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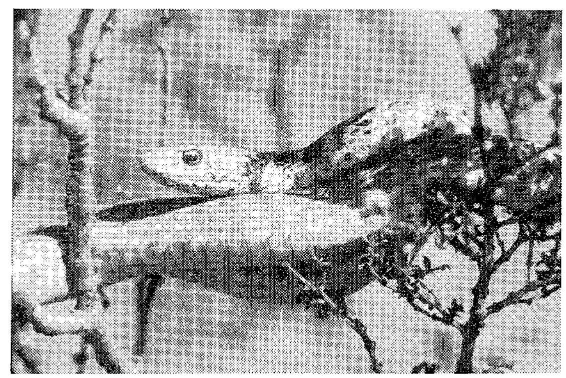
September 1994

Biodiversity and the Threatened/Endangered/Sensitive Species of Fort Irwin, CA

The National Training Center Mission, Training Effects, and Options for Natural Resources Management and Mitigation

by Anthony J. Krzysik



Properly designed and implemented inventory, assessment, and monitoring programs are important components of environmental compliance for U.S. Army training installations. In earlier work, a statistically rigorous and quantitative assessment and monitoring program for arid and semiarid ecosystems was developed and initiated in the Mojave Desert. The program was implemented in March 1983 at Fort Irwin, CA, the Army's National Training Center (NTC), to monitor woody perennial vegetation and vertebrate populations. Data from that program, and ongoing work by the author, have produced analytical capabilities to quantitatively assess the effects of training activities on ecosystems at landscape scales. Such assessments are needed to determine environmental mitigation and management priorities, and future monitoring and research needs.

This report describes the biological and geophysical characteristics and environment of Fort Irwin, describes the Army training mission at the NTC, and summarizes the effects of the military training mission at Fort Irwin on woody vegetation and the vertebrate fauna. A detailed assessment of the current status of threatened, endangered, and sensitive animals and plants is also given. Priorities for environmental management, mitigation, research, and monitoring at Fort Irwin—based on sound ecological principles and the author's cumulative research in the Mojave Desert ecosystem—are discussed.

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Foreword

This study was conducted for Headquarters, U.S. Army Forces Command (FORSCOM) under Military Interdepartmental Purchase Requests (MIPRs) JE-02-91 [10/22/90]; and FE-017-91 [9/30/91], reimbursable work unit "Army Training Activities at the National Training Center and Their Effects on Wildlife and Their Habitats." The FORSCOM technical monitor was Stuart Cannon, FCEN-RDF.

The work was performed by the Environmental Natural Resources Division (EN) of the Environmental Sustainment Laboratory (EL), U.S. Army Construction Engineering Research Laboratories (USACERL). Dr. William Severinghaus is Chief, CECER-EN, and William Goran is Chief, CECER-EL. The USACERL technical editor was Gordon L. Cohen, Information Management Office.

LTC David J. Rehbein is Commander and Acting Director, USACERL, and Dr. Michael J. O'Connor is Technical Director.

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1 Introduction

Background

The U.S. Department of Defense has the legal responsibility for managing the natural resources on its training lands, and the Department of the Army has made a commitment to become exemplary in issues of environmental compliance. Strongly pertinent environmental mandates and documents include the *National Environmental Policy Act (NEPA)*, *Endangered Species Act*, *Clean Water Act*, *Migratory Bird Conservation Act*, Executive Orders 11990 (Protection of Wetlands) and 11988 (Floodplain Management), and Army Regulations (AR) 200-2, AR 420-74, and AR 420-76.

Important components of environmental compliance are properly designed and implemented inventory, assessment, and monitoring programs. The author has researched and developed a statistically rigorous and quantitative assessment and monitoring program for arid and semiarid ecosystems (Krzysik 1984, 1985, 1987). The program was implemented in March 1983 at Fort Irwin, CA, the Army's National Training Center (NTC), to monitor woody perennial vegetation and vertebrate populations. Data from that program and ongoing research and development by the author have developed analytical capabilities to quantitatively assess the effects of military training activities on ecological communities and ecosystems at landscape scales.

Objectives

The objectives of this report are to:

1. Describe the biodiversity, geophysical characteristics, and environment of Fort Irwin, and provide a thorough summary of the plant communities and vertebrates that live in the area
2. Describe the Army training mission at the NTC
3. Provide a summary of the effects of the military training mission at Fort Irwin on the installation's woody vegetation and vertebrate fauna
4. Discuss priorities for management, mitigation, research, and monitoring based both on the current research and the author's cumulative work in this area.

Approach

The author summarized pertinent observations and published findings from his previous research on the plant and animal communities of Fort Irwin. To support those observations and findings, the author conducted a comprehensive literature survey pertaining to plant and animal communities naturally occurring within desert environments in the vicinity of Fort Irwin, including migratory species that may use any part of the installation during part of their life cycle.

Training activities at Fort Irwin were described and quantified, with special attention to the force-on-force battle exercises conducted regularly at Fort Irwin's National Training Center. The author's previous research and all other pertinent literature were surveyed to compile a summary of both the known and potential effects of training activities on Fort Irwin's biodiversity.

Scope

Although the assessment and monitoring program was developed for arid ecosystems and initially implemented in the Mojave Desert, the overall concept, approach, experimental and sampling design, and statistical analyses are directly applicable to any ecosystem. Of course, details of sampling design and field methods will differ because these directly depend on ecosystem type and the specific objectives of assessment and monitoring (including desired accuracy and precision).

This report, and companion reports on the Federal threatened Desert Tortoise (Krzysik 1994a) and the State threatened Mohave* Ground Squirrel (Krzysik 1994b) were motivated by extensive biological (Krzysik 1990a) and ecological (Krzysik 1991) assessments that the author conducted at Fort Irwin for the NTC and U.S. Army Forces Command (FORSCOM).

* Although the name of the desert is spelled with *j*, the name of the ground squirrel is correctly spelled with an *h*.

2 Site and Setting

Introduction

Fort Irwin consists of three management units: the National Training Center (NTC), Goldstone Deep Space Communications Complex, and Leach Lake Air-to-Ground and Air-to-Air Gunnery Range (also known as Leach Lake Bombing Range) (Figure 1). Fort Irwin is 2600 sq km in size, about the size of Rhode Island. The Goldstone complex (135 sq km) is leased and operated by the National Aeronautics and Space Administration (NASA) and the Jet Propulsion Laboratory (JPL). The Leach Lake Gunnery Range (369 sq km) is leased to George Air Force Base.

The U.S. War Department withdrew land from the public domain in 1940 and established the Mojave Army Antiaircraft Range (Camp MAAR). Camp MAAR was activated on 8 August 1940, and troops first occupied the post in June 1941. On 4 November 1942, the reservation was renamed Camp Irwin after Major General George Leroy Irwin, World War I battle commander of the 57th Field Artillery Brigade. During this period, the armored division of General George S. Patton's Third Army was trained at the installation. Patton also conducted maneuvers in other parts of the California desert. The post was put on surplus status on 8 September 1947, and the property was transferred to the War Assets Administration on 13 October 1948. Camp Irwin was reactivated on 16 July 1951 for training troops involved in the Korean conflict, and was under the command of the U.S. Sixth Army, with headquarters at the Presidio of San Francisco. Camp Irwin was redesignated as the Fort Irwin Armor and Desert Training Center on 1 August 1961, and the status of the fort was upgraded to a permanent Class I installation. Fort Irwin was again closed in January 1971 and placed on maintenance status under the jurisdiction of the California Army National Guard (CAARNG). The fort was used as a training ground for CAARNG troops from 1972 to 1980. In August 1979, Fort Irwin was selected as the site for the Army's National Training Center. The regular Army, under U.S. Army Forces Command (FORSCOM), resumed operation of Fort Irwin in January 1981, and the NTC was officially reactivated on 1 July 1981. The first NTC training exercise took place 13 April 1981, but the major force-on-force exercises began 17 January 1982. Therefore, there was a cumulative total of 35 years of military training activities on Fort Irwin before the NTC mission was implemented. The NTC was originally equipped to

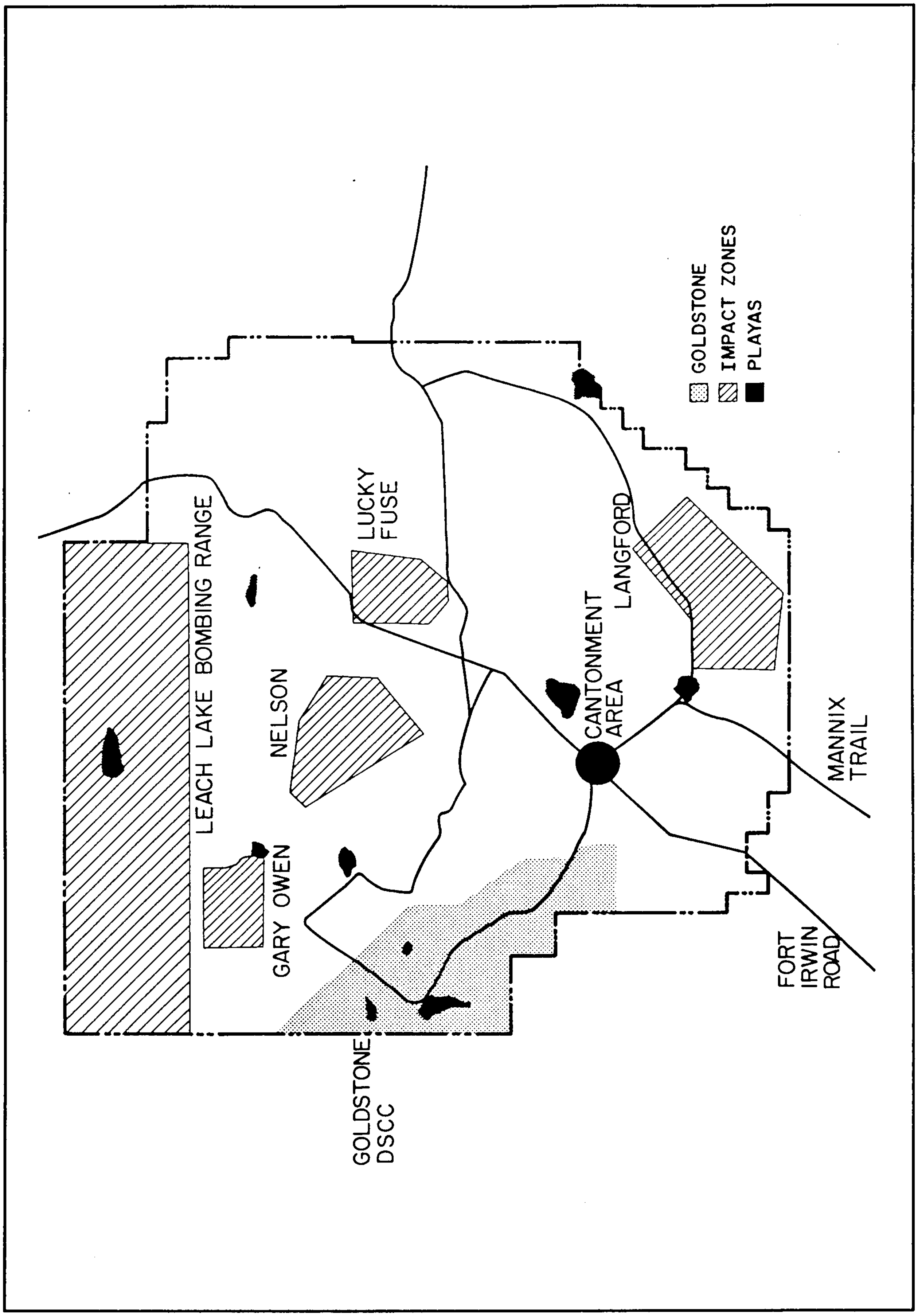

Figure 1. Fort Irwin, CA.

support battalion task force training. During the mid-1980s, the Army mission shifted to supporting brigade operations during a portion of each rotation.

Present Use

The purpose of the NTC is to provide tough, realistic combined-arms and combined-services training in accordance with current battle doctrine in a mid- to high-intensity environment. The conditions that prevail closely approximate those of actual combat. The climate and terrain are harsh, intensifying the stress and fatigue for soldiers and materiel. The NTC exposes soldiers—many for the first time—to a level of stress unequaled outside of actual combat. The NTC gives the commanders and soldiers a chance to train as they will fight, make mistakes, learn from them, and survive. The uniqueness of NTC activities is a critical component of its mission. The instrumented battlefield provides instant feedback and heightens learning at all levels. The NTC also provides a data source for training, doctrine, organization, and equipment improvement. The NTC is the premier warfighting academy in the nation.

The NTC is uniquely equipped and organized to provide tough, realistic wartime training to improve the combat readiness of heavy maneuver battalions and support units. Every year, 14 rotations, consisting of two heavy battalions and support units (approximately 4500 soldiers) come to the NTC for intensive combat training against an opposing force. During their 23-day stay at Fort Irwin, units experience 14 days of training that include both force-on-force and live-fire training. Units are equipped with the Multiple Integrated Laser Engagement System (MILES), which uses laser "bullets" to simulate the lethality and realism of the modern tactical battlefield. The system is highly valued for its ability to accurately assess battle outcomes and teach soldiers the skills required to survive in combat. Details of training are discussed later in this report, under "Training Mission." Two books describe battle activities at the NTC (Bolger 1986; Halberstadt 1989). The California National Guard often trains on the weekends between scheduled NTC training rotations.

The Goldstone site was selected in the spring of 1958. The original size of Goldstone was 189 sq km, but the NTC has gradually withdrawn lands for its own use in the northern and southern extremes of the site, including the Pioneer site in the northeastern portion. The primary activity at Goldstone is two-way communications with deep space probes and satellites such as those launched in the Pioneer, Ranger, Surveyor, Mariner, Viking, and Voyager flights. Between 1958 and 1987, the Goldstone network has provided support to 25 space flight projects involving 66 unmanned Earth-orbiting, lunar, and planetary spacecraft (NASA 1988). Six satellite tracking antennas (12 to 70 m diameter) are located at the five building complexes presently in use at Goldstone: (1) Echo, built in 1959 and enlarged in 1961 and 1978; (2) Venus, built in 1962; (3) Mojave, built in 1964; (4) Apollo, built in 1965; (5) Mars (built in 1966 and enlarged in 1988; (6) and Uranus, built at the Mars site in 1984 (JPL 1988). An additional building complex, the Pioneer site, was deactivated in 1981. In 1985 the Pioneer antenna was designated a National Historic Landmark by the U.S. Department of Interior.

Although Goldstone is off limits to Army training activities, the construction of a tank trail in 1985, which runs along the entire length of Goldstone, has provided the opportunity for occasional roadside bivouacs and off-road travel by tactical vehicles. The primary disturbances by Goldstone personnel have been the construction and maintenance of access roads—especially along power and communication lines—and the burying of power and communications cables. Construction activities have continued into the present. An additional antenna was added at the Mars antenna site in 1984, and one is presently being built at the Apollo site. The Pioneer site was returned to the NTC in 1985, and is presently being used as housing and laboratory facilities for visiting researchers, an oil analysis lab, and a target range (pistol, rifle, skeet) by the Fort Irwin Rod and Gun Club. The gun club comprises military and civilian personnel, and their target range was constructed in the summer of 1989. The buildings and other facilities at the Pioneer site are in poor condition. Off-road vehicle use is minimal at Goldstone since public access is denied and personnel are confined to paved and maintenance roads.

The Leach Lake Gunnery Range has operated since 1965. It is used regularly by the U.S. Air Force for live-bomb practice. It is off limits for ground use because of the high risk of unexploded ordnance. Military and civilian personnel working near the gunnery range have reported detonations induced by rapid atmospheric temperature changes.

Geography

Fort Irwin is located in San Bernardino county in southeastern California, about 65 km northeast of Barstow. Most of the land surrounding the installation is public land managed by the Bureau of Land Management (BLM). The western boundary of Fort Irwin is adjacent to Naval Air Weapons Station, China Lake (Mojave B Ranges). The southern boundary of Death Valley National Monument is close to the northeast boundary of the installation. The only established paved road and official entrance is Fort Irwin Road.

Geology

Fort Irwin is located in the Basin and Range geologic province. This geologic feature formed in the Cenozoic Era from movements related to the San Andreas and Garlock faults about 40 million years ago. Geological characteristics of the landscape are block-faulted mountain ranges separated by alluvium-filled basins. Rocks within the installation range from Precambrian metamorphic to Cenozoic volcanic and sedimentary. The Tiefort and Granite Mountains are primarily composed of granite, while the Avawatz consist of Precambrian metamorphic rocks older than 600 million years. Volcanics and intrusives of tertiary age (2 to 70 million years old) occur at Goldstone and adjacent Fort Irwin. The volcanics include basalt flows, andesites, volcanic tuff and breccia, plugs, and dikes. The Garlock fault, which is the second longest fault in the state (250 km), crosses the northern portion of Fort Irwin. This fault is a system of northeast- and east-trending faults that averages 11 km in width. The fault exhibits left lateral displacement that has been estimated at 80 m during the past 10,000 years. Other fault traces at the NTC show parallelism with the Garlock fault. The NTC is in Zone 4 of the "Earthquake Hazards of the U.S." map produced by the Earthquake Information Center. Zone 4 is described as an area where "major destructive earthquakes may occur."

Climate

The Sierra Nevada Mountains to the west, the Tehachapi range to the southwest, and the San Gabriel and San Bernardino Mountains to the south effectively isolate the Mojave Desert from precipitation. The desert receives winter rains (November to March) from storms originating in the Pacific Ocean that are pushed across the Sierra Nevadas. These winter rains can be persistent, but are generally of low intensity. In the spring, these storm systems move northward, and stronger storm cells originating in the Gulf of Mexico, moving west and northwest, dominate the Southwest. Therefore, the most eastward U.S. desert—the Chihuahuan Desert—is characterized by summer thunderstorms. The Sonoran Desert, lying between the Mojave and Chihuahuan, possesses a bimodal rainfall pattern with an east-west gradient representing the predominance of summer-to-winter precipitation. The Mojave receives occasional summer rains, which are highly unpredictable events, usually occurring in the form of brief, intense thunderstorms. Summer thunderstorms are not as important as the winter rains to primary productivity in the Mojave Desert ecosystem: most vegetation is dormant in the summer, high evaporation rates prevail, and runoff is very intense. Annual precipitation in the Fort Irwin region averages 6 to 8 cm. The amount is highly variable, however, both from year to year and from area to area (Krzysik, unpublished data from Goldstone and China Lake), and summer rains are particularly patchy across the landscape.

The mean high temperature for July is 39 °C (102 °F), and the mean low for January is -1 °C (30 °F) (Naval Air Weapons Station, China Lake, unpublished weather data spanning 20 years). These typically represent the hottest and coldest months, respectively.

Strong winds are common at Fort Irwin, particularly in the winter and spring. Winds of 30 km/hr are typical. Strong fronts may produce persistent winds of 60 km/hr, and occasional gusts of 80 to 120 km/hr have been recorded. These winds, when combined with the loose, fine sands of training areas, produce sandstorms in which visibility is reduced to only a few meters.

Topography and Terrain

Physiographically, Fort Irwin is located in the central Mojave Desert. This region is characterized by rugged block-faulted mountain ranges separated by alluvium-filled basins. The basins consist of broad valley plains, gentle sloping bajadas (ancient coalesced alluvial fans), and rolling hills with low relief. The lowest basins form playas, or dry lake beds. The eroding mountains produce talus slopes, boulder fields, and rocky or gravelly alluvial fans (pediments) that merge into the sandy soils and fine gravels of bajadas and plains. During moist periods in the geologic past, playas were ancient lakes. They now receive runoff and fine sediments from the surrounding uplands. The occurrence of standing water in these playas is brief and highly sporadic. A dominant visual feature of the landscape, especially impressive from an aerial view, is the extensive and complex dendritic network of canyons, arroyos, and washes. These ephemeral waterways are of high ecological value. They are maintained by the erosive power of water, and form the network of channels that transports water from all upland sites—mountains, alluvial fans, bajadas, and valleys—to the playas. Washes often form extensive networks of braided channels on bajadas with low relief. Other common features of the landscape include rolling hills with gravelly or rocky substrates, highly fractured boulder ridges, rugged outcrops of granite or volcanic basalt, desert pavement, and sand dunes. Springs and seeps are uncommon occasional features of the Mojave Desert landscape, but are, nevertheless, exceedingly critical for resident and migratory wildlife. The complex geomorphology of the Fort Irwin landscape is one of the main determining factors of its biodiversity patterns (Figure 2). Complex topography provides a diversity of local environments, microclimates, soils, and moisture gradients. This directly influences the spatial distribution and species composition of plant communities.

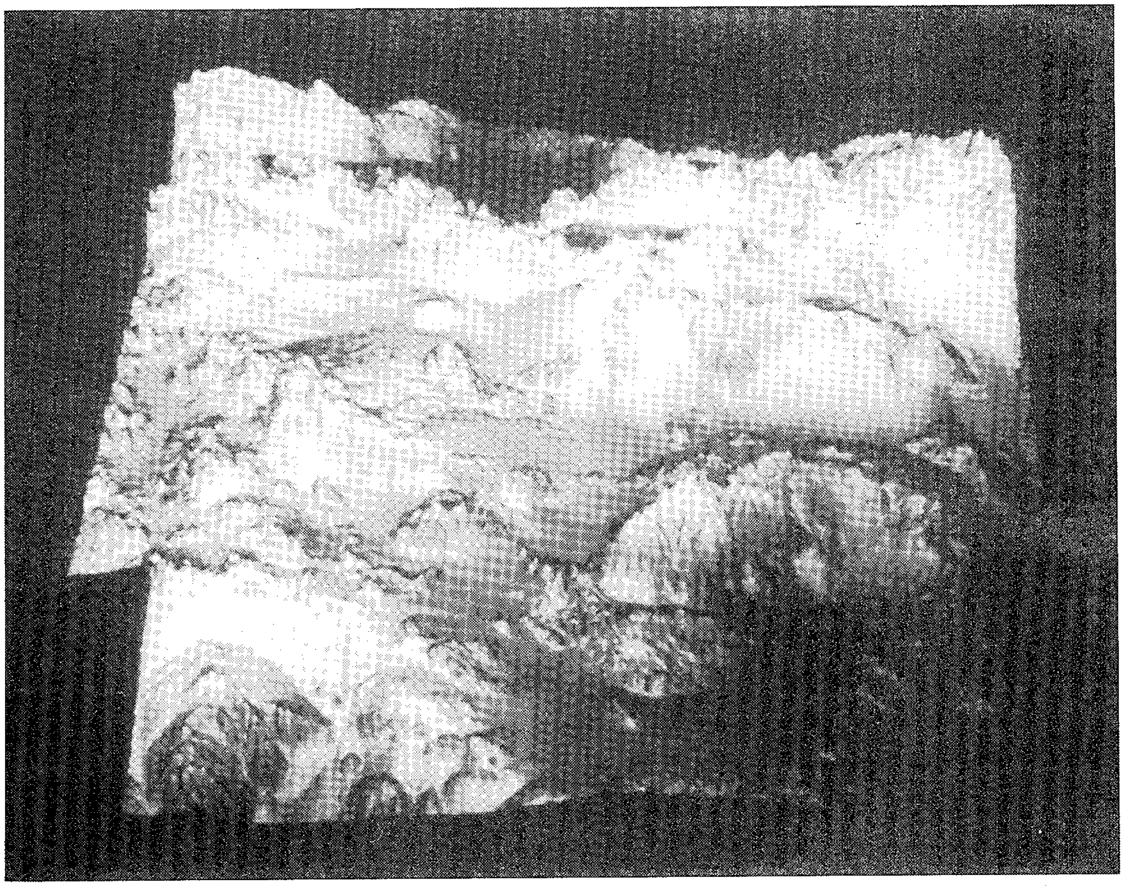

Figure 2. Topographical projection of Fort Irwin landscape.

Five mountain ranges, or portions of them, lie within the boundaries of Fort Irwin: the Granite, Tiefort, Avawatz, Quail, and Paradise ranges. The foothills of three additional mountain ranges—the Alvord, Soda, and Owlshead ranges—fall along the installation's boundaries. Avawatz's tallest peak (1876 m) lies 350 m outside of the fort's boundary. The highest elevation within Fort Irwin is nearby at 1865 m, in the northeastern portion of the installation and 200 m from the boundary. The lowest elevation is about 390 m, near Bitter Spring in the southeastern portion of the installation.

Soils

About 60 percent of Fort Irwin consists of bedrock at or near the surface. The remaining 40 percent is underlain by alluvial and lacustrine deposits. Soils and substrates are of three fundamental types.

One type represents the bare bedrock—usually mountains or hills—or associated shallow, stony soils that are rarely over 25 cm deep. About 30 percent of the fort is devoid of soil cover.

Another type of soil is represented by the sandy and gravelly soils on terraces, fans, bajadas, and nearly level sand plains. Particle size composition is generally poorly sorted. Soil depth may be a meter or more in valley plains, becoming progressively shallower higher up on bajada slopes. Soils derived from granitic rocks are silty-sandy-fine gravel in composition, while soils derived from decomposing volcanic rocks are silty-gravel.

The third type of soil is represented by the clays and silts that overlay strata of mixed coarse- and fine-grained soils. These silty-clays contain evaporated salts, and may be many meters thick. They form the basins called playas (dry lake beds).

Desert pavement is a characteristic of desert soils (Krzysik 1985). Coarser gravels remain on the surface after wind and water have removed the finer soil particles. Black or dark shiny coatings can often be seen on desert pavement gravels and rocks. This is *desert varnish*, formed by weathering, chemical, or biological action that deposits iron and manganese oxides. Algae, bacteria, and chemistry interact to form crusts and develop a cohesive integrity to the remaining surface particles. The complete process is not well understood. This armor surface, which may take hundreds or thousands of years to completely form, effectively protects desert surfaces from erosion caused by raindrop detachment, eolian (wind) and fluvial (flowing water) processes.

Water-impervious caliche layers are frequently encountered in the Mojave Desert. Caliche is a hardpan petrocalcic cement-like layer formed by the cementing action of calcium carbonate with such materials as pebbles, gravels, silica, and iron compounds (Schlesinger 1985). Caliche layers may be thick or thin, and they may occur near the surface of the soil or buried at great depths. These layers are commonly exposed in washes, where erosive forces scallop numerous small caves.

Hardened soil crusts form on clay or silty desert soils through the biological activity of resident cyanobacteria, green algae, and lichens. These cryptogamic crusts stabilize surface integrity and resist wind and water erosion from both raindrops and surface flows. These crusts also fix atmospheric nitrogen in low quantities, but these quantities are important to the nitrogen cycle in desert ecosystems (Skujins 1984).

Water Resources

Surface water is extremely scarce on Fort Irwin. The only naturally occurring permanent surface water resources are six springs that produce small quantities of water. Table 1 lists permanent and intermittent springs at Fort Irwin.

Table 1. Fort Irwin springs.

Name	UTM Coordinates
Permanent Springs	
Bitter Spring	NK 518982
Cave Spring	NK 516329
Devouge Spring	NK 382256
Garlic Spring	NK 327984
Leach Spring	NK 152342
Two Spring	NK 330335
Intermittent Springs	
Arrastre Spring	NK 545350
Desert King Spring	NK 260312
Drinkwater Spring	NK 366247
Noname Spring	NK 377228

*UTM: Universal Transverse Mercator

Jack Spring (NK 220898) is located approximately 100 m off-post. Fort Irwin and BLM have performed some maintenance on this spring.

All springs on Fort Irwin are off limits to tactical vehicles. To minimize the effects of military personnel and equipment on springs, field personnel are briefed before each training rotation on the location of springs and their off limits status. Fencing and metal crossbars have been erected at portions of the springs likely to be approached by tactical vehicles. This has reduced accidental damage to the springs.

The only permanent lentic (standing) waters on the installation are about 15 ha* of manmade effluent ponds and wetlands at the sewage treatment plant. These four ponds and a small lake are maintained by chlorine-treated water from the plant. A rich diversity of songbirds, waterfowl, shore and wading birds, and raptors use these ponds and wetlands. The area is very heavily used by migratory birds, but is also important to permanent resident, spring-breeding, and overwintering birds. The policy of Fort Irwin is to keep this ecosystem supplied with an adequate supply of water at all times to maintain the aquatic, wetland, and riparian communities.

Perennial streams do not occur on Fort Irwin, but are represented by ephemeral channels known as washes, or xeroriparian communities. Surface flows in washes are very brief events, and are generally associated with severe thundershowers. Washes are a very common feature of desert landscapes. They vary a great deal in width, depth, gradient, and substrate characteristics. Sandy washes are found where the terrain or eroded canyon floors are relatively flat. Washes become progressively rockier when their gradients become steeper. Runoff from washes and overland sheet flows eventually drain into playas (ephemeral desert lakes). Most of Fort Irwin's runoff accumulates in its own playas. However, southern portions of the installation drain into the Coyote and West Cronese lakes.

