all-terrain vehicles); 4 = motorcycle routes; 5 = wash or routes that have no observable use.

In analyzing the data, we consider there to be five Route Types that better describe the roads, trails, and washes than the "Route Type" data listed above. These are color coded on various maps (see Map 1 in Section 8.0.) and data sheets (see Appendix D), and are described as follows:

Route Type & Color Code

High Use Truck Route - established routes with moderate to high use — Purple

Low Use Truck Route - established routes with low use — Green

Cycle Route - routes that are only used by motorcycles — Brown

Washes - with or without vehicular use — Blue

Indiscernible - routes that do not exist or are not being used for travel — Pink

2.3.4. *Berms.* A berm is evidence that the route was bladed with heavy equipment. There are usually field notes describing routes that are marked as bermed; the notes generally refer to the age of the berm, indicating if it is very old or appears to be currently maintained.

2.3.5. *Straying Potential.* The Straying Potential is a relative indicator of the ability of a vehicle operator to leave (stray from) a given route. Where "SP = 1," there is a high likelihood of straying from the route; in many cases, significant straying was observed. Such routes may be in poor condition so that the rider cannot see them well enough to stay on the route. Where "SP = 3," there is a low likelihood that the rider can leave the route; adjacent substrates, particularly in hilly and mountainous areas, usually restrict the rider to the route. Well established roads, such as Camp Rock Road or SV 183, have berms and are so clearly discernible that leaving them would be an intentional act. The Straying Potential is often supplemented by field notes, delineated by "SP* = 1."

2.3.6. *Concealment Potential.* The Concealment Potential is a relative indicator of how easy or difficult a route would be to conceal so that new visitors to the area would not likely see it. Other data categories that help determine this index include Use, Width, Substrate, Topography, and Condition. A route marked as "CP = 0," is considered relatively easy to conceal. Such a route would typically have Use = 1, Width = 3 to 8 feet, Substrate = sandy or hard-packed dirt, Topography = plain, and Condition = poor. A route that would be difficult to conceal, indicated by "CP = 1," would have Use = 3, Width = 6 to 15 feet, with variable substrates and topography, and usually Condition = good or moderate. Where field notes were recorded, "CP* = 1."

Another field note that was often recorded is referred to as the "distance to obscurity," which is the point at which a route disappears from view when observed from the main road. Whereas the width and use of a road are essential factors in facilitating or preventing route closure, the observable length of the road is equally important. Assuming that vertical mulching or some other camouflaging technique would be used to conceal or close a route, a six-foot wide road that is visible for 100 feet would be more easily concealed ("CP = 0") than a six-foot wide road that is visible for 500 feet ("CP = 1"), all other variables being the same.

2.3.7. *Topography*. Pertinent codes include "PLA" (plain), "HIL" (hilly), and "MOU" (mountainous). "Plain" refers to an area of little topographic relief, or flat areas. "Hilly" areas are the transition between Plain and Mountainous areas, often referred to as the "upper bajada." "Mountainous" areas are upper elevation zones, typically characterized by extremely rocky substrates.

2.3.8. *Route Condition*. Applicable codes are "GO" (good condition), "MO" (moderate), and "PO" (poor). Routes in Good Condition are well established, easily discernible, usually with moderate or heavy use. Most of the routes currently designated as "Open" in the Study Area are in Good Condition. As the name implies, routes in Moderate Condition are somewhere in between the Good and Poor categories. Routes in Poor Condition may be falling apart, are often difficult to follow, and typically have low or no use. Routes that could not have been found without the inventory map, and most of the washes in the Study Area, are examples.

We collected data on most of the routes within both the North and South DTEZ areas, with the exception of the Cinnamon Hills, where the vast majority of routes were created and are exclusively used by motorcycles. Data gaps include mountainous areas in the west-central portions of the Study Area and mountainous and braided wash areas to the southwest.

2.4. Management Prescriptions. The Council reviewed the following documents to ensure that the recommendations given in Section 5.0. are consistent with guidelines and management prescriptions included in them: *Federal Register* notice for Critical Habitat (U.S. Fish and Wildlife Service 1994a); Desert Tortoise (Mojave Population) Recovery Plan (U.S. Fish and Wildlife Service 1994b); the California Desert Conservation Area Plan (Bureau of Land Management 1980); and the 1982 Amendment (Bureau of Land Management 1982). The Council considers prescriptions given in these four documents to constitute the foundations on which route designation should be based.

2.5. Bureau of Land Management Biological Information. The Council used two other documents to arrive at the open and closed recommendations presented in Appendix E: *West Mojave Route Designation: Ord Mountain Pilot Unit: Biological resource screening components* (Bureau of Land Management 1997) and the "Biological Resource Overlays," which are maps that depict the four DTEZs and sensitive biological resource areas. The resource areas include raptor nesting sites, areas used by Nelson's bighorn sheep, and Unusual Plant Assemblages (UPA). The screening components document and the Overlays, combined, provided an essential tool in determining sensitive biological resources, if any, that may be impacted by use on a given route.

3.0. Results

3.1. Data Analysis. Data relative to Route Type and use, substrates, wash communities, topography, condition, Straying Potential, and Concealment Potential are summarized in the eight tables in Appendix C. The following comprehensive table includes all of the summary data and is followed by a bullet summary of points the Council considers to be significant.

3.1.1. *Route Types*.

- High Use Truck Routes constitute about a third of routes observed; 141 miles or 38% of Route Types surveyed. Most routes that are designated as "Open Routes" in the Ord Mountain Emergency Route Network were characterized as High Use Truck Routes.
- Most routes accessing abandoned mine claims were characterized as Low Use Truck Routes.
- Cycle Routes comprise the majority of routes in the eastern portions of the South DTEZ, in the Cinnamon Hills area.
- Indiscernible Routes constitute only 4% of the routes, which is indicative of a comprehensive inventory; we were unable to find about 16 miles of such routes; we suspect that these may be very old, undetectable routes or washes.
- Washes constitute about a third of the routes observed; 106 miles or 29% of Route Types surveyed; about a quarter of these (26% or 28 miles) showed no evidence of vehicle use. Washes comprise the majority of routes in the North DTEZ.

3.1.2. *Route Use*.

- Washes are about equally split among no use (26%), light use (23%), moderate use (28%), and heavy use (21%).

Table 2. Summary for all Route Types assessed within the Study Area.

