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Original Research

Mortality and Operational Attributes Relative to Feral Horse and Burro Capture Techniques Based on Publicly Available Data From 2010-2019

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ABSTRACT

Management of excessive feral horse (*Equus ferus caballus*) and burro (*Equus asinus*) populations in the United States and globally has been a controversial subject for decades. I reviewed all available US federal feral horse and burro daily gather reports from 2010 to 2019 to extract equine species, technique (bait trapping or helicopter gathering), reason (emergency or other), number gathered, number of mortalities, and mortality attributes (acute or chronic/pre-existing condition, specific cause). I found 70 reports (bait trapping burros n = 10, bait trapping horses n = 24, helicopter gathering horses n = 21) from 9 states (AZ, CA, CO, ID, MT, NV, OR, UT, WY) representing 28,821 horses and 2,005 burros. For bait trapping, 100 animals died (4 burros, 96 horses) with 16 acute causes (1 burro, 15 horses) and 84 chronic/pre-existing causes (3 burros, 81 horses). For helicopter gathering, 268 horses died with 62 acute causes and 206 chronic/pre-existing causes. Mortality ratios did not differ by capture technique ($P > .05$) for broken necks, emaciation, acute causes, or chronic/pre-existing causes. The most common mortality-causing problems were structural deformations, club foot, blindness, and emaciation. The more horses gathered per day resulted in a greater proportion of chronic/pre-existing mortalities for both trapping techniques, but only an increase of acute mortalities for helicopter gathering. The slope suggests 1 acute mortality for every 300 horses gathered. The capture mortality rate across all gathers [1.1% (368 mortalities out of 30,826 horses and burros captured)] is below a general threshold of 2% suggested for wildlife studies.

1. Introduction

Management of excessive feral horses (*Equus ferus caballus*) and burros (*Equus asinus*) in the United States has been a controversial and costly subject for many decades [1]. Population growth of these two equine species has been increasing dramatically over the last ten years with the current on-range population estimates of 88,090 animals (71,892 horses and 16,198 burros) which is greater than the federally mandated appropriate management level of 26,690 total horses and burros by a factor of >3× [2,3]. A common approach to feral horse and burro population management is gathering and removing horses from rangelands which is guided by the 1971 Wild Free-Roaming Horse and Burro Act (WFRHBA) [4] and subsequent amendments including in the 1976 Federal Land and Policy Management Act [5] and 1978 Public Rangelands Improvement Act [6]. Many of the feral horses and burros in the United States reside on public rangelands administered by the Bureau of Land Management (BLM) within the Department of the Interior; however, >46,000 horses and burros reside in "off-range" temporary holding and >90,000 free-roaming horses and burros also occur on Native American reservations [2,3].

The associated authority for equine gathering procedures are established for BLM Wild Horse and Burro Specialists and contracting partners by the 1971 WFRHBA as amended and are used regularly [4–6]. The standard operating procedures (SOPs) for gathering equids have been refined to optimize animal safety and include the use of helicopters and bait/water trapping [7]. In

Animal welfare/ethical statement: This is a third-party assessment of federally approved horse and burro gathers which are under the purview of the Bureau of Land Management (BLM).

Conflict of interest statement: The author has not received any funding for this particular mortality analyses and all research, analyses, and writing were conducted independent of BLM input. However, the author has received funding from BLM for unrelated research using GPS/VHF collars on feral horses and has been an observer of bait trapping and helicopter gathering in Wyoming, USA, only for the purposes of being on-site to place collars on horses.

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addition, reporting requirements for BLM Wild Horse and Burro Specialists are mandated [8]. Bait and water trapping techniques (henceforth "bait trapping") have been around for millennia and use discrete water (in the summer) and feed (both in the summer or winter if forage is limiting) placed in a corral with a gate that can be closed remotely (Fig. 1A). In other countries, bait trapping horses is a common population management technique, such as Australia's Kosciuszko National Park (Fig. 1B) [9].

Helicopter gathering ("helicopter drive trapping" in some BLM documents; mustering in other regions of the world) is commonly used in extensive landscapes for gathering livestock and for capturing wildlife species [7,10,11] (Fig. 1C). Helicopter gathers use a helicopter to locate and then herd animals toward a set of corrals. For horses specifically, a ground crew is often used along with a domestic horse that leads horses into the corrals. Corrals often have wings comprised of light-weight material that is visible to animals to help funnel them to the corrals. In other countries, helicopter gathering is regularly used, such as for New Zealand's Kaimanawa horses (Fig. 1D) [12]. For both bait trapping and helicopter gathering, traps and temporary holding sites are placed as close to animal locations as possible to reduce the likelihood of injury and stress to the animals [7].

Regardless of technique, the physical handling of any large animal, including wildlife and livestock, brings certain risks for both the animals and their handlers [13]. For animals, such risks include acute injuries incurred during the gathering process or chronic and/or pre-existing conditions that either manifest during the gathering process or that are a welfare concern to supervising veterinarians, agency staff, contractors, and the public [14]. However, stationary bait trapping techniques differ from helicopter gathering techniques in terms of relative labor demands, time constraints, weather limitations, and physical stimulation and stress imposed on ungulates [15]. There is some evidence that helicopter gathering may affect feral horse reproduction [16] although other studies have shown no effect [17]. In addition, because horses and burros may incur new injuries or exacerbate old injuries or conditions during the gathering process, veterinary oversight beyond the mandate for helicopter gathers only may be necessary to optimize animal safety and welfare [7].