* ha: hectare; 1 ha = 10,000 m^2, or 2.47 acres.

Rainfall—either directly or as surface flow in washes or overland sheets—rapidly percolates into sandy and gravelly desert soils. However, much of the desert surface consists of mountains, exposed bedrock, caliche layers, and cryptogamic crusts that resist water infiltration. Additionally, the sparse and often dormant vegetation, small amount of litter, and low organic content of the soil cannot absorb much moisture. Therefore, an appreciable amount of precipitation ends up in playas. Playas have low infiltration rates because of the high clay content of their dense soils. The combination of high insolation—the high duration and intensity of solar energy received—high temperatures, low humidity, and high winds are responsible for very high evaporation rates. Therefore, playas possess highly alkaline and saline soils, and are often encrusted with alkali salts. Table 2 lists the names, locations, and sizes of the playas on Fort Irwin.

Table 2. Fort Irwin playas.

Name	UTM Coordinate	Area (ha)
Leach Lake	NK 290378	526
Goldstone Lake	NK 095130	500
Bicycle Lake	NK 340040	378
Red Pass Lake	NK 586025	342
Langford Lake	NK 345947	243
Nelson Lake	NK 205205	171
Drinkwater Lake	NK 425280	137
McClean Lake	NK 214275	117
Dixon Lake	NK 085192	18.1
Kent Lake	NK 133163	15.5

3 Plant Communities

Rowlands et al. (1982) divide the Mojave Desert into five regions: northern, eastern, central, southwestern, and southcentral. Fort Irwin is located almost dead center in the central region. Many biologists divide the Mojave Desert into four regions: northern, eastern, southern, and western. Under this classification, Fort Irwin is located in the western region of the Mojave. Floristically, the Mojave Desert represents a transition between two much larger deserts, the Great Basin to the north and the Sonoran to the southeast. Some scientists have suggested that the Mojave Desert should not be characterized as a separate physiographic entity, but as a transitional zone. However, since one-fourth of the Mojave's plant species are endemics, while nearly 80 percent of its 250 species of annuals are endemics, MacMahon (1988) argues that the Mojave Desert should maintain its individual status. The Mojave is botanically impoverished, particularly the central region. Brown et al. (1979) have recognized seven vegetation series in the Mojave Desert scrub. Four are present at Fort Irwin: creosote bush, saltbush, mesquite, and blackbrush. A fifth series, Joshua tree, can be found near the installation's southwestern and northwestern boundaries. The two Mojave Desert vegetation series not represented at Fort Irwin are the bladder sage and catclaw acacia series. The scientific names of many California plant taxa recently have been revised in a major study (Hickman 1993). Changed names are indicated by a "dagger" symbol (†). See Appendix for a table of revised nomenclature.

Creosote Bush Scrub Series

Shrubs

Creosote bush (Larrea tridentata) and burroweed (Ambrosia dumosa, also called burrobush or white bursage) form the most characteristic association of the Mojave, dominating the vegetation in 70 percent of this desert (Shreve 1942). With few exceptions, the creosote bush scrub series dominates at Fort Irwin. Commonly, over 90 percent of the woody vegetation cover is creosote bush, or a combination of creosote bush and burroweed. Burroweed is a much smaller shrub. It may often be numerically more abundant than creosote bush, but projected foliar cover and volume is generally (but not always) dominated by creosote bush. Occasionally at local sites, creosote bush may represent the only woody species. This species is associated with a very wide range of soil types and textures, from sandy or loamy to rocky. Creosote bush is abundant on well-drained sandy plains and flats, alluvial fans, bajadas (ancient coalesced fans), and the slopes of hills and mountains. It is also found in washes, on rocky outcrops, and on steep slopes, but it may no longer be dominant.

Creosote bush is limited by winter temperatures to elevations below 1500 meters (Vasek and Barbour 1988), and extends up fans and slopes to about the lower snow line (isoclimatic line for six consecutive days of freezing) (Shreve 1942). Beatley (1974) has also suggested that its northern limits may be influenced by excessive winter rainfall. Creosote bush is conspicuously absent around playas because of high salinity (Wallace and Romney 1972), or because the dense, fine-textured basin soils are low in oxygen (Lunt et al. 1973). Beatley (1975) has proposed that the dense cold air draining into lower basins may be an important feature limiting creosote bush on playas. Creosote bush and burroweed size and rigor are strongly influenced by water availability, and the largest individuals are characteristically found along the edges of washes and roads. Vasek and Barbour (1988) report that temperature may be a more important variable than rainfall in creosote bush productivity.

The species composition and diversity of shrubs co-occurring with creosote bush apparently depend on a variety of factors, many of them unknown. Important factors can be generalized to include annual rainfall, topographical complexity, soil type and texture, and community stability and age. In stable old communities, creosote bushes form circular or elliptical patterns. As shrubs die, new stems sprout from the roots, replacing the originals along the outer periphery. The resulting growth pattern is a ring or ellipse of satellite shrubs called a clone. The shrubs within a clone are genetically identical to each other and their ancestor (Barbour 1969, Johnson et al. 1975, Vasek et al. 1975, Sternberg 1976, Vasek 1980). Clones may be thousands of years old, and represent (at least genetically) some of the oldest known organisms. On rocky slopes, washes, and eroding soils where communities are younger, creosote bush occurs as individual shrubs.

Typical shrubs that occur within the creosote bush series at Fort Irwin are listed in Table 3. Common and widespread species besides burroweed include Mormon tea, desert thorn, cheesebush, desert senna, bladder sage, spiny hopsage, goldenhead, turpentine broom, and indigo bush. California buckwheat and krameria are abundant on gravelly bajadas and eroding granite slopes. (This buckwheat species is also an important member of the endangered California coastal scrub ecosystem.) Occasionally some of these species may be more abundant than burroweed (e.g., spiny hopsage), and in local communities like washes, rocky slopes, or boulder outcrops, some may even predominate over creosote bush. Gravelly or rocky alluvials are more diverse than valley bottoms. Granite boulder fields, limestone outcrops, local areas of alkaline

Table 3. Typical species within the creosote bush series at Fort Irwin.

Bladder Sage, Paper-bag Bush		Salzaria mexicana
Brickell bush, Incienso		Encelia farinosa
California Buckwheat, Wild Buckwheat		Eriogonum fasciculatum
Cheesebush		Hymenoclea salsola
Cotton-thorn		Tetradymia spinosa
Desert Senna, Desert Cassia		Cassia armata[†]
Desert Thorn		
	Desert Tomato	Lycium andersonii
	Peach Thorn	Lycium cooperi
	Rabbit Thorn	Lycium pallidum
Goldenbush		
	Cooper Goldenbush	Ericameria cooperi
	Cliff Goldenbush (granite)	Ericameria cuneata
	Showy Goldenbush	Ericameria linearifolia (Ericameria = Haplopappus)
Goldenhead		Acamptopappus sphaerocephalus
Indigo Bush, Dalea		
	Mojave Indigo Bush	Psorothamnus arborescens (= Dalea arborescens)
	Dotted Dalea	Psorothamnus polydenius (= Dalea polyadenia)
Krameria, Little-leaved Ratany		Krameria parvifolia[†]
Mormon Tea		Ephedra californica Ephedra nevadensis Ephedra viridis
Saltbush		
	Shadscale	Atriplex confertifolia
	Desert Holly (washes)	Atriplex hymenolytra
Spiny Hopsage		Grayia spinosa
Turpentine Broom		Thamnosa montana
Winter Fat		Ceratoides lanata[†] (= Eurotia lanata)

Note: There are many other smaller woody and semiwoody perennials in this scrub series; see text.

or saline soils, and springs or seeps are characterized by flora other than the surrounding creosote/burroweed scrub. Goldenbush is often associated with granite outcrops or granite-derived gravelly or rocky soils. Cooper goldenbush is probably the most common species of this genus at Fort Irwin, while cliff goldenbush and pungent brickellia (Brickellia arguta) occur in crevices at granite outcrops and boulders. Pygmy cedar (Peucephyllum schottii) may be abundant in rocky canyons at higher elevations. Seep willows (Baccharis sp.)[*] are characteristic species of desert springs and seeps, but may also be associated with major washes and canyons. Winter fat, cotton-thorn, chaffbush (Amphipappus fremontii), rabbitbrush (Chrysothamnus), and

* sp.: species.

species typically associated with other Mojave vegetation series, like saltbush (Atriplex sp.), may locally be common in creosote scrub. Shadscale is probably the best example of a saltbush that occurs in some creosote scrub communities. Many species of shrubs attain their largest sizes and greatest densities in washes. The best examples at Fort Irwin are Mormon tea, bladder sage, cheesebush, desert senna, and brickell bush.

Perennial Plants

Cactus is not a conspicuous element in the Mojave desert ecosystem, and this family is poorly represented in both abundance and species richness. Five species are readily seen at Fort Irwin. Beavertail (Opuntia basilaris) and silver cholla (O. echinocarpa) are widespread, but only locally common species, preferring gravelly or rocky slopes. Cotton-top cactus (Echinocactus polycephalus) can be very common locally on rocky slopes. Hedgehog cactus (Echinocereus engelmannii) prefers similar habitat as cotton-top, but is rarer and more local in distribution at Fort Irwin. Pencil cholla (O. ramosissima) occurs in sporadic large clumps, some covering 2 to 3 m^2. Scattered individuals can also be found.

Button encelia (Encelia frutescens) and desert croton (Croton californicus) are small, woody perennials common in sandy, disturbed, heavily used training areas of the installation. Other common perennials in these areas are prickly poppy (Argemone corymbosa), locoweed (Astragalus sp.), and jimsonweed (Datura sp.). Mojave aster (Xylorhiza tortifolia = Machaeranthera t.) and desert trumpet (Eriogonum inflatum—sometimes an annual) are abundant on gravelly or rocky slopes. Other common perennials include desert globemallow (Sphaeralcea ambigua), desert straw (Stephanomeria pauciflora), desert alyssum (Lepidium fremontii), sand mat (Euphorbia polycarpa[†] and E. albomarginata[†]), wishbone plant (Mirabilis bigelovii), desert parsley (Lomatium mohavense), and desert hyacinth (Dichelostemma pulchellum[†]). Prince's plume (Stanleya pinnata) and the desert lily (Hesperocallis undulata) are tall, showy plants that may be 1 m or more in height. Prince's plume is very impressive when it forms large monotypic stands, as the one on the southwestern edge of Goldstone. Other beautiful perennials, not often seen, are the desert Indian paintbrush (Castilleja chromosa[†]) and the closely related owl clover (Orthocarpus purpurascens[†]). The coyote melon or common gourd (Cucurbita palmata) is conspicuous in washes. Other perennials commonly encountered in washes are sandpaper plant (Petalonyx thurberi), hole-in-the-sand-plant (Nicolletia occidentalis), wild rhubarb (Rumex hymenosepalus), Prince's plume, desert tobacco (Nicotiana trigonophylla[†]), and sacred datura (Datura meteloides[†]). Woody perennials common in washes include Bush senecio (Senecio douglasii[†]), desert straw, and sweet bush (Bebbia juncea).

Big galetta grass (Hilaria rigida†) is the most abundant and widespread perennial grass at Fort Irwin. It is most abundant in sandy areas. Two other common perennial grasses are Indian rice grass (Oryzopsis hymenoides†), also partial to sandy areas, and desert needle grass (Stipa speciosa†).

Annual Plants

Annual plants are characteristic of deserts. Although small individually, they represent the most abundant and widespread flora at Fort Irwin. Since the Mojave Desert is characterized by a winter rainy season, annuals are most conspicuous in the spring (winter annuals), and are strongly dependent on the amount of winter rains. Winter rainfall greater than 15 mm is ideal for the germination of annuals (Vasek and Barbour 1988). Winter annuals may grow more vigorously after shrub destruction (Beatley 1966). Although a few annuals bloom in the fall in response to periodic and unpredictable summer thundershowers, autumn blooms are generally poor. This is in contrast to the Sonoran Desert, which experiences two blooming seasons—each with its characteristic species—in response to two rainy seasons.

The most abundant and widespread annual forbs on Fort Irwin are heron bill (Erodium cicutarium) (introduced from the Mediterranean), checkered fiddleneck (Amsinckia tessellata) (an invader from the coastal scrub ecosystem), and approximately 10 species of buckwheat (Eriogonum sp.). Other common annuals include pincushion flowers (Chaenactis sp., mainly C. fremontii), phacelias (Phacelia sp., especially P. tanacetifolia and P. fremontii), yellow frocks (Eriophyllum ambiguum), woolly daisy (Eriophyllum wallacei), desert dandelions (Malacothrix glabrata and M. coulteri), coreopsis (Coreopsis bigelovii), evening primrose (Camissonia sp., primarily C. boothii, C. brevipes, C. campestris, and C. claviformis), desert goldpoppy (Eschscholzia glyptosperma and E. minutiflora), lupines (Lupinus sp.), Mentzelia sp., (especially M. affinis), Gilia sp., forget-me-nots (Cryptantha sp.), desert chicory (Rafinesquia neomexicana), combseeds (Pectocarya sp.), yellow peppergrass (Lepidium flavum), purple mat (Nama demissum), chia (Salvia columbariae), Eriastrum sp., scale bud (Anisocoma acaulis), desert fivespot (Eremalche rotundifolia), desert sunflower (Geraea canescens), and Spanish needle (Palafoxia arida).

Annual forbs common in sandy habitats in heavily used training areas include Russian thistle or tumbleweed (Salsola iberica† = S. australis† = kali†, Asian exotic), desert primrose (Oenothera deltoides, and O. primiveris), sand verbena (Abronia villosa), and desert marigold (Baileya pleniradiata—sometimes a perennial).

A number of annuals in this locale are often overlooked. Picturesque small species include Mojave desert star (Monoptilon bellioides), desert monkey flower (Mimulus bigelovii), hairy lotus (Lotus tomentellus[†]), punctured bract (Oxytheca perfoliata), Langloisia sp., and Mohavea sp. Larger species include: California mustard (Thelypodium lasiophyllum[†]), tansy mustard (Descurainia pinnata), and introduced mustards (Cruciferae). Obscure species include woolly plantain (Plantago insularis[†]—can be very abundant locally), rigid spinyherb (Chorizanthe rigida, found only on gravel or rocky substrates), brittle spineflower (C. brevicornu), and desert velvet or turtleback (Psathyrotes ramosissima). The desert puffball (Podaxis pistillaris) (Gasteromycetes) is one of the few fungi encountered in the Mojave Desert.

Schismus and red brome grasses are extremely abundant and widespread annuals at Fort Irwin, responding in the spring to winter rainfall. Red brome (Bromus rubens[†]) is a European introduction that is abundant on gravelly bajadas. Schismus, a native of the Mediterranian region, is ubiquitous at Fort Irwin. It represents the major component of ground cover in sandy, heavily used training areas. There is disagreement about the species of this grass. A 1984 plant survey at Fort Irwin listed only Schismus barbatus in its inventory (U.S. Army Environmental Hygiene Agency 1984). A survey conducted in 1985 listed only S. arabicus (Lee and Ro 1986). The U.S. Fish and Wildlife Service (1988) survey in the Fort Irwin proposed expansion area only listed S. arabicus.

Saltbush Scrub Series

Saltbush scrub is often called the *alkali sink* community (Munz and Keck 1949) since these communities are typically found surrounding playas. The central portion of a playa consists of dense, fine-textured silts and clays forming a saltpan, where salinity typically exceeds 6 percent and plants are absent. At the edge of a playa is a horizontal gradient of salinity and alkalinity, the details dependent on site-specific geology, soils, and topography (Hunt 1966, Mitchell et al. 1966, West and Ibrahim 1968). Saltbush communities may also be associated with springs, seeps, or major washes. The transition between saltbush scrub and creosote scrub is usually surprisingly sharp, apparently in response to some combination of soil salinity, alkalinity, oxygen depletion, or winter cold-air flow into basins.

Hunt (1966) recognized three potential zones surrounding playas, each characterized by plant life forms: salt-tolerant phreatophytes, fresh-water phreatophytes, and xerophytes. The xerophytic phase occurs farthest from the playa, generally up fans or slopes, and is characterized by dry soils lying above the water table and low salinity/alkalinity. The phreatophytic (or halophytic) phase is characterized by the availability of groundwater to plant roots, and by a gradient of salinity/alkalinity. At most locations in the Mojave Desert this zone possesses high salinity or alkalinity.

Hunt's examples in Death Valley are illustrative. The upper fans of Death Valley contained creosote scrub. Farther down the slopes, closer to the playa, creosote bush graded into the xerophytic phase of saltbush scrub: desert holly (Atriplex hymenolytra) on gravelly fans, and allscale (cattle spinach) (A. polycarpa) on sandier and less salty fans. Desert holly is often associated with soils containing a high percentage of carbonate rocks. The phreatophytic bands began with honey mesquite (Prosopis glandulosa) if the salinity was less than 0.5 percent; next came arrowweed (Pluchea sericea), and sometimes common reed (Phragmites australis), when salinity was less than 2 percent; then saltgrass (Distichlis sp.), with salinity 1 to 3 percent (or sometimes higher); and finally pickleweed (Allenrolfea occidentalis), which tolerates 6 percent salinity—the highest of any vascular plant. Inkweed or seepweed (Suaeda moquinii) was found over a relatively wide range of salinities, with a salt tolerance between that of arrowweed and saltgrass. Four-winged saltbush (Atriplex canescens) was sometimes associated with arrowweed. At edges of playas, gradients in vegetation zones are not usually simple, since there is distributional overlap among vegetation, with the more salt-tolerant species overlapping into zones of lower salinity (Hunt 1966). Furthermore, in the interior edge of the playa, halophytes may occur in patches on soil mounds raised only several centimeters to decimeters—even a meter— above playa level (Vasek and Barbour 1988). These patches increase in size and density as the halophytic community grades into the xerophytic community.

Some researchers consider shadscale (Atriplex confertifolia) scrub as a distinct plant association in the Mojave Desert (e.g., Billings 1949, Turner 1982, Vasek and Barbour 1988). Brown et al. (1979) classify the shadscale scrub series as part of the Great Basin Desert, where it often occurs in broad valleys with alkaline soils. Like blackbrush (see below), shadscale—dominated communities are often found in the elevational or latitudinal transition between creosote bush scrub and sagebrush scrub. Sagebrush scrub is dominated by big sagebrush (Artemisia tridentata). The latitudinal transition represents the boundary between the Mojave and Great Basin Deserts. In the Mojave Desert, shadscale scrub is typically found on steep mountain slopes with heavy, rocky, arid soils in the northern portion of the desert. The transitional role of shadscale is apparently environmental, because the species tolerates lower temperatures than creosote bush and greater soil aridity than big sagebrush.

The three dominant species in Mojave Desert saltscrub are xerophytic and not particularly salt tolerant: allscale, shadscale, and desert holly (listed in their relative order of importance). All three species are abundant at Fort Irwin in suitable habitat. Good examples of saltbush scrub can be found at playas on Fort Irwin. There is a broad expanse of shadscale at the north end of Goldstone Lake. Other shrubs associated with shadscale at this locality are spiny sagebrush (budsage) (Artemisia spinescens), allscale, and desert tomato. Allscale becomes more abundant at the southern end of this playa, with four-winged saltbush appearing in several places. The Nelson Lake saltbush scrub is almost pure allscale, while at Drinkwater Lake the dominant Atriplex is four-winged saltbush. Russian thistle can often be found in saltbush scrub, especially in sandy areas. A tall, dense stand of this species can be found in the southwest portion of Langford Lake.

The Bitter Spring area has a well developed saltbush community with quail bush (Atriplex lentiformis), desert holly, allscale, and four-winged saltbush. Quail bush is the largest native saltbush, attaining heights and diameters of about 2 m at the spring's edge. It tolerates high alkalinity, and needs an ample supply of water. Arrowweed is a major species at the springs. Alkali goldenbush (Haplopappus acradenia†) is also characteristic. Other abundant species are saltgrass (Distichlis spicata), common reed, cattail (Typha latifolia), spikerush (Eleocharis sp.), and bulrush (Scirpus sp.). The latter five species possess high dispersal abilities, and rapidly and effectively colonize spring and seep areas in the desert. Desirable riparian trees like cottonwood (Populus fremontii), willow (Salix gooddingii), and desert willow (Chilopsis linearis) are found only as occasional individuals at Fort Irwin springs.

Four-winged saltbush is occasionally associated with major washes at the installation. Desert holly is commonly found in rocky (often steep) washes, with good examples represented in the southern portion of Fort Irwin. Shadscale is occasionally associated with the creosote bush series. This is not typical with other saltbush species. A mixed community of shadscale and creosote bush can be found just south of Goldstone Lake. Parry saltbush (Atriplex parryi) is a small saltbush, sporadically distributed at Fort Irwin. It has a higher salt tolerance than most saltbush species (Bradley 1970).

Many of the common species occurring in the creosote bush series also occur in the saltbush series, although generally in lower numbers. Characteristic species, restricted to the installation's alkali sink saltbush scrub, include molly (Kochia californica), inkweed, and pickleweed.

Mesquite Series

Mesquite is associated with springs at Fort Irwin. The largest stand of mesquite is located at Bitter Spring. This species is honey mesquite (Prosopis glandulosa). Screwbean mesquite (P. pubescens), a species less tolerant of salt, occurs at Paradise Springs along with honey mesquite. Both species of mesquite are found at Garlic Spring. The distribution of mesquite depends on available groundwater. However, groundwater does not have to be near the surface, since mesquite is characterized by exceedingly deep taproots. Mesquite along rivers is generally located on the higher secondary terraces. At Bitter Spring, mesquite is located on higher ground along the flow of the spring, and in the large wash below the spring where surface flow is ephemeral. The mesquite at Bitter Spring is very heavily parasitized by mistletoe (Phoradendron californicum). One of the most abundant and persistent shrubs at desert springs is saltcedar (Tamarix ramosissima, possibly = T. chinensis [Hickman 1993]). There is controversy about the taxonomy and nomenclature of southwestern Tamarix. This Asian native is widespread in the California deserts, and is increasing its dominance at Bitter Spring.

Blackbrush Series

Creosote bush is replaced by blackbrush (blackbush) (Coleogyne ramosissima) above elevations of 1500 m, and where the northern Mojave desert blends into the Great Basin desert. Blackbrush communities are widespread between 1200 and 1800 m on upper bajadas and rocky alluvial mountain slopes in the Mojave Desert. Blackbrush can tolerate lower winter temperatures than creosote bush, but apparently requires higher moisture and is not as drought tolerant. Most plant species in this community can be found in creosote bush scrub or juniper-pinon woodland. In southern Nevada, only 9.2 percent of the species found in the blackbrush community are restricted to that community only, in contrast to community restriction in 46.5 percent of the species in creosote bush scrub (Vasek and Barbour 1988). The blackbrush series is best represented at the extreme northeastern corner of Fort Irwin, in the Avawatz Mountains. Scattered junipers (Juniperus californica) are only found in this area, restricted to elevations above 1500 m. The Avawatz Mountains possess a unique flora at Fort Irwin, including the best example of yucca woodland; the area requires further botanical investigation. Fort Irwin does not include elevations high enough to support the juniper-pinon community.

Joshua Tree Series

Joshua tree woodlands border Fort Irwin to the southwest and northwest and occur in the Avawatz Mountains, but the tree does not occur as a dense series on the installation. Interestingly, the Joshua tree (Yucca brevifolia) encompasses the entire periphery of the Mojave Desert, with the exception of the southeastern portion. However, this species only occurs sporadically in the central portion of the desert. Joshua trees characterize the Mojave Desert, but at the southeastern boundary of the Mojave, Joshua trees continue southeastward into the Sonoran Desert west of Prescott, AZ. Because of their large size in relation to other vegetation, they appear to dominate a vegetation association. However, in a dense Joshua tree community in the eastern Mojave, Vasek and Barbour (1988) showed that this species ranked 14th in importance out of the total of 22 plants present. Importance values are based on the combination of density, cover, and frequency of occurrence in samples. In an extensive study of Joshua tree woodlands, Rowlands (1978) concluded that the species was found in many different plant communities, and was not restricted to any particular vegetation association. Furthermore, Joshua trees did not contribute substantially to quantitative descriptions of stand compositions. They are only vegetational dominants in the visual sense. However, even if Joshua trees may not be useful in classifying vegetation associations, they represent an important ecological component of the Mojave Desert ecosystem. Joshua trees provide important perching and nesting sites for birds. Fallen trees, branches, and leaf litter provide cover and foraging substrate for secretive and nocturnal lizards, including the desert night lizard (Xanthusia vigilis), banded gecko (Coleonyx variegatus), and Gilbert's skink (Eumeces gilberti).

Joshua trees are generally restricted to elevations between 900 and 1500 m, but they can be found down to 600 m. The upper elevation limit, as with creosote bush, is set by the number of consecutive days temperatures are below freezing. The lower elevational limits are generally attributed to greater moisture and lower evapotranspiration rates at higher elevations. However, Went's (1957) data suggest that after an individual reaches a given size, seasonal exposure to low temperature is needed for optimal growth during the following spring and summer. Joshua trees occur in the elevational transition between creosote bush scrub and juniper-pinon woodland. Therefore, they occur in the same elevational zone as blackbrush or shadscale. However, Joshua trees grow on sandy, loamy, or fine, gravelly loose soils on gentle slopes (Webber 1953, Turner 1982) while blackbrush and shadscale are found on heavy or rocky soils, often on steep slopes.

Most plant species found in Joshua tree woodlands are also common representatives of creosote bush scrub: big galleta grass, desert needle grass, Cooper goldenbush, bladder sage, Mormon tea, cheesebush, and pencil cactus. Other species of yucca are usually present with Joshua trees, especially mojave yucca (Yucca schidigera). At Fort Irwin, outside the Avawatz Mountains, Joshua trees occur as scattered individuals at higher elevations, primarily in western and northern portions of the installation. The mojave yucca is even scarcer.

4 Wildlife

Large Mammals

The only large mammals confirmed to live on Fort Irwin are wild burros (Equus asinus) and desert bighorn sheep (Ovis canadensis).

Burros and their sign are most readily observed at the spring areas. The Leach Spring area has the highest density of burros on the installation, with an estimated population of 40 to 50. Burros, their scats (feces), tracks, and browsing signs are frequently encountered at Bitter Spring and Cave Spring. Occasionally, fresh sign can be found near the installation's western boundary. BLM removed a herd of about a dozen burros in 1989 from Paradise Springs, just southwest of the installation. BLM's goal is to remove all burros from Fort Irwin, Naval Air Weapons Station, China Lake (NAWS), and Death Valley National Monument. Burros are considered a nuisance because they destroy vegetation (by eating and trampling it), and their feces contaminate aquatic ecosystems. They compete for forage with native desert species, especially the desert bighorn.

Over the past 5 years, California Department of Fish and Game personnel have reported numerous sightings of desert bighorns in the Avawatz Mountains (Vernon Bleich 1990, California Fish and Game, personal communication). These rugged, steeply rising mountains are in the northeastern portion of the installation and adjacent BLM lands. All sightings were from helicopter surveys. Bighorns are also found in mountain ranges that surround Fort Irwin, and their populations are expanding in the numerous mountain ranges of the eastern Mojave Desert (V. Bleich). There are authentic current records for the Owlshead Mountains, north of Fort Irwin. Forty bighorns have been released into the Eagle Craigs on China Lake, just west of Fort Irwin. There is a report that several bighorns crossed Interstate 15 and were seen in the Soda Mountains, southeast of Fort Irwin, but these were transients. Bighorns are a shy species, and the noise of Army maneuver activities and live-fire training probably discourages bighorns from using Fort Irwin to any appreciable extent.

There have been sightings of mountain lions (Felis concolor) on Fort Irwin. One helicopter pilot reported seeing one in the Tiefort Mountains, and another helicopter pilot reported seeing a lion in the Alvords, just south of the installation. Other sightings have been reported at the "Valley of Death" (southern corridor, the valley south of Tiefort), the "Golf Course" at the sewage ponds, and crossing the Fort Irwin road near the boundary of the installation. Historically, mountain lions probably did not occur in the Mojave Desert. In their extensive work on the vertebrates of the eastern Mojave Desert, Johnson et al. (1948) made no reference to the mountain lion. Lions were once abundant in the San Bernardino Mountains, which form the desert's southern boundary about 100 km from Fort Irwin. A few lions are probably still present there, but urban and recreational development have been extensive. Mountain lions are primarily associated with deer populations. Mule deer were introduced into several mountain ranges in the eastern Mojave Desert in the 1930s and 1940s. Within the past 30 years, mountain lions or their sign have been confirmed in 9 of 16 mountain ranges east of Fort Irwin: four sightings, four bighorn kills, one set of tracks, and four rumors (V. Bleich 1990). These lions are presumed to be transients. It is possible that this large predator is an occasional transient at Fort Irwin. Confirmed sightings have occurred in mountains from which Fort Irwin is visible. Prey on the installation could include burros, coyotes, and jackrabbits. Excessive noise levels and other disturbances create an unfavorable environment for this species at Fort Irwin, however.

