MEMORANDUM

To: Chad Benson, John Hall (BLM)
CC: Scott Fluer, Hollè Waddell, Paul Griffin (BLM)
From: Michelle Crabb (BLM) WHB Program Population Biologist
Date: 05/31/2022
RE: Statistical analysis for 2021 survey of wild burro abundance in the Alamo, Havasu, and Big Sandy HMAs, AZ

Summary Table

Survey Area and Dates	Start date	End date	Area names	Area IDs
	11/15/2021	11/18/2021	Havasu HMA, HA	AZ0010
	11/15/2021	11/17/2021	Alamo HMA, HA	AZ0005
	11/15/2021	11/19/2021	Big Sandy HMA	AZ0004
Type of Survey	Simultaneous double-observer			
Aviation Details	Pilots: Cody Johnson and John Kelly, El Aero. Helicopters: N226GM, N910BR			
Agency Personnel	Observers: Chad Benson, John Hall, Erik Duarte, Michelle Crabb (BLM), Ian Latella, Zara Kidwai, Marshal Lindsay, Hailey Nelson (AZGFD) Helicopter Manager: Matt, Luis (BLM)			

Summary Narrative

In November 2021, Bureau of Land Management (BLM) personnel conducted simultaneous double-observer aerial surveys of the wild burro populations in Havasu, Alamo, and Big Sandy herd management areas (HMAs; Figure 1). Additionally, Havasu and Alamo Lake herd areas (HAs) were surveyed to determine number of animals continuing to inhabit these areas. These areas were reassigned from the northern portion Havasu and eastern portion of Alamo Lake HMAs respectively through the Lake Havasu Resource Management Plan, 2007 (Figure 1). Surveys were conducted using methods recommended by BLM policy (BLM 2010) and a National Academy of Sciences review (NRC 2013) with detailed field methods described in Griffin et al. (2020). Two helicopters were used to survey this area due to its large size, and lack of physical barriers to prohibit movement of wild burros between HMA/HAs. These data were analyzed using methods in Ekernas and Lubow (2019) to estimate sighting probabilities for wild burros, with sighting probabilities then used to correct the raw counts for systematic biases (undercounts) that are known to occur in aerial surveys (Lubow and Ransom 2016), and to provide confidence intervals (which are measures of uncertainty) associated with the abundance estimates.

Table 1. Estimated abundance (Estimated No. Burros) is for the number of burros in the surveyed areas at the time of survey. 90% confidence intervals are shown in terms of the lower limit (LCL) and upper limit (UCL). The coefficient of variation (CV) is a measure of precision; it is the standard error as a percentage of the estimated abundance. Number of burros seen (No. Burros Seen) leads to the estimated percentage of burros that were present in the surveyed area, but that were not recorded by any observer (Estimated % Missed). The estimated number of burros associated with each HMA but located outside the HMA's boundaries (Est. No. burros Outside HMA) is already included in the total estimate for that HMA.

Area	Age Class	Estimated No. Burros	LCL[a]	UCL	Std Err	CV	No. Burros Seen	Estimated % Missed	Estimated No. Groups	Estimated Group Size	Foals Per 100 Adults[b]	Est. No. Burros Outside HMA
Alamo HMA	Total	1,087	1,017	1,298	105.3	9.7%	765	29.6%	240	4.5	7.5	517
	Foals	76	67	98	10.9	14.3%	55					
	Adults	1,011	951	1,208	97.5	9.6%	710					
Big Sandy HMA	Total	319	254	368	36.4	11.4%	244	23.5%	88	3.6	3.9	8
	Foals	12	9	23	5.1	42.3%	9					
	Adults	307	245	355	34.0	11.1%	235					
Havasu HMA	Total	325	351	431	25.6	7.9%	304	6.5%	65	5.0	16.0	181
	Foals	45	46	61	4.5	10.0%	42					
	Adults	281	304	374	23.0	8.2%	262					
Survey Total	Total	1,731	1,651	2,012	119.8	6.9%	1,313	24.1%	393	4.4	8.3	706
	Foals	133	133	176	13.1	9.9%	106					
	Adults	1,599	1,508	1,851	111.0	6.9%	1,207					

[a] The lower 90% confidence limit is based on bootstrap simulation results or the number of burros seen, whichever is higher.

[b] The estimated ratio of foals to adults reflects what was observed during this November survey. This ratio does not necessarily represent the full cohort of foals for this year, some of which may have died before the survey or were large enough to be included with the adult count. It is possible that some foals may have been born after the survey, in December 2021.