Route Type	Substrate (miles)	Width (feet)	Length (miles)	Use (miles)	Straying Potential (miles)	Concealment Potential (miles)	Topography P = Plain H = Hill M = Mountain (miles)	Condition P = Poor M = Mod G = Good (miles)
Wash	Sand = 42 Sand/HPD = 13 Sand/HPD/Rock = 12 HPD = 11 Ø data = 9 Rock = 7 Other = 12	87 routes Min = 3 Max = 120 Mean = 15.3	106 miles 29%	Heavy = 23 Mod = 30 Light = 25 None = 28	High = 16 Mod = 17 Low = 32 Ø data = 41	Hard = 45 Easy = 21 Ø data = 40	P = 47 P - H = 33 H = 10 H - M = 3 M = 0 P - H - M = 0	G = 13 G - M = 14 M = 15 M - P = 16 G - P = 2 P = 47
High Use Truck	HPD/Rock = 49 HPD = 45 Rock = 27 Sand/HPD =12 Ø data = 3 Other = 5	101 routes Min = 1 Max = 18 Mean = 9.4	141 miles 38%	Heavy = 73 Mod = 59 Light = 9 None = 0	High = 33 Mod = 41 Low = 36 Ø data = 31	Hard = 108 Easy = 3 Ø data = 30	P = 63 P - H = 45 H = 20 H - M = 6 M = 0.5 P - H - M = 5	G = 117 G - M = 13 M = 2 M - P = 1 G - P = 4 P = 0
Low Use Truck	Rock = 30 HPD/Rock = 16 Ø data = 5 HPD = 6 Sand/HPD = 3 Other = 2	75 routes Min = 6 Max = 40 Mean = 9.1	62 miles 17%	Heavy = 0 Mod = 2 Light = 60 None = 0	High = 7 Mod = 20 Low = 25 Ø data = 10	Hard = 42 Easy = 10 Ø data = 10	P = 20 P - H = 18 H = 10 H - M = 8 M = 1 P - H - M = 2	G = 22 G - M = 10 M = 20 M - P = 8 G - P = 0 P = 1
Cycle	HPD = 14 Ø data = 12 Sand/HPD = 8 HPD/Rock = 7 Rock = 2	31 routes Min = 1 Max = 7 Mean = 3.8	43 miles 12%	Heavy = 17 Mod = 19 Light = 7 None = 0	High = 29 Mod = 2 Low = 0 Ø data = 12	Hard = 17 Easy = 14 Ø data = 12	P = 25 P - H = 1 H = 5 H - M = 0 M = 0 P - H - M = 0	G = 8 G - M = 2 M = 7 M - P = 6 G - P = 5 P = 4
Indiscernible	Ø data = 16	26 routes Min = N/A Max = N/A Mean = N/A	16 miles 4%	Heavy = 0 Mod = 0 Light = 0 None = 16	High = N/A Mod = N/A Low = N/A Ø data =16	Hard = 0 Easy = 6 Ø data = 10	P = 3 P - H = 2 H = 0 H - M = 0 M = 0 P - H - M = 0	G = 0 G - M = 0 M = 0 M - P = 0 G - P = 0 P = 16
Totals	**HPD = 76 HPD/Rock = 72 Rock = 66 Ø data = 45 Sand = 42 Sand/HPD = 36 Other =19 Sand/HPD/Rock = 12**	**320 routes Min = 1 Max = 120 Mean = 9.4**	**368 miles**	**Heavy = 113 Mod = 110 Light = 101 No use = 44**	**High = 85 Mod = 80 Low = 93 Ø data = 110**	**Hard = 212 Easy = 54 Ø data = 102**	**P = 158 P - H = 99 H = 45 H - M = 17 M = 1.5 P - H - M = 7**	**G = 160 G - M = 39 M = 44 M - P = 31 G - P = 11 P = 68**

• When one combines Indiscernible Routes (16 miles) with washes having no evidence of use (28 miles), a total of about 44 miles (12%) of "routes" is not currently supporting vehicle use.

3.1.3. *Substrates.*

• As may be expected, sand is the prevalent substrate of Washes; 42 miles (40%) are mainly characterized by sand, and sand is a major component of 67 miles (63%) of the routes surveyed.

• Even so, rocky substrates (7 miles or 7%) or hard-packed dirt substrates (11 miles or 10%) are the main substrates of other Washes.

• Although not reflected in the data, wash substrates to the north tend to be light-colored, fine-grained sand, whereas many of the washes to the south are comprised of dark-colored, coarse-grained sand. Wash substrates in the north appear less stable and are not as easily compacted, whereas more of those to the south are compacted. Exceptions to these generalizations can certainly be found in either area.

3.1.4. *Berms.*

• For 129 of 141 miles (91%) of High Use Truck Routes and for 58 of 62 miles (93%) of Low Use Truck Routes, surveyors recorded the presence or absence of a berm, which, when present, indicates that the route had been constructed using heavy equipment. We found that 78 of the 129 miles (60%) of the High Use Truck Routes and 26 of the 58 miles (45%) of the Low Use Truck Routes had berms. As such, 104 of 187 miles (55%) of both types of Truck Routes were bermed. The data show that rocky substrates comprised about 122 miles of the 203 miles (60%) of Truck Routes that were surveyed.

• For comparison, no berms were recorded on the 43 miles comprising Cycle Routes, most of which (22 miles or 71% of routes for which substrate data were recorded) run through non-rocky substrates. In other words, 71% of the Cycle Routes identified by our surveys occur in non-rocky substrates and none were created by heavy equipment.

3.1.5. *Route Widths.*

• There is no appreciable difference between average widths of High Use (9.4 feet) and Low Use (9.1 feet) Truck Routes. As implied by the name, the main difference between these Route Types is the use of the route. As reported above, about half of these routes (104 of 187 miles or 55%) were originally created by heavy equipment, as evidenced by berms.

• Washes, by far, have the most variable widths, ranging from as few as three feet to as many as 120 feet wide. Since these are rough averages, Daggett Wash, which was estimated to be 120 feet wide, is actually several hundred feet wide at its widest point.

• As may be expected, routes created by motorcycles (Cycle Routes) tend to be narrower than other Route Types. No Cycle Routes had berms, which leads us to conclude that they were created by sustained cross country travel rather than heavy equipment. We certainly expect that motorcyclists use other Route Types, but few trucks use Cycle Routes.

3.1.6. *Topography.*

• These data **do not** represent the percentage of routes in the Study Area that are in Plain versus Mountainous areas, as we did not assess all routes occurring in the area. They do reflect that we concentrated most of our efforts in non-mountainous areas.

• The prevalence of Cycle Routes in Plain areas (81%) is likely due to restrictions created by substrates; rugged cliff faces, exposed bedrock, etc. present more restrictions to the average cyclist than does open valley, non-rocky alluvium. Additionally, most of the assessed Cycle Routes were observed in the relatively flat alluvial areas west and south of the Cinnamon Hills.

• Hilly and mountainous areas comprise 19% of the Low Use Truck Routes that were assessed. This prevalence (High Use Truck Routes are the next highest at 9%) is due mostly to the inclusion of old mine roads within the Low Use Truck Route category.

3.1.7. *Route Condition.*

• The data indicate that 85% of High Use Truck Routes are considered to be in Good Condition. No High Use Truck Routes were identified as being in Poor Condition.

• Although Washes are represented in every Condition category, most (44%) were identified as being in Poor Condition; the next highest percentage was 15% for Moderate - Poor Condition. This is particularly true in the North DTEZ, where 74 of the of the 208 miles surveyed (35%) occur in washes and 45 miles (61%) are considered Poor, Poor - Moderate, or Poor - Good.

3.1.8. *Straying Potential.*

• About 50% of the Washes are considered to have Low Straying Potential because vehicles are generally restricted to the sandy substrates between elevated, often rocky banks; once a vehicle gets into the wash, it may be difficult to get out. So, whereas adjacent areas may be somewhat "protected," plant communities and substrates within the washes, some of which are more than 100 feet wide, are subject to vehicle impacts.

• Other washes, such as E19 (see route data in Appendix D and Map 1 in Section 8.0.), represent an extreme potential for straying. The southern portions of this route, which offer little resistance to straying, are only a few degrees off the natural flow of the many washlets in the area. As such, northbound traffic, for example, can easily leave the route and continue traveling north in one of the many washes.

