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Dehydration and mortality of feral horses and burros: a systematic review of reported deaths

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Abstract: Water is a requirement for all organisms, including equids. Dehydration-caused mortality of feral horses (*Equus ferus caballus*) is often cited as a cause of concern and as justification for management of feral horses, yet a paucity of information exists on the matter. We conducted a systematic review from September 1, 2020 through January 15, 2021 of available news reports of feral horse and burro (*E. asinus*) dehydration mortalities and public interventions to save horses using a public search engine with *a priori* defined search term combinations and additional snowball sampling. We found 15 uniquely reported mortality incidents representing 744 horse in the United States and Australia that occurred between 1976 and 2019; no similar reports for burros were found. Mortalities occurred during hotter and drier than normal conditions with occurrences escalating through the summer and fall. The number of horses per dehydration mortality event ranged from 1–191 with a mean of 50 horses. Mortalities occurred on a wide range of land jurisdictions including private lands, tribal lands, national forests, national parks, and Bureau of Land Management lands. Increasing feral horse populations in western North America and Australia, coupled with the drought forecasts over the next century, simply cannot be ignored. This study represents the first global and longitudinal assessment of feral horse dehydration mortalities.

Key words: drought, *Equus asinus, E. ferus caballus*, feral burro, feral horse, management, mortality, thirst, water, welfare

Large populations of feral horses (*Equus ferus caballus*) and burros (*E. asinus*) inhabit landscapes in North America and Australia (Scasta et al. 2020). In the United States, many of these equids inhabit federally owned land and are protected by the 1971 Wild Free-Roaming Horses and Burros Act (WFRHBA; Public Law 92-195). This governmental mandate includes emphasis for maintaining healthy equid populations in tandem with a natural ecological balance with other soil, plant, water, wildlife, livestock, and recreational features (Scasta et al. 2018). The mandate also requires the inventory and removals of horses and burros when deemed overpopulated by the Bureau of Land Management (BLM) and U.S. Forest Service (USFS).

As of March 1, 2021, the BLM estimated there were 71,735 horses and 14,454 burros on designated herd management areas (HMAs). This estimate is >300% the nationwide appropriate managagement level of 26,770 (BLM 2021). The USFS estimated there are 7,100 horses and 900 burros on herd management territories (USFS 2021). There are additional horses on lands managed by other authorities including tribes with an estimated population of >90,000 feral horses and unknown numbers of burros (U.S. Government Accounting Office 2017) and national parks, national seashores, national recreation areas, and state managed lands (Schoenecker et al. 2021). These equids primarily inhabit arid and semi-arid rangelands in the western United States. that are prone to extreme moisture variability and have the greatest risk of degradation from mismanaged grazing of all the rangeland biomes (Holechek et al. 1995). In Australia, an estimated 400,000 horses and burros inhabit similar ecosystems where the same welfare concerns exist (Garrott and Oli 2013, Scasta et al. 2020). Feral horses in Australia also occur across a variety of jurisdictions.

Climate change with greater variability of extreme events, such as heat waves and droughts, increases the potential for ecological impacts to arid ecosystems and the equids that inhabit them (Intergovernmental Panel on Climate Change 2014). Climate forecasts for the western United States include widespread aridification and decadal to multidecadal droughts, indicating a pronounced shift in the hydrological paradigm (Overpeck and Udall 2020). Terrestrial water storage is predicted to "substantially decline" through the United States in both the mid (2030–2059) and late (2070–2099) twenty-first century, with "extreme droughts" forecasted to also become more frequent (Pokhrel et al. 2021). The southwestern United States is also anticipated to be affected particularly severely due to increasing runoff and soil moisture deficits and increased evaporative losses (Cook et al. 2019).

These forecasts, coupled with the growing horse and burro population, are concerning because all large terrestrial mammals require a regular source of water to maintain hydration and normal physiological function (Fuller et al. 2016). Without water, horses and burros enter dehydration, which is a deficit of total body water accompanied by the disruption of metabolic processes that can ultimately lead to mortality (Friend 2000, Muñoz et al. 2011). Deprivation of water is not only a function of variable weather and climatic patterns but is also a function of management, availability, and inherent environmental constraints (Carlson et al. 1979, Hampson et al. 2010, Fuller et al. 2016). For feral horses and burros, information inferring how many die due to water deprivation in extensive rangeland environments is relatively underreported and unknown in terms of cause-specificity; yet, it is often cited as the impetus for management interventions by federal agencies. For example, official justification for the 2020 Montezuma Peak Wild Horse and Burro Gather states "…action is needed due to lack of water and declining health of the wild horses and burros—the Montezuma Peak HMA has a history of water issues during dry spring and summer months" (BLM 2020). In addition, dehydration has been implicated as the cause of mortality in federal gather reports (Scasta 2020).