Abundance Results

The estimated total burro abundance within the surveyed area is reported in Table 1. Observers recorded 287 burro groups, of which 274 burro groups had data recorded properly 'on protocol' and that could be used to compute statistical estimates of sighting probability. All of the 287 groups seen were used to calculate the abundance estimate. Any burro groups that were seen twice (double counted), or that were identified as domestic and privately owned, were not used to calculate abundance; however, such groups can be used to parameterize sighting probability if they were recorded on protocol. Coefficient of variation (Table 1) values of less than 10% indicate high precision resulting from high detection probabilities; values between 10-20% indicate medium precision resulting from lower detection probabilities; and values greater than 20% indicate low precision resulting from very low detection probabilities.

Double observer aerial surveys of burros typically contain unmodeled heterogeneity in detection probabilities (discussed below) that cause abundance estimates to be biased too low. Consequently, the abundance estimate presented in Table 1 is likely to be substantially lower than the true number of burros present in the surveyed area. For reference, a 2017 double observer burro survey and analysis of Sinbad HMA, UT, underestimated burro abundance by approximately 20% compared to tallies of known individuals. In the absence of better information, adding approximately 20% to the abundance estimate reported in Table 1 (Estimated No. Burros) may lead to more accurate results. However, it is not possible from the available data, or the analysis presented here to assess the actual additional percentage that should be added.

The mean estimated size of detected burro groups, after correcting for missed groups, was 4.4 burros/group across the surveyed area, with a median of 4.0 burros/group. There were an estimated 8.3 foals per 100 adult burros at the time of these surveys (Table 1). Surveys flown before July are unlikely to include all foals born this year, while surveys flown during or after July would not include foals that were born this year but died before the survey.

Sighting Probability Results

The combined front observers saw 63.1% of the burro groups (65.3% of the burros) seen by any observer, whereas the back seat observers saw 69% of all burro groups (70% of burros) seen (Table 2). At least one observer (front or back) missed 67.9% of burro groups seen by the other. These results demonstrate that simple raw counts do not fully reflect the true abundance without statistical corrections for missed groups, made possible by the double observer method and reported here. Direct counts from aerial surveys underestimate true abundance because some animals are missed by all observers; this analysis corrects for that bias (Lubow and Ransom 2016). The analysis method used for the surveyed areas were based on simultaneous double-observer data collected during these surveys.

The sample size of observations following protocol was 274 burro groups. Survey datasets with sample size less than 20 groups cannot be analyzed using these methods; sample sizes of 20 to

40 groups are considered low and have high risk of containing unmodeled heterogeneity in sighting probability; sample sizes of 41-100 groups are moderate and can estimate effects of many but likely not all potential sightability covariates; and sample sizes >100 groups are large and can account for most sightability covariates.

Unmodeled heterogeneity in detection probability is a systematic problem in double observer aerial surveys of burros, and solving this problem is an area of active research. Burros are difficult to see from the air, and some types of groups are so difficult to see (e.g. groups that are small, standing still, and in heavy tree cover) that they are practically never detected by any observer. When certain types of groups are never seen, their sightability characteristics cannot be described by any set of covariates, and this class of groups disappears from the analysis. Conversely, other types of groups are easy to see (e.g. large groups in open vegetation, close to the helicopter, and running) and every observer sees them nearly every time. The "easy-to-see" types of groups thereby become over-represented in the data. Furthermore, covariates that sharply reduce detection probability might never be described and thus cannot be modeled. As a result, the double observer model tends to over-estimate detection probability for the burro population as a whole. When the detection probability estimate is biased high, the correction factor for how many groups were missed is biased too low. Consequently, unmodeled heterogeneity in detection probability causes double observer analyses to underestimate true burro abundance.

All models used in the double-observer analysis contained an estimated intercept common to all observers. Informed by *a priori* reasoning and preliminary analyses showing overwhelming support, I also included additional parameters in all models for effects; (1) distance of burros from the flight path; (2) observations by front-seat observers on the pilot's side; (3) effect of pilot CJ, and (4) effect for individual back seat observers. I evaluated 4 additional possible effects on sighting probability by fitting models for all possible combinations with and without these effects, resulting in 16 alternative models. The 4 additional effects examined were: (1) burro group size; (2) high contrast lighting; (3) percent vegetation cover; and (4) burro group activity. Due to minimal support during preliminary analyses and *a priori* reasoning, I did not consider effects on detection probability of visual field or rugged topography. I did not consider effects on detection probability of snow cover due to insufficient variation in the values of this covariate. Covariates and their relative effect on sighting probability are shown in Table 3.

Groups that were recorded on the centerline, directly under the aircraft, were not available to backseat observers. For these groups, backseat observers' sighting probability was therefore set to 0. Sighting probability for groups visible on both sides of the aircraft was computed based on the assumption that both backseat observers could have independently seen them, thereby increasing total detection probability for these groups relative to groups available to only one side of the helicopter.

There was moderate support for group activity (38.4% of AICc model weight), and percent concealing vegetation (62.9%). There was weak support for group size (29.7%), and high contrast lighting condition (29.3%). As expected, visibility was higher for burro groups that were larger, moving, in high contrast lighting, and lower for groups that were farther from the transect, on the pilot's side, and in greater vegetation (Table 3).