• About half of the Low Use Truck Routes are considered to have Low Straying Potential due, in part, to the inclusion of many old mine roads with their associated rocky substrates and defining berms.

• 94% of Cycle Routes are considered to have High Straying Potential. Although a "main route" often occurs, the routes are narrow (3.8 feet on average) and

81% of those observed occur on topographic Plains. In places, such routes are difficult to see or follow, which leads to higher incidences of straying.

3.1.9. *Concealment Potential.*

• As may be expected, closing or camouflaging Truck Routes is considered to be difficult; only about 13 of 163 miles (8%) are considered to be relatively easy to conceal.

• About one-third of washes are considered relatively easy to conceal, which is mostly affected by the observation that about one-quarter of the washes observed (28 of 106 miles) show no evidence of being used for vehicular travel. In these cases, "doing nothing" would be the best approach to closing the wash.

• Cycle Routes are about equally split between being relatively easy (45%) and relatively difficult (55%) to conceal. This is likely due to the narrow width of cycle routes (3.8 feet), which correspondingly leads to a relatively short "distance to obscurity."

• Indiscernible Routes are, in effect, already closed.

3.1.10. *Summary of Observations for All Route Types in High Desert Tortoise Emphasis Zones.* In Table 2 we combined all the data that are presented in the Appendix C tables to reflect route characteristics throughout the Study Area. In the next table we present the same data types for only those trails occurring in the North and South High DTEZs. Some pertinent comparisons between these data and the data for the entire Study Area follow Table 3.

3.1.11. *Comparisons Between Route Types in the High DTEZ Versus the Entire Study Area.* Tables 2 and 3 are provided to allow comparisons between North and South High DTEZ areas and the entire Study Area. The following comparisons are noteworthy:

The percentages of the Study Area's Route Types in High DTEZ areas are as follows:

Route Type	Study Area	High DTEZ Area (%)
Washes	106 miles	74 miles (70%)
High Use Truck	141 miles	70 miles (50%)
Low Use Truck	62 miles	21 miles (34%)
Cycle	43 miles	37 miles (86%)
Indiscernible	16 miles	6 miles (37%)
Total	**368 miles**	**208 miles (56%)**
	320 routes	**134 routes (42%)**

• A majority of Wash (70%) and Cycle Routes (86%) assessed by this study occur within High DTEZ areas. Though not calculated, most Washes are probably located in the North DTEZ and most Cycle Routes are found in the South DTEZ, particularly west of the Cinnamon Hills.

Relative to use, the following comparisons are made:

Use category	Study Area	High DTEZ Area (%)
Heavy	113 miles (31%)	106 miles (51%)
Moderate	110 miles (30%)	57 miles (27%)
Light	101 miles (27%)	23 miles (11%)
No Use	44 miles (12%)	21 miles (10%)
No Data	0 miles (0%)	1 mile (1%)
Total	**368 miles (100%)**	**208 miles (100%)**

• About half of the routes in the High DTEZ area (51%) are receiving heavy use as compared to only about a third (31%) of all routes throughout the Study Area.

4.0. Discussion

4.1. Management Prescriptions. The Bureau and/or Service have already developed programmatic plans that, if implemented, would govern the ultimate designation of routes in the Study Area. Applicable sections of these plans are summarized in the following paragraphs.

4.1.1. *California Desert Conservation Area Plan* (Bureau of Land Management 1980) and *1982 Amendment Decision to the California Desert Conservation Area Plan* (Bureau of Land Management 1982). The California Desert Conservation Area Plan and its 1982 Amendment cite the goals (see Section 1.4. above) for motor vehicle use throughout that California Desert Conservation Area. The following elements are very important relative to conservation of tortoises, and are taken, verbatim, from the two documents:

"Minimizing the damage to soil, watershed, vegetation, air or other resources and to prevent impairment of wilderness suitability."

"Minimizing the harassment of wildlife or significant disruption of wildlife habitats. Special attention will be given to protect endangered or threatened species and their habitats."

"Some fish and wildlife resources requiring special management direction can be protected in Multiple Use Class L through the number and location of routes approved."

"In general, where other land uses (...vehicle use, intense visitor use) are found to adversely affect officially listed and sensitive species or other significant wildlife resources, action will be taken to remove or reduce impacts."

"Avoid or minimize damage or degradation of the natural, cultural, and aesthetic values of the desert."

4.1.2. *Desert Tortoise Critical Habitat Designation* (U.S. Fish and Wildlife Service 1994a). The *Federal Register* notice identifies Critical Habitat as "(i) the specific areas within the geographic area occupied by the species on which are found those physical or biological features (I) essential to the conservation of the species (II) which may require special management considerations and protection..." "Conservation is further defined as to use and the use of all methods and procedures which are necessary to bring an endangered species or threatened species to the point at which the mea-

Table 3. Summary for all Route Types assessed within High Desert Tortoise Emphasis Zones

Route Type	Substrate (miles)	Width (feet)	Length (miles)	Use (miles)	Straying Potential (miles)	Concealment Potential (miles)	Topography P = Plain H = Hill M = Mountain (miles)	Condition P = Poor M = Mod G = Good (miles)
Wash	Sand = 34 HPD = 11 Sand/HPD = 10 Sand/HPD/Rock = 9 Ø data = 4 Sand/Rock = 4 Rock = 2	50 routes Min = 4 Max = 120 Mean = 20.3	74 miles 35%	Heavy = 21 Mod = 22 Light = 16 No use = 15	High = 12 Mod = 8 Low = 18 Ø data = 36	Hard = 28 Easy = 11 Ø data = 35	P = 36 P - H = 26 H = 7 Ø data = 5	G = 9 G - M = 7 G - P = 2 M = 12 M - P = 12 P = 31
High Use Truck	HPD = 35 HPD/Rock = 20 Rock = 13 Ø data = 2	37 routes Min = 6 Max = 18 Mean = 10.0	70 miles 34%	Heavy = 48 Mod = 22 Light = 0 No use = 0	High = 27 Mod = 15 Low = 12 Ø data = 16	Hard = 54 Easy = 0 Ø data = 16	P = 34 P - H = 20 H - 13 Ø data = 3	G = 62 G - P = 4 M = 1 M - P = 1 Ødata = 2
Low Use Truck	Rock = 7 HPD = 7 Ø data = 2 HPD/Rock = 2 Sand/HPD = 2 Sand/HPD/Rock = 1	25 routes Min = 6 Max = 40 Mean = 9.8	21 miles 10%	Heavy = 20 Mod = 0 Light = 0 No use = 0 Ø data = 1	High = 7 Mod = 4 Low = 3 Ø data = 7	Hard = 12 Easy = 2 Ø data = 7	P = 12 P - H = 1 H = 3 Ø data = 5	G = 6 G - M = 4 M - 4 M - P = 4 P = 1 Ødata = 2
Cycle	HPD = 11 Ø data = 10 Sand/HPD = 8 HPD/Rock = 7 Rock = 1	22 routes Min = 2 Max = 7 Mean = 4	37 miles 18%	Heavy = 17 Mod = 13 Light = 7 No use = 0	High = 26 Mod = 0 Low = 0 Ø data = 11	Hard = 15 Easy = 12 Ø data = 10	P = 22 H = 5 Ø data = 10	G = 5 G - P = 4 M = 7 M - P = 7 P = 4 Ødata = 10
Indiscernible	Ø data = 3 HPD = 3	Not Applicable	6 miles 3%	No use = 6	Not Applicable	Not Applicable	P = 3 Ø data = 3	P = 6
Totals	**HPD = 67 Sand = 34 HPD/Rock = 29 Rock = 23 Ø data = 21 Sand/HPD = 20 Sand/HPD/Rock = 10 Sand/Rock = 4**	**134 routes Min = 2 Max = 120 Mean = 11.0**	**208 miles**	**Heavy = 106 Mod = 57 Light = 23 No use = 21 Ø data = 1**	**High = 72 Mod = 27 Low = 33 Ø data = 70 N/A = 6**	**Hard = 109 Easy = 25 Ø data = 68 N/A = 6**	**P = 107 P - H = 47 H = 28 Ø data = 26**	**G = 82 G - M = 11 G - P = 10 M = 24 M - P = 24 P = 42 Ødata = 14**

sures provided by the Act are no longer necessary, i.e., the species is recovered and removed from the list of endangered and threatened species."

