Indirect Effects of Development on the Flat-tailed Horned Lizard

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Prepared by

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ABSTRACT

We assessed indirect effects of human activity on adjacent populations of flat-tailed horned lizards by sampling plots at increasing distances from agricultural or urban development that abutted undeveloped flat-tailed horned lizard habitat. Surveys consisted of one-hour presence-absence searches on one-hectare plots centered at 50, 250, 450, and 650 meters from disturbance. Detection rates were low, and horned lizard scats were used to indicate presence when lizards were not found. The data were analyzed using logistic regression analysis. Distance to disturbance was found to be a highly significant factor in whether or not flat-tailed horned lizards were present. Probability of presence increased significantly with increasing distance from disturbance, indicating a negative indirect effect to at least 450 m away from agricultural or urban areas. We suspect the impact is mainly due to increased predator density near human activity. Harvester ants, the main prey of flat-tailed horned lizards, were not diminished near agriculture. We did not evaluate presence of invasive species but discuss this as another risk associated with human development.

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INTRODUCTION

Habitat loss through human activities is considered the leading agent of species declines, followed by threats from non-native species (Czech and Krausman 1997, Wilcove *et al.* 1998). Habitat destruction comes from a variety of human activities, with agricultural and urban development topping the list (Wilcove *et al.* 1998). While it is understood that either activity makes former habitat completely unusable for the flat-tailed horned lizard (FTHL), *Phrynosoma mcallii*, the extent to which negative indirect effects impact adjoining populations has not been established (FTHL ICC 2003).

The FTHL has the most limited range of any of the 14 species of horned lizards (Sherbrooke 2003). It is found only in the extreme southwestern corner of Arizona, the southeastern corner of California, and adjoining portions of Sonora and Baja California, Mexico (Stebbins 2003, FTHL ICC 2003). While a variety of human activities have modified or destroyed habitat throughout the Sonoran Desert (Lovich and Bainbridge 1999), agricultural and urban development have been the primary causes of habitat loss within the range of the FTHL. As of 1997 approximately 24,000 acres of FTHL habitat had been converted to agricultural and urban use in Arizona and 877,000 acres in California (Hodges 1997). While it has been suspected that the impact to FTHL populations is greater than the total acreage directly converted to human use (FTHL ICC 2003), no data to measure indirect effects have previously been available.

In May 2004 we conducted a series of time and area-constrained presence-absence searches for FTHL near Yuma, Arizona. We surveyed plots beginning at places of human activity (agricultural or urban development) and extending into adjacent undeveloped desert land, with a goal of assessing whether or not human activities have a measurable indirect effect on FTHL populations.

METHODS

We surveyed 4 plots along a 650 m transect at each of 27 sites, selected randomly from a pool of all possible sites (provided by Fred Wong, Bureau of Land Management, Yuma) that met the following criteria: 1) a sharp edge between agricultural or urban development and undeveloped desert, 2) development was at least one year old, 3) no major road within 200 m, 4) no additional disturbances or other transects within 500 m, and 5) no protruding or recessed edges of the disturbance within 200 m on either side of the transect. We avoided areas close to heavily-traveled roads in order to limit our study to the effects of agricultural and urban development, but a few sites close to roads were included to increase sample size. We conducted some additional surveys away from disturbance to test the methodology, but did not include these in analyses (Fig. 1).

At each of the 27 sites we placed four one-hectare plots in a line going perpendicular to the edge of human activity, for a total of 108 total sample plots. The center of the first plot was placed 50 m from the disturbance (so that one edge of the plot touched the human disturbance), and other plots were placed 250 m, 450 m, and 650 m away from the edge of disturbance.

Each plot was surveyed by a single person. Two observers worked together at a site to survey all 4 plots between sunrise and 9:30 AM. In the case of evening surveys we sampled two plots one evening and the remaining plots the following evening. To survey a plot an observer navigated to the coordinates of the plot center using a handheld GPS unit and flagged the center point with a pin flag. The approximate edges of the plot were delineated by pacing from the center point, and searches were constrained to within these boundaries for one hour. We randomly chose which plots to survey first, with the constraint that a near plot (50 m or 250 m) and a far plot (450 m or 650 m) were always surveyed simultaneously.