Contextually, equid water requirements can vary depending on individual circumstances. A 500-kg horse that is not pregnant, not lactating, and/or not working (e.g., being directed to labor by a human) requires a minimum of 25 L per day. If consuming dry feed only, water intake may double. Pregnant and nursing mares have an increased water requirement up to 60–70 L per day, and a horse working for 1 hour during the heat of the day requires approximately 72 L per day (Ralston 2021). Such knowledge of horse water requirements is relevant as feral horses have constrained thermoregulation options, particularly in the relatively open rangelands of the western United States and Australia.

While feral horse and burro populations continue to grow and the climate changes, the manifestation of dehydrated horses and burros is of escalating concern. Yet, the National Research Council (2013) suggested that allowing horse populations to "…expand to the level of 'self-limitation' such that suffering and death due to disease, dehydration, and starvation accompanied by degradation of the land—are also unacceptable." The frequency and magnitude of dehydration in feral horses is largely unknown but may be exacerbated by drought. To address this information need, we completed a systematic review of news reports concerning horse and burro deaths and human interventions to provide food and water to avoid mortalities.

Methods

We used the generic Google search engine to systematically review available news reports of feral horse or burro dehydration mortalities and interventions to save at-risk horses and burros. We defined search term combinations *a priori* and used both the Google "news" and "all" functions for searching and screening results. For deaths (e.g., mortalities), we used 4 search term combinations: "wild horse dehydration death," "feral horse dehydration death," "feral horses die of dehydration," and "wild burro dehydration death." For interventions, we included 8 search terms: "wild horse water," "wild burro water," "wild horse watering," "wild burro watering," "wild horse feed," "wild burro feed," "wild horse feeding," and "wild burro feeding." Due to result saturation, we also used snowball sampling such that when a result mentioned a specific dehydration and mortality event, we performed a separate search for the specific event. For deaths and in-

Table 1. Summary of feral horse (*Equus ferus caballus*) dehydration mortalites in the United States and Australia found in the systematic search of news sources conducted September 1, 2020 through January 15, 2021. Reports ranked by number of horse mortalities. URL = Uniform Resource Locator.

Number of horses dead	Country	State	Year	Month	Jurisdiction; Source; URL
191	United States	Arizona	2018	May	Tribal; CBS News; https://www.cbsnews.com/news/horses-found-dead-southwest-drought-arizona-najavo-nation/
140	Australia	Northern Territory	2019	January	Unknown; Alice Springs News; https://alicespringsnews.com.au/2019/01/23/horses-perish-near-santa-teresa/
124	United States	New Mexico	1994	August	Military; LA Times; https://www.latimes.com/archives/la-xpm-1994-08-07-me-24454-story.html
100	United States	North Dakota	1987	Unknown	Private; US General Accounting Office - Report to Secretary of the Interior (GAO/RCED-90-110)
70	United States	Nebraska	1987	Unknown	Private; US General Accounting Office - Report to Secretary of the Interior (GAO/RCED-90-110)
50	United States	Utah	1976	July	Military; Deseret News; Utah State Veterinarian Report (Unclassified AD A032563); https://www.deseret.com/2005/8/28/19909203/mysterious-deaths-ex-soldier-links-horses-malady-in-1976-to-his-poor-health#wild-horses-sick-with-an-unknown-ailment-drink-from-a-watering-hole-on-dugway-proving-ground-in-july-1976
19	United States	Utah	1999	November	Bureau of Land Management; Deseret News; https://www.deseret.com/1999/11/30/19478159/thirst-claims-19-wild-horses-br-animals-stick-with-water-hole-even-after-it-s-dry
17	United States	Arizona	2013	July	Tribal; Desdemona Despair; https://desdemonadespair.net/2013/07/arizona-horses-dying-as-navajo-nation.html
13	United States	Nevada	2010	July	Bureau of Land Management; Las Vegas Sun News; https://lasvegassun.com/news/2010/jul/22/blm-more-than-600-mustangs-rounded-up-in-nevada/
8	Australia	Northern Territory	2013	May	Aboriginal; Horse Talk News; https://www.horsetalk.co.nz/2013/05/11/planned-aust-aerial-cull-target-10000-horses/
4	United States	Colorado	2014	June	National Park; Denver Post; https://www.denverpost.com/2014/07/31/wild-horse-deaths-at-mesa-verde-highlight-problem-at-national-park/
4	United States	Arizona	2018	July	Tribal; Arizona Central News; https://www.azcentral.com/story/news/local/arizona-environment/2018/07/13/volunteers-help-navajo-gray-mountain-wild-horses-during-drought-overpopulation-concerns/770454002/
2	United States	Nevada	2016	September	Bureau of Land Management; Free Range Report; https://freerangereport.com/wild-horses-in-crisis-photos-from-the-rangeland/
1	United States	Arizona	2017	May	Forest Service; White Mountain Independent Central News; https://www.wmicentral.com/news/latest_news/advocates-say-horses-need-water-now/article_b210138a-cdbc-59bd-8bdb-06dfaed16a36.html
1	United States	Arizona	2018	June	Tribal; Arizona Daily Sun; https://azdailysun.com/news/local/in-the-midst-of-drought-volunteers-bring-food-and-water-to-gray-mountain-wild-horses/article_bd3e7766-1905-58d0-9364-e641962dfe1b.html