The *Federal Register* notice provides the following conclusions relative to off-highway vehicle use in the desert:

"Negative effects range from minor habitat alteration to total denudation of extensive areas. While direct effects are immediate (mortality from crushing, collection, and vandalism), indirect effects can be either immediate (disruption of soil integrity; degradation of annual plants, grasses, and perennial plants; and/or destruction of desert tortoise shelter sites), delayed, and/or cumulative (soil loss due to erosion, soil compaction and its effects on annual and perennial plants, water pollution, and litter and refuse) (Biosystems Analysis 1991)."

"The Service was unable to identify significant economic impacts to recreation activities due to critical habitat designation."

"Some recreational activities may be relocated or restricted due to critical habitat designation, particularly OHV use."

"In addition, the impact of OHVs on tortoises has increased over the last decade due to changes in BLM zoning, increases in OHV use, and the proliferation of illegal roads, a factor that results in serious environmental impacts and a difficult management issue for the BLM."

"OHV activities within the designated critical habitat are not the only activities that may adversely affect the desert tortoise and its habitat."

"The negative impacts of OHV activity on desert tortoise habitat have been quantified extensively since the early 1970. Tortoises are adversely affected by OHVs through loss of forage and vegetative cover; increased mortality from crushing, collection, and vandalism; and soil compaction and loss of burrow sites. Because the use of OHVs in desert areas is a highly charged issue, much of the attention has been placed on the review of studies and the appropriate use of statistical tests in quantifying [sic] *the resultant data."*

"Protection measures were implemented by the BLM in 1988 through its Rangewide Plan to reduce OHV use throughout the range of the desert tortoise in category I and II habitats. As stated in the Draft Economic Impact Analysis, in its off-highway users guide, California listed 24 OHV recreational areas managed by Federal, State, and other agencies in Imperial, Riverside, and San Bernardino Counties. Four sites in the guide lie just outside proposed CHUs [Critical Habitat Units]. Critical habitat designation as proposed will not affect OHV use at these four sites. The other three States also offer areas for use by OHV enthusiasts."

"Any use of vehicles off of designated roads and trails, for whatever the reason, can negatively impact the desert ecosystem. The Service is not singling out organized OHV user groups in this assessment. However, the actions of hiking, camping, and birdwatching, provided they do not involve use of vehicles off of designated roads and trails, are not likely to adversely modify critical habitat. The Service recognizes that most recreational activity is not commercial. However, most OHV races involve profits for the promoters, which is considered a commercial enterprise."

"The Service anticipates that, although Federal land managers may close some roads as a result of critical habitat designation, there will still be opportunities for scenic touring and other motorized uses on designated roads and trails within CHUs."

"The Service anticipates that the land management agencies will designate roads and trails within critical habitat, and that they will close some roads that are secondary and not necessary for access to private lands or mines. Activities considered not likely to adversely affect critical habitat include hunting, picnicking, casual horseback riding (on designated roads and trails), camping, birdwatching, bike riding (on designated roads and trails), hiking, and motor vehicle use on designated roads."

4.1.3. *Desert Tortoise (Mojave Population) Recovery Plan* (U.S. Fish and Wildlife Service 1994b). The Study Area is within the Ord-Rodman Desert Wildlife Management Area (DWMA) identified in the Service's 1994 document. The Desert Tortoise (Mojave Population) Recovery Plan indicates that there are "immediate effects" (loss of soil, loss of annual plants / grasses, loss of perennial plants, loss of desert tortoise burrows, and crushing desert tortoises) and "delayed and cumulative effects" (loss of soil, soil compaction, effects on annual plants, effects on perennial plants, effects on live desert tortoises, effects on other vertebrates) associated with off-highway vehicle use (see Section 5.2. below).

The Desert Tortoise (Mojave Population) Recovery Plan lists the following (verbatim) recommendations relative to off-highway vehicle activity; **bold** font appears in the original text:

"The following activities should be prohibited throughout all DWMAs because they are generally incompatible with desert tortoise recovery and other purposes of DWMAs:"

"• All vehicle activity off of designated roads; all competitive and organized events on designated roads."

"The following activities are compatible with desert tortoise recovery and may be allowed in DWMAs:"

"• Limited speed travel on designated, signed roads and maintenance of these roads."

"• Non-consumptive recreation (e.g., hiking, birdwatching, casual horseback riding, and photography)."

"• Parking and camping in designated areas."

"Recommended management action:"

"• Restrict establishment of new roads in DWMAs."

"• Implement closure to vehicular access with the exception of designated routes, including Federal, State, and County maintained vehicle routes."

"• Implement emergency closures of dirt roads and routes as needed to reduce human access and disturbance in areas where human-caused mortality of desert tortoises is a problem."

5.0. Recommendations

One real challenge to route designation is the formulation of general, programmatic guidelines for route closure. The Bureau needs to develop a set of standard criteria that will govern the selection of routes that would remain open versus those that should be closed. In this section, the Desert Tortoise Council makes such recommendations to the Bureau.

5.1. Route Types Recommended for Closure. The Service has identified DWMAs and desert tortoise Critical Habitat as essential to tortoise recovery; the Bureau is mandated to "maintain stable, viable [tortoise] populations and protect existing tortoise habitat values" in Category I Habitat and to "maintain stable, viable [tortoise] populations and halt further declines in tortoise habitat value" in Category II Habitat; the multi-agency WMCMP will likely identify "core areas" that will be targeted for private land acquisition and subsequent management for the recovery of the Mojave Desert tortoise population.

Within these essential areas, the Council recommends that the following Route Types be closed:

Routes that were established after 1980 should be closed. It is incumbent upon the Bureau to implement its own plans. As per the 1982 Amendment (Bureau of Land Management 1982), routes that did not exist prior to 1980 should be closed. We understand from Brad Blomquist that pre-1980 aerial photographs of most of the WMCMP area are available but that it would be very expensive to digitize all of routes on them. Although complete digitization of all routes within the WMCMP area may be cost prohibitive, it would not be that costly to check all routes on the proposed network to be sure that pre-1980 routes are not included. Therefore, in order to implement the Bureau's requirements set forth in 1982, the Bureau should review pre-1980 aerial photographs for the proposed route network and eliminate all routes that did not exist prior to 1980.