Thus, there exists many complex questions attributed to (1) the increase of feral horse and burro populations over the last decade, (2) the need to optimize animal safety during gather procedures, and (3) the need for a more in-depth understanding of daily capture rates of different capture techniques. I therefore analyzed publicly available data for US BLM–authorized horse and burro gathers nationally. I specifically addressed explicit research questions about mortalities relative to gather type, equine species, and operational attributes, specifically the number of animals gathered per day. This information will be of use to other countries seeking to adopt or revise capture techniques, will enhance US BLM horse and burro gathers for BLM staff planning and conducting gathers, and will inform veterinarians overseeing horse and burro health during gathers.

2. Materials and Techniques

2.1. Source of Data

From September 1 to November 25 of 2019, I reviewed all publicly available BLM feral horse and burro gather reports for all the western US states using daily gather reports [18]. These reports are the result of a 2010 mandated reporting requirement for BLM Horse and Burro Specialists [8]. Reports were reviewed and data were systematically extracted and organized into a database that included the equine species of focus for a gather (horse or burro), type of capture technique (bait trapping or helicopter gathering), reason for the gather (emergency or other), number of animals gathered, number of daily mortalities, and mortality attributes (acute or chronic/pre-existing condition, specific cause). By assessing daily gather reports, I then calculated proportions of mortality relative to the total number of animals gathered and relative to type of capture technique and the proportion of mortality attributes. These calculations were stratified for three capture technique and equine species combinations available in the data: bait trapping burros, bait trapping horses, and helicopter gathering horses. In addition, I calculated the number of animals gathered per successful gather day relative to capture technique and species.

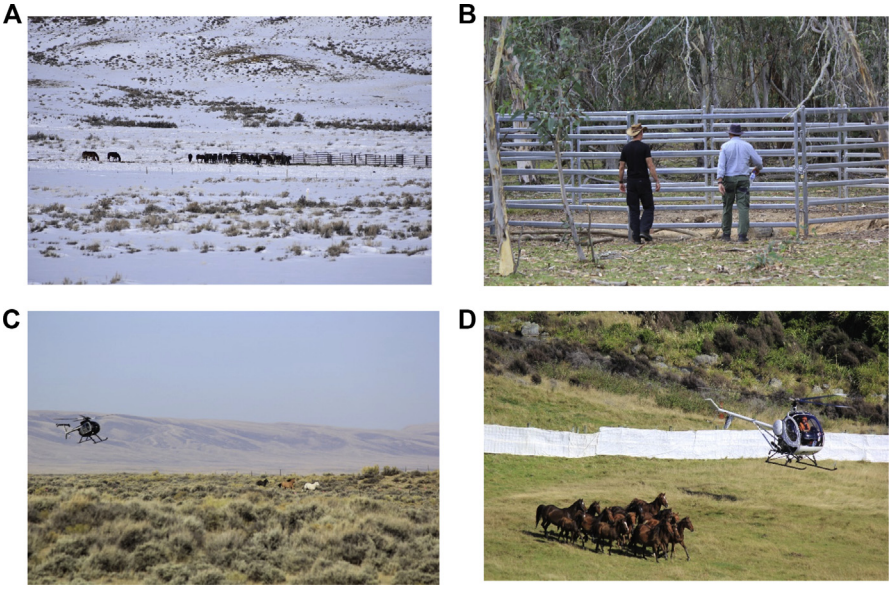

Fig. 1. Demonstration of international use of equine capture techniques. (A) Bait trapping in Wyoming, USA, during the winter, (B) bait traps in Australia's Kosciuszko National Park, (C) helicopter gather in Wyoming, USA, and (D) helicopter gather (muster) of Kaimanawa horses in New Zealand. Photo credit for all photos to J.D. Scasta.

2.2. Statistical Analyses

I examined three explicit research questions. First, is bait trapping or helicopter gathering safer for horses and burros in terms of acute and/or chronic—pre-existing mortality causes? To accomplish this and for the appropriate analysis, I stratified equine mortalities at the individual gather level by equine species and cause (acute or chronic/pre-existing), calculated the proportion of equine mortalities relative to the total numbers of animals gathered, and transformed the proportions using an arcsine transformation to meet assumptions of normality. I then ran analysis of variance models with either acute mortality or chronic/pre-existing mortality as a response variable and capture technique (bait trapping or helicopter gather) and then equine species as main fixed effects. I then conducted pairwise comparisons between the three capture techniques and equine species combinations.

The second research questions was, is bait trapping or helicopter gather more effective in terms of daily capture success? For the number of animals gathered per successful gather day, I analyzed the mean number of animals gathered per day as the response variable and capture technique as the main fixed effect, and then similar to the aforementioned analyses, I conducted pairwise comparisons between the three capture techniques and equine species combinations [19]. Because ~92% of mortalities (337 of 367) occurred on days equines were gathered, as opposed to days when they were only shipped or unsuccessful trap days, I then calculated the mean daily acute and chronic/pre-existing mortalities and plotted those relative to the mean number of equines gathered per day (only for days with at least 1 equine gathered) and used linear least squares regression stratified by capture technique to determine strength and significance of relationships.

