Preliminary Report on the Spring Survey of Desert Tortoises at the Goffs Permanent Study Plot and Special Project on Effects of Roads

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Introduction

The Goffs Permanent Study Plot (PSP) was established in 1977 through the auspices of the Bureau of Land Management (BLM) and was previously sampled in 1977, 1980, annually between 1983-1986, 1990, and 1994. This site and three others (Chemehuevi Valley, Fremont Valley, and the Desert Tortoise Research Natural Area/Interpretive Center) became part of a research project titled "The Effects of Roads on Desert Tortoise Populations and on Ecosystem Health in the Mojave and Colorado deserts of California." This project, which was initiated in spring of 1999, primarily was funded by USGS/WERC in FY99 and FY00. During FY00 Len Gaydos and Matt Brooks provided ~$17,000.

Methods

The Methods are discussed in detail in the Study Plan and are not repeated here. In March of 2000, we began the second year of work by setting up an enlarged plot of approximately 1.6 square miles at the Goffs PSP. The enlarged plot (hereinafter referred to as the Road Plot) included the original Goffs PSP (hereinafter referred to as the Goffs PSP), which was a square mile, as well as an expansion that allowed for sampling along and adjacent to the western edge of the Goffs Road. All field work for the tortoise and soil sampling was completed by mid-June and then the Road Plot was dismantled. The field team for tortoise surveys consisted of Tracy Goodlett, Glenn Goodlett, Kemp Anderson, and Tim Shields, all with considerable field experience with tortoises and vegetation. I visited the plot on several occasions to work with the field team. Three ill tortoises were salvaged for necropsy and sent to Dr. Bruce Homer at the Department of Pathobiology, University of Florida. The results of the necropsies and elemental analysis of kidney, liver, and keratin are expected to require up to four months. Blood samples were collected from several other tortoises and analyzed for presence of antibodies to *Mycoplasma agassizii*, the causative pathogen for upper respiratory tract disease, using an enzyme-linked immunoassay (ELISA) test. Nasal washes or flushes of the nares were conducted on the same tortoises for a polymerase chain reaction (PCR) test and cultures for *Mycoplasma agassizii* and an unnamed species of *Mycoplasma*. The blood and nasal samples were analyzed through the efforts of Dr. Mary Brown, Department of Pathobiology, University of Florida.

During the week of April 24, I and Dr. Maurice Chaffee from the USGS's Geologic Division in Denver sampled plants and soils, sediments, and rocks in transects running from the Goffs Road into the interior of the road plot. We collected 43 single and duplicate specimens of

Pleuraphis rigida, Opuntia basilaris, Schismus sp., *Chamaesyce* sp., and *Ditaxis* species for elemental analysis. The specimens were analyzed at Actlabs-Skyline in Tucson for heavy metals and other elements by INAA and ICP-MS and I recently received an excel file of the data. Dr. Maurice Chaffee is arranging for analysis of soil, sediment, and rock specimens separately. Dr. David Miller and associate (USGS, Geologic Division, Menlo Park) also visited the site to begin surficial studies of the plot and surrounding area.

Results and Discussion

Demographic data on live tortoises. The following summary is preliminary and focuses on the live tortoise data for the Goffs PSP, specifically numbers of tortoises registered by size, age-class, and sex, as well as densities by size-class. The data sheets for journal notes, live desert tortoises, health profiles, dead tortoises, predator sign concentrations, plant transects, and anthropogenic impacts have been evaluated and reviewed but not yet finalized. Tables for the Road Plot data set have not been prepared yet because they are not usable in year-to-year comparisons.

The desert tortoises on the Goffs PSP were considered to represent a stable population between the late 1970s and 1994. The population was treated as the Gold Standard for "healthy" tortoise populations in relatively undisturbed habitats in California. Some demographic data from 1980-1994 are compared with the spring 2000 findings in Tables 1 and 2. Between 1980 and 1994, from 220 to 296 tortoises were registered on the plot in each of the three sample years shown. Prior to 2000, the lowest figure occurred in 1990, a very dry year when spring activity was limited. The major change occurred in 2000, when only 30 tortoises were found, from 10.1 to 13.6% of the 1980, 1990, and 1994 figures.