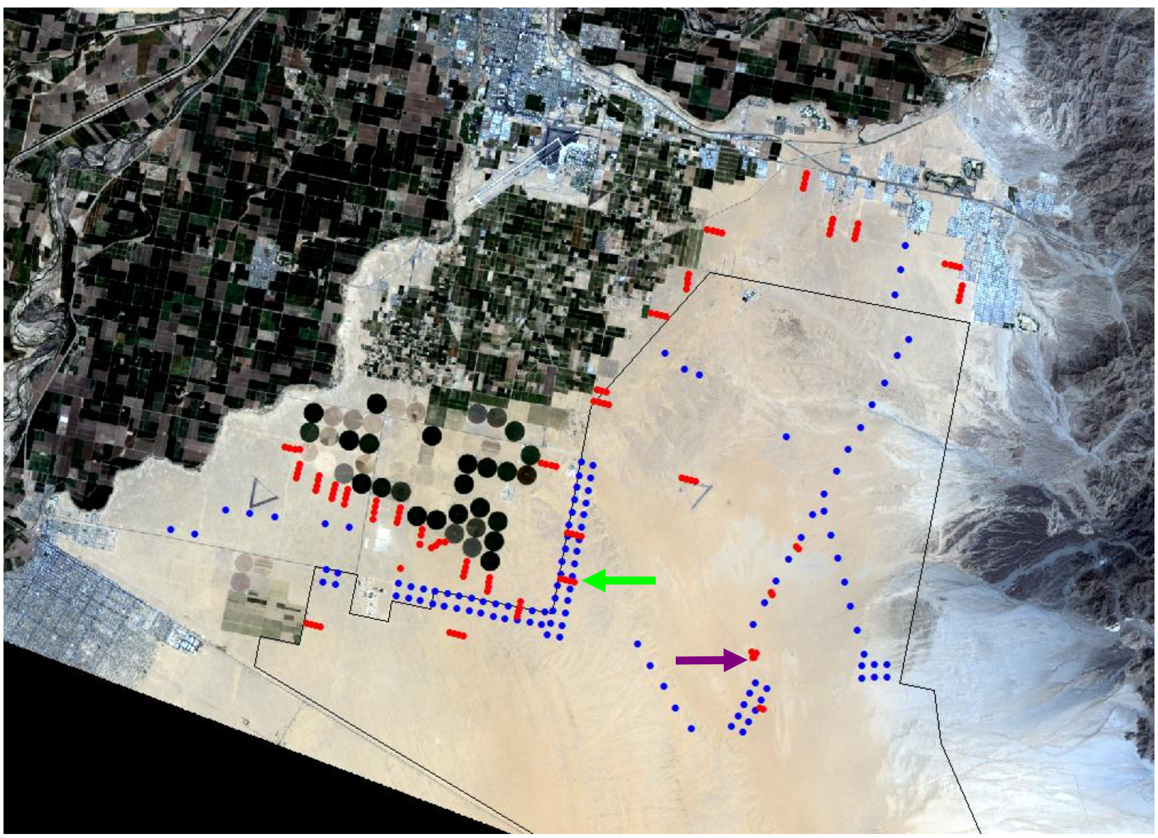
Data that were collected include date, time, location in UTMs, type of disturbance (agricultural, urban, or both), tracking conditions, percentages of different substrate components (fine sand, coarse sand, gravel, rock), number of scat, tracks, and FTHLs found, roundtail ground squirrel (*Spermophilus tereticaudus*) density (high, medium, or low based on tracks, burrows, and vocalizations), number of black harvester ant mounds (*Messor pergandei*) observed, and a density estimate of FTHLs. In short the methodology was similar to the presence-absence surveys conducted in 2003 by Young *et al.* (2004) except that we surveyed each plot for a full hour regardless of whether or not a FTHL was caught because we wanted to estimate FTHL density instead of just determining presence or absence. Factors that we considered for the density estimate included number of FTHLs found, number of tracks, number of scat, distribution of tracks and scat throughout the plot, freshness of tracks and scat, tracking conditions, and overall habitat quality. Tracking conditions were relatively poor this year due to dense annual vegetation and high rodent activity (in response to winter rainfall), so we had to rely more heavily on indirect measures of FTHL presence.