Medium-Sized Mammals

Two medium-sized mammals, the coyote (Canis latrans) and the blacktailed jackrabbit (Lepus californicus), along with the raven, represent the most conspicuous fauna of Fort Irwin. Both of these mammals are abundant and widespread throughout the installation. Jackrabbits, responding to cover and food resources, are less abundant in training areas, where their density decreases proportionally to the loss of shrub and ground cover. Coyotes possess large home ranges and commonly move through even severely disturbed terrain. They readily dig up buried refuse at bivouac or rest sites. Coyotes are a nuisance at the housing section of the cantonment area, apparently feeding on refuse, pet cats, and pet dogs. The primary natural prey of coyotes are rodents and jackrabbits, but they are highly opportunistic, and feed on lizards, snakes, birds, etc. They frequently dig up rodents, and their diggings are evident throughout the installation.

Bobcats (Lynx rufus) are widespread and reasonably common at Fort Irwin. They are nocturnal and very shy, so they are difficult to observe. Their presence and relative abundance can be verified by their scat. Bobcats require extensive cover and are therefore found in rugged, rocky boulder outcrops, mountainous areas, or in dense vegetation cover. A bobcat lives at the sewage ponds near the cantonment area, an "oasis" where common reed and saltcedar thickets provide dense cover, and food is abundant (A. Krzysik, personal observation). Bobcats can live in any of the rugged hills or mountain areas of the installation, but are more abundant at Goldstone and along the boundaries of the installation where there is less noise and disturbance. Bobcats feed primarily on rodents and rabbits.

Kit fox (Vulpis macrotis) are widespread and common at Fort Irwin but, like bobcats, they are very shy and nocturnal. Their presence is primarily verified by their burrows and scats. Although they are more abundant in quiet and less-impacted areas, their burrows can occasionally be found in even severely disturbed training areas where there is very little vegetation. They feed on rodents, but based on examination of their scats by the author, their primary prey at Fort Irwin appears to be insects (especially beetles) and scorpions.

The desert cottontail (Sylvilagus audubonii) is common in various locations on the installation. It is primarily restricted to spring or seep areas, and is abundant at some of the tracking stations at Goldstone—especially the Echo site. This species requires more dense cover for escaping predators than does the jackrabbit. It may also need more succulent vegetation.

The badger (Taxidea taxus) is a rare resident of Fort Irwin. Despite extensive fieldwork, the author has seen only one individual, just south of the Mars site at Goldstone (20 April 1986). Badger presence is characterized by their large and extensive burrows, and by their extensive excavations of rodent burrows, the occupants of which are their main prey. There is an old badger burrow just west of the guard gate at Goldstone. There are also several badger burrow systems near the southern boundary of the installation and one in the central corridor, at the bottom of a bajada on the northeast slope of Tiefort.

The ring-tailed cat (Bassariscus astutus), an extremely shy nocturnal relative of the raccoon, is present, but rarely observed. It feeds primarily on rodents and—when available—wild berries and fruit. This animal is found in boulder outcrops, rocky canyons, and similar rugged habitats. On at least two occasions this species was seen by security guards at Goldstone—at the Venus site and at the Pioneer site. These sites offer appropriate habitat, and the guards provided accurate descriptions of the animal.

Small Mammals

Insectivores

The only record of shrews or moles on Fort Irwin is the author's 19 April 1984 capture of a desert shrew (Notiosorex crawfordi) on a volcanic basalt ridge, locally known as "thė whale," on the southeastern portion of the installation. The specimen was caught in a Museum Special snap-trap baited with peanut butter and oatmeal. This is not an optimal sampling method for shrews; they are more effectively sampled using pitfall traps—buried number 10 tin cans (i.e., 3-lb coffee cans) baited with tins of sardines perforated with holes. It will not be known if this species is common or widespread at Fort Irwin until adequate sampling is conducted with pitfall traps. No other species of insectivore are expected to be found on the installation. This capture may be a new range extension for the desert shrew, since its known range is limited to eastern and southern San Bernardino county.

Bats

There has never been a bat survey conducted at Fort Irwin. Bats are relatively common around the sewage ponds, the springs, pools of water at playas, rocky canyons, boulder outcrops, and mountainous regions. Bats are generally identified "in hand," so they must be captured by setting mist nets in appropriate habitat. The best place to set up mist nets for bats is over aquatic habitats: ponds, streams, springs, even small standing pools. Sampling is local; the nets must be monitored continuously to release captured specimens uninjured and minimize damage to the nets. One recently developed method shows great promise for easily and accurately conducting bat surveys. Bats in flight constantly produce acoustical radar signals, both to locate insect prey and to avoid obstacles in their paths. A sonograph system is used to record these signals in a graphical format. Since each species produces its own unique acoustics, species recognition is accomplished without harm to the bats, and without the bias of interspecific variation in catchability. One problem with this method is that bats often produce more than one type of sound, depending on whether they are feeding or navigating. Also, it has proven difficult to identify the various species of Myotis because their vocalizations are so similar.

Rodents

Extensive monitoring of rodent populations at Fort Irwin has been conducted by the author (Krzysik 1984, 1985, and in preparation). Most of these surveys have been limited to five large study sites. However, efforts have been made to sample most of the available habitat types on the installation. All species of rodents present at Fort Irwin are geographically widespread, and habitat type is more critical to their presence than spatial location within the installation. Additional sampling on the periphery of the installation is desirable for the possibility of documenting new range extensions. Additional sampling is also needed at all springs and seeps, in the Avawatz Mountains, and a few other identified localities. Three major habitat parameters in the Mojave Desert environment determine the composition of rodent communities: (1)

the extent of shrub cover and vegetation volume, (2) substrate texture (surface particle sizes), and (3) the presence of perennial surface water, or ground water close to the surface. However, floristics (plant species compositions) also play a role. Since the presence of water at springs and seeps produces dense and complex vegetation, it is impossible without experimental manipulations to judge if vegetation density, diversity, the presence of water, or some combination of these are the appropriate environmental features selected by the rodent community at spring areas. Scientific names of mammals are from Jones et al. 1992.

Pocket Gophers. The Botta's pocket gopher (Thomomys bottae) is widespread and relatively common at Fort Irwin. No other species of pocket gophers are expected to live within the installation. Capturing pocket gophers requires special traps, and these have never been used at the fort. However, the author has captured one in a Museum Special snap-trap (15 April 1983). The presence of gophers is evident from their characteristic diggings. These diggings are widespread at Fort Irwin, particularly in unimpacted valleys with deep sandy-loam soils. Gophers are absent where the soil has been compacted by training vehicles and vegetation has been drastically reduced. Pocket gophers are also found locally throughout the installation on gravelly, and even rocky, slopes, where there are pockets of suitable soil.

Ground Squirrels. The white-tailed antelope ground squirrel (Ammospermophilus leucurus) is very abundant and widespread at Fort Irwin. All ground squirrels are diurnal, so they make easy targets for predators. This species can be found in a variety of habitats, but it apparently requires good cover. Antelope ground squirrels are found in undisturbed creosote scrub, and in rocky areas. Granite or the black volcanic basalt rocky ridges (e.g., the Whale) offer appropriate cover, even in areas where shrub cover has been reduced by training vehicles. Also on bajadas, where shrub cover has been reduced, this species is still found along rocky washes where adequate cover is still available in the form of rocks and vegetation. On the south end of Goldstone Lake, antelope ground squirrels are found in a sand dune habitat where the primary vegetation is shadscale and Russian thistle. Therefore, they can also be associated with saltbush scrub.

The round-tailed ground squirrel (Spermophilus tereticaudus) has been captured on Tiefort's south bajada, in the broad valley south of Tiefort (southern corridor), and near the southern border of Fort Irwin. The species does not appear to be common. Sandy substrates were always typical at capture sites. In the southern corridor, shrub cover may be highly patchy because of habitat damage from tactical vehicles. This species has been captured where shrub cover losses are appreciable.

The Mohave ground squirrel (Spermophilus mohavensis) is a state threatened species. Its entire geographic range occupies a small area in southern California, but it may be common at a few limited localities. Fort Irwin lies in the northeastern extreme of its range. The author has trapped this species over a wide range of habitats between the southern corridor of the installation and Goldstone. The Mohave ground squirrel is uncommon at Fort Irwin, and populations appear to be highly fragmented. Most captures of this species have been in well developed creosote/burroweed scrub (20 to 25 percent shrub cover), with eroded granite substrate in the 3 to 10 mm particle size. This species has also been captured in saltbush scrub on both sand dune and silty/pebble substrates, on gravel/rocky alluvium, and in training areas with 2 to 6 percent shrub cover. The author has captured a morphological intermediate of the two Spermophilus species on the Tiefort southern alluvial. This individual may have been a hybrid.

These three species of ground squirrels are the only species expected at Fort Irwin. The Mohave ground squirrel is discussed in detail in a separate USACERL Technical Report, *The Mohave Ground Squirrel at Fort Irwin, California: A State Threatened Species* (Krzysik 1994b).

Heteromyid Rodents. Heteromyid rodents are kangaroo rats and pocket mice. These are by far the most abundant, widespread, and characteristic rodents of all North American deserts. Merriam's kangaroo rat (Dipodomys merriami) is abundant and the most widely distributed rodent at Fort Irwin. This species is found in a wide range of shrub cover, ranging from 1 to 30 percent, in both creosote and saltbush scrub, and prefers substrates that are sandy, silty, or gravels less than 1 cm in size. They may be absent on steep gravel or rocky slopes, but are present on gravel or rocky gentler bajadas when finer soils are found beneath the larger surface particles, or pockets of sandy substrates are available. Their burrows are often associated with creosote bush. On gravelly bajadas, suitable soil textures are found beneath creosote bush, and the roots may help to stabilize burrow walls. Kangaroo rats are important keystone species in the desert landscape. They are critical in maintaining ecosystem integrity. Long-term removal of kangaroo rats has caused dramatic habitat changes, from dominance by perennial woody vegetation to grasslands (Brown and Heske 1990).

The desert kangaroo rat (Dipodomys deserti) occurs in loose sandy substrates, such as sand dune areas and eolian sandy deposits around playas, or in disturbed training areas. This species is often associated with low shrub cover (less than 3 percent). Such habitats are prevalent in the southern corridor of Fort Irwin, where this species is locally common.

The presence of the panamint kangaroo rat (Dipodomys panamintinus) at Fort Irwin extends the known range for this species from western San Bernardino county. This species is probably more typical in yucca woodland. At Fort Irwin, the author has found this species to be associated with high shrub cover (20 to 30 percent) in creosote scrub, usually where there are many species of shrubs present. Substrates ranged from fine to coarse surface gravels overlaying silty to sandy substrates. This species has been captured at four sites in Goldstone. Although local in distribution, it is common at three of the four sites.

The great basin or chisel-toothed kangaroo rat (Dipodomys microps) has only been captured in two areas at Fort Irwin. The species is reasonably common around Goldstone Lake, where it occurs in shadscale scrub and, to a lesser degree, in mixed creosote bush/shadscale scrub. Three individuals have also been captured near the southern boundary of the installation in a diverse creosote bush scrub. This species was previously unknown in the Fort Irwin area, and is more characteristic of saltbush scrub and sagebrush in the Great Basin Desert to the north, and, to some extent, pinon-juniper associations in the Mojave.

The little pocket mouse (Perognathus longimembris) is the smallest and most abundant rodent in suitable habitat. The density of this widespread species is directly related to the extent of shrub cover in creosote and saltbush scrub. The little pocket mouse reaches its greatest densities at Goldstone in unimpacted valleys where shrub cover ranges from 20 to 30 percent. It is probably most abundant in creosote scrub, but is also very common in saltbush scrub. The species prefers fine gravel substrates (3 to 10 mm), but also sand, and it may be common on gentle bajadas where fine soils are covered with gravel measuring 2 to 6 cm.

The long-tailed pocket mouse (Chaetodipus formosus) is the most abundant rodent on gravelly or rocky slopes or hills. This species is primarily characterized by gravel substrates, and its burrows are often dug under rocks. The long-tailed pocket mouse is not as sensitive to shrub cover as the little pocket mouse.

The desert pocket mouse (Chaetodipus penicillatus) is apparently rare at Fort Irwin and has been captured primarily at Bitter Spring in association with quail bush. This species prefers sandy habitats.

Two additional heteromyids that may potentially occur on Fort Irwin are the San Diego pocket mouse (Chaetodipus fallax) and the great basin pocket mouse (Perognathus parvus).

Cricetid Rodents. The southern grasshopper mouse (Onychomys torridus) is found primarily in creosote, but also saltbush scrub. It possesses similar habitat requirements as the little pocket mouse, except that it is even more dependent on the availability of high shrub cover. The grasshopper mouse is absent in sparse shrub cover, while the little pocket mouse may be present at low densities. The grasshopper mouse also appears to be strongly partial to fine gravel, but may also be common on sandy substrates. This species may also be found on gravelly bajadas, but it is primarily found in valleys.

The deer mouse (Peromyscus maniculatus) is uncommon but widely distributed at Fort Irwin. This species may exhibit large variations in population density from year to year in response to rainfall-dependent primary productivity. This species is also associated with high shrub densities in creosote scrub, like the grasshopper mouse and little pocket mouse. However, unlike these two species, the deer mouse may also be locally common in the vegetation thickets associated with springs.

The canyon mouse (Peromyscus crinitus) is abundant in its specialized environment: boulder outcrops, canyons, rocky ridges, rocky washes, and any other very rocky environment. It is only a transient in the creosote scrub community on its emigration to more suitable habitat. This species and the pack rat are usually the primary (or only) rodent inhabitants of the rugged boulder fields that are common in the Mojave Desert.

The cactus mouse (Peromyscus eremicus) has been found primarily at Bitter Springs and Paradise Springs, where it is abundant. Vegetation associations are mesquite and saltcedar.

The brush mouse (Peromyscus boylii) and the pinon mouse (P. truei) occur in the general Fort Irwin region, but are associated with more productive plant communities, such as those found at high elevations where evapotranspiration rates are lower. Pinon pine and juniper woodlands represent a good example. This vegetation community is not represented at Fort Irwin, and is generally limited to elevations above 2200 to 2500 m in the Mojave Desert. The only potential Fort Irwin locality for these species would be in the Avawatz Mountains, where there are California junipers and complex plant communities.

The desert pack rat or woodrat (Neotoma lepida) is apparently heavily dependent on cover. This species is common in boulder outcrops, rocky ridges and hills, rocky canyons and washes, or any other rocky habitat. This species is commonly associated with canyon mice. Individual pack rats may also be associated with small isolated rock piles. Pack rats are also common in mesquite thickets at springs. Very rarely, a pack rat nest is constructed in the tangled thicket at the base of an old creosote bush.

The author has captured western harvest mice (Reithrodontomys megalotis) in moist vegetation thickets at Paradise Springs, just southwest of Fort Irwin, but not on the installation itself. This species is associated with productive grassy habitats and is expected to be found at the major springs on Fort Irwin.

Birds

Raptors

Ravens are the most conspicous bird at Fort Irwin, since they are abundant in the cantonment area of the installation. Although ravens have always been a component of the Mojave Desert fauna, their population density in the western Mojave has soared over the past two decades as a direct consequence of human influx into the desert. Important components of human-modified desert landscapes for ravens include roads (for road-kill scavenging), power transmission towers and fences (for nesting and perching), landfills and garbage dumps, water availability, and agriculture. Ravens are primarily predators and scavengers, but will also feed on agricultural products. They feed at refuse containers, field bivouac camps, landfills, and garbage dumps. Occasionally, up to 40 or more ravens can be seen at one time in the cantonment area where drinking water is available, such as the water pipe at Bicycle Lake and the sewage lake. There is some evidence that nesting pairs of ravens in the Mojave Desert sometimes feed hatchling desert tortoises to their nestlings, since juvenile tortoise carcasses with characteristic puncture wounds have been found accumulating at raven nests (Berry 1985; Esque and Duncan 1985; Woodman and Juarez 1988). The bird-damage control section of the U.S. Department of Agriculture has developed a controversial plan for reducing raven populations in the western Mojave Desert (see Krzysik 1989, 1994a).

Although ravens are seen most frequently at Fort Irwin because of their attraction to the cantonment area, red-tailed hawks, kestrels, and burrowing owls are common raptors throughout the installation. Red-tails feed on rodents, snakes and lizards. Kestrels feed primarily on large insects when they are available, and also on small rodents, lizards, and—occasionally—birds. Burrowing owls feed on insects and rodents, and occupy the abandoned burrows of ground squirrels, tortoises, badgers, and kit foxes. These owls are capable of enlarging, repairing, and modifying selected burrows. Coopers hawks are often seen at Bitter Spring and the sewage ponds. They feed primarily on birds. Golden eagles can usually be seen at the installation, especially at Goldstone and around the Tieforts. They may nest in the Tieforts and along the Goldstone-China Lake boundary. Their prey consists chiefly of jackrabbits and ground squirrels. Harriers migrate through the fort. In the spring they are often seen foraging for rodents in a characteristic low flight pattern. Prairie falcons are also occasional visitors, and may nest in rugged areas of the installation. Their preferred prey is ground squirrels. Great-horned owls are permanent residents, and screech owls and barn owls are seen occasionally. Long-eared owls migrate through Fort Irwin. The status of other owls on the installation is unknown.

Songbirds

The most abundant nesting bird at Fort Irwin is the horned lark, a widespread species that nests on plains and bajadas where there is appreciable bare ground. Population densities of this species has been found to be statistically similar in an unimpacted Goldstone valley and in the heavily impacted valley of the southern corridor (Krzysik 1984, 1985). The most characteristic bird of the creosote scrub is the black-throated sparrow, which tolerates some reduction of shrub cover. LeConte's thrasher is uncommon, but also a characteristic species of creosote and saltbush scrub. It requires spinescent (spiny) shrubs or cholla cactus (silver cholla on the installation) for its nests. The sage sparrow and verdin nest only in habitats with well developed shrub cover. Brewer's sparrows are common spring migrants whose populations vary appreciably from year to year. White-crowned and song sparrows are common winter residents and migrants, particularly around springs and the sewage ponds.

Flycatchers, although not as abundant as sparrows, are well represented in the Fort Irwin fauna. Western kingbirds, ash-throated flycatchers, Say's phoebes, and black phoebes can be found at springs or at the wastewater treatment facilities. Say's phoebe can also be found along rocky ridges or outcrops.

The rock wren is very common in rocky outcrops, ridges, and slopes. The loggerhead shrike can also be found in rocky areas, and in creosote scrub.

Structural diversity in the vegetation, such as is found in stands of Joshua trees, other yuccas, or well developed stands of silver cholla, attract cactus wrens, mockingbirds, Scott's orioles, and shrikes.

Other Birds

In addition to raptors and songbirds, a broad diversity of other bird taxa can be seen at the installation's sewage ponds and wetlands. Structural diversity, the abundance of vegetation, and the presence of aquatic habitats at springs and the wastewater treatment facilities attract many breeding (permanent and summer species), migratory, and wintering birds. *The ecological significance and biological importance of these habitats cannot be overstated.* Canada geese and, occasionally, white-fronted geese overwinter. Common waterfowl include ruddy ducks, cinnamon teal, mallards, and green-winged teal. Wading birds seen include black-crowned night herons, snowy egrets, great egrets, bitterns, and white-faced ibis. Coots are very common. Many species of shore bird and songbird are common migrants through these desert oases. More than 70 bird species have been observed at Bitter Spring and the wastewater treatment facilities (A. Krzysik and T. Clark [former Fort Irwin ecologist], personal observations). It should be noted that this number represents a minimal estimate because surveys have been infrequent, and primarily have been conducted in the spring.

Gambel's quail, widely distributed at Fort Irwin, are partial to spring areas and undisturbed locations with good vegetation cover. Chukar, a partridge introduced from Asia Minor, is found in rocky habitats and rugged canyons. Both of these species probably require a supply of perennial water.

Amphibians

No amphibian species has been reported as native to Fort Irwin. However, it is possible that introduced individuals may be found at some of the springs or wastewater treatment facilities. The nearest location of amphibians is at Paradise Springs, 1 km west of the southwestern tip of Fort Irwin. Confirmed species are the western toad (Bufo boreas) and the Pacific chorus frog (Pseudacris regilla) (A. Krzysik, personal observation). A resident who lives near the springs has described another tree frog seen in the area (Don Parker 1989, personal communication). On the basis of the observer's description, the frog would appear to be the California chorus frog (Pseudacris cadaverina). These three anurans were probably introduced (on purpose or by accident) into Paradise Springs. There is the remote possibility that one or both of the tree frogs may represent Pleistocene relict populations.

Lizards

Lizards represent the most conspicuous and abundant reptiles at Fort Irwin. Three very abundant species at Fort Irwin are the western whiptail (Cnemidophorus tigris), side-blotched lizard (Uta stansburiana), and zebra-tailed lizard (Callisaurus draconoides). The whiptail can be found in virtually any kind of habitat—valleys and plains, hills, bajadas, fans, slopes, and springs. Substrates vary appreciably, from sandy, to fine or coarse gravels, and rocky areas. Although this species is relatively common in training areas where shrub cover has been reduced, it reaches its greatest density in unimpacted habitats, where it actively searches for insects under shrubs and in litter debris. The side-blotched lizard requires cover. This small lizard is most abundant in rocky habitats, but it is present in lower densities where shrub cover is in the 20 to 30 percent range. This lizard is rare in training areas where shrub cover has been reduced and rocks are scarce or absent. The zebra-tailed lizard lives in open, sandy habitats, where it sits in the open looking for insects and scanning for predators. It reaches its highest densities in large sandy washes where vegetation is sparse. It also is relatively common in training areas where shrub cover has been reduced, and soils or desert pavement have been disturbed to produce sandy substrates.

The desert iguana (Dipsosaurus dorsalis) is another species that appears to prefer sandy substrates. Although patchy in distribution, it is relatively common at Fort Irwin, even in heavily used training areas with low shrub cover. The iguana is also encountered in some salt bush/creosote scrub sand dune areas, and fine gravel bajadas. This species is herbivorous, and feeds a great deal on burroweed.

The horned lizard (Phrynosoma platyrhinos) appears to be less common than the four species discussed above, but it is difficult to see because of its cryptic coloration and habit of "flattening itself and freezing" to blend in with the substrate. It appears to be most abundant on gravelly bajadas, but is common in valleys, and can be found in sandy or rocky areas. Although rare, it is found in heavily used training areas with low shrub cover. Ants are its primary prey.

Four less common species listed in order of estimated decreasing abundance, are the leopard lizard (Gambelia wislizenii), chuckwalla (Sauromalus obesus), desert spiny lizard (Sceloporus magister), and collared lizard (Crotaphytus insularis). All are large species. The chuckwalla is a sedentary herbivore found only in boulder outcrops. On hot days it can be seen sunning itself on a favorite boulder very close to an escape crevice. The dark coloration and frequent sunning, even in hot weather, must be an aid to digesting large amounts of plant material. The leopard and collared lizards are active predatory species that feed on insects and smaller lizards. These ecological trophic equivalents—animals with similar food habits—occur in different habitats. The leopard lizard is found in creosote scrub, and appears equally at home on sandy or gravelly substrates. Although more common in unimpacted habitats, the species does occur in training areas with reduced shrub cover. The collared lizard, like the chuckwalla, occurs in boulder outcrops, or in rugged rocky habitats. The desert spiny lizard is also partial to boulders and rocky areas, but in the case of this species, an isolated boulder or rock pile surrounded by typical creosote scrub is adequate.

Individuals can be seen sunning themselves on individual boulders, but escape is close by, either under a boulder or into a nearby rodent burrow.

The desert night lizard (Xantusia vigilis), banded gecko (Coleonyx variegatus), and Gilbert's or red-tailed skink (Eumeces gilberti) are nocturnal and very secretive lizards. Therefore, these species are very difficult to find or observe, even though they may be locally common. These species frequently use the downed trunks, branches, and leaf litter from Joshua trees or other yuccas for cover and foraging sites. Since yuccas are not prevalent at Fort Irwin, these species are probably rare on the installation. The author has observed four individual desert night lizards at Goldstone, all associated with Joshua tree debris.

Two other species of lizard may occur on Fort Irwin: the fringe-toed lizard (Uma scoparia) and the brush lizard (Urosaurus graciosus). The fringe-toed lizard is a sand dune specialist, and has been seen near the installation, just to the south. This species should be found in the southern portion of the installation where there is appropriate habitat. The brush lizard probably does not occur at Fort Irwin, but is abundant in the southern Mojave (A. Krzysik, personal observation). This species prefers a denser and more complex vegetation structure to climb on and forage for insects, and to escape predators.

Snakes

Snakes are very difficult to observe in the desert, because most are strictly nocturnal, and all are highly secretive. They usually hide in rodent burrows or piles of rocks and boulders. Even common species may never be seen. The three most common species of snake observed by the author at Fort Irwin are the sidewinder (Crotalus cerastes), red coachwhip (Masticophis flagellum), and gopher snake (Pituophis melanoleucus). The latter two species possess an active search strategy for finding prey. Both are crepuscular (active in early morning and evening), and even diurnal (active during the day). Therefore, it is not surprising that these species are encountered in the field. Coachwhips can be found in a wide range of habitats. Gopher snakes appear partial to gravelly bajadas. Sidewinders live on sand dunes, but the author has found them to be most abundant on the fine granite gravels in valleys, or on bajadas within 1 to 2 km of granite boulder outcrops. This habitat possesses dense populations of the little pocket mouse, probably the main prey of sidewinders. Speckled rattlesnakes (Crotalus mitchelli) are common inhabitants of rocky rugged hills and slopes. Despite intensive field work for many years at Fort Irwin, the only other snake species encountered in the field by the author have been patch-nosed (Salvadora hexalepis), long-nosed

(Rhinocheilus lecontei), shovel-nosed (Chionactis occipitalis), and glossy (Arizona elegans) snakes.

On the basis of field guide distributions and specimens examined by the author that were captured by personnel stationed at Fort Irwin, other species of snake occurring on the installation include the Mojave rattlesnake (Crotalus scutulatus), kingsnake (Lampropeltis getulus), night snake (Hypsiglena torquata), and leaf-nosed snake (Phyllorhynchus decurtatus). Based on the available habitat and environment at Fort Irwin, other species that may be found there include the ground snake (Sonora semiannulata), rosy boa (Lichanura trivirgata), blind snake (Leptotyphlops humilis), lyre snake (Trimorphodon biscutatus), black-headed snake (Tantilla planiceps), and striped whipsnake (Masticophis taeniatus).

Desert Tortoise

The desert tortoise is treated in detail in Krzysik and Woodman 1991 and in a separate USACERL Technical Report, *The Desert Tortoise at Fort Irwin, California: A Federal Threatened Species* (Krzysik 1994a).

5 Threatened, Endangered, and Sensitive Species at Fort Irwin

Introduction

The California Department of Fish and Game (May 1990, 1991) checklists comprise threatened and endangered (Federal or State) animals found in the state. In addition to these species, the California checklist also contains species that are known to be rare or declining in the state. They may not be in jeopardy in other parts of the country, or they are not Federally listed because other listings have taken a priority. These species are generally known as "sensitive species." Only three species officially listed as threatened or endangered on these lists have been observed on Fort Irwin: the desert tortoise, a Federal and State threatened species; the Least Bell's vireo, a Federal and State endangered species; and the Mohave ground squirrel, a State threatened and Federal Category 2 candidate species. The desert tortoise and Mohave ground squirrel are discussed in separate reports, currently in preparation. The *1989 Annual Report on the Status of California's State Listed Threatened and Endangered Plants and Animals* (California Department of Fish and Game, March 1990) lists 140 taxa of plants. With a single exception, there are no known listed Federal or State threatened or endangered plants on Fort Irwin. The U.S. Fish and Wildlife Service has recently proposed listing the Lane Mountain milk-vetch (Astragalus jaegerianus) as a Federal endangered species, and it is expected to be officially listed before this report is published (Ray Bransfield, Endangered Species Biologist, U.S. Fish and Wildlife Service, May 1992). A biological assessment of threatened, endangered, and sensitive species of animals and plants on Fort Irwin was submitted to the NTC and FORSCOM (Krzysik 1990a).