The numbers of breeding tortoises registered per unit area (in this case, per square mile) can be one measure of well-being of populations when compared across years. The figures in Table 1 show only total numbers, not sexes of the subadult and adult tortoises. Figures for males were higher than females in 1980 but females were predominant in 1990 and 1994. Between 1990 and 1994, the numbers of breeding females ranged from 74 to 98. The important change appears to have come between 1994 and 2000. Of the 13 tortoises in the subadult and adult size classes found in 2000, only four were females and all four were subadult or small adults. In comparisons of gross numbers of registered tortoises, there has been a decline of 94-95% of the female tortoises of breeding size. The analysis of shell-skeletal remains will reveal whether more females than males died and if the differences are significant. Overall, we can state that both the number and size of the breeding females have declined markedly.

No statistically significant changes occurred in tortoise densities for the samples taken between 1980 and 1994. The reader can quickly determine this by looking at whether the 95% confidence intervals overlap for each size class and between years. In contrast to the 1980-1994 samples, the density figures for 2000 show a statistically significant decline in all the size classes described in Table 2. For all sizes of tortoises, the decline is ~76 to 80% when measured by the changes in densities. The most marked differences are in the larger size classes (large immature, subadult and adult tortoises), where the change in midpoint estimates is about 90%. The midpoint estimate for all sizes of tortoises (88) on the plot may be optimistic. This figure and

large confidence interval are based on the lack of recaptures of many of the small tortoises. In spring of dry years, tortoise activity is limited and animals are infrequently above ground. The smaller individuals are especially difficult to locate. In addition, if the tortoises are ill, then activity levels may be even lower. By the time we conducted the second census in May, many tortoises were deep in their cover sites, out of view, and although we knew where some of them were, we have to actually see them to include them in the census and density estimate. If annual and herbaceous perennial plant production had been higher in spring of 2000, we would have higher success rates in recapturing tortoises, thereby narrowing confidence intervals and improving estimates of tortoises in the smaller size classes. In spite of these weaknesses in the sampling techniques and quantitative analyses, I and the field staff believe the decline in tortoises between 1994 and 2000 has been substantial and significant.

Health profiles and necropsies. I also have not yet evaluated the 35-mm slides of tortoises and compared them to the health profile data sheets for consistency, so the following results are prelminary.

The majority of the tortoises on the Goffs PSP (N = 30) and Road Plot (N = 54) showed signs of shell lesions typical of cutaneous dyskeratosis on the plastron, carapace, forelegs, or combinations of those areas. We salvaged three tortoises with moderate to severe lesions and, although several more were also candidates, I delayed making decisions on salvaging more until the tortoises were no longer easily accessible. The three salvaged tortoises were No. 543 (unsexed, 174 mm MCL), No. 841 (male, 242 MCL), and No. 842 (males 238 mm MCL). On gross necropsy, the tortoises exhibited abnormalities in the thyroid, liver and other organs, and lesions typical of cutaneous dyskeratosis were evident on the shell and limbs. Levels of T_4, a thyroid hormone assay, for the three necropsied tortoises were either higher or lower than the range we have for other tortoises from other sites in California. Cutaneous dyskeratosis may be playing a role in the high mortality rates, but may not be the sole cause. None of the three tortoises sent for necropsy tested positive for upper respiratory tract disease (URTD) using the ELISA test. Blood was drawn from an additional four tortoises and nasal washes were taken from six tortoises. One blood sample was compromised in shipping. None of the three necropsied tortoises or the three tortoises with viable blood samples tested positive with the ELISA test. The PCR and culture results (N = 9) are not yet available. The six ELISA samples of tortoises from a the total sample of 54 observed represents an 11% sample. When the PCR and culture results are available, it may be possible to say more about the role of URTD in the high mortality rates here. Currently there is no evidence for a major role.

