Appendix E

M E M O R A N D U M

DRAFT – FOR INTERNAL REVIEW

To: Rob Sharp, Paul Griffin (BLM)
CC: Lisa Grant, James Price, Bob Hopper, Justin Rodgers, Alan Shepherd, Bruce Rittenhouse (BLM)
From: L. Stefan Ekernas, USGS
Date: 5 July 2018
RE: Statistical analysis for 2018 survey of horse abundance in Liggett Table, Palomino Buttes, and Warm Springs HMAs, Oregon

I. SUMMARY TABLE

Survey areas and Dates:	**Start date**	**End date**	**Area name**	**Area ID**
	6/18/2018	6/19/2018	Warm Springs HMA	OR0007
	6/19/2018	6/19/2018	Palomino Buttes HMA	OR0006
	6/21/2018	6/21/2018	Liggett Table HMA	OR0037
Type of Survey	Simultaneous double-observer			
Aviation Company	Jairus Duncan (pilot), El Aero, Bell 206 L4 Long Ranger (N226GM) Keegan Bolton (pilot), Reeder, Bell 206 L4 Long Ranger (N356L)			
Agency Personnel	Rob Sharp, Rick Knox, Kyle Jackson, Jim Wagner, James Price, Derek Hammer, and Scott Yamasaki (BLM)			

TABLE 1. Estimated abundance (Estimate) is for the number of horses 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 population. Number of horses seen (No. Seen) leads to the estimated percentage of horses that were present in the surveyed area, but that were not recorded by any observer (% Missed). The estimated number of horses associated with each HMA but located outside the HMA's boundaries is already included in the total estimate for that HMA.

Area	**Age Class**	**Estimate (No. Horses)**	LCL[a]	UCL	Std Err	CV	No. Horses Seen	% Missed	Estimated # of Groups	Estimated Mean Group Size	Foals per 100 Adults	Est. No. Horses Outside HMA
Liggett Table HMA	Total	91	86	113	13.1	14.4%	86	5.5%	14	6.5	21.1	36
	Foals	16	15	21	2.7	17.1%	15					
	Adults	76	71	96	10.7	14.1%	71					
Palomino Buttes HMA	Total	241	228	282	26.2	10.9%	228	5.4%	23	10.5	24.9	0
	Foals	48	45	57	5.9	12.2%	45					
	Adults	193	183	226	20.4	10.6%	183					
Warm Springs HMA	Total[b]	852	831	921	33.2	3.9%	831	2.4%	61	14	22.8	7
	Foals[c]	158	154	169	5.1	3.2%	154					
	Adults	694	677	752	28.9	4.2%	677					

[a] The lower 90% confidence limit is based on bootstrap simulation results or the number of horses seen, whichever is higher.
[b] 30 burros and 1 mule were also seen at Warm Springs HMA. I included the mule observation in the analysis of detection probability for horses. I did not have enough data to estimate detection probability for burros, with only 5 groups seen.
[c] In one large group of 82 adults, observers could not get an accurate count on foals even after reviewing video and photos of the group. Only 4 foals were seen in that group, which may be an undercount.

II. NARRATIVE

In June 2018 Bureau of Land Management (BLM) personnel conducted simultaneous double-observer aerial surveys of the wild horse populations in the Liggett Table, Palomino Buttes, and Warm Springs herd management areas (HMAs; Figure 1). Surveys were conducted using methods recommended by BLM policy (BLM 2010) and a recent National Academy of Sciences review (NRC 2013). I analyzed these data to estimate sighting probabilities for horses, which I 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.

<u>Abundance Results</u>

The estimated total horse abundance values (Table 1) within or associated with the surveyed HMAs were relatively large. Observers recorded 94 horse groups, of which 90 horse groups had data recorded in a way suitable to be used in computing statistical estimates of sighting probability. All 94 observations made during 2018 aerial surveys were used to inform the total estimates of abundance. Confidence intervals and coefficients of variation for the total horse abundance estimate in Warm Springs HMA was quite precise (<10% CV), but uncertainty was higher in Palomino Buttes and Liggett Table (Table 1).