"Non-essential" routes in washes should be closed. As per the 1982 Amendment (Bureau of Land Management 1982), washes with no evidence of prior use should be closed. Our field work indicates that about 28 miles of washes observed showed no evidence of prior use. Most routes in washes should be closed for the following reasons: (a) as routes, washes generally are in poor condition; (b) routes within washes often dead-end into rock boulders or dense vegetation, where the rider is required to back track or crush vegetation, thereby damaging more shrubs; (c) wash-adapted resources, such as desert willow and cat-claw acacia, are not as often found in upland areas, and are particularly important to nesting birds; (d) tortoises are known to use washes as travel and feeding corridors (Jennings 1992, 1993); (e) caliche coversites and overhangs are common in some washes, including the northern portions of the Study Area, and are used by tortoises for cover; etc.

Whereas it may not be feasible to close every route in every wash (nor can we adequately define "non-essential"), there should be clear, justifiable reasons for keeping a route open within a given wash. The Bureau should acknowledge how important washes are to tortoises and many other wildlife species by closing as many routes in washes as possible. In no way should there be a *de facto* statement that vehicle travel is allowed in all washes. We *strongly* recommend that the following wording be used in management prescriptions, brochures, and other route designation literature: "Unless signed as 'open,' all washes are closed to vehicular travel."

Routes that are in poor condition should be closed. These are routes that are difficult to see and follow; there may be a significant amount of revegetation that has occurred; they are often associated with washes leading into dead-end cul-de-sacs, which results in damaged vegetation. The Indiscernible Route types identified in this study should be closed throughout the WMCMP area. In our estimation, the ideal route is 6 to 10 feet wide, heavily used, easily seen, and not redundant with adjacent routes.

Routes that show evidence of natural revegetation should be closed. As per the 1982 Amendment (Bureau of Land Management 1982), routes that do not show evidence of significant use [including all Indiscernible Routes and many washes] should be closed. Such routes are not being used enough to warrant Open Route designation. They are (a) often ill-defined and lead to vehicle stray; (b) provide reduced visibility to operators, which may lead to more tortoises being crushed; and (c) a means of reducing the ultimate cost of reclamation; natural revegetation, where it has already occurred, is the least expensive form of reclamation.

Redundant routes should be closed. We use "redundant" to indicate routes that provide the same or similar access opportunities from point A to point B. Every route is an impact, some more, some less, so multiple routes providing access between the same two points are considered unnecessary. A well established, high use route, with low Straying Potential (SP = 3) should be chosen over a route with lower use and higher Straying Potential.

Dead-end routes with no obvious through-destination should be closed. Such routes lead to dumping, target shooting, route proliferation, and illegal camping, among other things. Once vehicle users get to the obvious end of the road, they often continue into the desert on multiple routes and tracks that result in significant proliferation and ground disturbance.

"Non-essential" roads through topographically Plain areas should be closed. The Bureau has concluded that "...elevations less than 4,000 feet and slopes less than 30 degrees support the bulk of tortoise numbers" (Bureau of Land Management 1997). It is likely that similar areas within the WMCMP area also support the bulk of tortoises. Routes through such areas in the WMCMP area that meet other criteria (routes in washes, dead-end routes, redundant routes, etc.) should be the first priority for closure.

5.2. Other Considerations to Facilitate Designation and Implementation of the Final Route Network. In order to realize its mandates, the Bureau should consider the following guidelines for route designation:

As the highest priority, designate routes within Critical Habitat Units and DWMAs first. Within the WMCMP area, the Bureau should consider Critical Habitat and DWMAs the most important planning areas and should consider designation in these areas the first and highest priority. These lands should be treated as essential to the survival and recovery of the tortoise (U.S. Fish and Wildlife Service 1994a, 1994b), and be managed to maintain stable, viable populations of tortoises (Bureau of Land Management 1988).

De-emphasize off-highway vehicle recreation opportunities in the Study Area and other Critical Habitat/DWMAs. The key words here are "vehicle recreation." Throughout this document we have emphasized the federal agency decisions to identify these lands as essential to tortoise recovery. If vehicle recreation remained on designated or even existing routes, the impacts associated with vehicles would be diminished. Unfortunately vehicles do not stay on trails and vehicle recreation has resulted in physical damage to the desert ecosystem.

The Johnson Valley Open Area to the east and northeast, which is the Mojave Desert's largest designated open area, and the Stoddard Valley Open Area to the northwest are designated for unrestricted vehicle recreation. The proximity of these areas to the Study Area has already affected the Critical Habitat. The Council's data show that the proximity of Johnson Valley Open Area has resulted in relatively heavy motorcycle use in areas west of the Cinnamon Hills. The Bureau's inventory shows that few of these trails existed prior to 1980, that there has been a 27% increase in the number of trails in the area.

Any discussion of annexing the Cinnamon Hills into the Johnson Valley Open Area is *strongly* discouraged, as such expansion would eliminate about a third of the South DTEZ and would likely result in increased cycle use to the west, which comprises the remainder of the emphasis zone. Insisting on numerous Open Routes in desert tortoise Critical Habitat is analogous to insisting that there be Critical Habitat in Open Areas.

Through route designation, implementation, and enforcement the Bureau must proactively control the direct effects of off-highway vehicles on the Study Area and throughout the West Mojave Desert. Failure to do so will continue to expose tortoises and Critical Habitat to the following documented, deleterious effects (see Desert Tortoise (Mojave Population) Recovery Plan (U.S. Fish and Wildlife Service 1994b) for the following literature citations):

Loss of burrows and tortoises (Burge 1983; Bury 1978; Bury and Luckenbach 1986; Bury and Marlow 1973; and Luckenbach 1975).

Adverse effects on soil biology (Baldwin and Stoddard 1973; Bodman and Constantin 1965; Dickey et al. 1973; Gilette and Adams 1973; Hinckley et al. 1983; Nakata 1983; Sheridan 1979; Stull et al. 1979; Webb 1983; Webb et al. 1978; Wilshire 1977a, 1977b, 1979, 1980; Wilshire and Nakata 1976; and Wilshire et al. 1977).

Adverse effects associated with human vandalism, poaching, and commercial trade (Berry 1984b, 1986a, 1990, as amended; Berry and Burge 1984; Berry and Nicholson 1984b; Berry et al. 1986a; Bury and Marlow 1973; Campbell 1981; Ditzler 1991; Ginn 1990; Howland 1989; Jaeger 1950; Jennings 1991; St. Amant 1984; Stewart 1991; Schneider and Everson 1989; and Swingland and Klemens 1989).

Adverse effects on plant life (Adams et al. 1982a, 1982b; Biosystems 1992; Bureau of Land Management 1975; Bury and Luckenbach 1983, 1986; Bury et al. 1977; Davidson and Fox 1974; Keefe and Berry 1973; Lathrop 1983a, 1983b; Rowlands et al. 1980; Vollmer et al. 1976; Wilshire 1979; and Wilshire et al. 1975, 1977).

Route designation in the Study Area and throughout the West Mojave is essential and should be implemented as soon as possible to minimize the adverse effects documented in the above-referenced documents.

The Bureau must consider the "Cumulative Effect" of route designation within the WMCMP area. At present, there is a high likelihood that Fort Irwin may expand into the Superior-Cronese Critical Habitat Unit, leaving only three Critical Habitat Units within the West Mojave Recovery Unit (Fremont-Kramer, Joshua Tree, and Ord-Rodman Critical Habitat Units). The southward expansion of Fort Irwin would eliminate more than 300,000 acres of Critical Habitat from the West Mojave Recovery Unit. If this expansion occurs, the importance of the Ord-Rodman Critical Habitat unit will become inestimable.