Primarily because of the difficult tracking conditions, we lacked confidence in the density estimates and chose to not present any summary data on these estimates or use them for estimating effects of disturbance. Since 75% of the estimates were either 0 or 1 anyway it seemed prudent to base analyses simply on presence or absence and do a logistic regression analysis instead of a linear regression. We counted presence for any plot where a FTHL was captured, but also for any plot (outside the range of desert horned lizards) with at least 3 scats found, or at least one definite track plus a scat. If we were near where desert horned lizards were known to occur we only counted FTHL captures as presence. During the 2003 presence-absence surveys we only counted presence when we found a FTHL, thus avoiding any false presences but risking false absences. The change in protocol this year is because our ability to find FTHLs was so much lower than last year (due to tracking conditions). We would have created too many false absences if we had relied solely on captures.

We performed a logistic regression analysis using stepwise selection (SAS 2004). Stepwise selection begins with no independent variables in the model. It adds variables one at a time by comparing the *P*-values for the F statistics of the possible independent variables (the variable with the lowest *P*-value is added first). Unlike forward selection, in stepwise selection a variable that has already been added to the model does not necessarily stay there (if the F statistic changes too much in presence of other variables then it is dropped from the model). The stepwise selection process ends when no variable outside the model has an F statistic that is significant at the specified entry level (we used $P < 0.05$ as the entry criteria). The independent variables that were available for selection by the model were distance from disturbance, northing coordinate, easting coordinate, percentages of fine sand, coarse sand, and gravel, tracking rating, type of disturbance, observer, and probability of presence values (from the model of predicted distribution that was created with 2003 presence/absence survey data) (Young *et al*. 2004).

After running the logistic regression model we plotted predicted presence at each sampling distance and compared mean values of these predictions with t-tests. We ran a separate logistic regression analysis that forced type of disturbance (agricultural, urban, or both) to stay in the model to evaluate differences between disturbance types. Data for ground squirrel density and density of active black harvester ant mounds were summarized but not statistically analyzed.

Figure 1. Sample plots for 2004 indicated by red dots. Blue dots indicate 2003 presence-absence samples used to create a model of predicted distribution. Some samples (such as indicated by the green arrow) are adjacent to disturbance that is new since the time of this satellite image in the year 2000. Other samples (such as indicated by the purple arrow) are not adjacent to disturbance and were not included in any analyses. A black line shows the boundaries of the Yuma Desert Management Area



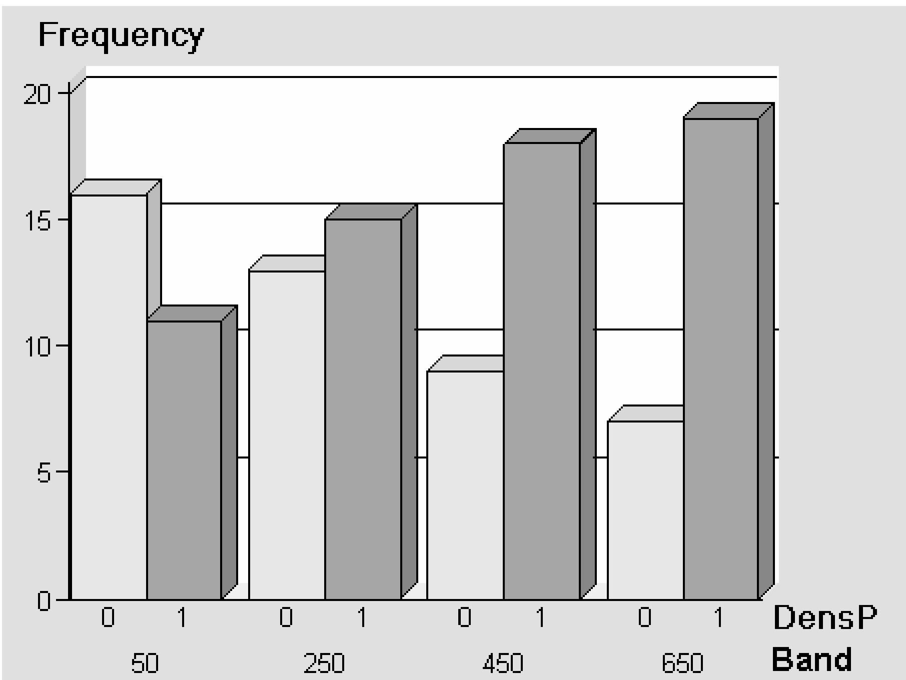
RESULTS

We surveyed 27 sites, with 4 plots per site, for a total of 108 plots sampled as 27 replicates per distance treatment. Of the 27 different sites that interfaced between human disturbance and desert, 18 were adjacent to agriculture, 5 next to urban development, and 4 were a mixture of agricultural and urban impacts. FTHL presence was counted at 1 or more plots at 22 of the 27 sites, while 5 sites had absence at all 4 plots. Presence was confirmed by capture of at least one