The third research question was, what are the most frequent medical conditions leading to equine mortalities? I thus summarized reported medical condition and cause of mortality or need for euthanasia for horses and burros relative to capture technique (bait trapping or helicopter) and acute or chronic/pre-existing status of the condition for 32 different identified medical conditions. Given the variability in detail and medical records provided, some of the reported categories are not mutually exclusive, and thus the presentation here reflects that level of variability rather than inclusivity or exclusivity. Finally, I also calculated mortality ratios for broken necks (a specific acute cause of mortality), emaciation (a specific chronic cause of mortality), acute mortalities, and chronic/pre-existing mortalities for horses relative to capture technique and then compared relative risk and mortality ratios between techniques using an independent samples *t*-test, effect size (Cohen's d), and 95% confidence intervals [19,20].

3. Results

3.1. Horse and Burro Gather Report Summary

I found 70 reports (bait trapping burros n = 10, bait trapping horses n = 24, helicopter gathering horses n = 21) from 9 states (AZ, CA, CO, ID, MT, NV, OR, UT, WY) representing 28,821 horses and 2,005 burros (Tables 1 and 2). Reports represented 1,006 unique daily gather activity summaries with 760 of the daily reports being successful gather days, where at least one horse or burro was gathered. No gather reports were available for New Mexico. In a few instances, gather reports were omitted because of confounding factors making it difficult to interpret data, particularly those gathers that were explicitly for administering contraception treatments for research purposes. The 70 gather reports with suitable data in total represented 30,826 total equids (2,005 burros captured with bait trapping, 5,564 horses captured with bait trapping, and 23,257 horses captured with helicopter gathering) (Table 3). Of those reports, 34 used bait trapping (Table 1) and 36 used helicopter gathering (Table 2). For burros, bait trapping techniques were the only technique used (never helicopter gathers of burros), but both bait/water trapping and helicopter gathering procedures were used for horses (Tables 1 and 2).

Table 1
Details about the bait trapping studies with publicly available gather reports including state, equine species, year, and name of gather.

State	Species	Year	Name of Gather
AZ	Burro	2017	Planet Ranch *Nuisance*
	Burro	2019	Big Sandy *Nuisance*
	Burro	2019	Black Mountain *Nuisance*
CA	Burro	2018	Outside Chemehuevi
	Burro	2018	Piute Mountain
NV	Burro	2017	Johnnie
	Burro	2017	Marietta
	Burro	2018	Bullfrog
	Burro	2019	Bullfrog
	Burro	2019	Seven Troughs
CO	Horse	2016	Sand Wash Basin
	Horse	2018	Little Books
MT	Horse	2015	Pryor Mountain
NV	Horse	2016	Goshute *Emergency*
	Horse	2016	Maverick-Medicine *Emergency*
	Horse	2016	Pancake *Emergency*
	Horse	2016	Stone Cabin
	Horse	2016	Wood Hills *Emergency*
	Horse	2017	Antelope Valley Private Land
	Horse	2018	Antelope Valley and Goshute *Emergency*
	Horse	2018	Antelope Valley Deer Spring *Emergency*
	Horse	2018	Outside Goshute
	Horse	2018	Pancake
	Horse	2018	Spruce-Pequop *Emergency*
	Horse	2018	Wild Horse Range *Emergency*
	Horse	2019	Antelope Valley
	Horse	2019	Caliente Complex *Nuisance*
	Horse	2019	Red Rock *Emergency*
OR	Horse	2016	South Steens
	Horse	2018	South Steens
UT	Horse	2018	Cedar Mountain *Emergency*
	Horse	2018	Range Creek
WY	Horse	2013	McCullough Peaks
	Horse	2017	Adobe Town

3.2. Total Mortalities Reported

Across all gather reports, 368 mortalities were reported, 364 horses and 4 burros, representing 1.26% of horses and <1% of burros (Table 3). Acute causes of mortality were noted for 77 horse mortalities and 1 burro mortality. Chronic/pre-existing causes of mortality were noted for 287 horse mortalities and 3 burro mortalities (Table 3).

3.3. Trap Techniques and Mortalities

Relative to capture technique, there were 148 daily gather reports for bait trapping burros, 402 daily gather reports for bait trapping horses, and 456 daily gather reports for helicopter gathering horses (Table 1). This accounted for 2,005 burros and 5,564 horses gathered with bait trapping and 23,257 horses gathered with helicopters. A total of 100 animals died during bait trapping (4 burros, 96 horses) with 16 acute mortality causes (1 burro, 15 horses) and 84 chronic/pre-existing causes (3 burros, 81 horses) (Table 3). A total of 268 horses died during helicopter trapping with 62 acute mortality causes and 206 chronic/pre-existing mortality causes (Table 3). The proportion of mortalities relative to the total number of animals gathered for acute mortality causes was 0.0005

Table 2
Details about the horse helicopter gathers with publicly available gather reports including state, year, and name of gather.