I estimate the mean size of detected horse groups, after correcting for missed groups, to be 12.1 horses/group across the surveyed area, with a median of 9.0 horses/group. I estimate 23.1 foals per 100 adult horses at the time of these surveys, with only modest variation between areas. Given the June survey date, this value may not represent all foals born in 2018.

<u>Sighting Probability Results</u>

The combined front observers saw 84.4% of the horse groups (87.3% of the horses) seen by any observer, whereas the back seat observers saw 77.8% of all horse groups (83.9% of horses) seen (Table 2). These results demonstrate that simple raw counts do not fully reflect true abundance without statistical corrections for missed groups made possible by the double observer method and reported here. There were undoubtedly additional groups not seen by any observer; I address this issue in the analysis that follows.

The sample size of observations (90 usable horse groups) was sufficient to parameterize sighting probability functions. I therefore did not pool data from this survey with any other surveys conducted in previous years. Observers were rotated appropriately in the back seat, photographed large horse groups, and carefully noted groups that were double counted; all observers had high detection probabilities, and the survey covered multiple HMAs to increase sample size. All these practices follow guidelines in the draft SOPs and the conduct of the surveys is commendable.

Informed by preliminary analyses, past analyses for this survey area, and *a priori* reasoning, I considered 32 alternative models. Based on preliminary testing, all models used in the double-observer analysis contained:

1. An estimated parameter for an intercept common to all observations; and

2. A parameter for an effect of horse groups located on the pilot's side of the aircraft.

In addition to these 2 parameters listed above, I tested 5 possible effects on sighting probability by fitting models for all possible combinations of these effects, resulting in 32 alternative models. The 5 effects were for (1) horse group size, (2) presence of trees around the horse group, (3) high contrast light, (4) group movement, (5) an average back seat effect. Preliminary testing showed more AICc support for a threshold rather than linear effect of concealing vegetation (trees). I did not include an effect for horse group distance to the transect line, because preliminary testing found implausible results that groups further from the transect line were more likely to be detected. Preliminary testing showed little support for differences between any of the back seat observers.

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

Support (measured as % of AICc model weight) was strong for an average back seat effect (79%), moderate for presence of trees within 10m of the group (47%) and the group moving (46%), and weak for high contrast light (35%) and group size (32%). As expected, estimated sighting probability was higher for groups that were larger, moving, and in flat light, and lower for groups in tree cover, on the pilot's side, and in high contrast light. Sighting probability was lower, on average, for back-seat observers, and did not differ measurably among the individual observers (Table 3)

Estimated overall sighting probabilities, $\hat{p}$, for the combined observers ranged across horse groups from 0.77-1.00. Comparing actual horses seen to the estimated abundance computed from the overall $\hat{p}$ from all HMAs combined, I estimate that 3.2% of the horses in these surveys were never seen by any of the observers, with some differences between HMAs (Table 1). A combination of large group sizes, few trees, and experienced observers with high acuity contributed to high overall detection probabilities. One observer became airsick and was replaced by a different observer the next day, but the airsick observer maintained high detection probability.

<u>Assumptions and Caveats</u>

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 that I list below. Considering the relatively high sighting probabilities and precision estimated for these surveys, the population estimates I present here appear to provide a sound and reliable basis for management decisions. Nonetheless, results of the analysis should always be interpreted with a clear understanding of the assumptions and implications.

1. The results obtained from these surveys are estimates of the horses present in the areas surveyed 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 each 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. Double-observer analyses cannot account for undocumented animal movement between, within, or outside of HMAs. The surveyed HMAs are largely enclosed by fencing, roads, or natural barriers. Although fences and topographic barriers can provide deterrents to animal movement that help to contain them within the areas surveyed, these barriers may not present either a continuous, unbroken barrier or an impenetrable one. It is always possible that the surveys did not extend as far beyond the boundary as horses might move. Consequently, there is the possibility that temporary emigration from the surveyed areas may have contributed to some animals that normally live in the target HMAs having not being present at the time of survey. In principle, if the level of such movement were high, then the numbers of animals found within the survey areas at another time could differ substantially. If there were any wild horses that are part of a local herd but were outside the surveyed areas, then the estimates in 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. Animal movements during a survey can potentially bias results if those movements result in unintentional over- or under-counting of horses. 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.