FTHL at only 27 of the 108 plots (25%), but we noted presence based on tracks, scat, habitat suitability, and captures at 63 plots (58%). Scat was the most common indicator of presence, with an average of 4 scats found per plot (35 maximum), compared to an average of 0.66 tracks (5 maximum) and 0.23 FTHLs (3 maximum) found per plot.

A bar graph showing how many plots had presence or absence at each of the distances from disturbance (50 m, 250 m, 450 m, and 650 m) shows a clear increase in frequency of FTHL presence with increasing distance from agricultural or urban development (Figure 2).

Figure 2. Bar chart of frequency of absence (0) or presence (1) of flat-tailed horned lizards at plots of increasing distances (in meters) from human disturbance.



The step-wise selection criteria only included the 2003 model predictions (P = 0.0133) and the distance from disturbance (P = 0.0148) as effects in the model. The predictions from the logistic regression analysis were plotted to visualize probability of presence at each of the four distances from disturbance (Figure 3). The mean predicted value at each distance was statistically different from the values at all other distances ($P < 0.05$).

When type of disturbance was forced into the logistic regression analysis along with the 2003 model predictions and distance from disturbance, type of disturbance did not have any measurable effect on probability of FTHL presence (P = 0.4363).

Ground squirrel densities were considered high at eight of the nearest plots, but at only one plot at each of the other distances (Table 1). Number of active black harvester mounds was higher at the two nearest plots than the two farthest plots (Table 1). Because ground squirrel data were subjective and ant data were not collected systematically, we did not statistically test for differences between distances for these variables.

Figure 3. A box plot indicating a positive relationship between the probability of occurrence of flat-tailed horned lizards and distance (in meters) from human disturbance. Predicted probability of occurrence at each sample plot was output from the logistic regression analysis that used output from a predictive model of distribution and distance from disturbance as predictive variables. The box encloses the middle 50% of the predicted values for each distance, the horizontal line within the box represents the median value, and the line extending beyond the box represents the range of values.