Estimated overall sighting probabilities, $\hat{p}$, for the combined observers ranged across burro groups from 0.20-1.00. Sighting probability was <0.7 for 67 (23%), and <0.5 for 28 (10%), and <0.3 for 6 (2%) of observed groups. In aggregate across all observed groups, the overall "correction factor" that was added on to the total number of wild burros seen was 31.8%. That is to say: 1,313 burros were seen, and adding another 31.8% of that number seen equals the total estimate of 1,731burros (Table 1). A different but mathematically equivalent interpretation is listed in Table 1 in the "Estimated % Missed" column, which shows that, overall, 24.1% of the burros that were estimated to be present during the survey were never seen by any of the observers (Table 1).

Assumptions and Caveats

Results from this double observer analysis are a conservative estimate of abundance. True abundance values are likely to be higher, not lower, than abundance estimates in Table 1 because of several potential sources of bias listed below. Results should always be interpreted with a clear understanding of the assumptions and implications.

1. The results obtained from these surveys are estimates of the burros present in the surveyed area at the time of the survey and should not be used to make inferences beyond this context. Abundance values reported here may vary from the annual March 1 population estimates for the HMA; aerial survey data are just one component of all the available information that BLM uses to make March 1 population estimates. Aerial surveys only provide information about the area surveyed at the time of the survey, and do not account for births, deaths, movements, or any management removals that may have taken place afterwards.

2. Simultaneous double-observer analyses cannot account for undocumented animal movement between, within, or outside of the surveyed area. Fences and topographic barriers can provide deterrents to animal movement, but even these barriers may not present continuous, unbroken, or impenetrable barriers. It is possible that the surveys did not extend as far beyond a boundary as burros might move. Consequently, there is the possibility that temporary emigration from the surveyed area may have contributed to some animals that are normally resident having not being present at the time of survey. In principle, if the level of such movement were high, then the number of animals found within the survey area at another time could differ substantially. If there were any wild burros that are part of a local herd but were outside the surveyed areas, then Table 1 underestimates true abundance.

3. The validity of the analysis rests on the assumption that all groups of animals are flown over once during a survey period, and thus have exactly one chance to be counted by the front and back seat observers, or that groups flown over more than once are identified and considered only once in the analysis. Flight line transects were spaced ½ mile apart, so there was nominally an opportunity to observe burros throughout the entire surveyed area. The drop-off in detection

probability as a function of distance (Table 3) was steep, but even for animals located at more than 400 m from the transect line, there was a non-zero probability of detection. Those lower detections for distance groups translated to higher correction factors for those groups, in their contribution to the estimated total abundance value (Table 1). Animal movements during a survey can potentially bias results if those movements result in unintentional over- or under-counting of burros. Groups counted more than once would constitute ‘double counting,’ which would lead to estimates that are biased higher than the true number of groups present. Groups that were never available to be seen (for example due to temporary emigration out of the study area or undetected movement from an unsurveyed area to an already-surveyed area) can lead to estimates that are negatively biased compared to the true abundance. The use of two helicopters at the same time in this survey is a technique that can improve the inference strength about estimated herd size, because the entire survey area is covered in half the time – thus, reducing the number of possible overnight movements and reducing the risk of groups being counted twice or not at all.

Survey SOPs (Griffin et al. 2020) call for observers to identify and record ‘marker’ animals (with unusual coloration) on paper, and variation in group sizes helps reduce the risk of double counting during aerial surveys. Observers are also to take photographs of many observed groups and use those photos after landing to identify any groups that might have been inadvertently recorded twice. Unfortunately, there is no effective way to correct for the converse problem of burros fleeing and thus never having the opportunity for being detected. Wild burros tend to move more slowly than wild horses. Despite this, because observers can account for burro movements leading to double counting, but cannot account for movement causing burros to never be observed, animal movements can contribute to the estimated abundance (Table 1) potentially being lower than true abundance.

4. The simultaneous double observer method assumes that all burro groups with identical sighting covariate values have equal sighting probability. If there is additional variability in sighting probability not accounted for in the sighting models, such heterogeneity could lead to a negative bias (underestimate) of abundance. In other words, under most conditions the double-observer method underestimates abundance.

5. The analysis assumes that the number of animals in each group is counted accurately. Standard Operating Procedures (Griffin et al. 2020) specify that all groups with more than 20 animals are photographed and photos scrutinized after the flight to correct counts. Smaller groups, particularly ones with poor sighting conditions such as heavy tree cover, could also be undercounted. Any such undercounting would lead to biased estimates of abundance.