Shell-skeletal remains. The initial laboratory work on the shell-skeletal remains was completed in August with the assistance of W. Bryan Jennings and R. Jennings. The preliminary summary indicated that remains of at least 400 tortoises were on the Road Plot (Tables 3-5). Another tabular analysis still needs to be prepared for the Goffs PSP alone. There are additional, unmatched fragments and remains in predator scats that could represent more tortoises. Where possible, fragments were matched to partial shell-skeletal remains collected during spring 2000. Remains in predator scats were evaluated to determine if bones/scutes represented new tortoises. The initial work required (1) reconstruction of each set of remains and identification of missing bones and scutes; (2) determination of size (carapace length at the midline, MCL), sex, and relative age; and (3) confirmation of identity (marked, unmarked tortoise, original identification

number); (4) estimate of time since death (e.g., < 1 month, < 1 year, 1-2 years, 2-4 years, and > 4 years) using keys; and (5) assignment of a potential cause of or contributors to death.

Shell-skeletal remains of approximately 400 tortoises were collected on the Road Plot; of the 400, 233 were on the Goffs PSP. At least 216 of the 400 remains were of previously marked tortoises. The 233 remains from the Goffs PSP represent tortoises that died between 1994 and 2000. The tables (Tables 3, 4, and 5) focus on remains from the Road Plot and provide valuable statistics on who has died, when the deaths occurred and gender. Note that subadult and adult tortoises formed the greater part of the sample. These remains are much easier to spot and persist longer than do remains of small juveniles. All size classes are represented. The figures in Table 2, which shows estimated time of death, indicate that the majority of deaths appear to have occurred between mid-1996 and mid-1999, although the death rate still appears high when the density of remaining live tortoises is considered.

The preliminary data on shell-skeletal remains support the live tortoise data set of a catastrophic decline. I anticipate that I will have summaries of data on shell-skeletal remains in tables for the Goffs PSP by late November. Such data will include size-age class structure of the dead animals, estimated years of death, estimated causes of or contributors to death, and locations of the dead animals. When the data are segregated for the Goffs PSP, then mortality rates can be calculated for the larger tortoises. I anticipate that only a small portion of deaths will be attributed to typical anthropogenic causes (e.g., roads, gunshot, vandalism). However, there are more road-related deaths than I anticipated.

Potential role of rainfall. Some biologists have asked whether precipitation levels may have induced or contributed to the population decline. Rainfall data from two nearby NOAA weather stations at Mitchell Caverns and Needles for the period 1976-1999 are displayed in Table 7 for both the hydrologic year (October 1-September 30) and "winter" (October 1-March 31). Long-term means for both hydrologic and winter rainfall are also included. High numbers of tortoises died between mid-1996 and mid-1999. With additional analysis, I will determine whether high mortality rates are correlated with any unusual droughts or sequences of droughts. At this time, I don't think the rainfall patterns were solely responsible for the declines.

Relationships of High Mortality Rates at Goffs and Other Sites

The preliminary findings on live and dead tortoises confirm our suspicions that death rates were abnormally high between 1994 and 2000 and at catastrophic levels. The high number of shells observed in the region by Ms. Kelly Hawk-Mee and other National Park Service personnel and by Mercy Vaughn and Steve Boland a few years ago were indications of a change in status of this population. The reasons for high mortality rates at Goffs may be similar to those for the Chemehuevi Valley and Wash, Ward Valley, and the Chuckwalla Bench. All of these populations have relatively high levels of shell lesions and shell disease.

Status of the Road Project: Funding and Future Actions

1. Chemehuevi Valley. This project was initiated in mid-FY99 with funds from USGS/WERC. The funds covered part of the project: unfunded tasks included

geochemical analyses of scute and bone and lab preparation of samples. For Chemehuevi I estimated the costs at $6580. The Alien Plant portion of the project was also not accomplished because of lack of funds. The cost estimated was $13,719 per year, including labor, travel, and supplies. Matt Brooks was a key person on this project. Therefore, for FY99, the shortfall was $20, 299.