Birds

A Least Bell's vireo (Vireo bellii pusillus) was sighted by the author at Bitter Spring in the spring of 1986, and was presumed to be a transient. This species prefers riparian willow (Salix sp.) or seep willow (Baccharis sp.) thickets. Three Least Bell's vireos have been collected at Furnace Creek Ranch in Death Valley, north of Fort Irwin. Two of these were collected in 1891, the other in 1920 (Grinnell 1923). Least Bell's vireos still occur at Death Valley. Desert oases and riparian spring communities are important habitats for these migrants. Reported Federal and State expenditures for the conservation of Least Bell's vireo totaled $9.2 million in fiscal year 1990 (U.S. Fish and Wildlife Service 1991). Only the spotted owl generated more funding ($9.7 million).

With the exception of the Least Bell's vireo, no other Federal or State listed threatened or endangered bird species has been verified at Fort Irwin. Wide-ranging raptors such as the peregrine falcon and bald eagle (both Federal and State endangered), or Swainson's hawk (State threatened) may occur occasionally as transients on Fort Irwin.

The California Department of Fish and Game (May 1990, 1991) checklists include at least 11 sensitive bird species found at Fort Irwin. These include the golden eagle, burrowing owl, black-tailed gnatcatcher, and LeConte's thrasher, which breed at Fort Irwin; Cooper's hawk, prairie falcon, and yellow warbler, which occur on the installation and probably breed there; the northern harrier and long-eared owl, which migrate through the fort; and the white-faced ibis and California gull, which are transients at Fort Irwin. Four species of wading birds—the black-crowned night heron, snowy egret, great egret and great blue heron—commonly occur as transients at Fort Irwin, particularly at the sewage-pond wetlands. These four are considered by the California Department of Fish and Game (1991) as species associated with declining habitats, such as riparian zones and wetlands. Undoubtedly, with more searching effort—especially during the spring and fall—more bird species are expected to be added to the Fort Irwin fauna from the checklists.

Mammals

The California checklists include 11 species of bats. The nectar-feeding Mexican long-tongued bat (Choeronycteris mexicana) probably does not wander far from the Mexican border, and Townsend's western big-eared bat (Plecotus t. townsendii) is coastal in distribution. However, the other nine bat species on the list could be residents, migrants, or transients at Fort Irwin. Bats have good dispersal ability, are difficult to observe, and are secretive. Furthermore, species-specific ecological needs (including habitat requirements) and geographical distributions are not well known for bats. Bats are locally common at Fort Irwin, but the installation's bat population has never been studied or surveyed. Species composition, distribution, and abundance of bats are unknown at Fort Irwin. With the exception of bats, no other species of mammals on the California checklists occur at Fort Irwin.

Five of the nine species of bat that may occur as residents, migrants, or transients on Fort Irwin are also Federal Candidate 2 species: the spotted bat (Euderma maculatum), California leaf-nosed bat (Macrotus californicus), occult (or Arizona) myotis (Myotis lucifugus occultus), cave myotis (Myotis velifer brevis), and the California mastiff bat (Eumops perotis californicus). The California species of special concern are the pale big-eared bat (Plecotus townsendii pallescens), pallid bat (Antrozous pallidus), pocketed free-tailed bat (Nyctinomops femorosaccus), and big free-tailed bat (Nyctinomops macrotis).

A mammal that merits additional comment because of its irregular distribution is the Panamint kangaroo rat (Dipodomys panamintinus). This species is common in several localities at Goldstone, and is found in diverse creosote bush scrub. The subspecies present at Goldstone is presumably D. p. mohavensis. This subspecies typically occurs in yucca woodland in the western Mojave Desert, primarily in the foothills of the Sierra, Tehachapi, and San Bernardino Mountains. Another subspecies occurs to the north in the Sierra and White Mountains. Three other subspecies represent montane-isolated populations in the Argus, Panamint, and Providence Mountains (Hall 1981). Panamint kangaroo rats are local and patchy in distribution and are susceptible to problems caused by urbanization and development.

Amphibians and Reptiles

With the notable exception of the desert tortoise (Krzysik 1994a), no officially listed or potentially endangered, threatened, or sensitive species of amphibians or reptiles occur at Fort Irwin. However, the fringe-toed lizard should be considered a sensitive species.

Plants

Table 4 lists the sensitive plant species of the Fort Irwin region. Codes used by the Federal government or the State of California for classifying sensitive plant species are also defined in Table 4. The 1985 botanical survey for threatened, endangered, and sensitive plants at Fort Irwin, by Mark Bagley, Mary DeDecker, and John Chesnut (Lee and Ro 1986), represents the only survey of its kind for this installation. Because of time and personnel constraints this survey did not include all portions of the installation. The survey team located two taxa from the list given in Table 4: Lane Mountain milk-vetch, also known as Jaeger milk-vetch or Goldstone locoweed (Astragalus jaegerianus); and a subspecies or variety of Mojave indigo bush (Psorothamnus arborescens var. arborescens). The more common variety of the Mojave indigo bush is Psorothamnus arborescens minutifolius. The present accepted taxonomic treatment of this genus is from Barneby (1977). Barneby's classification was also followed by Hickman (1993). Barneby separates these two varieties solely by flower size. P. a. arborescens, the rarer variety, has the larger flower. Both varieties are found at Fort Irwin. Usually these species are allopatric—distributed in nonadjacent geographical regions—but when they are found in proximity, var. arborescens is found on open flats and bajada slopes, while var. minutifolius occupies rockier sites in foothill canyons (Barneby 1977).

Table 4. Sensitive plant species of the Fort Irwin region; status and ecological characteristics.

Scientific Name Common Family Name	Status*	Flowering Time	Elevation in meters in feet	Plant Communities	Habitat Preference	Nearest Location(s) to Fort Irwin
Androstephium breviflorum small-flowered androstephium Liliaceae	1. None 2. SP? 3. 2 4. 3-1-1	April-May	550-2300m 1800-7500 ft	Creosote bush scrub	Dry sandy to rocky soil	Cronese Valley 16 km SE of Fort Irwin; Black Mts.
Arabis shockleyi Shockley's rock-cress Brassicaceae	1. C-3C 2. SP? 3. 2 4. 3-2-1	March-June (May)	1280-2320m 4200-7600ft	Blackbrush, Sage-brush, Pinion-Juni-per woodland	Calcareous and dolomitic out-crops, ridgetops and rocky slopes	San Bernardino Mts.; Cottonwood Mts.; Last Chance Mts.
Astragalus jaegerianus Lane Mt. milk-vetch, Goldstone locoweed, Jaeger milk-vetch; Fabaceae	1. C-2 2. S2.2 3. 1B 4. 3-3-3	April-June	900-1220m 3000-4000ft	Creosote bush scrub, Joshua tree woodland	Granite low ridges and desert mesas in granite sand and gravel soils	Southwestern Fort Irwin and adjacent BLM Lands, see Table 5.
Astragalus nutans Lax-flowered locoweed Fabaceae	1. None 2. SP? 3. 4 4. 1-1-3	March-June (Oct.)	450-1950m 1500-6400ft	Creosote bush scrub, Joshua tree woodland, Pinion-Juniper woodland	Sandy flats and stoney washes in foothills, loose slopes and ridges	Old Dad Mt. east of Fort Irwin; Granite Mts. SE of Fort Irwin
Brickellia knappiana Knapp's brickellia Asteraceae	1. C-3B 2. SP? 3. 3 4. 3-1-2	Sept.-Oct.	750-1220m 2500-4000ft	Mixed desert scrub, Joshua tree woodland	Rocky slopes, can-yon bottoms and walls, along streams and large washes	Panamint Mts.; Black Mts.; and Kingston Mts.

*1. Federal (U.S. Fish and Wildlife Service)
2. California Department of Fish and Game, Natural Heritage Division (Natural Diversity Data Base)
3. California Native Plant Society Listing
4. California Native Plant Society R-E-D Code

Scientific Name Common Family Name	Status*	Flowering Time	Elevation in meters in feet	Plant Communities	Habitat Preference	Nearest Location(s) to Fort Irwin
Calochortus striatus Alkali or streaked mariposa lily Liliaceae	1. C-C2 2. S2.2 3. 1B 4. 2-2-2	April-June	750-1400m 2500-4500ft	Springs and seeps	Alkaline meadows and springs/seeps	Paradise Springs, 0.5 km SW Fort Irwin; Rabbit Springs; Lucerene Valley
Castela emoryi Crucifixion Thorn Simaroubaceae	1. None 2. S2.2 3. 2 4. 3-1-1	June-July	below 610m below 2000ft	Creosote bush scrub	Gravelly areas, often at the margins of small playas. More typical of Sonoran Desert	About 16 km east of Alvord Peak, 4 km south of Fort Irwin
Chorizanthe spinosa Mojave spineflower Polygonaceae	1. C-3C 2. SP? 3. 4 4. 1-2-3	April-July	640-1050m 2100-3500ft	Creosote bush scrub, Joshua tree woodland	Sandy washes and flats, occasionally on gravelly slopes	Barstow area
Cordylanthus tecopensis Tecopa bird's beak Scrophulariaceae	1. C-2 2. S1.2 3. 1B 4. 3-2-2	Aug.-Oct.	60-750m 200-2500ft	Springs and seeps	Alkaline meadows with high groundwater	Amargosa River; Saratoga Spring, Death Valley about 10 km NE of Fort Irwin
Coryphantha vivipara[†] var. rosea Viviparous foxtail cactus Cactaceae	1. C-3C 2. None 3. 1B 4. 3-2-2	May-June	1210-1830m 4000-6000ft	Creosote bush scrub, Joshua tree woodland, Pinion-Juniper woodland	Dry gravelly or rocky slopes, limestone soils	Kingston Mts.; New York Mts.; NE San Bernardino Co.
Cryphantha holoptera Winged cryphantha Boraginaceae	1. None 2. SP? 3. 4 4. 1-1-2	March-April	below 610m below 2000ft	Creosote bush scrub	Moist washes, rocky slopes, and gravelly places	Black Mts.
Cymopterus deserticola Desert cymopterus Apiaceae	1. C-2 2. S2.2 3. 1B 4. 3-2-3	April	700-1310m 2300-4300ft	Creosote bush scrub, Joshua tree woodland	Sandy flats in old dune areas	Kramer
Dudleya saxosa ssp. saxosa Panamint live forever Crassulaceae	1. C-3C 2. SP? 3. 4 4. 1-2-3	May-June	910-2150m 3000-7100ft	Creosote bush scrub, Pinion-Juniper woodland	Dry rocky or stoney slopes and in bedrock cracks	Pilot Knob, China Lake NAWS, Mojave B South Range; Panamint Mts.

Scientific Name Common Family Name	Status*	Flowering Time	Elevation in meters in feet	Plant Communities	Habitat Preference	Nearest Location(s) to Fort Irwin
Eriophyllum mohavense Barstow wooly-sunflower Asteraceae	1. C-2 2. S2.2 3. 1B 4. 2-2-3	April-May	670-910m 2200-3000ft	Creosote bush scrub, playas	In the open on slight rises or ridges on desert flats, in clayey or loamy soils, some-times with some fine gravel but never rocky, hard-pans close to surface	Historical sites near Barstow
Linanthus arenicola Sand linanthus Polemoniaceae	1. C-3C 2. SP? 3. 2 4. 1-2-1	March-early May	760-1210m 2500-4000ft	Creosote bush scrub, Joshua tree woodland	Sandy soils, at least some rich in gypsum	Ubehebe Crater, Cottonwood Mts. (Death Valley Nat. Monu.); Barstow; Daggett
Mimulus mohavensis Mojave monkeyflower Scrophulariaceae	1. C-2 2. S2.2 3. 1B 4. 2-2-3	April-June	600-900m 2000-3000ft	Creosote bush scrub, Joshua tree woodland	Sandy and grav-elly soils	Dagget; Barstow; Victorville; Ord Mts.
Phacelia mustelina Death Valley round-leaved phacelia Hydrophyllaceae	1. C-3C 2. SP? 3. 1B 4. 2-1-2	March-June	900-2150m 3000-7000ft	Creosote bush scrub, Pinion-Juni-per woodland	Often on carbon-ates, in crevices and on ledges on granitic, vol-canic & lime-stone rock out-crops and cliffs, playas	China Lake, Seep Spring, Mojave B South Range; Playas just SE of Fort Irwin; lime-stone mountains bordering Death Valley
Phacelia parishii Parish's phacelia Hydrophyllaceae	1. C-3C 2. S1.1 3. 1A 4. Under Review	April-July	600-1600m 2000-6000ft	Playas, creosote bush scrub, Joshua tree wood-land	Edge of playas, Alkaline desert flats and slopes with Atriplex	Coyote Lake, just south of Fort Irwin; Barstow area
Psorothamnus arborescens var. arborescens (=Dalea a.) Mojave indigobush Fabaceae	1. C-3C 2. SP? 3. 4 4. 1-1-3	April-May	400-800m 1300-2600ft	Creosote bush scrub, Joshua tree woodland	Sandy slopes and along washes, stoney flats on granitic bedrock, and in alluvial fans	Southwestern, southern, and central Fort Irwin

Scientific Name Common Family Name	Status*	Flowering Time	Elevation in meters in feet	Plant Communities	Habitat Preference	Nearest Location(s) to Fort Irwin
Puccinellia parishii Parish's alkali grass Poaceae	1. C-2 2. SH 3. 1B 4. 3-2-2	April-May	800m —— 2900ft	Springs and seeps	Alkaline meadows, springs and seeps	Rabbit Springs, Lucerne Valley
Sclerocactus polyancistrus Mojave fishhook cactus Cactaceae	1. C-3C 2. SP? 3. 4 4. 1-2-2	April-early June	600-2120m 2000-7000ft	Creosote bush scrub, mixed desert scrub, Joshua tree woodland, Blackbrush & Sagebrush scrub	Often on limestone, well drained soils on rocky, gravelly mesas, slopes & outcrops; granitic soils, but occurs on a variety of soils	Indian Springs, China Lake, Mojave B South Range
Selaginella leucobryoides Mojave spike-moss Selaginellaceae	1. None 2. SP? 3. 4 4. 1-1-3	non-flowering plant	600-2300m 2000-7500ft	Creosote and Shadscale scrub; Pinion-Juniper woodland	Crevices and sheltered places in limestone and dolomite	Panamint Mts.; Kingston Mts.
Sphaeralcea rusbyi var.eremicola Rusby's desert mallow Malvaceae	1. C-2 2. S1.3 3. 1B 4. 3-2-3	April-June	970-1500m 3180-4920ft	Creosote bush scrub	Gravelly to rocky clayish soils of bajadas, slopes, and arroyos	Death Valley National Monument; Panamint Mts.

Table 4. (Cont'd).

Description of Codes Used for Sensitive Species Status

Federal (Federal Register 1991)

C-1: Category 1 - Taxa for which the Service has on file enough substantial information on biological vulnerability and threat(s) to support proposals to list them as endangered or threatened species.

C-2: Category 2 - Taxa for which information now in the possession of the Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support proposed rules.

C-3A: Category 3A - Taxa for which the Service has persuasive evidence of extinction.

C-3B: Category 3B - Names that, on the basis of current taxonomic understanding, do not represent distinct entities meeting the Act's definition of "species".

C-3C: Category 3C - Taxa that have proven to be more abundant or widespread than previously believed and/or those that are not subject to any identifiable threat.

California Department of Fish and Game (August 1991)

SP?: Species listed as a "Special Plant" but status is unknown.

SH: All California Sites are Historical.

S1: Less than 6 EOs* OR
Less than 1000 Individuals OR
Less than 2000 Acres

S2: 6-20 EOs OR
1000-3000 Individuals OR
2000-10,000 Acres

S3: 21-100 EOs OR
3000-10000 Individuals OR
10,000-50,000 Acres

S4: Apparently secure within California, but factors exist to cause some concern; there is some threat, or somewhat narrow habitat. No threat number.

S5: Demonstrably secure to ineradicable in California. No threat number.

*EO = Element Occurrence. Equivalent to the locality in which a population of a given species is found.

Table 4. (Cont'd).

Threat Number: Second Integer (e. g., S1.2)

.1 = Very Threatened

.2 = Threatened

.3 = No Current Threats Known

<u>California Native Plant Society</u> (Smith and Berg 1988)

1A: Plants presumed extinct in California.

1B: Plants rare, threatened or endangered in California and elsewhere.

2: Plants rare, threatened or endangered in California, but more common elsewhere.

3: Plants about which we need more information - A review list.

4: Plants of limited distribution - A watch list.

R-E-D CODE: Three Integer Values.

R (Rarity)

1 - Rare, but found in sufficient numbers and distributed widely enough that the potential for extinction or extirpation is low at this time.

2 - Occurrence confined to several populations or to one extended population.

3 - Occurrence limited to one or a few highly restricted populations, or present in such small numbers that it is seldom reported.

E (Endangerment)

1 - Not endangered.

2 - Endangered in a portion of its range.

3 - Endangered throughout its range.

D (Distribution)

1 - More or less widespread outside California.

2 - Rare outside California.

3 - Endemic to California.

Data for Table 4 were obtained from:

Munz (1974), DeDecker (1984), Lee and Ro (1986), Smith and Berg (1988), California Department of Fish and Game (August 1991), Federal Register (1991), Hickman (1993), and Krzysik (personal observation).

The Lane Mountain milk-vetch is considered rare or endangered by the California Native Plant Society (Smith and York 1984), and has recently been proposed for listing by the U.S. Fish and Wildlife Service as an endangered species. The California Department of Fish and Game lists it as a "special plants" species. Species on this list are being reviewed for possible listing.

The Lane Mountain milk-vetch has been reported in only seven collections from the central Mojave Desert between Barstow and the southwestern portion of Fort Irwin (Table 5). The entire known range of this species lies within 24 km of Fort Irwin. The rare milk-vetch was found in the southwest corner of Fort Irwin, bounded by UTM coordinates 170958, 170952, and 177947 (Lee and Ro 1986). The plants were found on shallow rocky granite-derived soil, on low rises and ridges or low hills in creosote bush scrub. Nearly all 89 of the individual plants located were found growing within the canopy of another shrub. Fourteen different shrub species were involved, but about half of the milk-vetch individually were associated with burroweed—an abundant species in the area.

The Fort Irwin population of milk-vetch was examined in 1990, and some offroad vehicle damage to the habitat was found. Vehicles had driven over the low hills and through the milk-vetch population, and a small bivouac was set up next to it. Since 1990 was the third straight year of an extended drought in the Mojave Desert, individuals of this species could not be located. March 1991 was an exceptionally wet month, however, and two milk-vetch individuals were located in this area in May. A relatively fresh set of tank tracks was found immediately adjacent to one of the plants. Ray and Connie Bransfield of the U.S. Fish and Wildlife Service located a large number of individuals of this species in the spring of 1992 at the localities given in Table 5. (The winter of 1991-1992 was abnormally wet).

Given the species' restricted range, its possible narrow ecological requirements, and since many of the records in Table 5 are so old, recent observations of the milk-vetch at Fort Irwin and on adjacent BLM land suggest that this region may host the last population of this species. Therefore, the area needs complete protection from offroad vehicles, grazing, and other disturbances caused by human activity.

Barneby (1977) reports that Psorothamnus a. arborescens is locally plentiful in scattered areas in the southwestern Mojave Desert, in western San Bernardino and adjoining Kern counties. It is usually found in creosote bush scrub on granitic bedrock. The Lee and Ro (1986) survey found var. arborescens to be common and widespread in southwestern and central areas of Fort Irwin, associated with sandy decomposed granite soils. In the southwestern portion of the installation, plants were found throughout Sector B, western portions of Sector C, and at Goldstone in all of the area south of the junction of Goldstone and NASA roads. The plants were found in main washes and on sandy bajada slopes. In the central portion of the installation, var. arborescens was found on sandy bajada slopes, in wash and sheet-flow areas just north of the Tiefort Mountains (UTM coordinates 430100 to 452100; and 394100, 409108, 413094, 399092); and on the south bajada of the Granite Mountains in the vicinity of Four Corners (392116, 370116, 350140, 370163) (Lee and Ro 1986). The author has also found this variety to be common and widespread in large washes and on sandy slopes throughout the southern portion of Fort Irwin. The occurrence of var. arborescens on the installation extends the previous northern range of this variety.

Psorothamnus arborescens var. arborescens is considered by the California Native Plant Society to be limited in distribution, but not endangered. It is Federally designated as a Category 3c species (widespread or not threatened at present). In California's Natural Diversity Data Base, it is considered a special plant.

Table 5. All known localities of the Lane Mountain milk-vetch, a Federal endangered species.

1.	Ten miles northwest of Paradise Rocks (Range?). Sec 21, T31S, R47E. 3400 ft. E.C. Jaeger s.n. (DS). April 16, 1939.
2.	Six miles northwest of Paradise Rocks (Range?). E.C. Jaeger s.n. April 1939. At about the same place as the type collection, Munz 16580.
3.	Type locality. Two miles south of Jay Mine, about 12 miles south of Goldstone (town) and 30 miles northeast of Yermo. Sec 33, T13N, R1E. About 3000 ft. P.A. Munz 16580 (Holotype, POM; isotype, CAS, GH, K, MO, WS). April 26, 1941.
4.	Fifteen miles north of Barstow on road to Superior Dry Lake. Sec 33, T12N, R1W. 3700 ft. P.A. Munz 16581 (RSA). April 26, 1941.
5.	Thirteen miles north of Barstow. Ripley and Barneby 3297 (NY, RSA). May 2, 1941.
6.	Southwest corner of Fort Irwin. UTM coordinates 170958, 170952, and 177947. April 11 and May 5, 1985. Lee and Ro (1986).
7.	About 4 km west of locality No. 6 on BLM land. Spring 1989. Mark Bagley.

6 Training Activities at the National Training Center

The Training Mission

The information and data in this section have been provided by the National Training Center (NTC) at Fort Irwin, and obtained from two books describing the training mission at the NTC; *Dragons at War: 2-34th Infantry in the Mojave* (Bolger 1986) and *NTC: A Primer of Modern Land Combat* (Halberstadt 1989).

The NTC portion of Fort Irwin is topographically divided into three regions, each representing a major training area. Live-fire exercises are primarily conducted north of the Granite Mountains. South of the Granites and north of the Tiefort Mountains is the central corridor, and south of the Tieforts is the southern corridor. These corridors comprise two large valleys, where massive force-on-force battle exercises take place.

The Training Forces

The NTC's main training mission is supported by intensive war game scenarios between opposition and American forces. The 177th Armored Brigade, permanently stationed at the NTC, is thoroughly trained in threat tactics and doctrine. This NTC brigade consists of two maneuver battalions: the 1st Battalion, 63d Armor; and the 1st Battalion (Mechanized), 52nd Infantry. The main arsenal of an armor battalion is the tank, and for a mechanized infantry battalion it is the M2 Bradley, which is rapidly replacing the armored personnel carrier (APC). M2 Bradleys may be thought of as fast, agile, lightweight tanks. The NTC units are known as the OPFOR (Opposing Force), and the two battalions are combined and organized as a Motorized Rifle Regiment. OPFOR currently operates at a strength of about 2200 soldiers, 265 tracked vehicles (tanks and APCs), and 635 wheeled vehicles. OPFOR tracked vehicles and support equipment are visually modified with fiberglass panels to represent the threat force.

The OPFOR opponent is the American force, or BLUEFOR. These commands are the rotational units that arrive at Fort Irwin from other Army training installations around the country. These units have already been well trained in standard U.S.

doctrine, and they generally rely on the latest tactical vehicles and equipment. The combined strength of a rotational unit is about 5500 soldiers, 500 tracked vehicles, and 1000 wheeled vehicles. Most vehicles used by BLUEFOR are maintained and stocked at Fort Irwin, but additional vehicles are also brought in during each rotation.

Another group involved in the NTC's training mission is the observer controllers (OCs), who come from the NTC Operations Group (OPS GRP) permanently stationed at Fort Irwin. The OCs function as referees for the various battle scenarios. They are in the field with BLUEFOR, observing, analyzing, and counseling the units on their performance throughout the planning, preparation, and execution of all missions. The OCs also assess and determine the "casualties" from simulated battlefield scenarios and weapon systems not represented by the MILES system. The size of the OC group is approximately 700 personnel, 42 tracked vehicles, and 460 wheeled vehicles.

A brigade comprises from two to five battalions. The rotational units coming to train at NTC typically consist of an armor (tank) battalion and a mechanized infantry battalion. Generally one rotational battalion at a time engages an OPFOR regiment. This gives OPFOR a 3:1 superiority, comparable to expected conditions on an actual battlefield. The main firepower of the combat units on both sides, and which is emphasized in the NTC's war scenarios, comes from armored vehicles—tanks and a variety of APC-type vehicles. The modern U.S. tank is the M1, but both the M1 as well as the older M60 are used. The main gun of the M1 is the 105 mm cannon (120 mm in the latest version). A variety of antitank and antipersonnel projectiles can be fired from these weapons. The M1 also carries one .50 caliber machine gun and two 7.62 mm machine guns. The APCs typically carry the .50 caliber machine gun and up to 11 combat troops. Modifications or upgrades of some APCs include the addition of 81 mm or 107 mm mortars; and the Improved TOW* Vehicle (ITV), which adds a TOW missile launcher mounted to the chassis and a smaller 7.62 mm machine gun. The TOW missile is the Army's principal antiarmor weapon. It is extremely accurate, and has a range of 3000 m. Newer versions have even greater range. The modern U.S. armored combat vehicle, the M2 Bradley, carries a 25 mm cannon, a TOW missile launcher, two 7.62 mm machine guns, and six mounted 5.56 mm rifles. The modern replacement for the jeep is the larger, more powerful High Mobility Multi-Purpose Wheeled Vehicle (HMMWV, or "Hummer"), which can also mount a TOW missile launcher or a heavy machine gun.

* TOW: Tube-Launched, Optically-Tracked, Wire-Guided (missile).

Force-On-Force Training

There are five fundamental missions (and variations) conducted at the NTC in the force-on-force combat exercises: (1) movement to contact, (2) hasty attack, (3) deliberate attack, (4) hasty defense, and (5) deliberate defense.

A *movement to contact* is conducted to gain or maintain contact with the enemy and develop the situation for a hasty or deliberate attack. The movement is characterized by a lack of information about the enemy, minimum combat power forward, and movement techniques that optimize flexibility and security. The lead company is deployed in a wedge formation, with one forward platoon and two trailing flank platoons. The companies trailing the lead company are deployed in column formation. The area covered in such a mission is 15 to 45 km long by 15 km wide, but most vehicles in the trailing elements are in a column along a well defined route. Two or three movement-to-contact missions are conducted at the NTC during each rotation.

The *hasty attack* is designed to exploit an opportunity, and gain or maintain the initiative. It is characterized by quick advance planning and coordination. Speed, violence, and rapid concentration of overwhelming combat power are used to stun or destroy the enemy. A hasty attack develops when (1) a movement to contact results in an engagement, (2) unexpected contact is made during a deliberate attack, (3) a further advance is ordered at the end of a deliberate attack, or (4) a counterattack is ordered when an unanticipated opportunity arises. The hasty attack is typically executed at the company level, and the size of the area involved depends on a wide variety of variables.

The *deliberate attack* typically occurs with a larger task force. It generally assumes that the enemy is established in a strongly held and well prepared defensive position that cannot be overcome with a hasty attack. The deliberate attack is designed to break through a defense into the weak area behind the lines. Usually there is sufficient time to obtain detailed information about enemy positions and strength, and to prepare the attack strategy. Since the enemy is well entrenched, a large force is required to penetrate and secure key positions identified in the terrain.

Defensive operations are undertaken to (1) destroy the enemy, (2) repel an enemy attack, (3) gain time, (4) concentrate forces elsewhere, (5) wear down enemy forces before an attack, or (6) retain key or decisive terrain. The primary difference between a hasty defense and a deliberate defense is the time allotted for preparation and planning.

In a *hasty defense*, the company conducts defensive operations as part of a larger force.

The *deliberate defense* incorporates preparation, planning, and key coordination with engineering support elements. Tank ditches, mine fields, concertina wire, foxholes, digging-in of tanks and APCs, and the exploitation of any landscape obstacles are all important strategies in a well planned, well executed deliberate defense. Fundamentally, the defense unit fights from covered, reinforced, and prepared positions, optimizing its use of the environment and terrain.