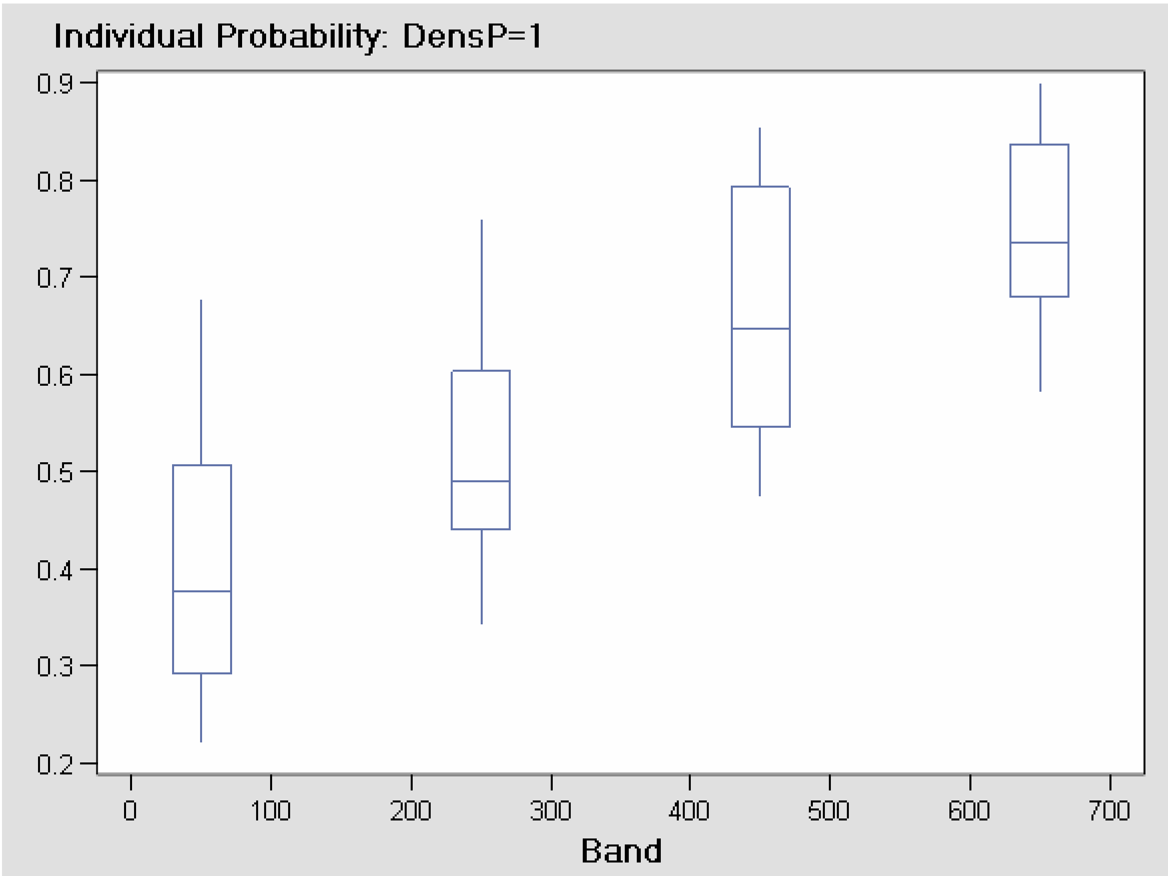


Table 1. Comparison of ground squirrel (*Spermophilus tereticaudus*) density categories and mean number of black harvester ant mounds (*Messor pergandei*) at increasing distances from human activity.

		Distance From Disturbance			
		50 m	**250 m**	**450 m**	**650 m**
Number of plots with different ground squirrel densities	Low	12	16	17	16
	Med	4	7	5	3
	High	8	1	1	1
Mean *Messor* mounds per plot		10.3	12.9	7.8	7.3

DISCUSSION

The data are very clear in any form—there is a negative effect on FTHLs that extends beyond the margins of human activity. While the main predictor of presence in the logistic regression model was the 2003 model of predicted distribution (which is a reflection of habitat suitability), the only other significant predictor of FTHL presence was distance from disturbance. There is a clear negative impact on FTHL presence to at least 450 m away from disturbance. We did not sample far enough away from disturbance to verify that we had reached the edge of the disturbance effect since predicted density did not reach an asymptote. However, our subjective opinion is that the rates of presence at the most distant plots were similar to those at areas far removed from disturbance. A measurable edge effect of 450 m is similar to other studies where it was found that most edge effects typically extend a few hundred meters into natural areas (Murcia 1995, Laurance 2000). We found no difference between agricultural and urban development, but it should be noted that our sample size from urban development was low (not surprising since agriculture commonly adjoins undisturbed habitat but urban areas generally do not).

We have documented that development along an edge of a management area impacts adjacent habitat, thus diminishing the overall reserve size. For example, a 40-acre field (1/4 mile square) that borders FTHL habitat on one edge (1/4 mile = 402 m) negatively impacts at least 45 acres of undisturbed FTHL habitat (402 m * 450 m = 180,900 m^2 = 18.1 ha = 44.7 acres). Management agencies need to consider that they will experience FTHL losses within their management areas on at least 180 acres per mile of edge that borders agricultural or urban development. Impacts from human activities are a leading cause of mortality within protected areas (Woodroffe and Ginsberg 1998). A visual estimate of the perimeter of the Yuma Desert Management Area shows at least 20 miles that border land that has been or may be converted to agricultural or urban development, for a potential indirect negative impact on FTHL populations on 3,600 acres of protected land. Because the habitat is still intact FTHL will continue to move into these areas, creating a population sink that will have a negative impact on the overall population on an ongoing basis. Such sinks would have the greatest impact on population dynamics in small habitat fragments with a high perimeter:area ratio and on species that range widely (Woodroffe and Ginsberg 1998). Fortunately, the Yuma Desert Management Area and other FTHL Management Areas are quite large relative to the movements of the FTHL, thus reducing the risk of extinction from edge effects within these reserves.