Contributions and collaborators: Dr. Chaffee contributed support of time during FY99 for soil sampling and a preliminary analysis of data. Because he found a lead anomaly adjacent to the west edge of the road (but not the eastern edge, where the wash and large berm have altered sheet flow), he requested that I sample the west edge of the road for plants, which would be additional costs of travel, lab analysis, and data analysis. Dr. Miller contributed the time and travel costs to prepare maps of surficial geology of the plot. Dr. Bruce Homer necropsied 3 tortoises from this plot and I added the data on elemental composition of liver, kidney and scute (keratin) into the data base for the survey of toxicants in tortoises in the California deserts. Dr. Wayne Alley (statistician) is assisting us with the analyses of data on toxicants. Matt Brooks and I are working on analysis of the data on the dry stems of the alien mustard, *Brassica tournefortii*, from 180 transects. As might be expected, the high numbers of the *Brassica* were near the road, but this alien could still be found at distances > 1.5 km from the road edge. We expect to prepare a paper on this project.

2. Goffs PSP and Road Plot. In FY00, the project was supported largely with USGS/WERC funds and again covered only part of the project. USGS/WERC funds did not cover geochemical analyses of scute and bone and lab preparation of samples ($6580) and the Alien Plant portion of the Study Plan ($13,719) for a shortfall of $20,299. Year-end funds were provided by Len Gaydos ($11,000 for geochemical analyses of scute and bone, a GPS unit and a Brunton compass) and by Matt Brooks ($1485 on INAA, ICP-MS for laboratory analysis of tortoise forage plants; $2,030 for analysis of soils, sediments, and rocks; and $2485 on initial sorting of some of the 400 shell-skeletal remains from Goffs). The year-end funds will cover most geochemical analysis of scute and bone of tortoises. Dr. Chaffee again contributed the cost of time and travel and some of the costs for analysis soils, sediments, and rocks. Dr. Miller contributed (and will contribute more) time for work on the surficial geology. Dr. Bruce Homer necropsied there tortoises from this plot, and his report is anticipated in late fall.

3. For FY01, I hope we can conduct the Alien Plant portion of the Chemehuevi and Goffs plots, and complete the geochemical analyses of scute and bone. Considerable additional time and effort must be spent in (1) analyzing the live and dead tortoise data (effects of roads); (2) analyzing the geochemical data on soils, sediments, and rocks and relationships to tortoise forage plants; (3) completing the field work on analysis of surficial geology of the Goffs plot and preparation of maps; and (4) initiating field work at Fremont Valley, the third plot. I anticipate shortfalls similar to those described above for the previous plots. In addition, I would like to sample forage plants at Chemehuevi and Goffs, if conditions permit. Both 1999 and 2000 were dry years at the plots, and common tortoise forage plants were difficult to find and the number of species was limited. I would like to return to both sites to get more samples. I estimate 6 days of

effort and travel costs of $420, plant analytical costs (INAA and ICP-MS) of $4,000 for a total of $4400.

I hope that David Miller and Maurice Chaffee will assist as they have done at the other sites during the past two years and that Matt Brooks will be able to work with us too.

4. Transfer functions for modeling road impacts. Now we have data for two roads with high and moderate traffic volume. By the end of FY01 will have a third site with low traffic volume. We will be in a good position to work on the transfer functions. The analysis will be more complicated and time consuming than originally anticipated because of the steep population declines at the first two sites. I plan to use live and dead tortoise data sets gathered over the last 20 years for the model, instead of confining the model to data from the 1990s.

5. Collaboration on effects of roads on sheet flow and productivity of vegetation and animals. The existing study sites have a wealth of data and offer tremendous opportunities to study and model effects of roads, berms of different sizes, washes, and railroads on sheet washing. I hope that we will be able to combine our energies to work on this project together.

6. Issues Other than the Roads: Findings on tortoise health and mortality rates. In the near future, a priority for tortoise research includes determination of (1) the extent of the region(s) affected by high mortality rates, and (2) causes and contributors to the high death rates. I and the field team have discussed methods for quickly evaluating tortoise mortality rates using modifications of existing techniques, as well as new techniques. Collectively we will have much better opportunities to determine causes and contributors to high mortality rates if we check our long-term sites more frequently and if we can survey large parts of critical habitats quickly with broad-brush techniques. We have a team of veterinary research scientists and scientists from the USGS capable of hastening analytical work on causes or contributors to death. The key hindrance to pursuing both of the above topics is lack of funding.