   Each HMA required multiple flights with intervening fuel stops that thereby created some opportunity for horses to move between surveyed and unsurveyed areas. The identification of 'marker' horses (with unusual coloration) in observed groups was recorded on paper, and variation in group sizes helped the observers to reduce the risk of double counting during aerial surveys. Observers also took photographs of many observed groups, and used those photos after landing to identify any groups that might have been inadvertently recorded twice. Unfortunately, there is no effective way after the survey to correct for the converse problem of horses fleeing and thus never having the opportunity for being detected. Because observers can account for horse movements leading to double counting, but cannot account for movement causing horses to never be observed, animal movements can contribute to the estimated abundance (Table 1) potentially being lower than true abundance

4. The double observer method assumes that all horse 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, even under ideal conditions the double-observer method tends, if anything, to provide underestimates of abundance.

5. I must assume that the number of animals in each group is counted accurately. In very large groups it may be common to miss a few animals unless photographs are taken and scrutinized after the flight. Relying on raw counts could lead to biased estimates of abundance. Observers in this survey followed draft SOPs for WHB aerial surveys, circling over many groups to get as accurate a count as possible and using photography for groups of >20 horses. Nonetheless, foals could not be accurately counted even from video in one large group in Warm Springs HMA. Foal numbers I report here may consequently be too low in this HMA.

Suggestions for Future Surveys

Observations about the data may offer opportunities to improve future surveys.

1. This survey had a high number of observers (5 back seat observers and 2 pilots in total). Reducing the number of observers would minimize potential error and improve uncertainty estimates.

TABLE 2. Tally of raw counts of horses and horse groups by observer (front, back, and both) for combined data from Liggett Table, Palomino Buttes, and Warm Springs HMAs surveyed in June 2018.

Observer	Groups Seen[a] (Raw Count)	Horses Seen[a] (Raw Count)	Actual Sighting Rate[b] (groups)	Actual Sighting Rate (Horses)
Front	76	853	84.4%	87.3%
Back	70	820	77.8%	83.9%
Both	56	696	62.2%	71.2%
Combined	90	977		

[a] Includes only groups and horses 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 horse groups for both front and rear observers during the June 2018 survey of Liggett Table, Palomino Buttes, and Warm Springs HMAs. Baseline case (bold) for horses presents the predicted sighting probability for a group of 9 horses (the median group size observed) that are not moving, with no trees, in flat light, not on the pilot's side, with the 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 shows in bold wherever they occur. Sighting probabilities are weighted averages across all 32 models considered (Burnham and Anderson 2002).

	Sighting Probability, Front Observer[a]	Sighting Probability, Back Observer	Combined Sighting Probability
Baseline	**92.4%**	**80.8%**	**98.5%**
Effect of group size (N=1)	92.1%	80.0%	98.4%
Effect of group size (N=20)	92.7%	81.7%	98.7%
Effect of moving	94.8%	86.4%	99.3%
Effect of trees	88.5%	72.5%	96.8%
Effect of high contrast light	90.4%	76.6%	97.8%
Effect of PilotSide	52.7%	**80.8%**	90.9%
Effect of back=front detection	**92.4%**	92.4%	99.4%