State	Year	Name of Gather
CO	2015	West Douglas
	2017	Cathedral Creek
ID	2015	Soda Fire *Emergency*
	2019	Challis
NV	2015	Fish Creek
	2015	Humboldt
	2015	Little Fish Lake
	2016	Eagle and Silver King
	2016	Owyhee
	2017	Fox and Lake Range *Emergency*
	2017	Reveille
	2018	Eagle *Emergency*
	2018	Owyhee Complex *Emergency*
	2018	Silver King
	2018	Triple B Complex
	2019	Fish Creek
	2019	Triple B Complex
OR	2015	Kiger and Riddle Mountain
	2018	Cold Springs
	2018	Warm Springs
UT	2017	Cedar Mountain
	2017	Frisco
	2018	Bible Springs
	2018	Muddy Creek
	2019	Onaqui
	2019	Range Creek
WY	2010	Adobe Town, Salt Wells
	2011	Antelope Hills—Great Divide Basin
	2011	Antelope Hills—Red Desert Complex
	2011	Little Colorado and White Mountain
	2012	North Lander Complex Conant Creek
	2013	Adobe Town, Salt Wells
	2014	Checkerboard
	2017	Adobe Town, Salt Wells, Great Divide Basin
	2018	Red Desert Complex
	2019	Fifteen Mile

(±0.0005, standard error) for bait trapped burros, 0.0041 (±0.0015) for bait trapped horses, and 0.0028 (±0.0005) for helicopter gathered horses and did not differ for capture technique ($F = 1.181$, $P = .281$) but did differ for equine species ($F = 5.437$, $P = .023$; Fig. 2). The proportion of mortalities relative to the total number of animals gathered for chronic mortality causes was 0.0019 (±0.0012, standard error) for bait trapped burros, 0.0127 (±0.0050) for bait trapped horses, and 0.0073 (±0.0013) for helicopter gathered horses and did not differ for capture technique ($F = 0.340$, $P = .562$) but did differ for equine species ($F = 4.956$, $P = .029$; Fig. 2).

3.4. Horse Medical Conditions and Need for Euthanasia

Table 4 shows all reported medical conditions and causes of mortality (both natural and euthanasia) for horses and burros

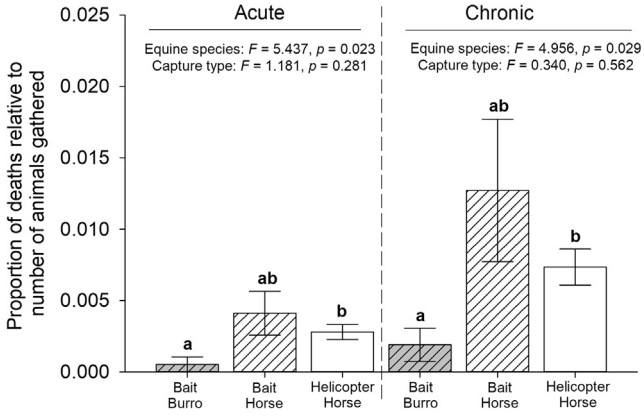

Fig. 2. Proportion of equine mortalities relative to equine capture technique and acute or chronic/pre-existing medical condition. Proportion data were transformed using an arcsine transformation to meet assumptions of normality and analyzed with analysis of variance (ANOVA) models with either acute mortality or chronic/pre-existing mortality as a response variable and capture technique type (bait trapping or helicopter gather) and then equine species as main fixed effects. Pairwise comparisons between the three technique and equine species combinations were assessed and are considered significantly different with different letters (a, b) at $P < .05$. Data from 70 publicly available gather reports (bait trapping burros n = 10, bait trapping horses n = 24, helicopter gathering horses n = 21) from 9 US states (AZ, CA, CO, ID, MT, NV, OR, UT, WY) representing 28,821 horses and 2,005 burros from 2010 to 2019.

relative to capture technique (bait trapping or helicopter) and acute or chronic/pre-existing status of the condition. Regardless of gathering procedure, the most common health problems and mortality cause identified was structural deformations for 58 horses which in our assessment, included developmental abnormalities and improperly healed bone breaks that resulted in deformed limbs, joints, or other features. The second-most common, which is a more specified form of structural deformation, was club foot for 42 horses. The third-most common was blindness for 44 horses. In some cases, specific details about a missing eye or eye injury were provided. The fourth-most common was emaciation and poor body condition for 33 horses and 1 burro. Horses identified as being emaciated often also had other noted problems including being old and tooth wear (although these were not always mentioned). When emaciation was assessed relative to total animals caught per capture technique, mortality ratios were 0.0033 (±0.0025) and 0.0009 (±.0004) for bait and helicopter, respectively, but did not significantly differ [$P = .254$, Cohen's d = 0.304, 95% CI (−0.217, 0.822)] (Table 5). The fifth-most common was broken legs for 29 horses and 2 burros. The sixth-most common was unknown for 28 horses. Broken necks were noted for 21 horses and 1 burro. Broken neck mortality ratios were 0.0026 (±0.0014) and 0.0006 (±0.0003) for bait and helicopter respectively, but did not differ significantly [$P = .112$, Cohen's d = 0.425, 95% CI (−0.099, 0.945)] (Table 5). Broken legs and broken backs occurred in both capture

Table 3
Summary data for 70 horse and burro gathers in the United States from 2010 to 2019 based on capture technique, equid species gathered, total gather days reported, total animals gathered, and total animals mortalities relative to acute or chronic/pre-existing conditions.