Table 1. A comparison of desert tortoises registered at the Goffs permanent study plot in 1980, 1990, 1994, and 2000 by size-age class, sex, and numbers of individuals located. These figures do not include the expanded plot for 2000, only the original plot. MCL = carapace length at the midline.

Size-age class	Years							
	1980		1990		1994		2000	
	Total	%	Total	%	Total	%	Total	%
Juvenile 1 (<60 mm MCL)	6	2.0	4	1.8	6	2.4	0	
Juvenile 2 (60-99 mm MCL)	20	6.8	24	10.9	10	4.0	4	13.3
Immature 1 (100-139 mm MCL)	41	13.9	27	12.3	24	9.6	6	20.0
Immature 2 (140-179 mm MCL)	43	14.5	22	10.0	32	12.9	7	23.3
Subadult (180-207 mm MCL)	36	12.2	27	12.3	43	17.3	5	16.7
Adult 1 (208-239 mm MCL)	83	28.0	65	29.6	78	31.3	2	6.7
Adult 2 (≥240 mm MCL)	67	22.6	51	23.2	56	22.5	6	20.0
Totals	296		220		249		30	

Table 2. A comparison of density estimates (numbers per square mile) for desert tortoises at the Goffs permanent study plot in 1980, 1990, 1994, and 2000 by size-age class using the Stratified Lincoln Index. The figures show the midpoint of the population estimate with the 95% confidence intervals (in parentheses) below. These figures do not include the expanded plot for 2000, only the original plot.

Size classes, strata	Point estimate (tortoises/square mile) with 95% confidence intervals			
	Year			
	1980	1990	1994	2000
All size classes	440 (370-522)	362 (286-457)	447 (353-567)	88 (34-230)
≥ 140 mm MCL (immature 2, subadult and adult tortoises)	259 (217-308)	210 (165-268)	280 (220-356)	24 (9-63)
≥180 mm MCL (subadult and adult tortoises)	195 (162-234)	172 (134-221)	228 (177-294)	18 (6-54)
≥208 mm MCL (larger adults)	160 (131-197)	129 (99-168)	174 (130-233)	10 (3-37)

enlarged plot of ~1.6 square miles, the Road Plot. The figures for the original plot, the Goffs PSP will be less, when they are calculated.

	No. of tortoises of each sex				
Size-age class	Unidentified	Female	Male	No.	(% total)
Juvenile 1	2	0	0	2	0.5
Juvenile 2	32	0	0	32	8.0
Juvenile (est.)	4	0	0	4	1.0
Immature 1	28	0	0	28	7.0
Immature 2	53	0	0	53	13.3
Subadult	7	69	22	98	24.5
Adult 1	3	75	35	113	28.3
Adult 2	0	3	65	68	17.0
Adult (est.)	2	0	0	2	0.5
Totals	131	147	122	400	100

Table 4. Estimated time since death for tortoises found dead at Goffs study site in 2000. The numbers shown in this table are for the new, enlarged plot of ~1.6 square miles, the Road Plot. The figures for the original plot, the Goffs PSP, will be less, when they are calculated.

	Estimated Time Since Death					
Size-age class	<1 mo	<1 yr	1-2 yrs	2-4 yrs	> 4 yrs	Unknown
		mid 2000-mid 1999	mid 1999-mid 1998	mid 1998-mid 1996	prior to mid-1996	
Juvenile 1	0	0	2	0	0	0
Juvenile 2	0	2	18	11	1	0
Juvenile (est.)	0	0	1	2	1	0
Immature 1	0	3	4	17	4	0
Immature 2	1	1	22	27	2	0
Subadult	0	4	42	41	11	0
Adult 1	0	6	28	62	17	0
Adult 2	0	9	25	27	7	0
Adult (est.)	0	0	1	0	1	0
Totals	1	25	143	187	44	0

site in 2000. The numbers shown in this table are for the new, enlarged plot of ~1.6 square miles, the Road Plot. The figures for the original plot, the Goffs PSP, will be less, when they are calculated.