With the FTHL Management Areas already established, one additional way to conserve FTHL populations would be to minimize edge effects on border areas (Woodroffe and Ginsberg 1998). This can be difficult, but in the case of the proposed Area Service Highway, the planned horned lizard-proof fence along the border of the Management Area should mitigate much of the impact. FTHL habitat occurs on both sides of the proposed highway along some stretches, but the fence will only be on the side that borders the Management Area. The success of minimizing impacts of the road could be studied by comparing plots on either side of the road at increasing distances from it. This would indicate both the effect of a road in FTHL habitat and also the effectiveness of horned lizard-proof fencing.

Artificially increased predator densities may be an important contributor to the negative correlation between FTHL presence and proximity to human development. As stated in the Rangewide Management Strategy (FTHL ICC 2003), “Predators, such as common ravens, American kestrels, and domestic dogs and cats, also increase in urban areas, resulting in increased predation rates on FTHLs in adjacent wildlands (Bolster and Nicol 1989; Cameron Barrows, CNLM, pers. comm.).” Although we cannot attribute the reduced presence of FTHLs near development to specific causes with certainty, the density of a major FTHL predator, the roundtail ground squirrel, was highest in the plots closest to human activity. Young and Young (2000) found that the roundtail ground squirrel killed a higher proportion of FTHLs carrying transmitters in the Yuma Desert Management Area than all other predators combined. Shrikes are almost certainly more common around agricultural fields, but we made no attempts to measure their density.

While we think increased predator density is the most likely cause for the observed decline in FTHLs near development, invasive species may also contribute. Biological invasions can spread far into a reserve, thus decreasing its effective area (Suarez and Case 2002). We did not evaluate presence or density of alien species, but they are known to be problems for other horned lizards. Argentine ants (*Linepithema humile*) invade coastal horned lizard (*Phrynosoma coronatum*) habitat much more readily in disturbed areas or adjacent to development (Suarez *et al.* 1998). These ants displace native ants and are not, themselves, eaten by horned lizards (Suarez *et al.* 2000). This “bottom-up” effect is different than the “top-down” effect of increased predator abundance, but can be just as threatening to a rare species, particularly when that species is a dietary specialist (Suarez and Case 2002). Fire ants (*Solenopsis invicta*), which have had adverse effects on the Texas horned lizard (*P. cornutum*), were found in Yuma on one occasion but have apparently been eradicated (L. Piest pers. comm.). We did not look for fire ants at the sites we sampled. We did count active mounds of *Messor pergandei*, which is a native harvester ant and an important food source of FTHLs (Young and Young 2000). Since we found more of these harvester ants closer to development, we suspect that fire ants had not invaded any of the areas that we sampled. We know invasive plants occur over wide areas of the Yuma Desert MA and suspect that they are more common closer to development. Invasive plants may negatively affect FTHLs but the actual impacts are unknown (FTHL ICC 2003) and we did not attempt to measure their presence or density in this study. Another factor that may cause decline in prey abundance is pesticide drift. Although harvester ants were more abundant closer to fields, we do not know which, if any, of these fields had been sprayed with pesticides applied by plane. Either there was no pesticide drift, or if there was there was no measurable negative impact on black harvester ants.

Presence-absence data yields less information than actual counts, but due to low detection rates this year we were limited to using only presence-absence data in the analyses. Because we did not resample sites and create a history of detection/non-detection for each site, it was not possible for us to estimate detection rates or true occupancy rates (MacKenzie *et al.* 2002). These estimates would be helpful for establishing differences in detection rates in different years, and we recommend including site resampling in future designs. If enough sites are resampled enough times, it is even possible to deduce abundance estimates from presence-absence samples (Royle and Nichols 2003). Since FTHL are easy to capture if detected, mark-recapture data can be collected during repeated site visits, which will yield better abundance estimates when combined with presence-absence data than the presence-absence data alone (Royle, pers. comm. 2005). If samples are repeated across years it is also possible to estimate extinction and recolonization rates (MacKenzie *et al.* 2003), which would be particularly valuable in areas where new disturbance occurs.

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APPENDIX

A CD containing the following has been deposited at AZGFD and BLM offices in Yuma

- Capture data (Excel file)
- Survey data (Excel file)
- Digital photos of captures
- Digital photos of habitat

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