Evaluation of Survey and Recommendations

It appears that survey protocols were followed well and with enough consistency among surveys to enable useful pooling of data for more precise estimates of sighting probability. Observers appear to have been well trained, and visibility conditions were very good to excellent. However, even the estimated abundance values in Table 1 should be viewed as <u>under</u>estimates of actual wild burro population size in the survey area because of the assumptions and caveats listed above, and because it is known that true burro group detection probabilities tend to be lower than values estimated by the double-observer data analysis method (Hennig et al., USGS Fort Collins Science Center, manuscript in review). It is especially commendable that BLM Arizona personnel collaborated to conduct these surveys with two helicopters simultaneously.

The survey covered all of the Alamo HMA and HA and extended beyond the boundary in a small section south of the HA. The survey covered the majority of the Big Sandy HMA and extended beyond the HMA boundaries to the NNW (Figure 1). One isolated section of the Big Sandy HMA was not covered. The northern and eastern portion of the Havasu HMA/HA were well covered. Areas within the Havasu HMA boundary that were not covered were residential areas or areas in which, according to local BLM and AZGFD personnel and based on visual observation of burros and burro sign, there are none to very few burros. Additional areas were planned to be surveyed but were not able to be flown due to mechanical issues with one of the helicopters. Where the survey covered areas outside of the HMAs/HAs, burros were still sometimes observed near the edge of the extended survey area. Consequently, it is difficult to be sure there were no additional burros inside or outside of the HMA in areas not surveyed and results should be understood to represent the burros present only in the area surveyed, which may not represent all burros that occasionally occupy this area. Therefore, careful consideration should be given to where burros were located near the edge of the area surveyed when planning whether to extend the survey area further in future surveys, to ensure covering all areas potentially occupied by burros associated with the HMAs/HAs or to confirm that the current survey boundaries do cover the full extent of burros' range in this area.

Table 2. Tally of raw counts of burros and burro groups by observer (front, back, and both) for combined data from the Alamo, Havasu, and Big Sandy HMAs surveyed in Nov 2021.

Observer	Groups seen[a] (raw count)	Burros seen (raw count)	Actual sighting rate[b] (groups)	Actual sighting rate[b] (burros)
Front	173	817	63.1%	65.3%
Back	189	876	69.0%	70.0%
Both	88	442	32.1%	35.3%
Combined	274	1251		

[a] Includes only groups and burros where protocol was followed.
[b] Percentage of all groups seen that were seen by each observer.

Table 3. Effect of observers and sighting condition covariates on estimated sighting probability of burro groups for both front and rear observers during the November 2021 survey. Baseline case (bold) for burros presents the predicted sighting probability for a group of 4 burros (the median group size observed), <100 meters from the transect, that are not moving, in 0% vegetation cover, not in high contrast lighting, not on the pilot side, with average back-seat observer. Other example cases vary a covariate or observer, one effect at time, as indicated in the left-most column, to illustrate the relative magnitude of each effect. Sighting probabilities for each row should be compared to the baseline (first row) to see the effect of the change in each observer or condition. Baseline values are shown in bold wherever they occur. Sighting probabilities are weighted averages across all 16 models considered (Burnham and Anderson 2002).

	Sighting Probability		
	Front Observer[a]	Back Observer[b]	Combined Observers
Baseline	**70.4%**	**80.7%**	94.3%
Effect of Group size (N=1)	69.9%	80.3%	94.1%
Effect of Group size (N=10)	71.3%	81.4%	94.7%
Effect of Distance = 100-200 m	61.8%	74.0%	90.1%
Effect of Distance = 200-300 m	52.9%	65.9%	83.8%
Effect of Distance = 300-400 m	42.9%	56.9%	75.4%
Effect of Moving	73.1%	82.7%	95.3%
Effect of Veg Cover (30%)	64.2%	75.9%	91.4%
Effect of Veg Cover (60%)	57.4%	70.0%	87.2%
Effect of High Contrast Light	71.9%	81.8%	94.9%
Effect of Pilot Side	17.4%	**80.7%**	84.1%
Effect of Pilot CJ	97.2%	**80.7%**	99.5%
Effect of Observer MC	**70.4%**	77.3%	93.3%
Effect of Observer IL	**70.4%**	69.5%	91.0%
Effect of Observer ZK	**70.4%**	46.1%	84.0%
Effect of Observer ML	**70.4%**	31.7%	79.8%
Effect of Observer HN	**70.4%**	79.3%	93.9%
Effect of Back=Front	**70.4%**	70.4%	91.2%

[a] Sighting probability for the front observers acting as a team, regardless of which of the front observers saw the burros first.

[b] Sighting probabilities for back observers for burro groups that are potentially visible on the same side of the aircraft as the observer. Sighting probability in the back is 0 for groups on the opposite side or centerline.

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Figure 1. Map of survey tracks flown (black lines), locations of observed burro groups (black and white circles), HMA boundaries (blue), and HA boundaries (purple).