Location of remains	No. of tortoises in each size-age class				
	Juvenile	Immature	Subadult	Adult	Unknown
Location within Habitat					
in the open	27	64	73	139	0
under a shrub	17	47	59	82	0
in a wash	5	9	24	30	0
partially buried	1	4	4	9	0
at a tortoise burrow	1	2	1	3	0
with other shells/bones	5	7	10	26	0
other	4	2	1	7	0
unknown	0	1	0	0	0
Totals	60	136	172	296	0
Location with Regard to Anthropogenic Activities					
No apparent relationship	31	68	87	159	0
Vehicle trails/tracks	0	0	1	4	0
Highway	2	1	0	2	0
Cattle (trailing, bedding, etc.)	5	11	9	18	0
Vandalism/gunshot	0	1	0	0	0
Other	0	1	1	0	0
Totals	38	82	98	183	0
Location with Regard to Predator					
No apparent relationship	1	33	78	93	169
Predator nest or perch	2	5	2	0	1
Canid den, burrow	3	0	1	3	3
Predator concentration, remains	4	0	0	2	10
Neotoma midden	5	0	0	0	0
Totals	15	38	81	98	183

Table 6. A summary of precipitation at two NOAA rainfall stations near Goffs between 1976 and 1999. Records for 98-99 and 99-00 are incomplete.

Mitchell Caverns		mm		mm	Needles		mm		
Year	Total year	Norm year	Oct-Mar	O-M norm	Year	Total year	Norm year	Oct-Mar	O-M norm
76-77	283.0	265.2	89.9	154.9	76-77	80.5	103.1	22.4	59.9
77-78	386.8	265.2	345.9	154.9	77-78	192.3	103.1	149.6	59.9
78-79	619.3	265.2	316.7	154.9	78-79	210.1	103.1	151.4	59.9
79-80	503.9	265.2	421.6	154.9	79-80	193.3	103.1	129.8	59.9
80-81	274.6	265.2	174.8	154.9	80-81	63.0	103.1	32.3	59.9
81-82	355.6	265.2	155.2	154.9	81-82	184.4	103.1	76.2	59.9
82-83	568.5	265.2	313.4	154.9	82-83	222.5	103.1	118.4	59.9
83-84	452.6	265.2	91.9	154.9	83-84	107.2	103.1	41.4	59.9
84-85	262.4	265.2	204.5	154.9	84-85	142.5	103.1	126.0	59.9
85-86	201.7	265.2	161.8	154.9	85-86	127.8	103.1	78.2	59.9
86-87	258.6	265.2	190.0	154.9	86-87	60.7	103.1	51.3	59.9
87-88	517.1	265.2	239.3	154.9	87-88	211.3	103.1	93.0	59.9
88-89	135.6	265.2	106.4	154.9	88-89	39.9	103.1	31.5	59.9
89-90	215.6	265.2	41.7	154.9	89-90	135.1	103.1	38.9	59.9
90-91	325.4	265.2	204.2	154.9	90-91	116.3	103.1	100.1	59.9
91-92	483.9	265.2	463.0	154.9	91-92	216.4	103.1	176.0	59.9
92-93	399.0	265.2	338.6	154.9	92-93	229.4	103.1	222.8	59.9
93-94	112.8	265.2	92.2	154.9	93-94	64.5	103.1	56.1	59.9
94-95	387.4	265.2	333.5	154.9	94-95	153.9	103.1	136.1	59.9
95-96	99.3	265.2	52.3	154.9	95-96	42.7	103.1	6.9	59.9
96-97	246.88	265.2	101.6	154.9	96-97	85.59	103.1	32.51	59.9
97-98	449.58	265.2	299.7	154.9	97-98	210.82	103.1	130.81	59.9
98-99	269.75	265.2	35.05	154.9	98-99	67.82	103.1	21.34	59.9
99-00		265.2	65.53	154.9	99-00		103.1	8.13	59.9