Field work necessary to establish a route network. The Council agrees with the Bureau (Brad Blomquist, pers. comm.) that it is infeasible to collect data on every route, trail, and wash within the 8.6 million-acre WMCMP area. We expect that the Bureau will use aerial photography and available knowledge of sensitive biological resources to designate a route network. Once the proposed network is identified, the Council considers it essential that the Bureau collect data and ground-proof that network. The field work should ensure that none of the routes in the preliminary network are in poor condition, unnecessarily in washes, or naturally revegetating, etc., as described above. Although it is not necessary to look at every route to determine the network, it is absolutely necessary that the proposed network is assessed to ensure that route designation will not violate the Bureau's mandate to protect tortoises and other natural resources in habitats deemed essential to tortoise recovery.

Use "Limited Route" designations where "Closed Route" designations are not feasible. There are numerous routes within the Study Area that, based on biological concerns alone, should be closed. However, these routes are on private land, have specific uses (access to active mines, access to on-going cattle operations, etc.), and other limiting factors that make closure impractical. In such cases, we recommend that only the miner, rancher, or other specific, non-recreation user be given permission to travel on those routes. Such routes should never be used for vehicle play and should not be designated open to the general public. This designation should be used sparingly, as it will likely be difficult for the Bureau to enforce illegal use of such routes.

Ensure that sufficient law enforcement officials are available to enforce the route network. The Council supports route designation, in part, because it allows the Bureau to enforce route closure; until the route system is designated, Bureau law enforcement officials cannot issue citations for illegal driving activities over most of the desert. As necessary, the Bureau should increase the number of park rangers or law enforcement rangers throughout the WMCMP area to ensure that recreationsists are keeping to designated, open routes.

Pursue a Memorandum of Understanding with Catellus Land Development Company to facilitate an appropriate route network. It is likely that the success of route designation and associated route closure in the Ord Mountains will be affected by private land ownership. We understand that most of the private land belongs to Catellus and that the entire Study Area is essential to the recovery of the desert tortoise. As such, we recommend that the Bureau pursue a Memorandum of Understanding with Catellus that would facilitate the Bureau's completion of a network inclusive of private lands and realize its mandate to manage the land for stable, viable populations of the desert tortoise. Where feasible, the Memorandum of Understanding should also cover the larger WMCMP area.

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We also commend the dedication of Bureau of Land Management employees involved in this project, particularly Brad Blomquist, Tom Egan, and Jeff Aardahl. The advanced technology provided by the Bureau has made the present study seminal; the 100% inventory combined with extensive ground-proofing provides, for the first time, an effective way to designate routes.

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Terms and Acronyms / Abbreviations (enclosed in parentheses) used

1982 Amendment - Formal amendment to the CDCA Plan revising the plan's motorized vehicle element.

Affected Interest - Bureau term for groups whose interests may be affected by the Bureau's planning efforts.

Area A ... Area I - Council term indicating Survey Areas in which data were collected for route designation.

Biological Resource Overlays (Overlays) - 1:24,000 scale maps showing sensitive biological resources known to occur in the Study Area.

Bureau of Land Management (Bureau) - Federal regulatory agency overseeing route designation.

Bureau's Inventory - Inventory of digitized routes and washes occurring within the Study Area.

California Desert Conservation Area Plan (CDCA Plan) - Bureau plan completed in 1980 with the stated goal of providing "...for the use of the public lands and resources of the California Desert Conservation Area, including economic, educational, scientific, and recreational uses, in a manner which enhances wherever possible - and which does not diminish, on balance - the environmental, cultural, and aesthetic values of the desert and its future productivity."

Class L (Limited Use) Areas - Bureau term and category that "...protects sensitive, natural, scenic, ecological, and cultural resource values" on lands that "...are managed to provide for generally lower-intensity, carefully controlled multiple use of resources, while ensuring that sensitive values are not significantly diminished."

Class M (Moderate Use) Areas - Bureau term and category that "...provides for a wide variety of present and future uses such as mining, livestock grazing, recreation, energy, and utility development" and is '"...designed to conserve desert resources and to mitigate damage to those resources which permitted uses may cause."

Closed Route - Bureau term indicating routes that are closed to all motorized vehicle use.

Concealment Potential (CP) - Council's determination of the relative difficulty of concealing a given route.

Critical Habitat - Defined by section 3(5)(A) of the Federal Endangered Species Act as "(i) the specific areas within the geographic area occupied by the species on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection."

Cycle Route - Council term indicating routes that are used primarily by motorcycles.

Desert Tortoise Council (Council) - Group established in 1976 to promote conservation of the desert tortoise in the deserts of the southwestern United States and Mexico.

Desert Tortoise Emphasis Zone (DTEZ) - Bureau term indicating various emphasis areas for tortoises.

Desert Tortoise (Mojave Population) Recovery Plan - Service's 1994 document that "...delineates reasonable actions which are believed to be required to recover and / or protect listed species."

Desert Wildlife Management Area (DWMA) - Areas identified in the Service's Desert Tortoise (Mojave Population) Recovery Plan for the tortoise in which "...actions must be implemented to provide for the long-term persistence of viable desert tortoise populations and the ecosystems upon which they rely."

Distance to Obscurity - Council term, relative to Concealment Potential, indicating the point at which a given route disappears from view when observed from the main route.

High DTEZ - Bureau term indicating areas with high "...habitat value...relative to their potential contribution to achieving desert tortoise population recovery."

High Use Truck Route - Council term indicating established routes with moderate to high use.

Indiscernible Route - Council term indicating inventoried "routes" that could not be found during data collection, or if found, showed no evidence of recent use.

Johnson Valley Open Area - Area east of Study Area with unrestricted vehicle recreation opportunities.

Low DTEZ - Bureau term indicating areas with low "...habitat value...relative to their potential contribution to achieving desert tortoise population recovery."

Low Use Truck Route - Council term indicating established routes with low use.

Moderate DTEZ - Bureau term indicating areas with moderate "...habitat value...relative to their potential contribution to achieving desert tortoise population recovery."

Non-DTEZ - Bureau term indicating areas with no "...habitat value...relative to their potential contribution to achieving desert tortoise population recovery."

North DTEZ - Council term identifying essential tortoise habitat in the north portions of the Study Area.

OM1, OM2, OM3, etc. - Specific routes designated by the Bureau as "Open" under the 1996 Emergency Route Closure in the Study Area.

Open Route - Bureau term indicating a route that is open to all motorized vehicle use.

Recovery Unit - Areas identified in the Service's Desert Tortoise (Mojave Population) Recovery Plan that are "...essential to the long-term recovery, viability, and genetic diversity of the desert tortoise."

Route - General term indicating roads, trails, washes, etc. that were identified by the Bureau's inventory that may or may not be used for vehicle travel.

Route Condition - Council term for the structural integrity of a given route; routes that are in Good Condition are well established and easily followed.

Route Type - Council term used to describe five categories of routes identified in the Study Area.

South DTEZ - Council term identifying essential tortoise habitat in the south portions of the Study Area.

Stoddard Valley Open Area - Area west of the Study Area with unrestricted vehicle recreation opportunities

Straying Potential (SP) - Council's determination of potential for vehicle straying from a given route.