Capture Technique Equine Species	Gather Days	Total Animals Gathered	Total Animal Mortalities	[a]Acute Mortalities	[b]Chronic/Pre-Existing Mortalities
Bait trapping					
Burro	148	2,005	4	1	3
Horse	402	5,564	96	15	81
Helicopter gathering					
Horse	456	23,257	268	62	206
Total	1,006	30,826	368	78	290

[a] Acute mortality considered when an animal dies or is euthanized due to acute injuries or medical conditions brought about by the gather and removal process including associated activities of capturing, sorting, and holding; includes undiagnosed mortalities.
[b] Chronic/pre-existing mortality considered when an animal dies or is euthanized for reasons related to chronic or pre-existing conditions such as poor body condition, lameness, serious physical defects, etc. Includes animals euthanized for conditions not brought about by the gather activity.

Table 4
Reported medical condition and cause of mortality or need for euthanasia for horses and burros relative to capture technique (bait trapping or helicopter) and acute or chronic/pre-existing status of the condition.

Diagnoses/Condition/Cause	Bait Trapping		Helicopter		Total
	Acute	Chronic	Acute	Chronic	
Aortic aneurysm			1		1
Blind		15		29	44
Broken back		2		6	8
Broken leg	4	11	11	5	31
Broken neck	10		12		22
Burn injuries				2	2
Capture myopathy			2		2
Cardiac arrest			1		1
Club foot		23		19	42
Colic		1	1		2
Dehydration		2			2
Emaciated		15		19	34
Head injury/fractured skull			4	1	5
Hernia				3	3
Hip dislocation				1	1
Infection				1	1
Laceration			3		3
Lameness		3		21	24
Neurologic disorder	1				1
New fatal injuries			11		11
Parasite infestation				6	6
Pneumonia		1		5	6
Pre-existing condition		1		7	8
Pre-existing wounds				7	7
Seizure			1		1
Strain			5		5
Structural deformation		7		51	58
Tooth loss		1		4	5
Toxicity			1		1
Tumors				2	2
Unknown	1	2	9	16	28
Weak				1	1
Total	**16**	**84**	**62**	**206**	**368**
Euthanasia	6	81	30	187	304
Natural	7	1	27	4	39
Unknown	3	2	5	15	25

Data derived from 70 horse and burro gathers in the United States from 2010 to 2019 using publicly available gather data as administered by the Bureau of Land Management.

technique with broken backs only noted as chronic/pre-existing. Other less-frequent health conditions included aortic aneurysm (1), burn injuries (2), capture myopathy (2), cardiac arrest (1), colic (2), dehydration (2), head injury/fractured skull (5), hernia (3), hip dislocation (1), infection (1), laceration (3), lameness (24 horses [no burros] reported and details include arthritis, fetlocks, laminitis, etc., [21]), neurologic disorder (1), new fatal injuries undefined (11), parasite infestation (6), pneumonia (6), pre-existing condition (8), pre-existing wounds (7), seizure (1), strain (5), tooth loss and wear (5), toxicity (1), tumors (2), and weakness (1) (Table 4).

Acute mortalities occurred in 10 of 24 bait trap gathers of horses and 23 of 36 helicopter gathers of horses (Table 5). Acute mortalities occurred in 15 of 5,564 horses caught with bait trapping and 62 of 23,257 horses caught with helicopter trapping (Table 5). For horse acute mortalities, the bait mortality ratio was 0.0041 (±0.0015) and the helicopter mortality ratio was 0.0028 (±0.0013), with a relative risk of 1.5. When analyzed, horse acute mortality ratios did not differ significantly [$P = .388$, Cohen's d = 0.229, 95% CI (−0.290 to 0.746)] (Table 5).

Chronic mortalities occurred in 13 of 24 bait trap gathers of horses and 26 of 36 helicopter gathers of horses (Table 5). Acute mortalities occurred in 81 of 5,564 horses caught with bait trapping and 206 of 23,257 horses caught with helicopter trapping (Table 5). For horse chronic mortalities, the bait mortality ratio was 0.0127 (±0.0050) and the helicopter mortality ratio was 0.0073 (±0.0013), with a relative risk of 1.7. When analyzed, horse acute mortality ratios did not differ significantly [$P = .220$, Cohen's d = 0.326, 95% CI (−0.195 to 0.845)] (Table 5).

3.5. Number Gathered Daily Relative to Capture Technique

For capture technique, the mean number of animals gathered per successful gather day was 20 (±6) for bait trapping burros, 19 (±3) for bait trapping horses, and 58 (±5) for helicopter gathering horses; significantly higher for helicopter gathering ($P < .001$; Fig. 3). The range of mean number of animals gathered per successful gather day was 7–63 for bait trapping burros, 4 to 67 for bait trapping horses, and 15 to 131 for helicopter gathering horses.