The realism of the force-on-force battle scenarios depends on the Multiple Integrated Laser Engagement System (MILES). In these simulated battles, eye-safe laser beams replace bullets, missiles, and artillery projectiles. All weapons on the battlefield are equipped with a small device that emits a pulse of light energy when activated by a blank but noisy round. All tactical vehicles and soldiers are equipped with multiple sensors to detect laser hits. Laser hits on a specific target are distinguished as a near-miss, a cripple hit, or a kill. The laser signals are coded to replicate the destructive power and range of the weapon being used. In other words, a rifle or machine gun laser cannot kill a tank—a TOW or tank-cannon-coded laser is necessary. However, a sniper with a rifle can kill a tank commander whose head is exposed. A killed target is out of the battle, since weapons are programmed not to function after a kill. The OCs possess "keys" to reactivate killed targets. As realistic and effective as MILES is for simulating combat with tanks, APCs, missiles, and infantry, it cannot realistically address other potent battlefield weapons such as minefields, artillery, mortars, aircraft strikes, antiaircraft guns, and chemical weapons. This is where the judgments of the OCs are critical. The OCs carry a pistol-sized master controller gun capable of killing any vehicle or soldier.

All spatial and temporal battlefield information generated by MILES, and enhanced by additional detailed data from the OCs, is sent to, analyzed, interpreted, and displayed by computers located in the Core Instrumentation Systems Building in the cantonment area of Fort Irwin. This complete analysis of force-on-force exercises under virtual combat conditions is the unique offering of NTC. The complete analysis is provided to the visiting unit as a take-home package to enhance future training at its home station. No other Army on earth can experience such realistic combat simulation and receive such a thorough proficiency evaluation without suffering casualties.

Live-Fire Training

The other important component of a rotational group's training is the live-fire exercises. Most live-fire training takes place within an extensive network of automated targets in the northern part of Fort Irwin. Machine guns, rifles, and the cannons of tanks and APCs use real ammunition. Live Hellfire missiles, 2.75 in. (70 mm) rockets, and TOWs are fired, but more advanced or powerful missile and rocket systems retain their MILES laser capabilities, because of the cost of using the actual responses. The firing units must also cross minefields, negotiate concertina wire, and deal with other obstacles while engaging the enemy. Sequential pop-up targets simulate progressive movement by the enemy, including alternating frontal and flank views to simulate movements around obstacles or responses to terrain contours.

Table 6. Total rounds fired at Fort Irwin Multipurpose Range Complex, 1981 to 1990.

Weapon	Rounds Fired
Pistol	435,690 (.45 cal, 38 spec, 9mm)
Rifle	2,633,701 (5.56 mm)
Shotgun	9,028 (12 ga)
Light Machine Gun	2,056,275 (7.62 mm)
Heavy Machine Gun	570,396 (.50 cal)
Grenade Launcher	305,686 (40 mm)
APC Cannon	232,188 (25 mm)
M1 Tank Cannon	36,655 (105 mm)
Other Tank Cannon	3,909 (35 mm, 90 mm)
Antitank Missles and Rockets	1,250 (60 mm, 80 mm, 84 mm)
Mortar	1,822 (4.2 in.)
Hand Grenade	3,447
Small Arms (Pistols, Rifles, Shotguns)	3,078,419
Machine Guns	2,626, 671
Grenade Launchers, Missiles, Rockets	306,936
Tank and APC Cannons	272,752
Hand Grenades	3,447
Mortars	1,822

Another important live-fire training complex is the much smaller Multipurpose Range Complex, located on Goldstone Road just east of Goldstone, which contains Ranges 1 through 8A. This range complex is used for small arms fire (rifle, pistol, and shotgun), both light and heavy machine guns (7.62 mm and .50 cal), grenade launchers, tank and APC cannons, mortars, antitank missiles, and hand grenades (Table 6). Most of the large projectiles used there are not explosive, but are TPT (training proficiency test) or high-velocity APDS (armor-piercing discarding sabot) rounds.

Magnitude of the Mission

As discussed earlier, armed forces training has been taking place at Fort Irwin since 1940, with training peaks during World War II, the Korean conflict, and the Vietnam conflict. The California National Guard used the installation extensively before it was reactivated as the NTC. In 1981 there were only three rotational exercises conducted at the NTC—on 13 April, 1 August, and 9 November. These exercises were not comparable to the present training mission since OPFOR was not involved. The first rotational training unit engagements against OPFOR took place on 17 January 1982. Including the three 1981 units, a total of 104 rotational units had trained at NTC through 1989 (Figure 3). This represented 1541 days in the field between 1981 and 1989 (Figure 4).

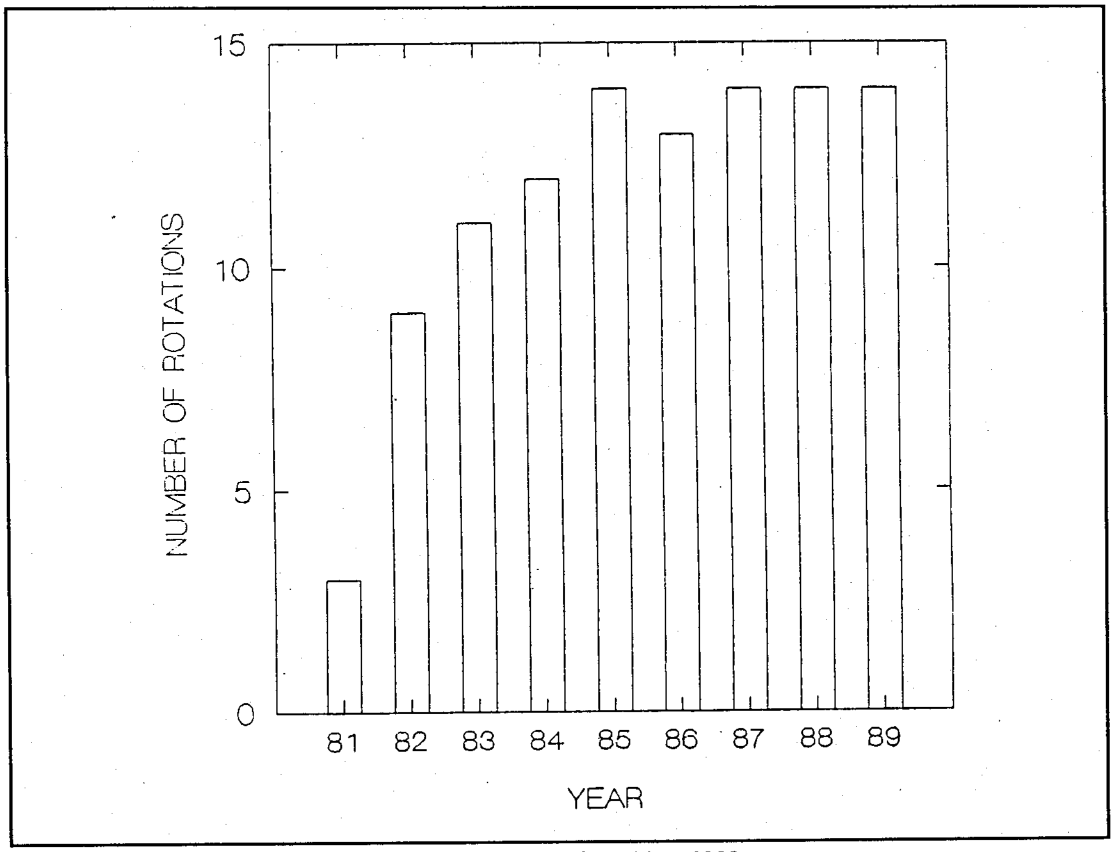

Figure 3. Annual number of training rotations at NTC, 1981 to 1989.

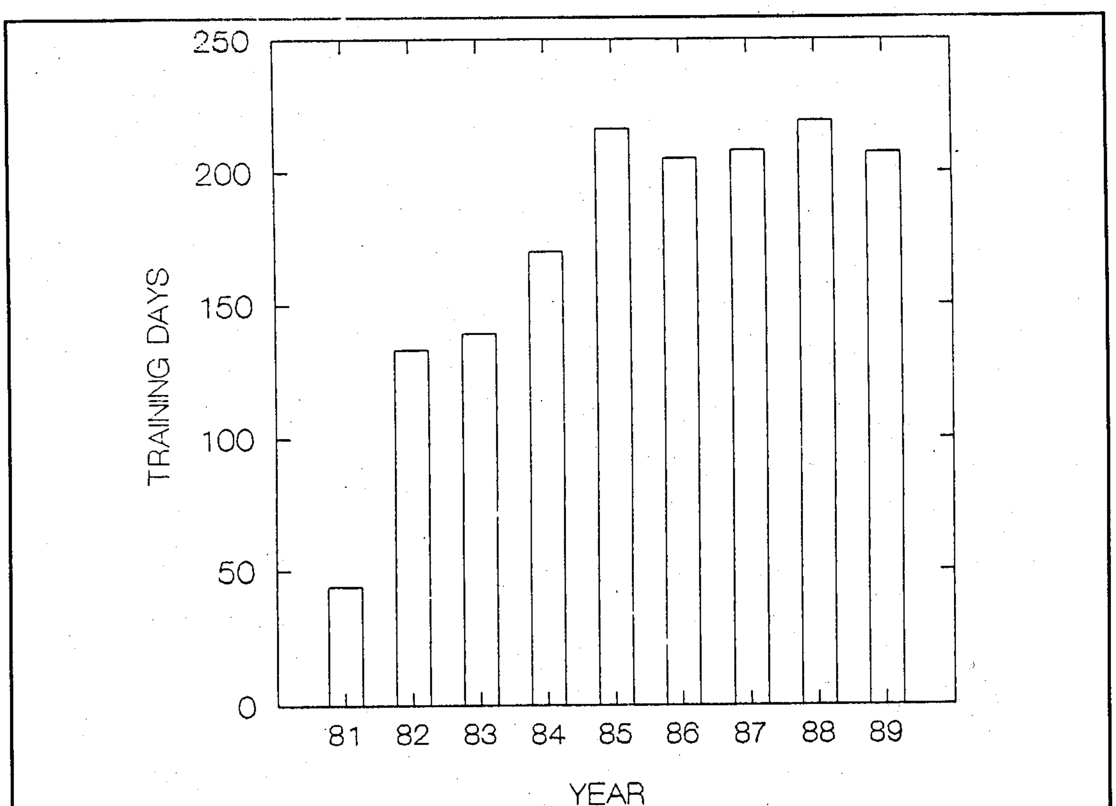

Figure 4. Annual number of training days at NTC, 1981 to 1989.

The present numbers of soldiers, tracked vehicles, and wheeled vehicles participating in rotational exercises are known for OPFOR, BLUEFOR, and OCs. However, when NTC began live fire operations in 1982, only the initial number of OPFOR personnel was known. Based on the assumption that the increase in OPFOR to present levels was accompanied by parallel increases in BLUEFOR, OCs, and all tactical vehicles, an exponential model was derived to estimate the initial values for all these parameters. In other words, since OPFOR personnel increased 8.8 percent a year, a comparable increase was assumed for BLUEFOR, OCs, and all tactical vehicles. In the actual calculations, it was assumed that combat strength for all parameters increased an *average* of 8.8 percent a year between 1982 and 1989. Figures 5, 6, and 7 show totals of 8.9 million man-days, 0.8 million track-days, and 2.4 million wheel-days, respectively, for the NTC mission between 1981 and 1989. These data include figures for the California National Guard, but CNG impact has been negligible, representing only 2.2 percent of the man-days, 3.0 percent of the track-days, and 0.6 percent of the wheel-days.

Soil Damage by Military Vehicles

Army training activities at Fort Irwin have produced soils with finer-than-usual surface textures (Krzysik 1985). Undisturbed desert soils consist of extensive areas of desert pavement (see "Soils" in Chapter 2). These crusts consist of gravels or pebbles. All offroad vehicles—particularly tracked vehicles in turning maneuvers—damage desert pavement. Vehicles disrupt surface integrity, expose underlying fine-particle soils, and shuffle soil layers. Therefore, soil fines are exposed to wind and water erosion, which may be extensive locally within NTC's two major training corridors. A single pass by an offroad vehicle can disturb desert pavement, but the effects of the damage and the rates of recovery are not known. In a similar fashion, offroad vehicles may seriously impact cryptogamic crusts, but qualitative data are lacking and recovery rates are not known.

Soil compaction is the other major problem caused by offroad training activities at Fort Irwin. Direct mechanical pressure from vehicles exerts both compaction and shear forces on soil surfaces. Damage is often related to the number of surface passes made by vehicles at a given location, but impact is widely variable, depending on such characteristics as grain size or soil moisture at the time of impact. A small number of passes—even a single pass—can be sufficient to cause severe compaction and lateral shear. Tracked vehicles generate greater shear stresses than other vehicles, owing at least in part to skid-steer turning maneuvers. Compaction and shear stresses both result in physical soil surface changes, including loss of aggregation and loss of tensile strength.

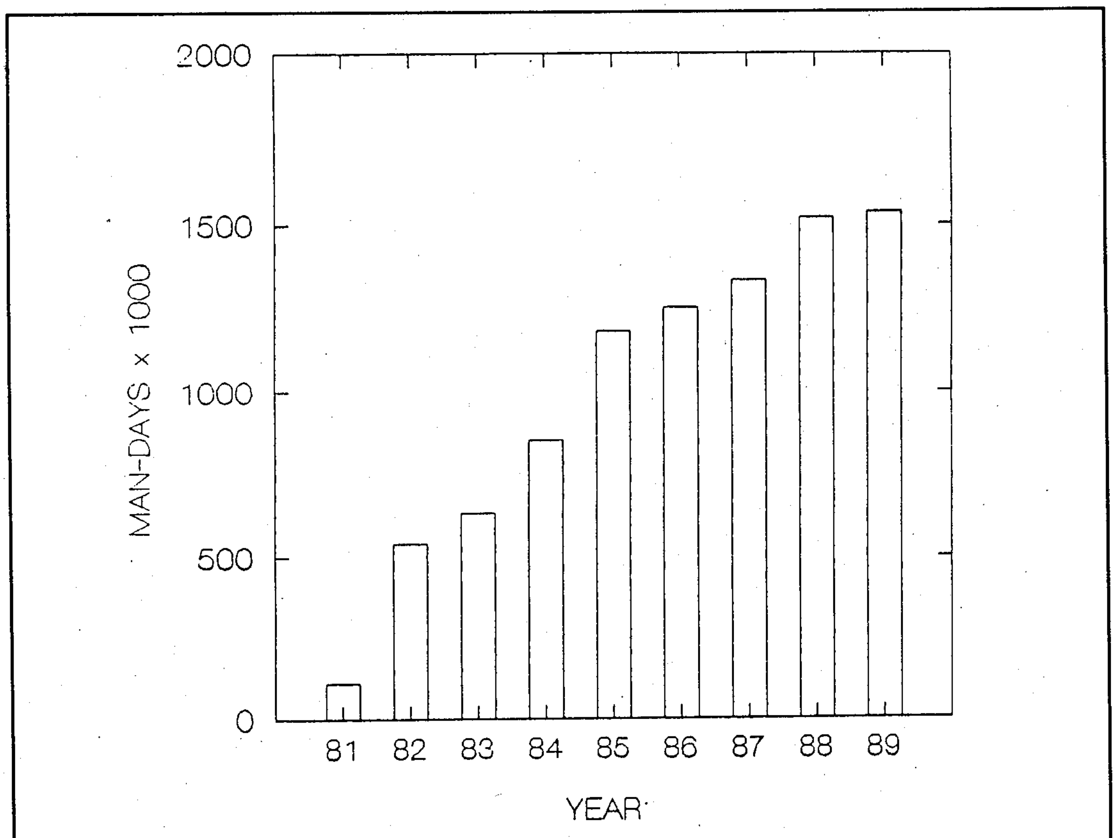

Figure 5. Annual amount of training in man-days at NTC, 1981 to 1989.

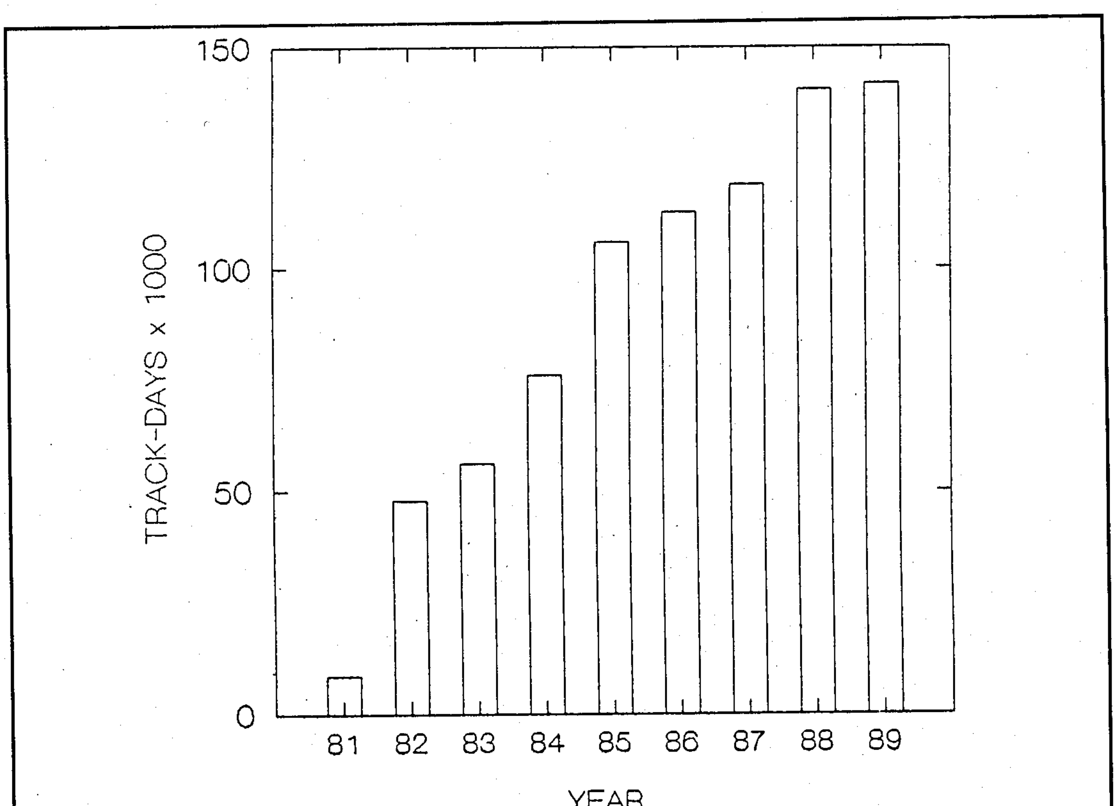

Figure 6. Annual amount of track-days at NTC, 1981 to 1989.

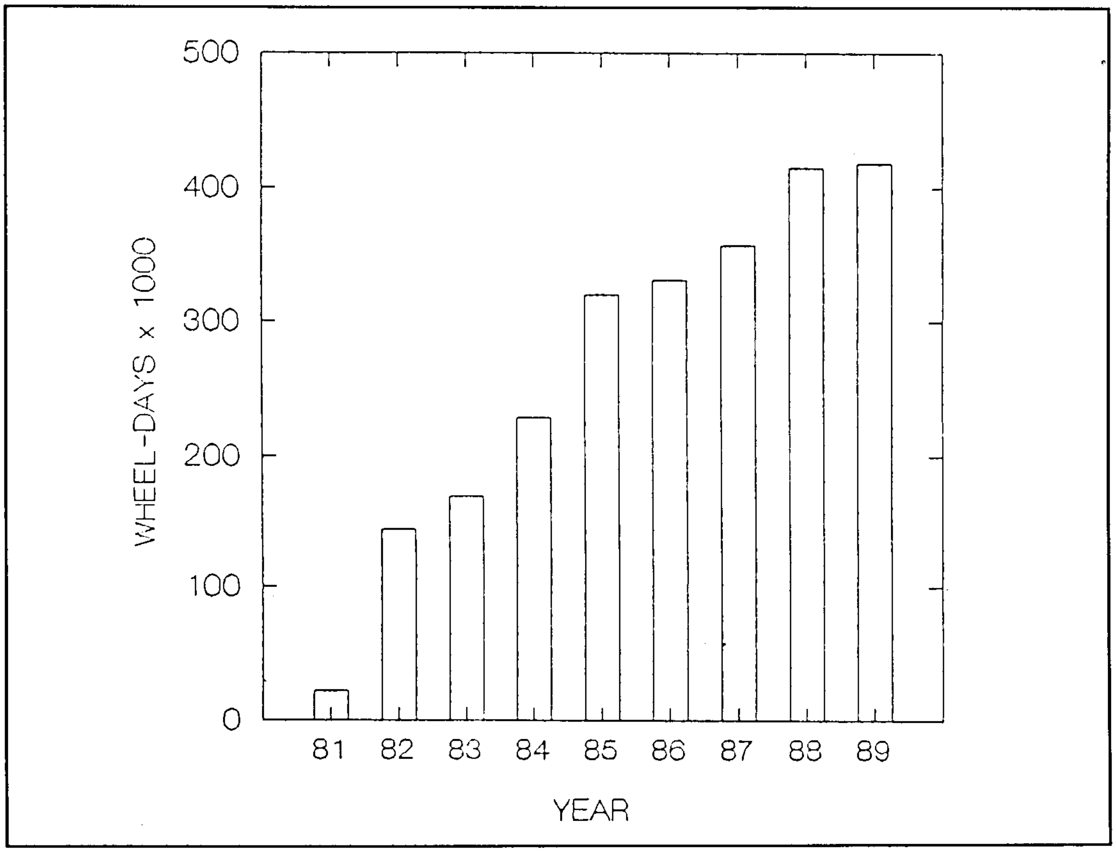

Figure 7. Annual amount of wheel-days at NTC, 1981 to 1989.

Lag gravels composing desert pavement and the coarser sands that make up alluvial desert surfaces (e.g., washes and fans) often form microbial or chemical crusts, as discussed under "Soils," in Chapter 2. Lateral shear from heavy vehicles breaks these crusts and exposes a mix of different particle sizes, ranging from cobbles and pebbles to sands and silts. Repeated shear will continuously expose any underlying finer-grained materials, dramatically accelerating wind (eolian) and flowing water (fluvial) erosion. Physical changes associated with direct soil disturbance (e.g., lowered porosity and permeability) tend to increase the volume of runoff, which accelerates fluvial erosion. In heavily impacted areas, strong winds produce severe dust storms in which visibility can be reduced to less than 5 m. Data show that training activities significantly increase the percentage of surface sand while decreasing the percentage of larger particles—coarse sand in valleys and gravel on alluvials (Krzysik 1985). For more detailed information on the effects of off-road vehicles and military maneuvers on desert soils, see Wilshire and Nakata (1976), Iwasiuk (1978), Iverson et al. (1981), Adams et al. (1982), Webb (1983), Prose (1985, 1986), Prose and Metzger (1985), and Prose and Wilshire (1986).

Since establishment of the NTC in 1981, maneuvers have been carried out over most of the installation. Military training at the NTC occurs primarily in areas where slopes are less than 20 percent. The landscapes in maneuver areas have been severely altered by NTC's ongoing training mission. Typically, tactical vehicle traffic and training activities occur in valleys, and effects on the landscape decline as one progresses up onto higher bajadas and alluvial fans toward the mountains (Krzysik 1985). As a result, most of the soil damage has occurred in the maneuver corridors of the installation's valleys.

7 Habitat Monitoring at Fort Irwin

Habitat parameters and wildlife populations were monitored at Fort Irwin between 1983 and 1989 at permanent plots established for this purpose in March 1983. Experimental treatment plots were carefully chosen to represent the typical training environment in the landscape. Control plots were chosen to represent as closely as possible the physiography of the treatment plots, but in a location completely free of habitat perturbations.

The experimental/sampling design was fresh and innovative, and based on probability sampling with a randomly selected starting point to establish a landscape-scale systematic grid. Double-nested 800 m x 200 m macroplots were established on this grid for vertebrate surveys (small mammals, birds, and lizards). Vegetation and other habitat parameters were sampled on 100 m x 4 m strip transects within each macroplot employing a systematic random triple-nested design. (Transects used at the control macroplots were 50 m x 4 m.) There were three important components to the authors design. The systematic component ensured complete and representative coverage of the landscape. The random component ensured unbiased sampling and independence of error terms. The nested component generated hierarchical levels for estimating variance components. The analysis of variance components form the basis of statistical validity (e.g., ANOVA, ANCOVA, GLIM [Generalized Linear Models]; and are mandatory for statistical inference, significance tests, conducting spatial or temporal analyses, and quantifying habitat or population heterogeneity or patchiness.

This experimental/sampling design was developed by the author as part of a comprehensive ecological assessment and monitoring protocol for conducting rapid economical biological surveys and habitat assessments consistent with ecological validity and statistical sufficiency. The protocol is named ECORAT (Ecological Rapid Assessment Technologies).

The southern corridor of NTC was selected as the location for two experimental treatment plots, since this valley is one of the two major training areas on the installation, and is used extensively for massive force-on-force war game exercises. One plot was established in the valley itself (ES) and the other was located on the south bajada of the Tiefort Mountains (EM). Each plot consisted of three subplots, and each subplot contained two macroplots for "replicates." The ES and EM treatments may also be considered as blocks in a nested hierarchical experimental design with subsampling. For vegetation surveys, each macroplot was replicated with four additional transects with systematic origins and completely random orientations. An additional subplot was added to each of the two plots in 1984. This experimental nested design with four hierarchical levels was employed to improve the efficiency of statistical analyses and interpretation. Two important considerations were involved in the selection of this experimental design. First, habitat damage by offroad vehicles is very heterogeneous and patchy, complicating both intrasite and intersite comparisons. Additionally, since funding and manpower were limited, it was desirable to economize sampling efforts while attempting to maximize the information acquired in the monitoring effort. Two control plots were established in Goldstone to match the experimental treatment plots: one in a valley (VC) and the other on a bajada (BC). Only two subplots were established for each control plot because the habitats within a plot were uniform and would not be subjected to training-related disturbances. Except for the number of subplots, the experimental design was identical to the one used in the NTC southern corridor. Goldstone is off limits to tactical vehicles and the public. Goldstone personnel and their vehicles use only established roads. Further details on the methods used, a detailed list of the habitat parameters monitored, and the location of the plots are reported in Krzysik (1985). The theoretical basis for analyzing the habitat data in terms of environmental gradients is provided in Krzysik (1987).

Two fundamental environmental attributes comprised the habitat parameters: (1) the physiognomy (structure) and floristics (species composition) of perennial woody and semiwoody vegetation (shrubs and semishrubs), and (2) the distribution of substrate particle sizes. It was decided not to monitor perennial nonwoody plants and annual vegetation (forbs and grasses). This vegetation is strongly dependent on the intensity and patterns of winter precipitation (and to a lesser degree temperature). Therefore, it is highly variable both spatially and temporally. For example, the height of these plants rapidly reaches its maximum, then drops sharply in only a few weeks. Superimposed on this is temporal variance due to the differences in elevation among sampling stations, and spatial variance due to highly localized precipitation patterns. Therefore, unless elevation differences are standardized by some unknown "correction factor," and all sampling stations are monitored simultaneously, the largest variance component among sampling stations is due to natural temporal variance (sampling sequence), and not to spatial differences (treatment effects) in habitat degradation. Annuals were not available for sampling in many of the monitoring seasons.

It was assumed that, when monitoring habitat changed in the southern corridor between 1983 and 1989, comparable changes were occurring in the central corridor—the other major training area at NTC. Field experience and qualitative observations by the author support this assumption.

Figure 8 shows the shrub cover monitored at the Goldstone valley control plot. Shrub cover averaged 2445 square meters per hectare (sq m/ha). Dividing the value of sq m/ha by 100 gives the shrub cover in terms of percentage (in this case, 24.5 percent). Creosote bush and burroweed comprised 80 to 90 percent, or more, of the shrub cover. Figure 9 shows the shrub cover monitored at the valley in the NTC southern corridor. Note that in 1983 shrub cover was only 2.5 percent (250 sq m/ha ÷ 100). Shrub cover has declined by 69 percent, reaching 0.77 percent in 1989.

Shrub cover at the Goldstone bajada control averaged 19.9 percent (Figure 10). Subdominant shrub species were more important on bajadas than in the valleys. In the NTC southern corridor, shrub cover on the high bajada of the Tieforts dropped from 10.3 percent in 1984 to 5.0 percent in 1989 (Figure 11), a decline of 51 percent. At the same time on the lower bajada, shrub cover dropped from 5.8 percent in 1983 to 1.9 percent in 1989 (Figure 12), a decline of 67 percent.

The data for all the years were averaged for comparative purposes. Figure 13 demonstrates the large differences in shrub cover that occurred in the Mojave Desert scrub between habitats impacted by military training activities and the natural ecosystem. The differences are even more dramatic when shrub volume is compared (Figure 14).