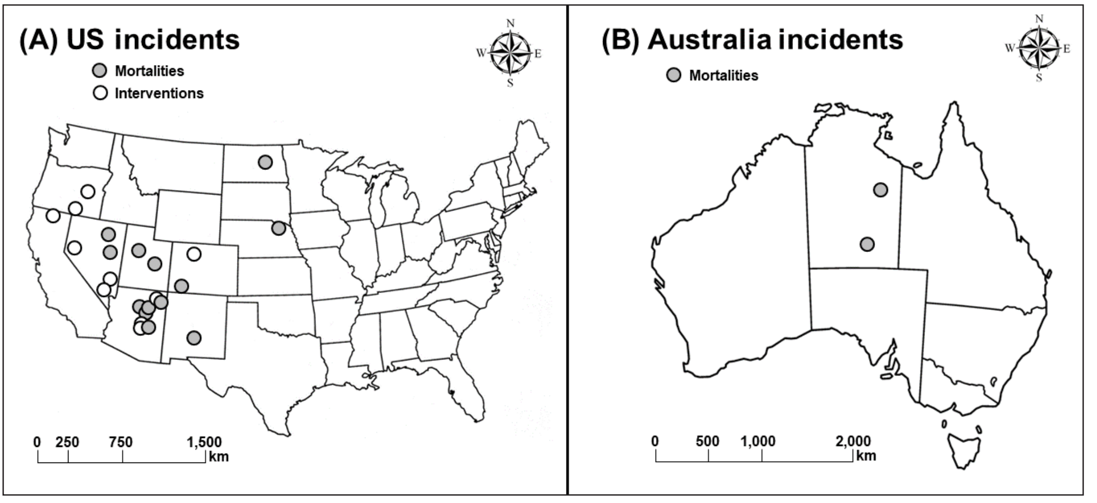

Figure 1. Incidents identified through a systematic review of reported cases conducted September 1, 2020 through January 15, 2021 of feral horse (*Equus ferus caballus*) mortalities due to dehydration and instances of intervention by people to avoid mortalities in (A) the United States and (B) Australia.

terventions, the top 100 results for each search term combination and search function option were reviewed with additional search results reviewed for >2,000 search results scoured in this study from Logan, Utah, USA, and Laramie, Wyoming, USA, from September 1, 2020 through January 15, 2021. For relevant events, a database was developed by systematically extracting the following variables: year, country, state, number of horses dead, and source Uniform Resource Locator.

For 11 reported case of mortalities, we were also able to acquire effective precipitation and temperature data for the approximate location of each reported incident (we could not derive weather data for the 2 Australia occurrences and could not derive timing details for 2 U.S. occurrences in Nebraska and South Dakota). Data were acquired using the Parameter-elevation Relationships on Independent Slopes Model (PRISM 2021) extrapolation method that uses digital elevation models at a 4-km resolution and ~10,000 weather stations (Daly et al. 2008). Stations are weighted relative to a physiographic similarity relative to the grid cell of interest based on the AN81d dataset (Daly et al. 2008). Because the cumulative effect of precipitation influences available water, we used effective precipitation considered to be from January through June for the reported year of the incident (Derner and Hart 2007, Connell et al. 2019). Because often only the month of the occurrence was known (and not the exact date), we used effective temperature considered to be the mean temperature of the month for the reported mortality incident (St-Pierre et al. 2003). Both effective precipitation and temperature were then relativized to the long-term 124-year mean for each variable from 1895 to 2019 derived from PRISM. We then assessed geographical concentration of dehydration deaths, distribution through time (both by year and month), potential effect of temperature and precipitation, and claims of interventions. Given the small sample size found in this study, we present the data descriptively to understand potential patterns explaining horse mortalities that were possibly due to dehydration.