Study Area - Refers to the Ord Mountain Pilot Study Area, the subject area for pilot route designation.

Technical Review Team (TRT) - An advisory group to the Bureau, in this case, for route designation.

Unusual Plant Assemblage (UPA) - Bureau designation of "...those stands of vegetation within the CDCA which can be recognized as extraordinary due to one or more factors..." including "...unusual age, unusual size, usually high cover or density, or disjunction from main centers of distribution."

U.S. Fish and Wildlife Service (Service) - In this context, the federal agency responsible for designation of Critical Habitat and completion of the Desert Tortoise (Mojave Population) Recovery Plan.

Washes - Council term indicating one of five Route Types that may or may not have vehicular use.

West Mojave Coordinated Management Plan (WMCMP) - Programmatic plan to provide guidance for development and conservation of natural resources within an 8.6 million-acre area of the West Mojave Desert.

Appendix B. Data Sheet and Code Descriptions

Table B1. Data code, description, and explanation for data collected within the Study Area.

Data Code	Description	Explanation
PLANT COMMUNITY		
"BBU"	Blackbush scrub	Plant community dominated by blackbush; *0 = no, 1 = yes*
"CRE"	Creosote bush scrub	Plant community dominated by creosote bush; *0 = no, 1 = yes*
"WAS"	Wash community	Plant community has desert willow, catclaw acacia, desert almond, rabbitbrush; etc. *0 = no, 1 = yes*
"YUC"	Mohave yucca	*Yucca schidigera* is common in the area; often associated with creosote or blackbush scrub; *0 = no, 1 = yes*
SUBSTRATE		
"ROC"	Rocky	Route is mostly rocky; typical of hilly and mountainous areas; *0 no, 1 = yes*
"SAN"	Sandy	Route is mostly sandy; typical of washes; *0 = no, 1 = yes*
"WASH"	Wash	Wash substrates characterize the route; *0 = no, 1 = yes*
"WASH*"	Note regarding wash	Field note describing the wash substrate; *0 = no, 1 = yes*
"HPD"	Hard-packed dirt	Route is mostly hard-packed dirt; typical of routes in valleys rather than in washes or in hilly or mountainous areas; *0 = no, 1 = yes*
DESCRIPTIVE DATA		
"WDT"	Width	Estimated width of a given route; *all measurements are in feet*
"SAMPLE LGN"	Length of route/wash assessed	Length of the route driven or walked to collect the data; *all measurements are in feet*
"ROUTE LGN"	Length of route/wash	Estimated length of inventoried route; *all measurements are in feet*
"USE"	Vehicle use	Relative amount of use on the route; *0 = none, 1 = light, 2 = medium, 3 = heavy*
"USE*"	Note regarding use	Field note describing route use; *0 = no, 1 = yes*
"TYP"	Route type	Type of route; *1 = single-track truck route; 2 = two-track truck route; 3 = all-terrain vehicle; 4 = motorcycle; 5 = no observable use, usually a wash*

Table B1. (cont.) Data code, description, and explanation for data collected within the Study Area.

Data Code	Description	Explanation
DESCRIPTIVE DATA (cont.)		
"BERM"	Bermed?	Presence of a berm, which signifies that the route has been or is being graded *0 = no, 1 = yes*
"SP"	Straying Potential	Relative amount of straying that was observed or could occur; valley areas generally have more straying than rocky, mountainous areas, where vehicles are restricted to the route by adjacent substrates and/or topography; *1 = high Straying Potential; 2 = moderate; 3 = low or no Straying Potential*
"SP*"	Note regarding Straying Potential	Field note describing Straying Potential; *0 = no, 1 = yes*
"CP"	Concealment Potential	Relative difficulty of closing, concealing, camouflaging, etc. a given route; *1 = relatively difficult, 0 = relatively easy*
"CP*"	Note regarding concealment	Field note describing difficulty of concealing a given route; *0 = no, 1 = yes*
TOPOGRAPHY		
"PLA"	Plain	Route passes through mostly plain or relatively flat areas; *0 = no, 1 = yes*
"HIL"	Hilly	Route passes through mostly hilly areas; *0 = no, 1 = yes*
"MOU"	Mountainous	Route passes through mostly mountainous areas; *0 = no, 1 = yes*
CONDITION		
"GO"	Good	Route is well defined, easy to follow, with good structural condition; *0 = no, 1 = yes*
"MO"	Moderate	Route is moderately well defined, moderately easy to follow, with moderately intact structural condition; *0 = no, 1 = yes*
"PO"	Poor	Route that is poorly defined, difficult to follow, with poor structural condition; *0 = no, 1 = yes*

Appendix C. Tabulated data for Route Types and use, substrates, route widths, topography, condition, Straying Potential, and Concealment Potential

Table C1. Route Widths and Use. In this table we summarize data for the five Route Types, indicating the total length and relative use of each type.

Table C1. Length and use of five Route Types comprising 368 linear miles in the Study Area

Route Type	Percent of Total	Route Length	Relative Use			
			No use (0)	Light (1)	Mod (2)	Heavy (3)
High Use Truck	38%	141 miles	0% 0/141 miles	6% 9 miles	42% 59 miles	52% 73 miles
Wash	29%	106 miles	26% 28/106 miles	24% 25 miles	28% 30 miles	22% 23 miles
Low Use Truck	17%	62 miles	0% 0/62 miles	97% 60 miles	3% 2 miles	0% 0 miles
Cycle	12%	43 miles	0% 0/43 miles	16% 7 miles	44% 19 miles	40% 17 miles
Indiscernible	4%	16 miles	100% 16/16 miles	0% 0 miles	0% 0 miles	0% 0 miles
5 Route Types	**100%**	**368 miles**	**12%** **44/368 miles**	**27%** **101 miles**	**30%** **110 miles**	**31%** **113 miles**

Table C2. Wash Substrates. Given variable substrates for a given route, more than one substrate type was often recorded. This data analysis resulted in as few as five combinations for Cycle Routes to as many as 10 combinations for Washes. Given the variability of Washes and the strong association with sandy substrates, wash data are separated from the other substrate data, which appear in Table C3.

Table C2. Substrates for Washes in the Study Area

Route Types	Route Length	Wash Substrates S = Sand, S/HPD= Sand/hard-packed dirt, S/HPD/R = Sand/hard-packed dirt/rock, HPD = Hard-packed dirt, NONE = No data, MISC = Other combinations totaled						
		S	S/HPD	S/HPD/R	HPD	NONE	R	MISC
Wash	106 miles	42 mi 40%	13 mi 12%	12 mi 11%	11 mi 10%	9 mi 8%	7 mi 7%	12 mi (4 others) 11%

Table C3. Substrates for Non-wash Routes. In Table C3, the prevalent substrate combinations are listed in the third through seventh columns, with the less prevalent combinations included in the eighth, Miscellaneous (MISC) column. Substrates are shown in descending order of prevalence; the most prevalent substrate for each Route Type appears in the third column, followed, in descending order, by the other substrate combinations in the fourth through eighth columns.