3.6. Mortalities Relative to Number Gathered per Day

When the average number of equids gathered per day was used to predict the mean daily mortalities only for days equids were actually gathered, relationships differed by equine species and capture technique. For bait trapping burros, the more burros trapped in a day had no significant or correlative effect on acute ($r^2 = 0.03$, $P = .656$) or chronic mortalities ($r^2 = 0.11$, $P = .341$) (Fig. 4A). For bait trapping horses, the more horses gathered per day had no significant or correlative effect on acute mortalities ($r^2 = 0.13$, $P = .083$); however, chronic mortalities increased ($r^2 = 0.36$, $P = .002$) (Fig. 4B). For helicopter gathering horses, the more horses gathered per day resulted in increased acute ($r^2 = 0.24$, $P = .003$) and chronic mortalities ($r^2 = 0.22$, $P = .004$) (Fig. 4C). When the slope ($m = 0.0035$) for the linear equation predicting increasing acute mortalities is examined, the increase of 1 additional acute mortality

Table 5
Mortality ratios for both capture techniques and relative risk for horse bait trapping relative to horse helicopter trapping for broken necks, emaciated condition, acute mortalities, chronic/pre-existing mortalities, and total mortalities.

Metric	Broken Neck	Emaciated	Acute Mortalities	Chronic Mortalities
Bait gather occurrence (of 24 gathers)	7 of 24	4 of 24	10 of 24	13 of 24
Helicopter gather occurrence (of 36 gathers)	8 of 36	8 of 36	23 of 36	26 of 36
Bait horse occurrence (of 5,564 horses)	9 of 5,564	14 of 5,564	15 of 5,564	81 of 5,564
Helicopter horse occurrence (of 23,257 horses)	12 of 23,257	19 of 23,257	62 of 23,257	206 of 23,257
Bait mortality ratio (± standard error)	0.0026 (±0.0014)	0.0033 (±0.0025)	0.0041 (±0.0015)	0.0127 (±0.0050)
Helicopter mortality ratio (± standard error)	0.0006 (±0.0003)	0.0009 (±0.0004)	0.0028 (±0.0013)	0.0073 (±0.0013)
Relative risk (bait/helicopter)	4.2	3.6	1.5	1.7
P-value (α = 0.05)	.112	.254	.388	.220
Effect size (Cohen's d)	0.425	0.304	0.229	0.326
95% Confidence intervals (lower, upper)	−0.099, 0.945	−0.217, 0.822	−0.290, 0.746	−0.195, 0.845

Data from 60 publicly available gather reports (bait trapping horses n = 24, helicopter gathering horses n = 21) from 9 US states (AZ, CA, CO, ID, MT, NV, OR, UT, WY) representing 28,821 horses from 2010 to 2019.

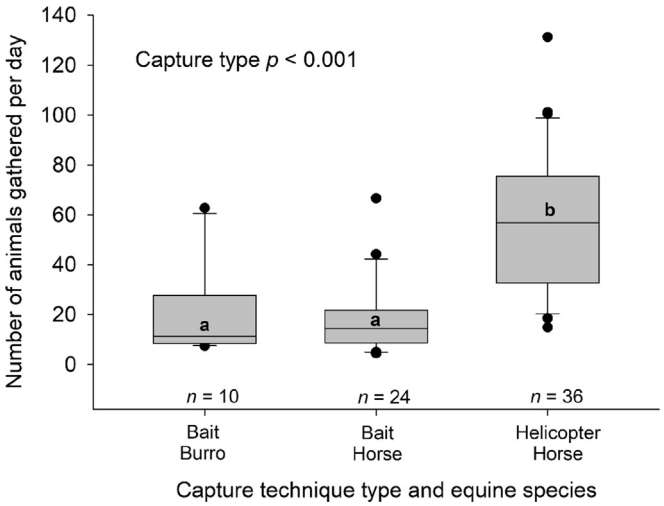

Fig. 3. Number of horses and burros gathered per day across 10 burro bait trap gathers, 24 horse bait trap gathers, and 36 horse helicopter gathers from 2010 to 2019 as administered by the Bureau of Land Management. Numbers are derived for days reporting at least 1 animal gathered as some daily reports were days where trapping efforts were made but no animals were caught. Pairwise comparisons between the three technique and equine species combinations were assessed and are considered significantly different with different letters (a, b) at $P < .05$. Data from 70 publicly available gather reports (bait trapping burros n = 10, bait trapping horses n = 24, helicopter gathering horses n = 21) from 9 US states (AZ, CA, CO, ID, MT, NV, OR, UT, WY) representing 28,821 horses and 2,005 burros from 2010 to 2019.

daily could be expected with gathering an additional 300 horses per day.

4. Discussion

4.1. Gathering Equids Reveals Many Chronic/Pre-existing Medical Conditions

The process of gathering equids, regardless of capture technique, reveals many chronic and pre-existing medical conditions from which feral horses and burros may be suffering. Structural deformities were the most common medical condition and included a wide range of conditions including deformities from developmental origins, improperly healed broken bones, etc. Specific structural deformities were diagnosed in some cases such as club foot which was the second-most prevalent issue. A limitation of this study is that often there were very limited details regarding the diagnoses of mortality making it difficult to understand more specific death causes. Regardless, research on feet of wild horses in New Zealand also revealed a frequent occurrence of foot abnormalities and undesirable foot morphometric traits [22]. Such feet problems can lead to subchondral bone sclerosis particularly in horses with severe articular cartilage damage with severity increasing as horses aged in the same population of New Zealand wild horses [23]. Reintroduction of Przewalski's horses (*Equus ferus przewalskii*) includes a selection criterion of captive breeding stock that addresses horse hooves [21]. Furthermore, lameness was noted in more than ten horses, and while causality for lameness was difficult to ascertain from the reports, it was often associated with feet and lower legs (i.e., fetlocks). Problems of the eyes, particularly blindness in one or both eyes, were the third-most common medical condition. Although blindness has not been studied much in wild horses, trauma can be a cause of blindness in horses generally and can be attributed to both perforation injury and blunt trauma injury leading to optic nerve atrophy [24].