Results

We found 15 reports of dehydration-related mortalities encompassing 744 horses and 0 burros (Table 1). Reported deaths found in the study only occurred in the United States and Australia (Figure 1). We found 8 reports of interventions at 10 different locations, all of which were located in the United States (Table 2). In addition to these quantifiable data, 1 report (https://www.indiancountrynews.com/index.php/news/wildlife/12610-drought-on-navajo-nation-hits-wild-horses) from Gallup, New Mexico, USA, only alluded to animals dying of dehydration and stated that "…rangers on patrol find hundreds of carcasses at dirt reservoirs" but did not include the specific number of deaths. In the United States, reports included

Table 2. Summary of interventions where supplemental feed and water are provided to feral horses (*Equus ferus caballus*) in the United States found in the systematic search of news sources conducted September 1, 2020 through January 15, 2021. Reports ranked by number of horses speculated to be positively affected. URL = Uniform Resource Locator.

Estimated number of horses affected	Country	State	Year	Month	Jurisdiction; Source; URL
3,000	United States	Nevada	2020	September	Nevada Department of Agriculture; This is Reno; https://thisisreno.com/2020/09/local-organization-seeks-volunteers-to-help-feed-virginia-range-wild-horses/
750	United States	Colorado	2018	June	Bureau of Land Management; The Fence Post; https://www.thefencepost.com/news/for-now-no-water-to-be-hauled-for-wild-horses-in-colorados-sand-wash-basin/
400	United States	Arizona	2019	October	National Recreation Area; Arizona Central; https://www.azcentral.com/story/news/local/arizona-environment/2019/10/01/how-many-horses-too-many-along-salt-river/2386789001/
250	United States	Arizona	2018	September	National Recreation Area; KJZZ 91.5 FM Radio; https://kjzz.org/content/703661/nonprofit-responds-drought-feeds-wild-horses-along-salt-river
230	United States	Oregon	2018	August	Bureau of Land Management; YouTube; https://www.youtube.com/watch?v=5y6QsBp2ZGA
200	United States	Arizona	2018	June	Tribal; Cronkite News; https://cronkitenews.azpbs.org/2018/06/29/grassroots-group-works-to-save-wild-horses-on-navajo-reservation/
Unknown	United States	California Nevada Oregon	2013	Unknown	Bureau of Land Management moving onto Private Land; Herald and News; https://www.heraldandnews.com/email_blast/dry-conditions-force-wild-horses-onto-private-land/article_2024155c-0a4b-11e4-824e-001a4bcf887a.html
Unknown	United States	Nevada	2013	July	Unknown; LA Times; https://www.latimes.com/science/sciencenow/la-sci-sn-drought-horses-grazing-20130715-story.html

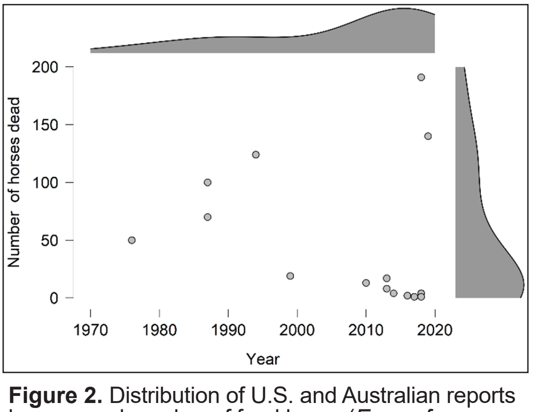

Figure 2. Distribution of U.S. and Australian reports by year and number of feral horse (*Equus ferus caballus*) mortalities attributed to dehydration found in a systematic review of news reports conducted September 1, 2020 through January 15, 2021. Gray shading indicates the relative density of data points relative to time (top relative to x-axis) and number of horses dead (right relative to y-axis).