Table C3. Substrates for the other four Route Types in the Study Area

Route Type	Route Length	Other Substrates R/HPD = Rock/hard-packed dirt, HPD = Hard-packed dirt R = Rock, S/HPD = Sand/hard-packed dirt, NONE = No data, MISC = Other combinations totaled					
		R/HPD	HPD	R	S/HPD	NONE	MISC
High Use Truck	141 miles	49 mi 35%	45 mi 32%	27 mi 19%	12 mi 8%	3 mi 2%	5 mi (3 others) 4%
		R	R/HPD	NONE	HPD	S/HPD	MISC
Low Use Truck	62 miles	30 mi 48%	16 mi 26%	5 mi 8%	6 mi 10%	3 mi 5%	2 mi (2 others) 3%
		HPD	NONE	S/HPD	R/HPD	R	MISC
Cycle	43 miles	14 mi 33%	12 mi 28%	8 mi 19%	7 mi 16%	2 mi 4%	0 mi (0 others) 0%
		N/A	N/A	N/A	N/A	NONE	MISC
Indiscernible	16 miles	-	-	-	-	16 mi 100%	0 mi (0 others) 0%

Table C4. Route Widths. In the following table we summarize the widths of the five Route Types. Width data are not applicable to Indiscernible Routes since those routes were not found.

Table C4. Widths for five Route Types comprising 368 linear miles in the Study Area

	Route Types				
Width Statistics	High Use Truck (feet)	Low Use Truck (feet)	Cycle (feet)	Wash (feet)	Indiscernible (feet)
Mean	9.4	9.1	3.8	15.3	0
Median	9	8	3	8	0
Minimum	6	6	1	3	0
Maximum	18	40	7	120	0
Sum	958	685	118	1328	0
Count	101	75	31	87	26

Table C5. Topography. Data were often collected to indicate transitions along a route from one topographic feature to another: from Plain to Hill; or a route basically stayed within a given topographic feature: Plain, Hill, etc. In the following table we summarize this data for the routes on which topography was recorded, which was approximately 328 of the 368 miles (88%) assessed by this study. Percentages given in columns three through eight indicate the prevalence of a given topographic feature relative to the Route Type that was assessed. For example, of the 94 miles of Washes assessed, 47 miles (50%) occurred in "Plain" or relatively level areas.

Table C5. Topographic features for five Route Types comprising 328 linear miles in the Study Area

		Topographic Feature					
Route Type	**Route Length**	**Plain**	**Plain to Hill**	**Hill**	**Hill to Mountain**	**Mountain**	**Plain to Hill to Mountain**
Wash	94 miles	47 mi 50%	33 mi 35%	10 mi 11%	3 mi 4%	0 mi 0%	0 mi 0%
High Use Truck	139 miles	63 mi 45%	45 mi 32%	20 mi 14%	6 mi 4%	0.5 mi 1%	5 mi 4%
Low Use Truck	59 miles	20 mi 34%	18 mi 30%	10 mi 17%	8 mi 14%	1 mi 2%	2 mi 3%
Cycle	31 miles	25 mi 81%	1 mi 3%	5 mi 16%	0 mi 0%	0 mi 0%	0 mi 0%
Indiscernible	5 miles	3 mi 60%	2 mi 40%	0 mi 0%	0 mi 0%	0 mi 0%	0 mi 0%
5 Route Types	**328 mi**	**158 mi 48%**	**99 mi 30%**	**45 mi 14%**	**17 mi 5%**	**1.5 mi 1%**	**7 mi 2%**

Table C6. Route Condition. Herein, "condition" refers to the structural integrity of each route relative to vehicle use. As such, a route with no vehicle use, including many washes, is considered to be in Poor Condition. Most of the designated Open Routes in the Study Area are well established and easily followed and are considered to be in Good Condition. Condition data were collected on 353 of the 368 miles of routes (95%) assessed by this study.

Table C6. Observed Condition of five Route Types.

Route Type	**Route Length**	**Percent Condition**					
		Good	**Good to Moderate**	**Moderate**	**Moderate to Poor**	**Good to Poor**	**Poor**
High Use Truck	137 miles	117 mi 85%	13 mi 9%	2 mi 2%	1 mi 1%	4 mi 3%	0 mi 0%
Wash	107 miles	13 mi 12%	14 mi 13%	15 mi 14%	16 mi 15%	2 mi 2%	47 mi 44%
Low Use Truck	61 miles	22 mi 36%	10 mi 16%	20 mi 33%	8 mi 13%	0 mi 0%	1 mi 2%
Cycle	32 miles	8 mi 25%	2 mi 6%	7 mi 22%	6 mi 19%	5 mi 16%	4 mi 12%
Indiscernible	16 miles	0 mi 0%	0 mi 0%	0 mi 0%	0.75 mi 5%	0 mi 0%	15.25 mi 95%
5 Route Types	**353 miles**	**160 mi 45%**	**39 mi 11%**	**44 mi 13%**	**31.75 mi 9%**	**11 mi 3%**	**67.25 mi 19%**

Table C7. Straying Potential. A relatively well-defined route through rocky areas will have an index of SP = 3, which is indicative of low Straying Potential; adjacent areas are so rocky that vehicle operators are restricted to the route. Other routes may be very difficult to follow, or adjacent substrates offer little resistance to straying vehicles; such routes are assessed as SP = 1. Straying Potential data were collected on 258 of 368 miles (70%) assessed by this study.

Table C7. Straying Potential of five Route Types.

		Route Lengths and Straying Potential		
Route Type	**Route Length**	**SP = 1 High Straying Potential**	**SP = 2 Moderate Straying Potential**	**SP = 3 Low Straying Potential**
High Use Truck	110 miles	33 miles 30%	41 miles 37%	36 miles 33%
Wash	65 miles	16 miles 25%	17 miles 26%	32 miles 49%
Low Use Truck	52 miles	7 miles 13%	20 miles 38%	25 miles 48%
Cycle	31 miles	29 miles 94%	2 miles 6%	0 miles 0%
Indiscernible	N/A	N/A	N/A	N/A
5 Route Types	**258 miles**	**85 miles 33%**	**80 miles 31%**	**93 miles 36%**

Table C8. Concealment Potential. This index indicates how easy or difficult it may be to conceal or camouflage a route. Wide routes, with heavy use, in level topography, with a "distance to obscurity" of 500 feet may be impossible to close, and are assigned CP = 1 (difficult). A narrow route, with little use, and a "distance to obscurity" of 100 feet is likely easier to conceal, and is assigned CP = 0 (easy). Concealment Potential data were collected on 266 of 368 miles (72%).

Table C8. Concealment Potential of five Route Types.

		Route Lengths and Concealment Potential	
Route Type	**Route Length**	**CP = 0 (Easy)**	**CP = 1 (Difficult)**
High Use Truck	111 miles	3 miles 3%	108 miles 97%
Wash	66 miles	21 miles 32%	45 miles 68%
Low Use Truck	52 miles	10 miles 19%	42 miles 81%
Cycle	31 miles	14 miles 45%	17 miles 55%
Indiscernible	6 miles	6 miles 100%	0 miles 0%
5 Route Types	**266 miles**	**54 miles 20%**	**212 80%**

Ord Mountain Pilot Study

Map 1. Five Trail Types

- High Use Truck Trail
- Low Use Truck Trail
- Wash Trail
- Cycle Trail
- Indiscernible Trail/No Use

A1 ... I26 = Trail segments with data

OM1, SV183, OJ208, etc. = Existing Open Routes

Map Source: Bureau of Land Management (1997)

Map Prepared by Ed LaRue, Desert Tortoise Council (1997)