4.2. Emergency Gathers Have Greater Frequency of Chronic/Pre-existing Medical Conditions

The greater relative occurrence for associated chronic/pre-existing mortalities may likely be skewed as a function of the greater proportion of emergency gathers. Specifically in this data set, emergency gathers of horses represented 42% of the bait trap gathers (10 of 24) but only 11% (4 of 36) of helicopter gathers. A plausible argument could be made that the prompt for emergency gathers is often inadequate forage and/or water and thus horses and burros that subsequently have lower body condition and other problems such as reduced immunity, etc. This notion is supported by relative proportion of emaciated horses for the different capture techniques (Table 5). Thus, prudence in capturing and shipping emaciated animals should be part of the welfare consideration integrated into wild horse and burro management similar to other wild herbivore management programs [25].

4.3. Helicopter Gathering Does Not Present Any Greater Risk of Mortalities

Helicopter gathering may be as safe, if not safer than bait trapping—a conclusion that seems counterintuitive given the perception that helicopter gathering may be perceived as a more dangerous and physically demanding technique particularly given the agitated escape behavior wild equids display in response to helicopters [12,26]. The notion of no greater risk for helicopter gathering may be supported by the proportionally lower incidence of broken necks and lack of statistical differences specifically and the similar proportion of acute mortalities generally when compared with bait trapping. Greater emphasis on SOPs for (1) gather operations generally [7], (2) daily gather reporting specifically [8], and (3) for helicopter pilots certification [27] may all have collectively enhanced gather implementation. In addition, in 2010, a private horse protection group worked with BLM to develop an Independent Designated Observer Pilot Program with independent observers (IOs), where equine specialists not affiliated with BLM observed 3 gathers in 3 states of a total of 352 horses [28]. The IOs observed four mortalities and multiple injuries and concluded that contractors and BLM staff were skilled at avoiding excessive stress on captured animals but also gave recommendations to improve facility design, handling of the horses, sorting techniques, transport practices, etc. [28]. Specifically, a focused emphasis on the design of gathers to optimize the care and welfare of horses and the precision with which pilots are handling horses and burros from the air may be outcomes of such high-level administrative direction and participatory involvement. In addition, helicopter gathering has a greater daily capture rate and may optimize animal handling times.

4.4. Need to Better Understand Unknown Mortality Causes and Capture Myopathy of Horses

Interestingly, capture myopathy was only noted for the death of 2 horses. The unknown causes of death in horses, coupled with the documented deaths attributed to strain/stress, seizure, and cardiac arrest (Table 4), in this study could be attributed to capture myopathy [13]. Capture myopathy is a noninfectious metabolic disease that is most commonly associated with pursuit, capture, restraint, and transportation of animals and the induced stress that can lead to death either during or after capture efforts [29]. Unfortunately, capture myopathy has been persistently difficult to diagnose and includes several different clinical syndromes including capture shock syndrome, ataxic myoglobinuric syndrome, ruptured muscle syndrome, and delayed peracute syndrome [13]. Owing to the absence of more detailed medical data