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

Literature Cited

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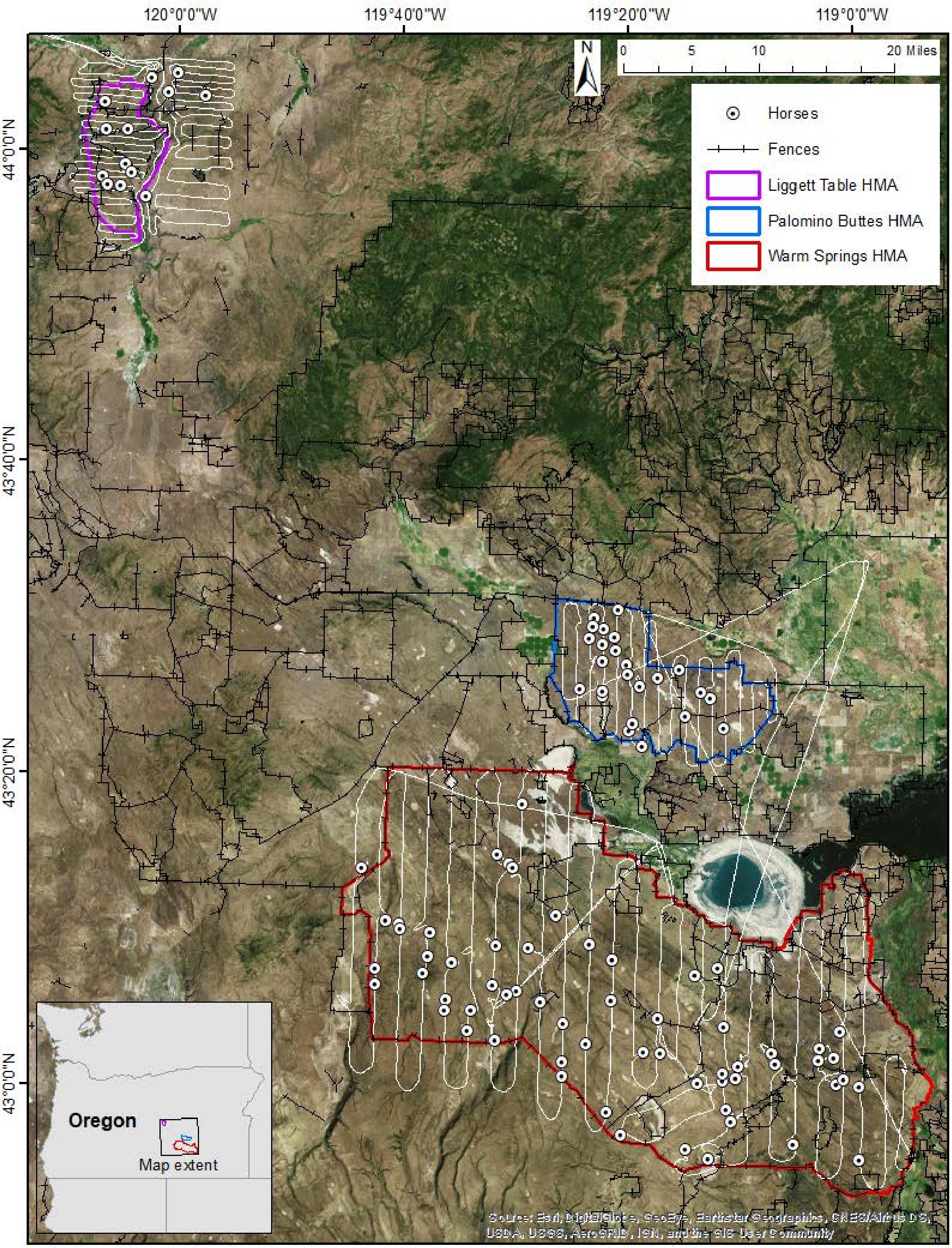
Burnham, K., and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Springer-Verlag, New York, New York.

Lubow, B. C., and J. I. Ransom. 2016. Practical bias correction in aerial surveys of large mammals: validation of hybrid double-observer with sightability method against known abundance of feral horse (Equus caballus) populations. PLoS-ONE 11(5):e0154902. doi:10.1371/journal.pone.0154902.

National Research Council. 2013. Using Science to Improve the BLM Wild Horse and Burro Program. The National Academies Press. Washington, D.C.

FIGURE 1 (following page). Maps of survey tracks flown (white lines), fences (black lines), locations of observed horse groups (black and white circles), and surveyed HMA boundaries.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