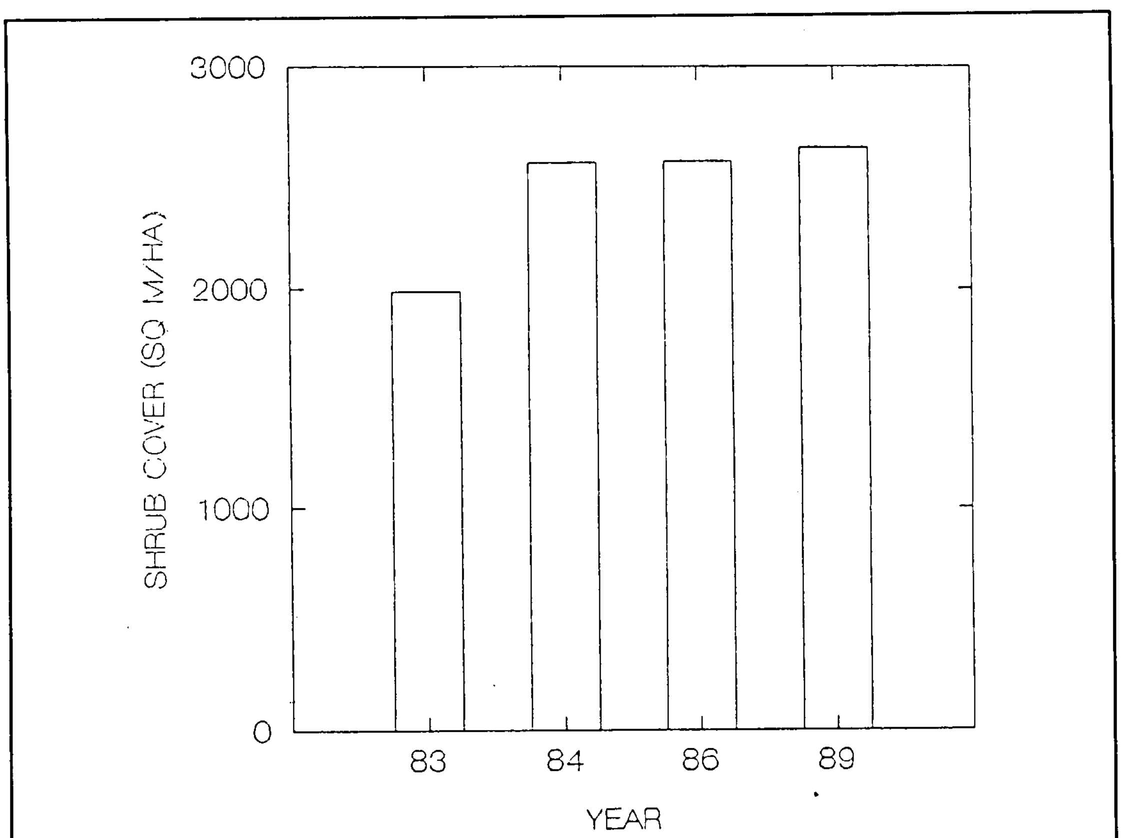

Figure 8. Shrub cover at Goldstone Valley control plot, 1983 to 1989.

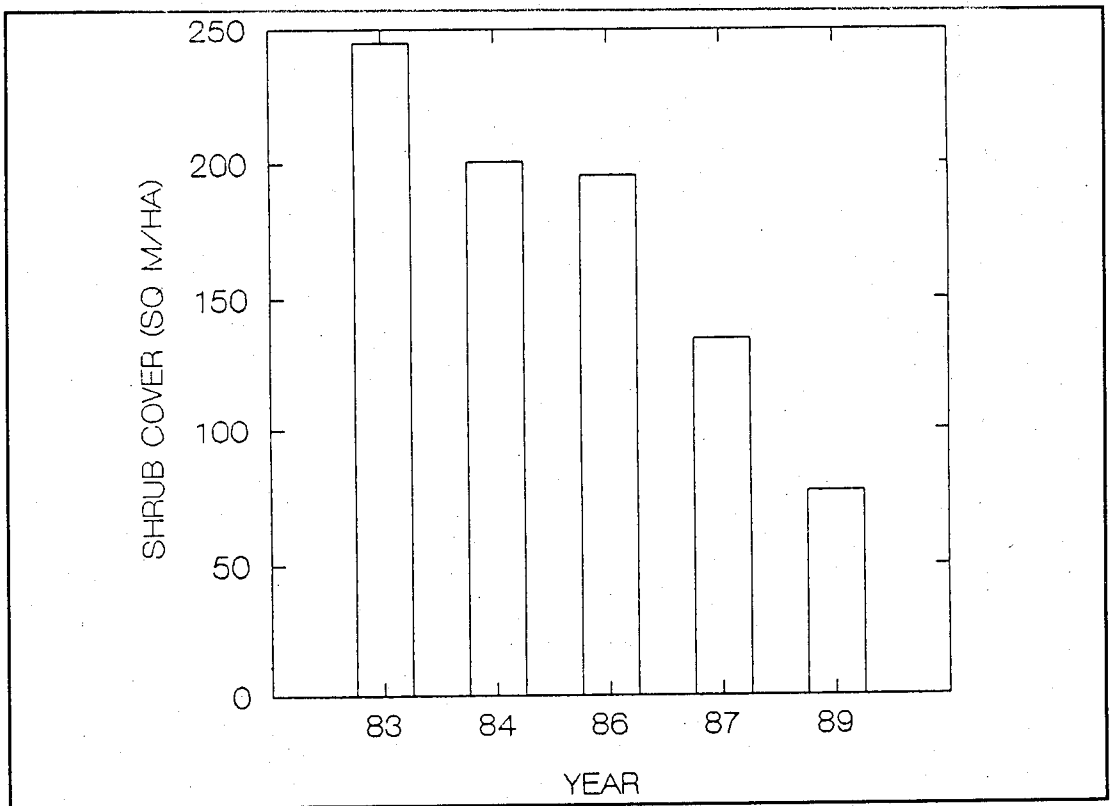

Figure 9. Shrub cover at NTC Southern Corridor Valley experimental plot, 1983 to 1989.

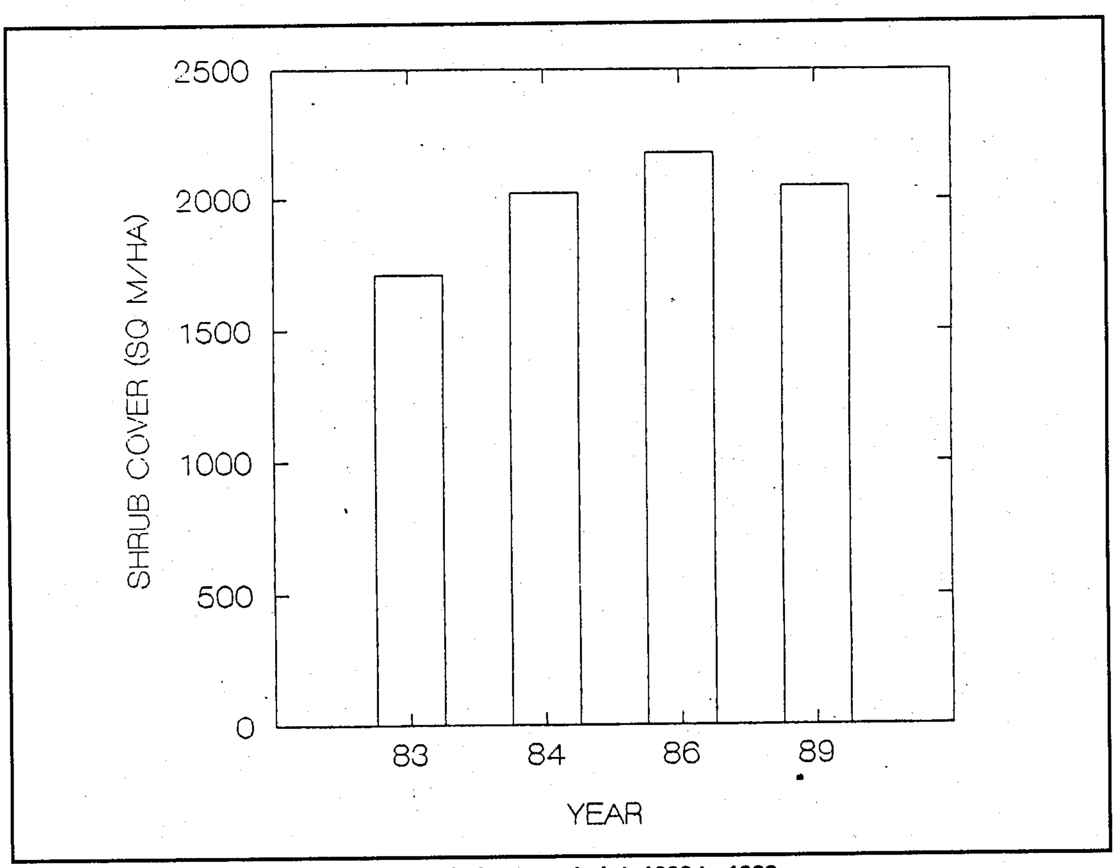

Figure 10. Shrub cover at Goldstone Bajada control plot, 1983 to 1989.

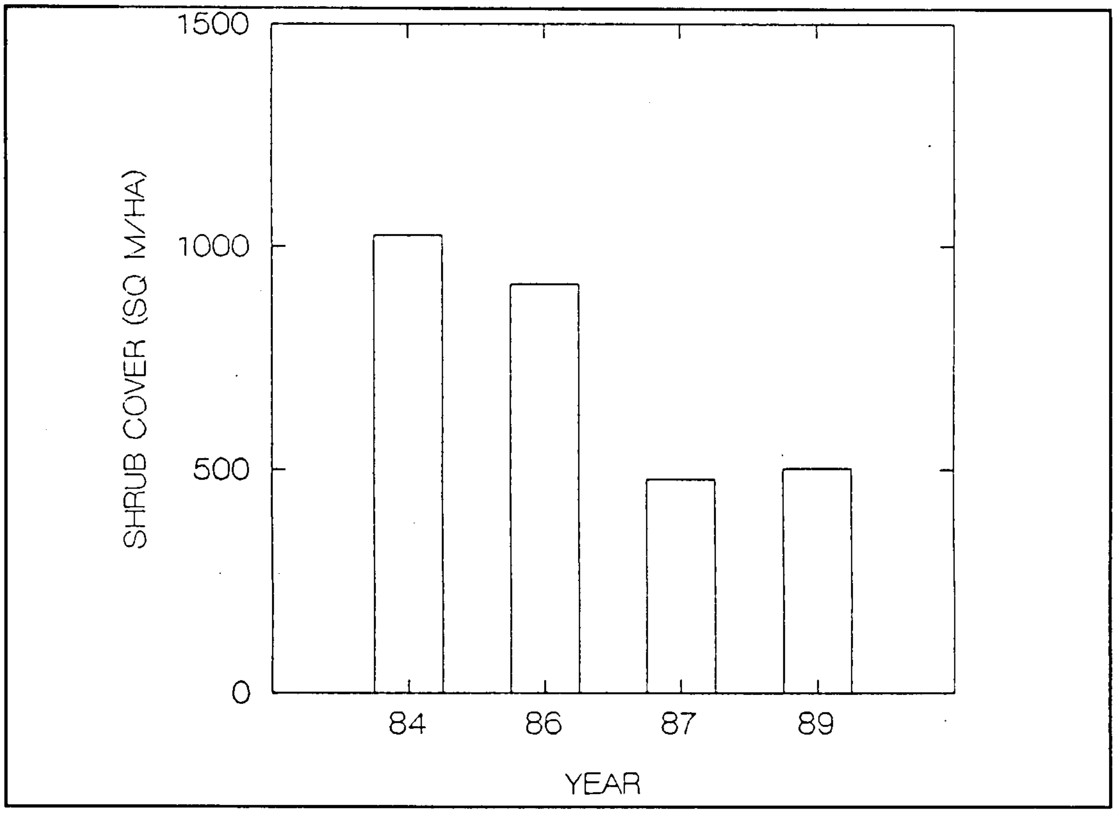

Figure 11. Shrub cover at NTC Southern Corridor High Bajada experimental plot, 1984 to 1989.

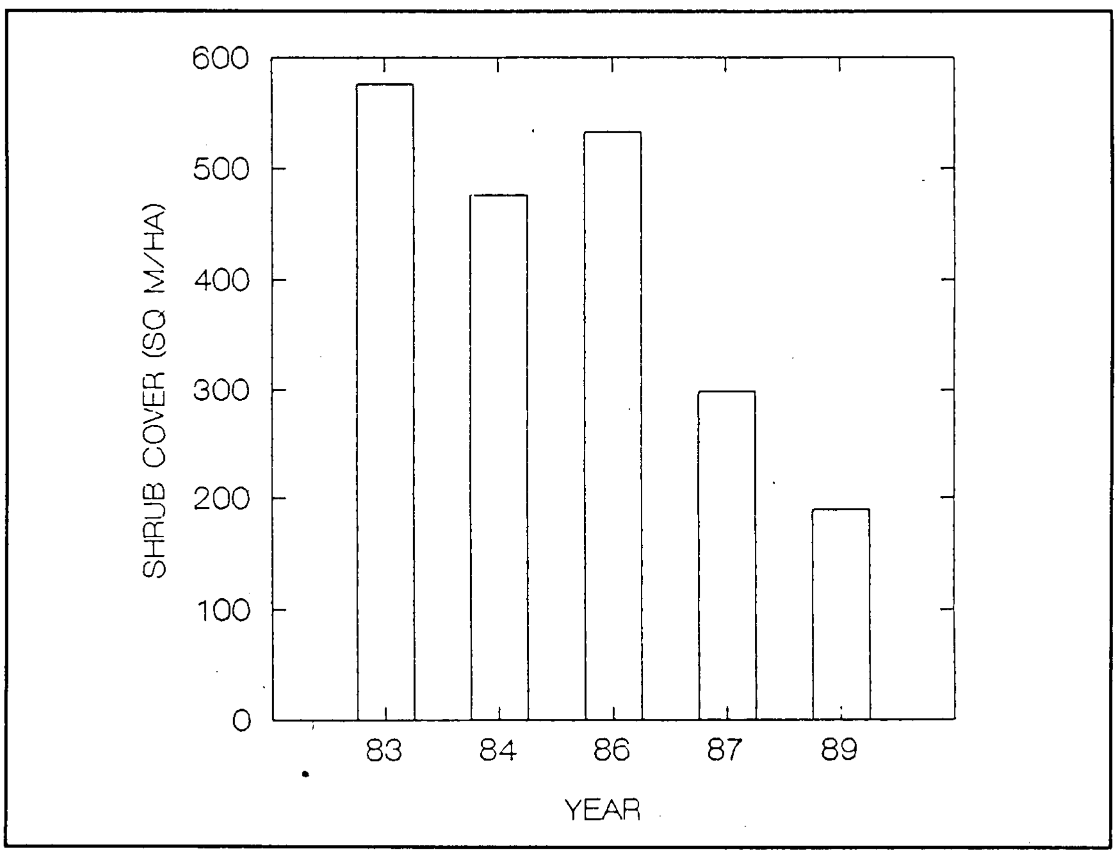

Figure 12. Shrub cover at NTC Southern Corridor Low Bajada experimental plot, 1983 to 1989.

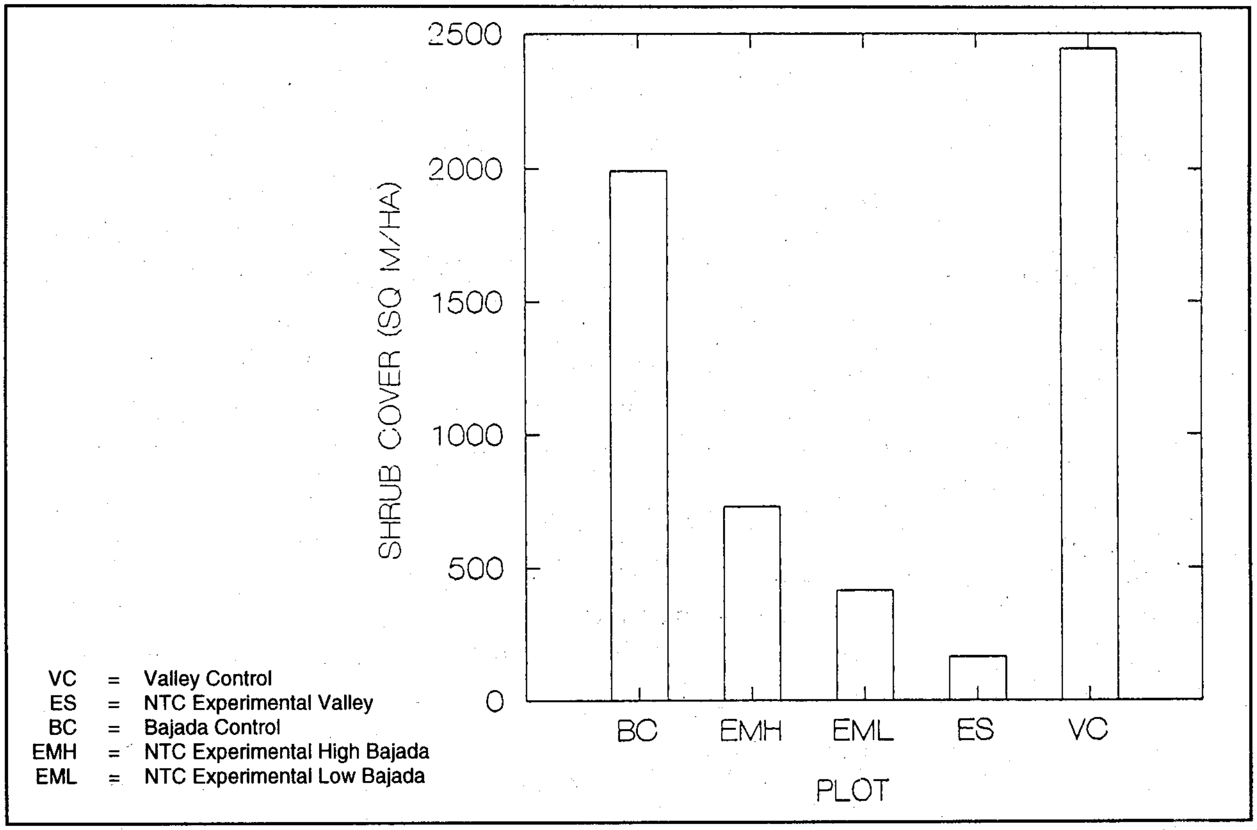

Figure 13. Shrub cover at five Fort Irwin monitoring plots.

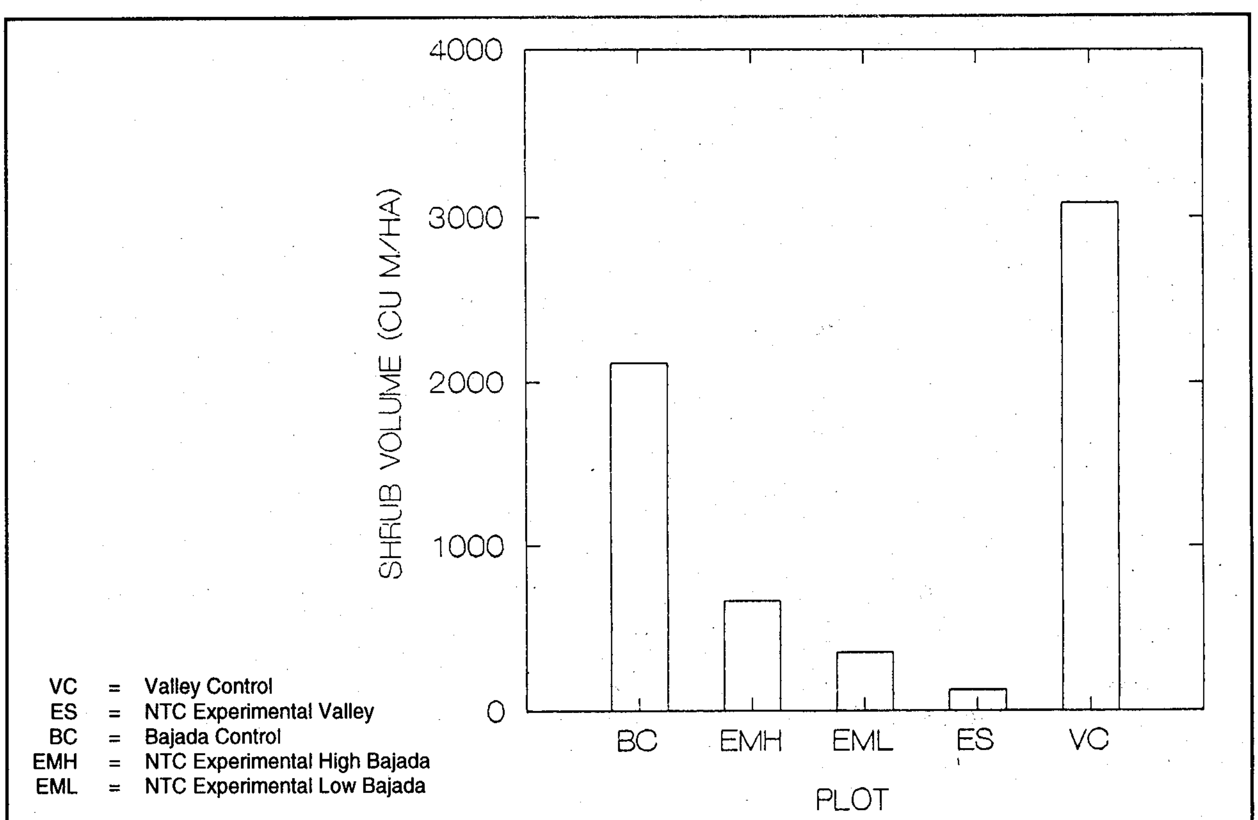

Figure 14. Shrub volume at five Fort Irwin monitoring plots.

Table 7 summarizes the shrub cover and shrub volume data for the monitoring program in the southern corridor of the NTC and at Goldstone, from 1983 to 1989.

Even in 1983, shrub cover was sparse in the valley of the NTC southern corridor. There was also an obvious gradient of increasing shrub density from the main road on the valley floor, up onto the bajada, and into the rocky alluvial fans and boulder talus of the Tiefort Mountains. The extent of habitat degradation closely paralleled tactical vehicle use in the corridor. Most vehicle action occurred through the main valley portion of the corridor. Since 1983, shrub cover has decreased all along this elevational gradient (or bajada). Over the past few years, tactical vehicles have penetrated more frequently into the high bajadas and alluvial fans of NTC. This may be attributed to the increasing use of longer range weapons and the desire to simulate larger battlefield scenarios. The number of roads, the intensity of road use, and offroad habitat damage have dramatically increased in the high bajada and alluvial boulder fields of the Tieforts since 1983—particularly since 1986. Figure 15 shows the cumulative increase in the use of tracked vehicles at NTC from 1981 to 1989. The data for wheel-days and man-days are comparable. For more details, refer to Figures 5, 6, and 7. Note the large utilization increases from 1984 to 1985. These are the two years that NTC cleared the impact areas for training maneuvers. Annual rotations first reached their high of 14 in 1985. (More detailed information about this habitat monitoring program is in preparation by the author.)

Table 7. Shrub cover and volume at five NTC monitoring plots.

Location	Plot	Year	Shrub Cover (sq m/ha)	Shrub Volume (cu m/ha)
Goldstone	Valley	83	1987	2202
		84	2574	3118
		86	2580	3135
		89	2638	3885
NTC	Valley	83	245	198
		84	201	163
		86	196	141
		87	135	90
		89	76.5	63.5
Goldstone	Bajada	83	1714	1671
		84	2022	2048
		86	2177	2362
		89	2050	2382
NTC	High Bajada	84	1025	979
		86	915	775
		87	477	400
		89	502	506
NTC	Low Bajada	83	576	524
		84	476	431
		86	532	442
		87	299	231
		89	189	145

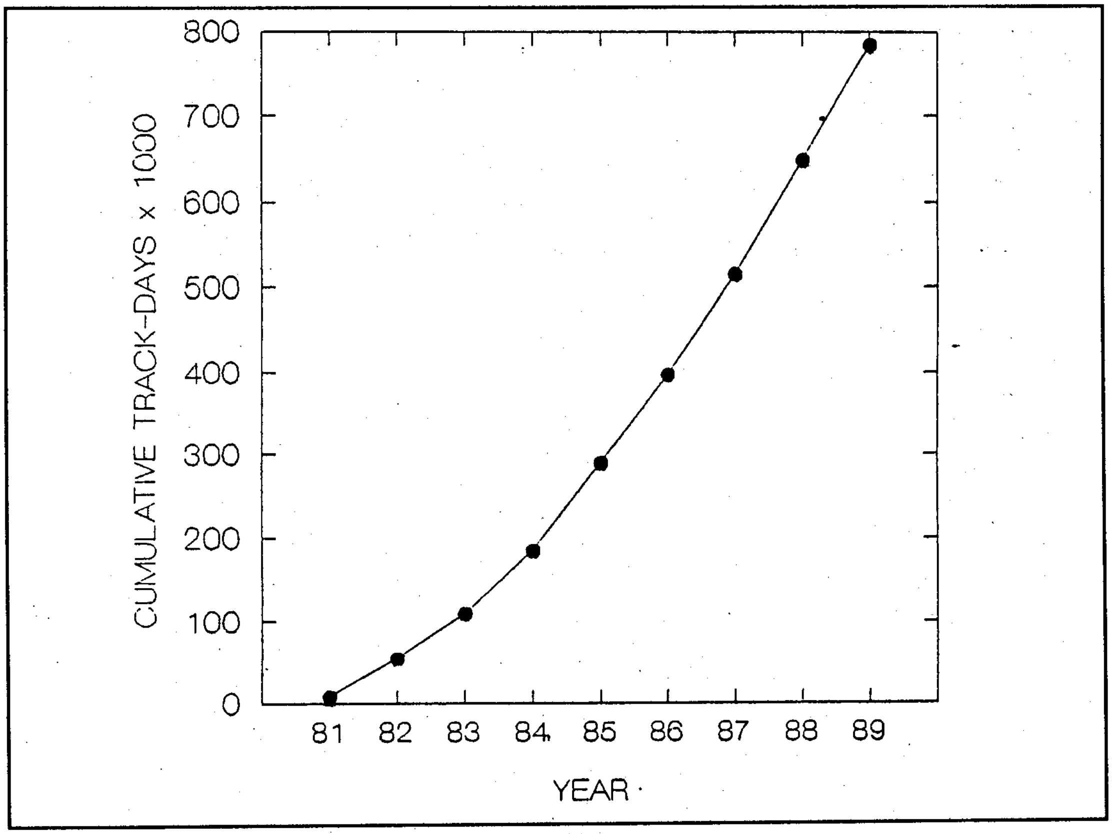

Figure 15. Increase in track-days at NTC, 1981 to 1989.

8 Effects of Training-Related Habitat Changes on Fort Irwin Wildlife

The following discussion of the effects of Army training activities at NTC on the Mojave Desert wildlife communities is intended to serve as a concise general summary. Further details, including a statistically based quantitative assessment, can be found in Krzysik (1984, 1985). More information on this subject are in preparation by the author. An ecological assessment of the military training effects on threatened, endangered, and sensitive species at Fort Irwin was submitted to the NTC and FORSCOM (Krzysik 1991).

Mammals

The species composition of Mojave Desert small mammal communities is directly related to three habitat parameters: (1) percent shrub cover, (2) substrate texture (surface particle size distribution), and (3) presence of water (e.g., springs, seeps, wetlands). Because wet habitats characteristically possess dense vegetation of species different than the surrounding desert scrub, the relative contributions of vegetation physiognomy, floristics, and water to the presence of specific animal species are impossible to sort out without manipulation experiments. It is reasonable to expect that all three habitat components are important factors affecting the species composition within these desert oases.

Morphological adaptations, foraging strategies, and body sizes of heteromyid rodents (kangaroo rats and pocket mice) have evolved for predator detection, avoidance, or escape when exploiting different habitat structures. Morphological adaptations include enlarged auditory bullae for detecting low frequency (1-3 kHz) sounds of attacking owls or snakes (Webster 1962, 1979, Webster and Webster 1971, Webster and Strother 1972); dorsally located eyes (Eisenberg 1975); and bipedalism for high-speed erratic movements (Bartholomew and Caswell 1951, Eisenberg 1963, Mares 1980). Bipedalism also permits retention of a generalized manus for harvesting and processing seeds, and cursorial modifications to the hind limb that reduce injury during high-speed maneuvers (Thompson 1985). Therefore, kangaroo rats are morphologically more specialized than pocket mice for exploiting the openings between shrubs. Predation risks are highest in the open areas between shrubs (Bartholomew and

Caswell 1951, Bartholomew and Carey 1954, Webster and Webster 1971, Eisenberg 1975, Mares 1980). Morphologically generalized rodents, such as the quadrupedal cricetids can best avoid predation by remaining within the shrub canopy.