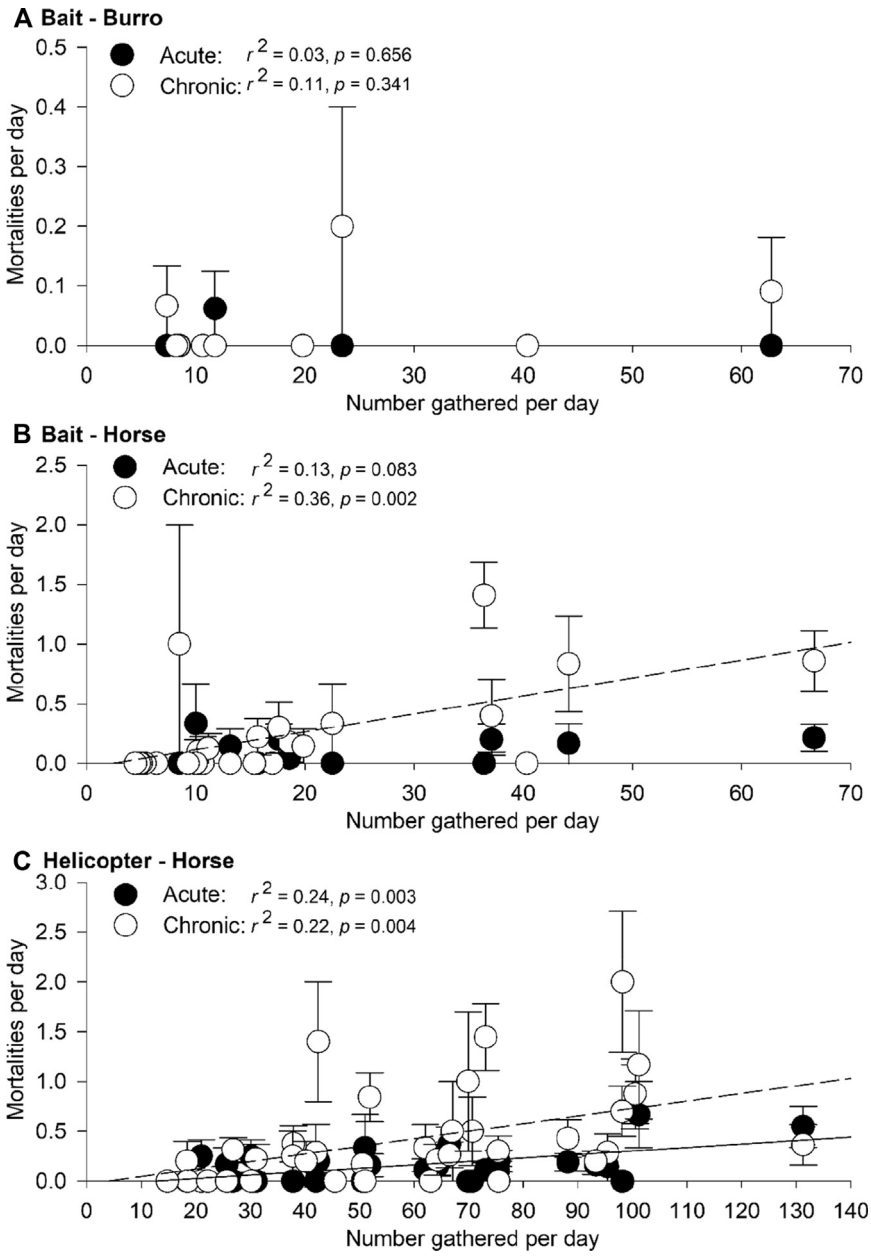

Fig. 4. Comparison of mean daily mortalities relative to mean number of equines gathered per day for (A) bait trapping burros, (B) bait trapping horses, and (C) helicopter gathering horses. Data from 70 publicly available gather reports (bait trapping burros n = 10, bait trapping horses n = 24, helicopter gathering horses n = 21) from 9 US states (AZ, CA, CO, ID, MT, NV, OR, UT, WY) representing 28,821 horses and 2,005 burros from 2010 to 2019. Significant trendlines graphed as solid lines for acute mortalities and dashed lines for chronic mortalities.

necessary to confirm diagnoses, more thorough investigations of unknown death causes are needed, particularly for helicopter gathers [30].

4.5. Comparison of Equid Mortality Rates to Other Wildlife Species and Capture Techniques

The total capture mortality rate across all gathers in this study [1.1% (368 mortalities of 30,826 horses and burros captured)], or for specific horse capture techniques (bait mean = 1.7% ± 0.5% SE; helicopter mean = 1.0% ± 0.1% SE), can be compared with capture-related mortality rates published for other wildlife species. For 5 wildlife species chemically immobilized in Scandinavia, the mean mortality rate was 2.3% and ranged from 0.7% to 3.9% [31]. For white-tailed deer caught with 4 different physical trapping techniques, capture-related mortality rates ranged from 2.0% to 20.7% [32]. For caribou calves darted from a helicopter, capture-related mortality rates ranged from 0.5% to 4.1% [33]. Thus, given the capture-related mortality rates from these studies, and the recommendation that >2% capture mortality is unacceptable [31], it seems that BLM horse and burro welfare is generally being optimized to a level acceptable across other animal handling disciplines [31]. It is important to note however that for several individual gathers, mortality rates exceeded 2% mortality. Two gathers were emergency gathers that had mortality rates >3.5% and >10.5% (2018 Wild Horse Range Emergency gather and 2016 Goshute Emergency gather, both in Nevada). In addition, one helicopter gather had a mortality rate >3.5% due to a prevalence of genetically related

structural deformations and lameness (2018 Warm Springs gather in Oregon, specifically "*angular limb deformities (ALD), conditions were indicated by club feet, severely overgrown hoof walls, collapsed heals, limb deformity, arthritic joints, toes pointed out at the fetlock, and lameness*"). Thus, a distinguishing feature of the US federal horse and burro management is the intervention when forage and water is limiting and/or when horses are suffering from other health problems, which is fundamentally different than capturing healthy animals for wildlife research. This emphasizes the continued need for quality equine veterinary care and the importance of having detailed medical history and veterinarian diagnoses and/or necropsies to move beyond lay terms and general attributions of mortalities.

5. Conclusions

This study assesses feral equine capture techniques in the United States, which is an important tool for when horse and burro overpopulation threatens the "thriving natural ecological balance" of rangelands [32,33]. My objective analyses of publicly available BLM equine gather data over 70 gathers, 9 states, 30,826 horses and burros, and a 10-year period has allowed for quantitative analyses that suggests helicopter gathering presents no additional risk for acute mortalities than bait trapping. Moreover, helicopter trapping can capture more horses per day. I also have provided details that both veterinarians and federal horse managers can use proactively when preparing for and supervising gathers; specifically, being aware of structural deformities, feet problems, blindness, and a greater prevalence of emaciated horses or acute mortality manifestations relative to capture technique and reason for a gather. In addition, emergency gathers may have a greater risk of mortalities attributed to handling weaker and sicker horses. My results should be considered in the context of repeatedly gathering mares for other treatments and could also guide animal welfare frameworks for US horses and burros [34–37].

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