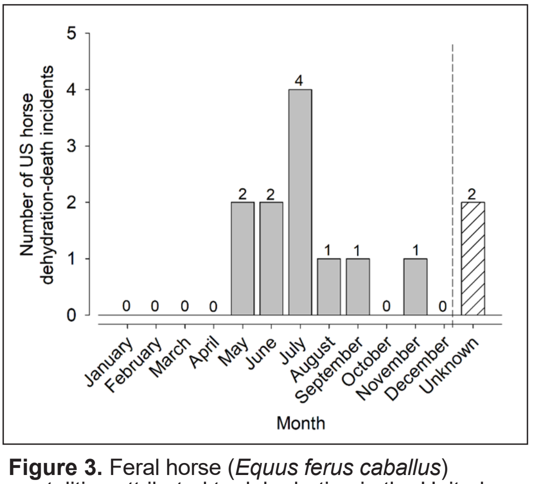

Figure 3. Feral horse (*Equus ferus caballus*) mortalities attributed to dehydration in the United States relative to month. Data were derived from a systematic review of news reports.

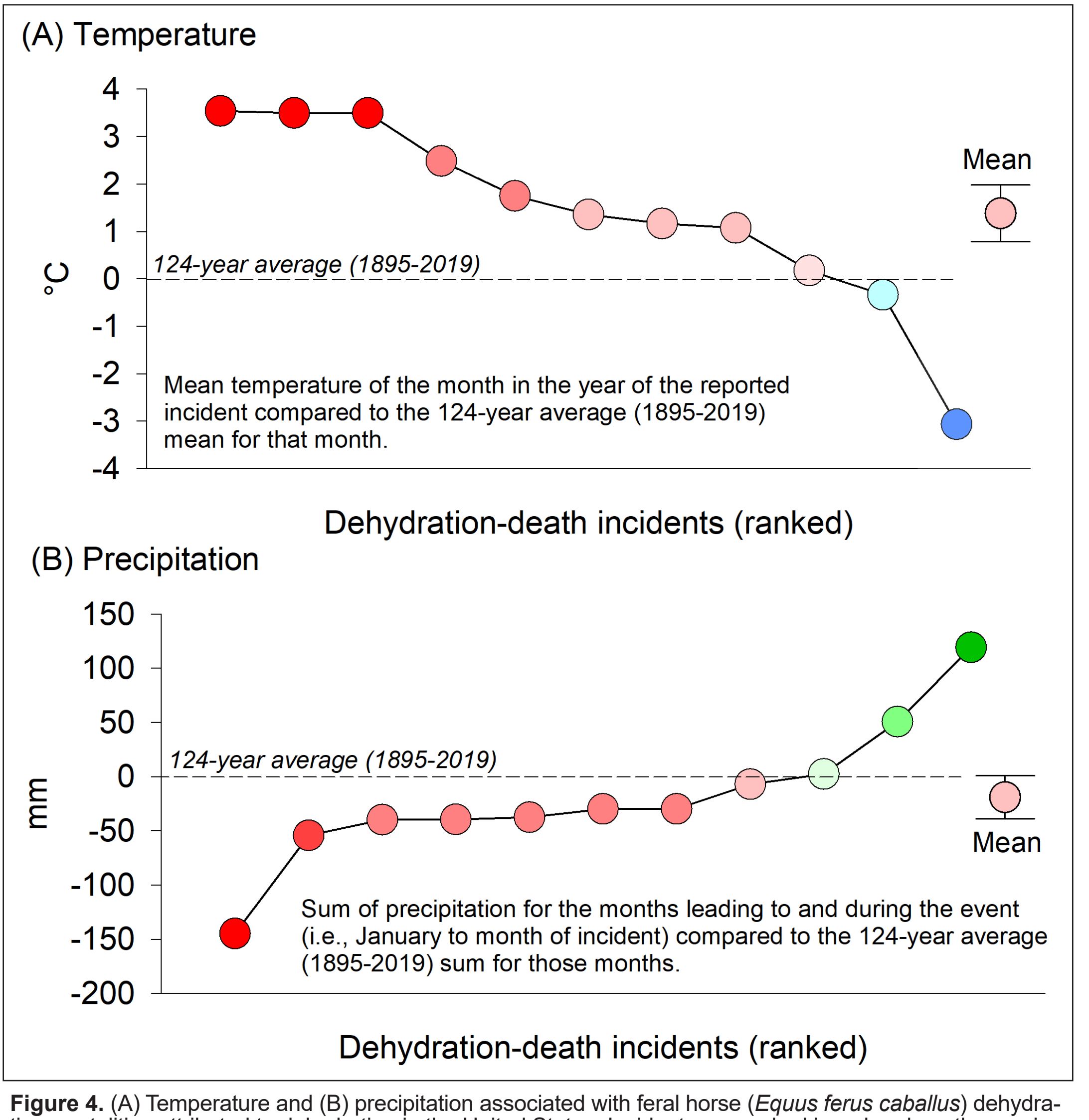

Figure 4. (A) Temperature and (B) precipitation associated with feral horse (*Equus ferus caballus*) dehydration mortalities attributed to dehydration in the United States. Incidents are ranked in order along the x-axis reflecting the order of y-axis values. Mortality data were derived from a systematic review of news reports. Temperature and precipitation data were derived from Parameter-elevation Relationships on Independent Slopes Model (PRISM) extrapolation method with temperature data as the mean temperature of the reported month of mortalities and precipitation as cumulative from January through June.

horses occupying a wide range of jurisdictions including private lands, military lands, tribal lands, national forests, national parks, and BLM lands. State agencies may also be managing dehydrated horses (Table 2). A report of horses under the jurisdiction of the federal government moving onto private lands during drought was also found (Table 2). In Australia, land jurisdiction was unknown for 1 report and was under the authority of an Aboriginal group in the other.

Reported events occurred from 1976 to 2019. When summarized by decade, there was a clear bias toward recent events, particularly in the last decade (Figure 2), which may be a function of increasingly available news sources that are archived. In the 1970s, only 1 event was noted involving 50 horses. In the 1980s and 1990s, there were 2 events in each decade involving 170 and 143 horses each decade, respectively. No events were noted in the 2000s. However, 10 events were noted in the last decade from 2010 to 2019 involving 381 horses. The number of horses per event ranged from 1–191 with an average of 50 horses per reported event (Table 1; Figure 2). In the United States, incidents primarily occurred in the late spring and summer months, with a few in the fall (Figure 3). In Australia, incidents occurred in the Northern Territory in January and May, which are in the summer and fall, respectively, being in the southern hemisphere (Table 1).