Field observations in natural habitats have verified that bipedalism and body size directly reflect foraging strategies in desert rodent communities (Rosenzweig and Winakur 1969, Rosenzweig 1973, Thompson 1982a, Kotler 1984). The largest bipedal rodent in the Fort Irwin community, the desert kangaroo rat, forages more in the open and travels greater distances between foraging patches. Merriam's kangaroo rat, with a body weight about one-third that of the desert Kangaroo rat, forages to a lesser extent in the open and travels shorter distances to foraging patches than its larger congener. Pocket mice, but especially the generalized and completely quadrupedal Peromyscus, forage beneath the protective shrub canopy and travel less in the open. A habitat manipulation experiment by Thompson (1982b), in which small cardboard shelters were placed in open areas between shrubs, demonstrated that the density of Merriam's kangaroo rat—the dominant species in the rodent community—decreased, but the abundance of one pocket mouse species and two species of Peromyscus increased.

Ecological studies at Fort Irwin have provided more evidence of the role that shrub cover plays in the organization of Mojave Desert rodent communities (Krzysik 1984, 1985, and in preparation). In an undisturbed valley at Goldstone, where shrub cover is 20 to 30 percent, three species of rodents are common: the little pocket mouse (20 to 150 per ha), Merriam's kangaroo rat (7 to 8 per ha), and the southern grasshopper mouse (2 to 4 per ha). White-tailed antelope ground squirrels and Botta's pocket gophers are present in lower numbers. Additionally, panamint kangaroo rats, deer mice, and Mojave ground squirrels are present at still lower densities. Three habitat transients are occasionally but consistently captured in the habitat: the long-tailed pocket mouse, the canyon mouse, and the desert pack rat. These latter three species occur in gravelly or rocky areas, or in boulder fields, and use the valley habitat as a dispersal route (see "Small Mammals" in Chapter 4).

At NTC, in the valley of the southern corridor, measured shrub cover has varied from 0.5 to 3 percent or less. In this sparse shrub cover the desert kangaroo rat (1 to 2 per ha) is the primary rodent, but Merriam's kangaroo rat is also present (0.5 to 5 per ha). The little pocket mouse and round-tailed ground squirrel are present at very low densities, and the grasshopper mouse is absent. Habitat transients are extremely rare. Much of this heavily used training area contains loose, shifting, sandy substrate —the preferred soil for the desert kangaroo rat and the round-tailed ground squirrel. In contrast to the relatively stable population densities of Merriam's kangaroo rat at the valley control site, populations may fluctuate annually in the southern corridor.

Further up the bajada shrub cover is 5-10 percent, occasionally higher in localized pockets. The little pocket mouse, although uncommon, is captured there with greater frequency. The grasshopper mouse is present, but very rare. In response to rocky-gravelly habitats on the bajada, long-tailed pocket mice are present. Where there are boulder canyons and rocky washes, the antelope ground squirrel, canyon mouse, and pack rat adds to the faunal diversity of bajadas.

Birds

The following information on Fort Irwin avifauna is from Krzysik (1984, 1985, and in preparation). The breeding density of horned larks in the wet spring of 1983, and the density of foraging flocks during the severe drought of 1984 was similar at the Goldstone valley control and in the southern corridor of the NTC. The horned lark is a ground-foraging and -nesting species that avoids dense ground and shrub cover (Bock and Webb 1984, personal observation). Creosote scrub species like the black-throated sparrow and LeConte thrasher tolerate some loss in shrub cover—possibly 50 percent or more. Other species that nest in the Mojave Desert nest only in the densest and tallest creosote scrub that is available. These include the sage sparrow, verdin, and house finch. Predatory species such as loggerhead shrikes, roadrunners, burrowing owls, and other raptors are usually found in unimpacted habitats, but are occasionally observed on training lands. Migratory species appear to be very sensitive to shrub cover and typically occur in the densest creosote scrub available or—preferably—in the dense, tall, and diverse vegetation of spring or riparian areas. These species include the white-crowned, song, Brewer's and chipping sparrows, warblers, flycatchers, orioles, grosbeaks, and tanagers. Some bird species that are partial to boulder outcrops, rocky hillsides or canyons do not strongly depend on shrub cover. However, noise may be more important in their distribution on Fort Irwin. Examples include the rock wren, Say's phoebe, and loggerhead shrike.

Red-tailed hawks, golden eagles, prairie falcons, and ravens forage over wide areas and nest on cliff faces. All three forage in all available habitats at Fort Irwin, from unimpacted areas, to those with appreciable shrub cover losses. The affect of noise on their foraging or nesting behavior at the NTC is unknown. Golden eagles have abandoned nests when they have been disturbed, but helicopter crews have observed them nesting in the Tiefort Mountains. This mountain range is surrounded by the southern and central training corridors, and is just east of and adjacent to the Bicycle Lake Airfield and Range Control. Consequently, this area experiences a great deal of disturbance from vehicles, troop movements, and all types of military air traffic.

Western kingbirds and ash-throated flycatchers require at least some trees for foraging, perches, and nesting sites. Black-tailed gnatcatchers require mesquite groves or comparable vegetation. Scott's orioles require yuccas for nesting, but forage in cactus groves and creosote scrub. Mocking birds require yuccas or trees. Cactus wrens require yuccas or chollas for nesting and foraging. Yucca or cholla groves are rare at Fort Irwin. Both types of vegetation are very sensitive to vehicle collisions. A large grove of silver cholla is present at the mouth of a canyon on the south face of the Granite Mountains, about 11 km east of Granite Pass. This cholla grove is located within tortoise site GE, which is recommended for complete protection.

At Fort Irwin, trees are found only at springs or wastewater treatment facilities. These areas are off-limits to training activities. These oases contain the densest concentrations of native and migratory birds found on the installation. Preservation of these habitats requires stringent protective measures. Furthermore, management activities should be implemented to enhance and expand the habitats in these areas.

Reptiles

The effects of Army training activities on the desert tortoise, a Federally listed threatened species, are covered in Krzysik and Woodman 1991, and in a separate USACERL technical report (Krzysik 1994a). Because snakes are highly secretive, and most species are nocturnal, they are difficult to observe or survey. On the basis of the author's field experience at Fort Irwin, however, a qualitative assessment can be made. Three species of snakes are commonly observed at Fort Irwin: the sidewinder, red coachwhip, and gopher snake (see "Snakes" in Chapter 4). These three species (and others) have been observed more frequently at Goldstone than on NTC training lands, where snakes are observed only infrequently (personal observation and interviews with trainers and Goldstone personnel).

There are four possible reasons for the scarcity of snakes on NTC training lands: (1) habitat changes, (2) decrease in prey, (3) noise and ground vibrations, and (4) intentional or accidental killings. Probably all four are important.

Snakes are K-selected; under natural conditions they have a low birth rate, but a high rate of survivorship. Therefore, snakes are sensitive to high mortality rates. Snakes are preyed upon primarily by hawks, owls, roadrunners, ravens, coyotes, and other snakes. The loss of ground cover increases the visibility of snakes to predators, and decreases available escape cover. Shrub loss also reduces the amount of shade in the habitat, so there is less area available for thermoregulation.

The loss of prey is a direct mechanism for eliminating snakes from a habitat. Many snake species, especially rattlesnakes and gopher snakes, prey heavily on rodents. Sidewinders prey heavily on the little pocket mouse, and this rodent is sensitive to shrub cover losses. Other rodents are also sensitive to shrub cover losses. The reduction of rodents in a habitat not only decreases the food supply, but snakes are critically dependent on rodent burrows for thermoregulatory sites, predator avoidance and escape, and hibernacula (hibernation sites). Decreasing shrub cover creates a favorable habitat for the large desert kangaroo rat, but the same habitat becomes less favorable for smaller rodents. Adult desert kangaroo rats are too large a prey item for the Fort Irwin snake community. Snakes feeding on arthropods (mainly insects), lizards, birds, or other snakes also find fewer prey items in habitats with shrub losses because insect biomass—the critical element in the food chain—is strongly correlated with shrub biomass.

Snakes can hear airborne sound waves and are very sensitive to ground vibrations. The magnitude of the offroad vehicle usage and live-fire exercises create substantial ground vibrations. It is not known how these vibrations affect wildlife, but the impact on the snake community must be substantial.

Snakes killed by tactical vehicles or soldiers have been observed at Fort Irwin (Krzysik, personal observation), but infrequently. Snakes are more often seen killed on asphalt roads, the warm surfaces of which attract snakes during cool nights. Road kills are difficult to quantify in the desert because carcasses are efficiently removed by ravens.

Lizards are subjected to the same habitat impacts as snakes by decreases in shrub cover: less protective cover, fewer insects to eat, and fewer rodent burrows to exploit. However, different species of lizards respond differently to the shrub losses caused by tactical vehicles. The western whiptail is the most widespread species of lizard and a habitat generalist, being found on sandy or gravelly substrates in creosote or saltbush scrub, or in boulders or rocky areas. This species actively searches for arthropods in the litter associated with shrubs, and relies heavily on nearby rodent burrows for escape and thermoregulation. Despite this dependence on shrubs, the whiptail is commonly found in heavily used training areas with less than 5 percent shrub cover. However, this species reaches its greatest abundance in undisturbed habitats.

The zebra-tailed lizard reaches its highest abundance in large, sandy washes where vegetation is sparse. It is not common in dense creosote scrub. The foraging strategy for this species is to sit patiently in the open where prey and predators both are easily located. It relies on high-speed bipedal locomotion for escape into a rodent burrow.

Zebra-tails often run farther than other species of lizards to their selected escape burrow. Zebra-tailed lizards are common in Army training areas with sandy substrates, apparently because the habitat is more open. Army tracked vehicles disrupt desert pavement to produce sandier substrates. Therefore, Army training activities at NTC have increased the habitat available for this species.

The side-blotch lizard is a small, abundant species that lies in rocky or boulder habitats, where they find cover beneath large rocks or in crevices. Such habitats are usually present on the high bajada or alluvial fans of mountain ranges. Army training activities are not as intense here at these locations as they are in the valleys below, and tactical vehicles do not destroy rock and boulder habitats. Therefore, training activities at NTC have not significantly affected this species. Side-blotch lizards are also found at lower densities in unimpacted habitats where shrub cover is high, especially low, dense shrubs like burroweed. Apparently, good cover is important to this species. However, side-blotch lizards are also occasionally seen in heavily impacted training areas with reduced shrub cover; such individuals are probably transients.

Desert iguanas are patchy in distribution at Fort Irwin. They are present in the heavily used southern corridor of the NTC, but are not as abundant as whiptails or zebra-tails. They apparently prefer sandy habitats in creosote or saltbush scrub, and appear to tolerate unusually wide ranges of shrub cover. This species is herbivorous, and feeds to a large extent on burroweed. The iguana's tolerance of shrub cover loss is surprising since burroweed, its common food item, is sensitive to vehicle collisions. Desert iguanas are not found in gravelly or rocky habitats. Therefore, they are rare or not present in most portions of Goldstone and northern regions of NTC.

Horned lizards and leopard lizards are uncommon but distributed widely throughout Fort Irwin. Although both can be found at very low densities even in heavily impacted training areas, they are more commonly observed in undisturbed habitats.

Chuckwallas, collared lizards, and desert spiny lizards are also uncommon lizards and closely associated with boulder fields and outcrops, or very rocky habitats. Since Army training damage to these areas is not extensive, these species are not seriously affected.

The desert night lizard, Gilbert's skink, and the banded gecko are secretive, nocturnal species associated with the litter and debris of Yucca woodlands. Therefore, prime habitat for these species is not present at Fort Irwin. Of the three, only the desert night lizard has even been sighted at Fort Irwin—at Goldstone (Krzysik, personal observation). Marginal habitat for these species is found in stands of Joshua trees and Mojave yuccas at Goldstone, the northern portion of NTC, and the Avawatz Mountains.

Since yuccas are sensitive to offroad vehicle impacts, Army training activities in yucca woodlands would seriously jeopardize the long-term survival of these species. However, in the short term, debris from vehicle collisions with yuccas would produce extra habitat (cover) for these species. These species may be more prevalent in creosote scrub than is generally believed. Extensive pit-fall trapping with drift fences would be necessary to verify this hypothesis. Banded geckos have been captured in creosote scrub habitat with pit-fall traps at the Marine Corps Air Ground Combat Center in the southern Mojave Desert (Krzysik, 1994 data).

9 Noise, Vibration, and Wildlife

Noise effects on wildlife can be classified into three categories (Janssen 1980): primary, secondary, and tertiary. Primary effects directly impair—either permanently or temporarily—an animal's ability to hear. Secondary effects are those that induce stress or behavioral changes in animals. Tertiary effects are a combination of primary and secondary effects that affect species population levels, for example causing population decline or extinction.

The importance of hearing to animals varies enormously across the animal kingdom. Hearing is very important to many bird species and some insects for successfully establishing and defending territories and attracting mates. Most species of small mammals place a premium on hearing to avoid predators. Many predators, including owls, locate prey by acoustical detection. Striped skunks and opossums prefer auditory cues to visual ones in locating prey (Langley 1979). Red foxes have been shown to readily locate a wide range of sound frequencies, presumably of adaptive value for locating prey (Isley and Gysel 1975). Bats depend primarily on acoustical radar signals for navigation, avoiding obstacles, and locating prey. Marine mammals and some insectivores also use echolocation for navigation and social interaction. Depending on the species, acoustics are important in frogs and toads for attracting mates, defending territories, and establishing social hierarchies. Desert tortoises produce vocalizations, which become more complex and more frequently used in older tortoises (Patterson 1971, 1976). Tortoise vocalizations are presumed to have social value, but their function and importance is unknown.

Kangaroo rats in particular have evolved highly specialized auditory systems: greatly enlarged auditory bullae, enlarged tympanic membrane, lengthened malleus, small stapes footplate, and greatly reduced ossicular ligaments (Webster 1961, 1962, 1963, 1979). These morphological adaptations all interrelate to greatly amplify sound. On the basis of the anatomy described above, the amplification ratio in Merriam's kangaroo rat is 97.2:1, compared to 18.3:1 in humans. The volume of the middle ears in this species is larger than its braincase. Kangaroo rats are also unusually sensitive to low-frequency sounds from 1 to 3 kHz (Webster 1962, 1979; Moushegian and Rupert 1970; Vernon et al. 1971; Webster and Webster 1971; Webster and Strother 1972; Heffner and Masterton 1980). This is an adaptation to detect predators, especially snakes and owls. Brattstrom and Bondello (1983) reported that under laboratory-controlled conditions, dune buggy noise levels impaired the hearing of desert kangaroo rats so severely that they were unable to detect and behaviorally react to sidewinders in the experiments. (Although Brattstrom and Bondello proved that auditory damage in desert kangaroo rats can prevent a response to sidewinders, this kangaroo rat is too large for sidewinders to prey on.)

Brattstrom and Bondello (1983) also reported hearing damage to the fringe-toed lizard—a sand dune specialist—caused by dune buggy noise. The high-intensity sounds of offroad motorcycles have been shown to severely damage the acoustical sensitivity of the desert iguana (Bondello 1976).

Frogs, toads, and salamanders have evolved auditory mechanisms that are unique among vertebrates, consisting of structures that transmit both substrate vibrations and airborne sound waves (Duellman and Trueb 1986). Frogs and toads are particularly adapted and sensitive to airborne sound (Capranica 1965, 1976; Wever 1979), but they can also detect ground vibrations through their forelimbs (Hetherington and Lombard 1982). Salamanders are very sensitive to ground vibrations (Ross and Smith 1980).

Brattstrom and Bondello's (1983) laboratory experiments demonstrated that Couch's spadefoot toad (Scaphiopus couchi) repeatedly emerged from its burrow in response to recorded motorcycle sounds. Spadefoot toads spend most of their lives underground in burrows to avoid the harsh hot and dry desert surface. They may remain in their burrows for a year or more (Mayhew 1965). Couch's spadefoots typically emerge only after severe summer thunderstorms. They emerge in massive numbers, and over a short time—about 12 days—must complete their reproductive cycle from egg laying to transformed tadpoles before the temporary pools dry up (Mayhew 1965). Couch's spadefoots encounter physiological stresses in water conservation and food storage while buried in their burrows (McClanahan 1967). The emergence of Couch's spadefoots in response to motorcycle sounds is highly detrimental to their survival because physiologically stressed individuals are being exposed to severe environmental conditions. Even though the spadefoot behavior was not reinforced with water or food, the toads repeatedly emerged in response to experimental sound exposure over a period of several weeks. Apparently, the spadefoots were misinterpreting motorcycle noise as the thunderclaps that accompany violent summer thunderstorms (Brattstrom and Bondello 1983).

In the bird community, auditory communication between mates, offspring, and potential rivals is of high survival value. The males of many bird species must establish and defend territories in order to reproduce. Reproductive success and, therefore, fitness, is directly linked to acoustical communication and perception. A highly adaptive feature in some bird species is their use of alarm or distress calls to warn other flock members of predator approach or attack (Krzysik 1989).

The effects of noise on desert birds is not well known (Luckenbach 1978; Berry 1980). Marler et al. (1973) demonstrated, however, that high noise levels produced permanent hearing damage in canaries. Allaire (1978) reported that the blasting noise from strip-mining operations did not appear to affect nearby nesting birds in an eastern deciduous forest, but ground nesting birds were very sensitive to the resulting dust and debris. Although birds may at first be frightened by loud or unfamiliar noises, they rapidly acclimate to sound stimuli, particularly if there is any temporal, spatial, or acoustical pattern to the noise (Krzysik 1989).

Most studies of the effects of noise on mammals have involved domestic animals, livestock, or, occasionally, wild ungulates (reviewed in Gladwin et al. 1988; Manci et al. 1988). Noise has been documented to produce hearing losses and damage to ear tissues; a wide variety of physiological and behavioral responses; and reproductive changes, including reduced fertility and increased miscarriages. In their review of the literature, Manci et al. (1988) indicated that environmental impact assessments rarely consider the effects of noise on wildlife because of the lack of data. They and other researchers (e.g., Bond 1971; Bender 1977; Fletcher 1980) emphasize that a great deal of additional research is necessary before many aspects of the effects of noise on wildlife are understood—particularly long-term effects and population viability.

Snakes are generally believed not to perceive airborne sound waves because they lack a middle ear cavity and a tympanic membrane (ear drum). The columella, an elongated bone connected to the inner ear, of snakes articulates with the quadrate bone instead of the tympanic membrane. As an adaptation for swallowing large prey items, a snake's quadrate is loosely attached with ligaments to the lower jaw and the dorsolateral portion of the skull. Wever and Vernon (1960) demonstrated that snakes hear aerial sounds in the range of 100-700 Hz, especially 100-200 Hz. Through this sensitivity snakes can perceive the vibrations caused by the movements of large animals. Snakes pick up sound waves through their lower jaw, quadrate, and even the columella. A snake with its head on the ground is extremely sensitive and responsive to ground vibrations. Lizards, turtles, tortoises, insects and other invertebrates, and small mammals are all sensitive to ground vibrations to various degrees. The major adaptive significance is probably the detection of predators. The effect of ground vibrations on wildlife has not been researched.

The Army training mission at the NTC creates high levels of noise and vibration. Very little field data are available on the effects of offroad vehicle noises and vibrations on wildlife (Krzysik 1985). Research on the effects of noise and vibration from Army training activities on resident wildlife has never been conducted. Until such research has been conducted, existing data pertaining to taxa similar to those found at Fort Irwin provide the best context for understanding the possible effects of training-generated noise on installation wildlife.

10 Chemicals and Wildlife

Other important environmental impacts associated with training activities at Fort Irwin that need to be addressed and researched include the effects of smokes, obscurants, irritants, and live-fire chemical residues.

Obscurant smokes are regularly used over large areas of the landscape at the NTC during the large-scale OPFOR-BLUEFOR force-on-force exercises. The smokes used in the largest quantities are vapor clouds of fogoil and tank diesel, and aluminum chloride mists generated from hexachloroethane and powdered aluminum. A wide variety of hazardous compounds have been identified in these smokes, including known mutagens, carcinogens, and toxins. Hazardous compounds in these smokes include chlorinated aliphatic and aromatic hydrocarbons, and heavy metals. In the spring of 1983, preliminary field experiments were conducted at Fort Irwin to study the affects of these smokes on the native plants and animals (Schaeffer et al. 1986, 1987). Spiderwort (Tradescantia) plants, burroweed, and five species of native resident rodents (three heteromyids and two cricetids) were exposed to varying concentrations of the three types of obscurant smokes. Also, using a standard bioassay method, Tradescantia clones were used to assess the mutagenicity of suspected compounds. The results of these field experiments suggested that the flora and fauna exposed to smokes were at a higher toxicological risk than control organisms. Plants experienced genotoxic damage and lower measures of fertility, energy production, and survival. Chromosome aberrations were found in some of the exposed rodents. The high variability of the assay results obscured distance-dependent relationships between exposure and effects. The effects of smokes, obscurants, irritants, and live-fire chemical residues on ecosystem processes and wildlife populations must be addressed, but have not yet been researched on any Army installation.

11 Habitat Fragmentation

Habitat fragmentation is ecologically undesirable because it causes four basic problems: (1) direct loss of habitat, (2) creation of edges between two dissimilar habitats, (3) gene pool isolation, and (4) the creation of small fragmented populations. These problems affect both animal and plant populations. Habitat fragmentation, including habitat loss, is the most important factor affecting biodiversity throughout the world (Myers 1980; National Research Council 1980; Burgess and Sharpe 1981; Noss 1983, 1987; Harris 1984; Wilcox and Murphy 1985; Wilcove et al. 1986; Alverson et al. 1994).

The direct loss of a specific habitat type on a landscape basis reduces the total number of individuals of each species associated with the habitat. If a large block of habitat is eliminated, species that are rare or patchy in distribution may become extinct, and even populations of common species may be dramatically reduced and subjected to higher extinction rates (Wilcox 1980).

The creation of edges—the area where two dramatically different habitats meet—creates favorable habitats for "edge species," but unfavorable habitats for species requiring continuous large blocks of a specific habitat type. All human activities that change the landscape create edges: urbanization, agriculture, livestock management (grazing and feedlots), timber harvest, surface mining, road construction, powerline and pipeline corridors, water management projects, and Department of Defense training and testing activities. Human activities are continually transforming the landscape into a mosaic of edge habitats at the expense of large blocks of continuous habitat. Species that are adapted to exploit edge habitat—particularly birds—have increased their populations dramatically. Examples include red-winged blackbirds, grackles, cowbirds, robins, cardinals, indigo buntings, catbirds, and house wrens. Conversely, some bird species—primarily neotropical migrant warblers such as black-throated blue, cerulean, parula, Canada, black-and-white, and worm-eating warblers, ovenbirds, and waterthrushes—cannot tolerate edges. They require large blocks of continuous forest, much larger than their territory size would indicate (Robbins et al. 1989). In many cases, the creation of edges or novel habitats directly harms resident species. Researchers have shown an increase of nest predation and cowbird parasitism in edge habitats (Wilcove et al. 1986; see references in Krzysik 1989). Urban or agricultural development, including roads and trails, is accompanied by offroad vehicles, dogs, cats, house sparrows, starlings, Norway rats, house mice, and humans armed with guns or collecting bags. The creation of edges and its effects on native desert fauna has never been addressed.

Isolated populations and gene pools have a higher probability of extinction than nonisolated ones. Much of this effect is related to the limitation of population sizes, as discussed below. Of the 77 species of birds and mammals that have become extinct in recent history, 53 were island species (Ziswiler 1967). An isolated population has little or no gene flow to and from other populations. This translates to severely limited genetic potential to adapt or evolve to changing physical (abiotic) or biological environmental conditions. Reduced gene flow creates the same genetic problems common to numerically small populations. Isolation also means that if local populations suffer extinction, recolonization potential is low or nonexistent.

Small populations are subjected to high extinction rates for a variety of reasons (Simberloff and Abele 1976, 1982; Franklin 1980; Soule 1980; Frankel and Soule 1981; Allendorf and Leary 1986; Boecklen and Simberloff 1986; Ledig 1986; Ralls et al. 1986). Often this concept is referred to as the minimum viable population (MVP) necessary for survival (Shaffer 1981; Soule 1983; Gilpin and Soule 1986). In practice, it has been difficult to estimate or calculate MVP for natural populations, but effective population sizes of from 50 to 500 individuals have been calculated for various species (Frankel 1983; Brussard 1986; Reed et al. 1986). By definition, an inherent characteristic of small populations is their isolation or fragmentation.

The primary problem for small populations is genetic drift, which arises when a small population is represented by only a limited sample of the species' gene pool (Franklin 1980). Gene frequency—the proportion of specific alleles in a population—changes from generation to generation, even in the absence of selection, mutation, or migration. These random changes gradually increase homozygosity in the population. Genetic drift leads to three harmful consequences for populations: inbreeding depression, decrease in genetic variability, and random changes in the phenotype. Inbreeding depression (Packer 1979; Frankel and Soule 1981; Ralls and Ballou 1983; Soule 1983; Ralls et al. 1986) reduces population fitness in two ways: it increases the chances for the expression of recessive lethal genes and directly contributes to the loss of heterozygosity. The fitness of a population is closely related to its genetic variability, or heterosis (Soule 1980; Falconer 1981; Frankel and Soule 1981; Allendorf and Leary 1986; Ledig 1986). It has commonly been observed in domestic animals that heterosis, the increase in heterozygosity produced by crossing different genetic lines or strains, results in increased vigor, growth, longevity, and fertility. Species mold their gene-based phenotypic expressions of morphology, physiology, and behavior in response to selective pressures from their physical (abiotic) and biological environment. This molding encompasses adaptation and evolution. Therefore, random changes in a species' evolved phenotype reduces fitness to their environment.

In addition to the genetics-driven causes discussed above, the MVP concept recognizes five other factors responsible for the high extinction rates of small populations: (1) demographic stochasticity, (2) environmental stochasticity, (3) natural catastrophes, (4) human impacts or accidents, and (5) social dysfunction.

Demographic stochasticity refers to the natural fluctuations in population parameters: birth and death rates, and sex ratios. Fluctuations in these parameters are inconsequential to large populations, but a decrease in birth rate, an increase in death rate, or a highly skewed sex ratio—even for only a brief period—can cause a small population to go extinct.

Environmental stochasticity refers to the natural random variability inherent in the physical and biological environment of a population. Physical factors include temperature, precipitation, humidity, and wind. Biological factors include food availability, competition, predation, parasites, and disease organisms. It is easy to visualize how a small population could be severely affected by a high variance in one or more environmental factors. Severe weather, possibly coupled with low food availability, makes individuals susceptible to predation, parasites, or disease organisms.

Natural catastrophes such as floods, drought, hurricanes, tornadoes, volcano eruptions, wildfires, and rampant disease can effectively eliminate a localized population.

Human impacts have exterminated or almost eliminated species that once possessed large populations over extensive areas (e.g., passenger pigeon, bison, bald eagle, peregrine falcon). Humans have been even more effective at eliminating or endangering small, localized populations. Seventy percent of Arizona's threatened or endangered vertebrates, and 73 percent of New Mexico's are riparian species (Johnson 1989). These species occur in limited populations over a very small portion of the landscape, and they are being dramatically affected by human activities. Important human impacts that have exterminated local populations and continually threaten the survival of others include habitat loss or degradation, pollution, introduction of predators or competitors, overharvest, and vandalism. Human impacts frequently have been intentional, but many are accidental. On Army training lands, small and localized populations are in danger of extinction from habitat destruction and deterioration. Direct threats to plant and animal safety include tactical vehicles, live-fire exercises, chemical smokes, munitions, vandalism, and the accidental release of toxic or hazardous waste, fuel, oil, or solvent.

Social dysfunction has not been considered in models of population viability analysis (PVA). However, at least theoretically, functional population size may be limited in some species because some threshold number of individuals is necessary for social order and interactions.

Habitat fragmentation is currently a serious issue in all ecosystems, but its devastating effect in desert ecosystems has been ignored or not fully comprehended. The implications of fragmentation do not appear to have greatly influenced the land-use decisions that are continually being made.

Deserts are defined by their shortage of water and the unpredictablity of supply. Desert plants and animals have evolved adaptations either to conserve water or extract it more effectively from the environment. In addition to the lack of water, desert plants and animals are subject to unusually high environmental stresses and hazards, including prolonged drought, flash floods, daily and seasonal extremes of hot and cold, severe lightning, high winds, and dust storms. Periodic but unpredictable extinctions of local populations are the rule, not the exception. Large, undisturbed blocks of desert landscapes containing mosaics of topographical, geomorphological, and biological features must be designated and preserved to ensure the survival of species and gene pools. By chance alone, larger areas contain more pockets of survivors than smaller areas. Larger landscapes encompass more habitats, and a greater variety of them. Therefore, survivors within larger habitats naturally represent a more diverse gene pool. Additionally, large regions possessing habitat heterogeneity can be excellent buffers against the extinctions caused by demographic and environmental stochasticity, because natural catastrophic events are not uniform across landscape mosaics. It is critically important to maintain or reestablish continuous stretches of habitat or habitat corridors to ensure the recolonizing of areas where local populations have become extinct. Therefore, habitat fragmentation—which is equivalent to habitat reduction, conversion, or deterioration—is highly damaging to the continued existence of structurally and functionally intact desert ecosystems.

12 Management and Research Needs

Mitigating the Effects of the NTC Mission on Resident Wildlife

The magnitude and intensity of the current NTC training mission, which involves massive war game scenarios over large expanses of the landscape, combine with the low and unpredictable precipitation patterns of the Mojave Desert to preclude vegetation/soil restoration or rest-rotation land management strategies. However, there are various habitat and wildlife management options that Fort Irwin could pursue depending upon the relative value that NTC, FORSCOM, or the Army place on meeting environmental compliance obligations versus training scenario freedom. The feasible management strategies include options that place no constraints on the training mission, and options that place minimal or moderate constraints on some components of the unrestricted freedom policy currently in place at the NTC.

Strategies Placing No Constraints on the Training Mission

Creating and Restoring Landscape Components. Fort Irwin could pursue three strategies to increase regional biodiversity with no impact on the NTC training mission. These strategies center on creating or restoring riparian and wetland ecosystems. These ecosystems are critical to the maintenance of regional biodiversity, and of paramount importance for breeding, migratory, and overwintering birds—particularly in arid landscapes (Krzysik 1990b, 1993):

1. The ponds and wetlands at the sewage treatment facility could be doubled or tripled in land area, and extensive riparian communities could be constructed at the site. Additionally, enhancement procedures could be developed to optimize the structural features (physiognomy) and floristic compositions of these new ecosystems. A multidisciplinary effort employing ecological, engineering, and geological approaches should serve as a template for the project in order to optimize hydrological parameters and features, and make sure the new wetland communities supported optimal biological diversity and wildlife values across broad taxonomic groups. A minimum of 300 m off limits buffer zones should be set up to protect these important biological resources.

2. All springs on and adjacent to Fort Irwin should be evaluated by ecological, hydrological, and geological criteria, and subsequently managed to maximize perennial surface water by means promoting long-term hydrologic stability. Removal of exotic vegetation, primarily saltcedar (tamarisk, Tamarix), should be accompanied by restoration with desirable native woody perennials: cottonwood (Populus fremontii), willow (Salix sp., especially S. gooddingii), desert willow (Chilopsis linearis), seep willow (Baccharis sp.), quail bush (Atriplex lentiformis) and other Atriplex, honey mesquite (Prosopis glandulosa), and screwbean mesquite (Prosopis pubescens). Native forbs and grasses could also be planted, but these typically colonize voluntarily. If burros pose a threat to developing vegetation or water quality, they would have to be removed. The strategy discussed above will increase landscape biodiversity and provide benefits to game species such as desert bighorns, Gambel's quail, chukar, and desert cottontails. Buffer zones should be established around all springs. These buffers should be at least 0.5 km wide, but a width of 1 km would be more effective at protecting these critical biological resources.

3. Studies should be conducted for optimizing the locations and site-specific construction details for guzzlers—artificial water catchments constucted to collect ephemeral runoff from washes, gullies, or arroyos, after storms. Guzzlers are generally used to provide water for game or stock animals. However, an innovative approach would be to use guzzlers to provide landscape patches of increased vegetation cover and diversity. Migratory birds would particularly benefit from such an application. Another ecologically beneficial application of guzzlers would be to combine an effective guzzler design in an optimal location with a well, in order to create new riparian or wetland habitats. Buffer zones of 300 to 500 m should be established around these guzzlers.

Environmental Education. Another strategy for reducing habitat and wildlife damage that would not put any constraints on the training mission could be the development of an in-depth environmental awareness and education program, for both stationed and rotational personnel. A well conceived program would have three focal points:

1. A reduction in unnecessary offroad impacts
2. A reasonable awareness of the vulnerability of wildlife, vegetation, and soils, combined with an attempt to minimize environmental damage when in field operations
3. Instruction to avoid collecting, harassing, or killing wildlife. Snakes, both poisonous and nonpoisonous, are particularly vulnerable on military installations to being collected or killed (Krzysik, personal observation).

The author has conducted extensive field investigations throughout Fort Irwin since 1983, and it is his opinion that some of the environmental damage incurred, particularly in high-quality habitats, could have been avoided without constraining the NTC training mission. Examples of excessive and harmful use of offroad vehicles is unnecessary for fulfillment of the NTC mission include:

1. Offroad travel in off limits areas such as Goldstone, posted areas, and—occasionally—off the installation
2. Frequent offroad driving parallel to the roads and washes that predominate the landscape and are already used extensively for cross-country travel
3. Excessive driving in the buffer zones at the installation's boundaries
4. Unnecessary travel in live-fire ranges outside of maintenance roads and target pads, including construction activities that are not carefully conducted under existing environmental guidelines
5. Casual or exploratory offroad driving, commonly by the observer controller group.

Excess environmental damage at Fort Irwin is not attributable to malice or ill intent. Most of the soldiers interviewed by the author expressed general concerns for the environment and wildlife. However, many perceived Fort Irwin as a "barren, lifeless wasteland." The soldiers were unaware of the biological richness, ecological complexity, and environmental fragility of desert ecosystems. An educational program in environmental awareness would go a long way to minimize the unnecessary offroad habitat impacts discussed in the examples above.

Ecologically important areas of the installation that would benefit from less offroad traffic include: (1) yucca or cholla (cactus) groves, (2) the taller, denser, and more diverse vegetation associated with the larger washes, arroyos, and canyons, (3) rugged rock outcrops, canyons, and steep rocky slopes, and (4) the ever-diminishing fragmented mosaics of creosote bush islands in the main training corridors. Note that all of these represent important habitat structural and diversity components necessary for species persistence and coexistence.

Yucca and cholla are very slow-growing, long-lived species. They are very fragile and sensitive to offroad vehicle damage (Krzysik, personal observation).

All xeroriparian vegetation represents an important component of the desert landscape. Typically, this vegetation represents the highest species richness in the landscape. It includes species obligatory to this community, as well as upland species. Although creosote bush and burroweed form the characteristic Mojave Desert upland scrub plant community, these species benefit from ephemeral water availability, and reach their greatest heights and vigor along first- and second-order washes, and along roads (Krzysik, personal observation). Parallelling plant vigor in roadside habitats, creosote bush can exhibit greater densities, species richness, and trophic complexity in its arthropod fauna (insects, spiders, and mites) than comparable plants in undisturbed upland habitats (Lightfoot and Whitford 1991). This has been found to be particularly true for sap feeders, but also for predators.

Rugged rocky and boulder areas represent landscape components that increase regional species richness. These habitats host plant and animal species not found on the creosote bush flats. This habitat offers a great deal of cover for smaller vertebrates (e.g., rodents, lizards, snakes), and also shelter and nesting opportunities for larger predators like raptors, bobcats, and ringtail cats.

Fragmented small islands of creosote bush represent the only available habitat in the southern and central training corridors. In 1983, when the author began monitoring the woody vegetation and vertebrates of Fort Irwin, these islands represented an important available habitat component for the surviving wildlife communities in the main training corridors. These islands stood like pedestals, elevated in the surrounding landscape. Their probable origin was as follows: military vehicles—particularly tracked vehicles—effectively exposed the fine soils underlying surface crusts and desert pavement. The high winds typical of the Mojave Desert picked up these fine soils and deposited them in the shrub canopy, where airflow velocities are reduced. This action resulted in a net transport of soil from disturbed traffic areas (until compaction sets in) to mosaic patches containing woody vegetation.

Despite the disturbed and degraded landscape, these habitat islands contained high densities of kangaroo rat burrows. Actually, some habitat disturbance benefits kangaroo rats, since they prefer sandy substrates and experience less competition from other rodent species when shrub cover is reduced (Krzysik 1984, 1985). Habitat disturbance also usually increases the productivity of annual plants, whose seeds are the staple diet of kangaroo rats. Kangaroo rats are a keystone species in this ecosystem. They maintain the dominance of woody shrubs over grasses (Brown and Heske 1990). They represent a critical component of ecosystem trophic structure and stability, since their large biomass sustains a wide assemblage of predators. Kangaroo rat burrows are highly critical to the persistence of the ecosystem: the burrows provide lizards and snakes a necessary habitat component for predator escape, thermoregulation, and hibernation. Furthermore, these burrows are probably just as important to invertebrates. Kangaroo rat burrows may also be an important vehicle for providing rainwater and air (both oxygen and nitrogen) to the root systems of shrubs.

Between 1983 and 1989, shrub cover declined by 69 percent, 67 percent, and 51 percent in the valley, low bajada, and high bajada of the southern training corridor of the NTC, respectively. In other words, these habitat islands have become increasingly fragmented over time. The islands became smaller, there were fewer of them, and the distances between them increased. Additionally, the soils surrounding the islands were becoming more compacted. Soil compaction reduces water infiltration (causing greater runoff and making less water available for plants), prevents seed germination, and prevents burrowing by both vertebrates and invertebrates. The loss of these habitat islands, although they only represented 2.5 percent of the landscape, will result in complete local collapse of this portion of the ecosystem.

Strategies Placing Minimal to Moderate Constraints on the Training Mission

In this classification of management strategies, an identifiable proportion of the habitat resources defined above would be designated for various levels of protection. Site-specific protection levels would be decided by consensus with NTC trainers and biologists. Trainers would identify and rank landscape training requirements; biologists would identify and rank the ecological significance of landscape elements. Through an analytical and quantitative optimization process, a decision can be made to manage various areas of Fort Irwin under one of four protection levels. These levels would depend on the relative rankings assigned by the trainers and biologists. The following levels of protection are recommended:

1. Complete Protection—area is completely off limits
2. Partial Protection—traffic permitted only on roads and trails
3. Conditional Use—only minimal damage to vegetation and soils is acceptable; trainers would be required to complete an environmental protection and awareness program
4. Unrestricted Use—would encompass most of the southern and central training corridors of Fort Irwin.

If Fort Irwin decided to manage some of its landscape as off limits habitat-protection zones, the NTC could make a good case for the need to acquire more training lands—lands that are not of high ecological value.

Management for Threatened, Endangered, and Sensitive Species

The creation or protection of habitats with significant ecological values, as outlined in the previous section, would go a long way simultaneously to provide habitats for threatened, endangered, and sensitive species.

The creation or enhancement of riparian and wetland ecosystems provides habitat for the Federal endangered Least Bell's vireo; the California special-concern species: yellow warbler, black-tailed gnatcatcher, Cooper's hawk, and white-faced ibis; and other state-listed sensitive species: the black-crowned night heron, great egret, snowy egret, and great blue heron. These habitats are probably important for other rare or sensitive breeding, migratory, overwintering, or transient species, but their dependence on central Mojave Desert wetland sites remains to be investigated and documented.

Complete-protection (off limits) zones should include areas of known distribution of threatened or endangered species. Management of the desert tortoise and Mohave ground squirrel at Fort Irwin is primarily dependent upon setting aside natural areas and protecting the habitat from destructive activities. Goldstone has been identified for protection as a natural area for the Mohave ground squirrel. Eight tortoise-management zones have been identified for protection on Fort Irwin, and one of these is located in Goldstone. Three of the other seven population pockets, including the major population, occur along installation boundaries; three are found in high bajadas; and one is found in a live-fire range (Krzysik and Woodman 1991). Two USACERL technical reports containing more information about the desert tortoise and Mohave ground squirrel are currently in press (Krzysik 1994a, 1994b). One of the boundary tortoise populations also shares habitat with the Mohave ground squirrel and the Lane Mountain milk-vetch. This area is in the southwestern portion of the installation. A portion of the area was withdrawn from Goldstone to increase the size of the area managed by the NTC. The southwestern portion of the installation, south of Goldstone's Venus site and west of Fort Irwin Road, requires more study to clarify the distribution and abundance patterns of these three listed species.

Identifying and protecting natural areas for the desert tortoise and the Mohave ground squirrel would concurrently protect sensitive animal and plant species. Like the kangaroo rat, the desert tortoise is a keystone species in the Mojave Desert ecosystem. Its burrows are used by a large number of species, including snakes, lizards, burrowing rats, and a wide variety of invertebrates (Krzyski 1994a). The desert tortoise is also an indicator species that effectively reflects the ecological condition and integrity of the Mojave Desert ecosystem. Protecting all available undeveloped habitat at Goldstone is critical for managing sensitive species and biodiversity. The tank trail through Goldstone directly bisects a center of biodiversity, as well as critical habitats for threatened and sensitive species. Eleven species of small mammals are found in this valley, including the Mohave ground squirrel and Panamint kangaroo rat. At least nine species of lizard are also found in this area, including the uncommon collared lizard. Five species of snake have been seen in this valley, but more are undoubtedly present. This area contains a major and dense population of sidewinders. Nesting birds and migrants are also diverse and abundant in this area. Nesting species include the burrowing owl, LeConte's thrasher, roadrunner, loggerhead shrike, kestrel, red-tailed hawk, black-throated and sage sparrows, verdin, horned lark, house finch, Gambel's quail, chukar, Say's phoebe, ash-throated flycatcher, western kingbird, and rock wren. Migratory species are diverse, and include warblers (especially yellow-rumped, Wilson's, and yellow), sparrows (especially white-crowned, Brewer's, song, and chipping), flycatchers, orioles, tanagers, grosbeaks, and harriers.

It is absolutely essential to protect the habitat from tactical vehicles that stray off the Goldstone tank trail. This trail enables tactical vehicles to enter Goldstone near the guard gate, traverse the length of Goldstone, and enter into the northwest portion of the NTC near Nelson Lake. Offroad violations in Goldstone have dramatically increased since this trail was constructed in 1985. At present, habitat damage is continuing, and even bivouacs and camps have occasionally been setup offroad. Even when tactical vehicles do not leave the main tank trail, the use of the road creates noise, ground vibrations, and a great deal of dust in the center of a major area of biodiversity. Snakes and lizards have been crushed on the road, but accurate documentation is difficult, because of rapid carcass removal by scavengers—especially ravens. The creosote scrub vegetation along the tank trail is heavily covered with traffic-generated dust. The habitat east of the trail is particularly affected. The effects of the dust on the reproduction, growth, and viability of the vegetation (and herbivores) are not known. A reduction of traffic would mitigate the present situation. The trail could possibly be eliminated by routing traffic through NTC, just east of Goldstone. Alternatively, wheeled vehicles could use the existing main road through Goldstone. If it is not feasible to remove the tank trail, four protection measures must be implemented:

1. The OPFOR, OCs, BLUEFOR, Range Control, and all field personnel must be briefed that offroad areas are absolutely off limits
2. Large, conspicuous signs must be placed at both ends of the tank trail warning that Goldstone habitats are off limits
3. The off limits regulation must be carefully monitored and enforced
4. Severe penalties must be implemented to ensure compliance to the off limits regulation.

Research and Monitoring Needs

Basic and applied research and monitoring program needs at Fort Irwin are as follows:

1. A research program is needed to develop the technology to create, restore, enhance, and manage riparian and wetland ecosystems in arid landscapes, and for optimal construction and location of guzzlers.
2. The effects of Army training activities on habitats and vertebrate communities should continue to be monitored as initiated in 1983, by the state-of-the-art ECORAT methods developed by the author. Monitoring should continue at the permanent experimental plots established in 1983, and additional plots using identical experimental/sampling design and methods should be established. The locations of new plots should be based on three criteria: (1) replicate plots in the central corridor, (2) plots in different plant communities, (3) plots representing a gradient of shrub cover to reflect varying intensities of training levels. Plot allocation can be determined by the iterative use of remote sensing and ground truthing.
3. Multivariate models of species-habitat relationships need to be refined, incorporating recent developments in nonlinear systems. At present there is a critical need for an accurate, consistent, and robust tortoise-habitat model.
4. Geographic information system (GIS) technology and spatial statistics need to be integrated to develop modeling and simulation capabilities for investigating landscape patterns, processes, and dynamics. This development, coupled with species-habitat models, would enable natural resource specialists to predict the distribution of any given species, and quantify habitat quality and availability.
5. Vegetation community maps should be developed for Fort Irwin employing remote sensing and GIS technologies. The analytical representation of species-habitat relationships and wildlife-habitat models should be integrated with the GIS and vegetation community data.
6. The monitoring of listed species (desert tortoise, Mohave ground squirrel, Lane Mountain milk-vetch) should continue and be expanded. Additional surveys are required to identify and locate unique or sensitive animal and plant species, and ecological communities. An immediate emphasis needs to be placed on conducting bat surveys to accurately assess the distribution and abundance patterns of all bat species on Fort Irwin. The surveys should include the identification, characterization, and status of resident, migratory, and transient species. The next stage of this effort should be to initiate quantitative ecological studies for determining habitat use/needs and trophic relationships of Fort Irwin's bat communities.
7. A research program should be initiated to assess and monitor the habitat needs of migratory and overwintering bird populations. The emphasis should be on avian use of springs, seeps, wetlands, and riparian ecosystems.

8. Novel strategies should be developed to mitigate negative effects on wildlife and habitat resources in heavily used NTC training ranges.
9. The role of Fort Irwin in contributing to regional biodiversity should be assessed. On this basis, wildlife and habitat management strategies are needed to maintain or enhance regional biodiversity and establish Fort Irwin's continued role in the regional context.
10. Fort Irwin should coordinate natural resources and biodiversity management strategies with Naval Air Weapons Station, China Lake; Marine Corps Air Ground Combat Center; Edwards Air Force Base; the Bureau of Land Management; and the National Park Service. This would represent a landmark proactive conservation initiative for ecosystem management at regional scales.

13 Summary

Fort Irwin is located in the central Mojave Desert, in a rugged landscape of mountain ranges, rolling bajadas, and extensive valley plains. This topography characterizes the basin and range geologic province. Fort Irwin consists of three distinct management units: the National Training Center (NTC), where military training maneuvers, war game scenarios, and live-fire exercises take place; the Goldstone Deep Space Communications Complex, a NASA-JPL facility off limits to military training; and Leach Lake Bombing Range, used by the Air Force.

Neither military trainers in general nor the public at large appreciate the biological richness, ecological complexity, and sensitive fragility of desert ecosystems. A simple plant community (creosote-burroweed scrub) dominates the installation's landscape, but the complex geomorphology and the presence of springs, seeps, and artificial wetlands provides habitat components for an unusually rich assemblage of biological resources.

Seventeen species of rodents have been collected by the author at Fort Irwin, including four species of kangaroo rats. Two of these species of kangaroo rats were previously unknown at the installation, and were not known to be associated with central Mojave scrub plant communities. Two additional species of Peromyscus may be found in the Avawatz Mountains of the fort. Three landscape habitat elements determine the major habitat partitioning by the rodent communities: extent of shrub cover, substrate texture (surface particle sizes), and presence of perennial surface water or groundwater close to the surface. However, floristics (plant species compositions) also play a role. The author's capture of a desert shrew at Fort Irwin represents the first record of an insectivore found within the central Mojave Desert. Other records are for the periphery of the desert. Eleven species of lizards were observed at Fort Irwin—substrate texture and shrub cover are the main habitat components determining their presence. Two other secretive and nocturnal lizard species are believed to live on the installation. Eight species of snakes have been directly observed, and evidence of four more has been confirmed by the author. Other evidence indicates the possible presence of six additional species.

The creosote-burroweed scrub on the installation typically hosts only five species of breeding birds, but wide-ranging raptors and others are present. The installation's rocky outcrops, canyons and arroyos, cliffs, cholla (cactus) or yucca (joshua trees) groves, springs, seeps, and riparian habitats appreciably increase the richness of the avian community. The ponds, wetlands, and riparian zones created at the installation's wastewater treatment plant have dramatically increased regional biodiversity. Despite only limited observations by the author, primarily during the spring, more than 70 species of birds have been observed at this locality. Observed species include breeding, overwintering, migratory, and transient individuals.

Fort Irwin is the permanent home to three species in jeopardy: the Federally listed desert tortoise (threatened) and Lane Mountain milk-vetch (endangered), and the California-listed Mohave ground squirrel (threatened). On a single occasion the author has seen a Least Bell's vireo (Federally listed) at Bitter Spring, but the individual was presumed to be a transient.

The California Fish and Game checklist of sensitive species includes 11 species of birds found on Fort Irwin: four of these species were observed to breed on the installation, three probably breed there, two migrate through the installation, and two are transients. Four species of wading birds often observed at Fort Irwin represent species that the checklist associates with California habitats in serious decline— wetlands and riparian. The California checklist also listed 11 species of bats, 9 of which may be residents (permanent or migratory), temporary migrants, or transients at Fort Irwin.

Therefore, despite a half-century of military training activities, Fort Irwin landscapes still contribute significantly to regional biodiversity.

Most training exercises at NTC, and therefore most habitat destruction, take place in two broad valleys—the southern and central training corridors. The more rugged mountainous or rocky portions of the installation are less impacted, but human incursions also occur to various degrees in these areas. On a localized basis, some of the rugged, rocky terrain provides favored bivouac areas, because they offer tactical concealment. However, because the primary habitat components for wildlife in these areas are boulders and rocks, these areas are not susceptible to the same direct destruction as the shrub communities, cryptogamic crusts, and desert pavements on the valley floor. The vertebrate communities in these rugged areas do not appear to have been heavily impacted by NTC's training mission. However, the effects of noise, vibration, chemical impacts, and human harassment have not been assessed. The impacts of such factors may be important for larger wildlife species. Additionally, these impacts may take longer to manifest themselves.

The reduction of perennial shrub cover and the replacement of tight, cohesive gravelly soil surfaces with loose, sandy substrates has shifted the structure of the original vertebrate communities to species that prefer very open habitats with loose, sand substrates or sand dunes. Birds represent the first faunal elements to respond to the reduction of shrub cover. The horned lark, a species preferring a great deal of bare ground, is typically the only bird species found in heavily used training ranges. Three rodents characteristic of creosote-burroweed scrub—the little pocket mouse, grasshopper mouse, and deer mouse, require high shrub cover, and are being replaced in training areas by the desert kangaroo rat, which prefers open habitats with loose, sandy soils. Zebra-tailed lizards and desert iguanas, both of which are partial to sandy soils, are characteristic lizards of training ranges. Although virtually all of the installation's lizard fauna can be found in NTC disturbed sites, they occur at a much lower density. The reduced shrub cover in training ranges makes lizards much more vulnerable to predation. There is also less shade and cover for thermoregulation, and food resources are appreciably reduced, including vegetation, litter, and arthropods.

The effects of reduced shrub cover and substrate changes on snake communities have not been quantified because snakes are primarily nocturnal and very secretive, making them very difficult to observe and study. Snakes are infrequently encountered in training ranges, perhaps in part because they are known to be very sensitive to vibrations, and can hear airborne low-frequency sounds. However, it is not known whether noise and vibrations or habitat changes are more important in limiting snake distributions in training ranges. Both may be equally important. Reduced shrub densities increase their vulnerability to predators, reduce their ability for thermoregulation, and decrease their food resources—small rodents, birds, lizards, and arthropods.

The author's research at Fort Irwin has focused on quantifying the effects of habitat changes on the structure and abundance patterns of vertebrate communities. Since funding was always low for this reasearch and time was very limited, the author was forced to develop highly economical biological inventory methods consistent with ecological validity and statistical sufficiency—ECORAT (Ecological Rapid Assessment Technologies). The research has developed (and continues to refine) species-habitat models that are directly applicable to managing wildlife resources. The models are useful for quantitative inputs whenever the effects of habitat changes on resident species must be assessed or predicted (e.g., biological assessments, environmental assessments, Environmental Impact Statements, and other regulatory and compliance documentation). The research also represents a direct introduction to studying the effects of habitat fragmentation, and the potential for incorporating mitigation corridors on landscape scales for regional resources and ecosystem management.

Other important training-related environmental impacts at Fort Irwin that must be addressed and researched include the effects of noise, vibration, smokes and obscurants, irritants, and live-fire chemical residues. The effects of such impacts on ecosystem processes and wildlife populations must be addressed, but have not yet been researched on any Army installation.

Strategies for mitigating the effects of the NTC mission on resident wildlife have been identified. Strategies that would cause no constraints or impacts on the training mission include:

- Enhancing and creating additional ponds, wetlands, and riparian zones at the installation's wastewater treatment facility and including a 300 m buffer zone
- Restoring, enhancing, and providing additional riparian habitats at springs on and adjacent to Fort Irwin, including the establishment of 0.5 to 1 km buffer zones
- Constructing guzzlers to create new riparian or wetland habitats
- Instituting a comprehensive and proactive environmental awareness and education program.

A strategy that would constrain the training mission to some degree is the setting aside of wildlife and habitat protection zones. Such zones could specify various ranges of protection, from complete protection (off limits), to permitting traffic on roads and trails only, to conditional use where a concentrated, preplanned effort is made to minimize damage to vegetation and soils.

Strategies have also been identified to protect threatened, endangered, and sensitive species. Details about these are being prepared for publication in separate reports addressing the desert tortoise and Mohave ground squirrel. The general approach would be to provide special management zones for the protection of sensitive species and communities.

Finally, the author has identified several high-priority research and monitoring needs for Fort Irwin, including:

1. Development of the technology to create, restore, enhance, and manage riparian and wetlands ecosystems
2. Continuation and expansion of the monitoring program established by the author in 1983, using the identical experimental design and sampling methods (ECORAT)
3. Incorporation of GIS technologies with the multivariate techniques developed by the author
4. Continuation and expansion of efforts to monitor listed and sensitive species and ecological communities, including migrating and overwintering birds
5. Development of novel strategies to mitigate the negative effects on wildlife and habitat resources in heavily used NTC training ranges

6. Assessment of Fort Irwin's role in contributing to regional biodiversity, and what management strategies are required to maintain or enhance its continued role within this regional context
7. Fort Irwin should coordinate its natural resources monitoring and management strategies with other DOD installations and other Federal agencies in the Mojave Desert within the context of a regional scale conservation effort directed at biodiversity maintenance and ecosystem management.

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Abbreviations and Acronyms

APC	armored personnel carrier
APDS	armor-piercing discarding sabot
BLM	Bureau of Land Management
BLUEFOR	American forces (in NTC war games)
CNG	California Army National Guard
DSCC	Deep Space Communications Complex
GIS	geographic information systems
HMMWV	High Mobility Multipurpose Wheeled Vehicle
ITV	Improved TOW Vehicle
JPL	Jet Propulsion Laboratory
MAAR	Mojave Army Antiaircraft Range
MILES	Multiple Integrated Laser Engagement System
MVP	minimum viable population
NASA	National Aeronautics and Space Administration
NTC	National Training Center (Fort Irwin)
NAWS	Naval Air Weapons Station, China Lake
OC	observer controller
OPFOR	opposing forces (in NTC war games)
PVA	population viability analysis
TOW	Tube-Launched, Optically Tracked, Wire-Guided (Missile)
TPT	training proficiency test
UTM	Universal Transverse Mercator (coordinate system)

Appendix: Revised nomenclature for Higher California Plants

Former Scientific Name	Current Nomenclature (after Hickman 1993)
Bromus rubens	B. madritensis ssp. rubens
Cassia armata	Senna a.
Castilleja chromosa	C. angustifolia (more study needed)
Ceratoides lanata	Krascheninnikovia l.
Coryphantha vivipara var. rosea	Escobaria v. var. r.
Datura meteloides	D. wrightii
Dichelostemma pulchellum	D. capitatum
Ephorbia albomarginata	Chamaesyce a.
Euphorbia polycarpa	Chamaesyce p.
Haplopappus acradenia	Isocoma a.
Hilaria rigida	Pleuraphis r.
Krameria parvifolia	K. erecta
Lotus tomentellus	L. strigosus
Nicotiana trigonophylla	N. obtusifolia
Orthocarpus purpurascens	Castilleja exserta
Oryzopsis hymenoides	Achnatherum h.
Plantago insularis	P. ovata
Salsola australis, S. iberica, S. kali (all misapplied)	S. tragus
Senecio douglasii	S. flaccidus var. douglasii
Stipa speciosa	Achnatherum speciosum
Thelypodium lasiophyllum	Guillenia lasiophylla

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