When assessing the temperature and precipitation conditions during dehydration deaths for incidents for which such data were available, hotter and drier conditions were prevalent. For temperature, 9 of the 11 incidents had warmer than average temperatures the month of the incident when compared to the long-term mean (Figure 4). The hottest conditionss were >3°C hotter than the long-term mean (Figure 4). For precipitation, 8 of the 11 incidents were drier than average in terms of effective precipitation when compared to the long-term mean (Figure 4). The driest conditions were nearly 150 mm below the long-term mean (Figure 4). This suggests that hotter conditions certainly exacerbate such mortalities and that drier conditions were associated with deaths for the specific horses in the data. For Australia, we were unable to develop similar weather data, but it is important to note that the 2 occurrences were in the hot desert and on the northern edge of the hot desert that characterizes a large swath of the interior of Australia.

Discussion

Climate change, horse population growth, and drought

This study is the first attempt to quantify horse deaths due to dehydration. It is important to note that multiple causes of death can co-occur with dehydration, including getting stuck in mud and starvation, and thus interpretation of news reports may include some speculation (Berger 1983). Regardless, though, the growing population of horses in North America and Australia, coupled with the drought forecasts over the next century, in the context of population management, simply cannot be ignored (Fuller et al. 2016). Evidence from our assessment suggests that hotter and drier conditions are when the majority of deaths from dehydration are likely to occur—conditions that we can expect to occur with greater frequency and magnitude in the coming decades (Overpeck and Udall 2020). In the United States, the relative concentration of deaths in the southwest and Great Basin regions are noteworthy, as these areas have the greatest densities of horses and are forecasted to have the greatest magnitude of climatic changes (Cook et al. 2019) with similar changes forecasted for Australia. It is comparatively noteworthy that no incidents were found in higher elevations with more snowfall such as Wyoming, USA, or New South Wales, Australia. The occurrences of horse dehydration deaths were variable across land surface ownership and jurisdiction. Such variability indicates this is a problem not only for federally managed horses but the many other horses that are not managed within a framework of the USFS or the BLM. For example, tribal lands, private lands, military lands, and national parks have experienced similar reported deaths, and additional horse management resources may need to be developed (Wallace et al. 2021). Finally, while the results may indicate that climate change could be contributing to the results in this study, other factors may confound the results, such as an increase of reports through time, increased media and public interest, etc.

Water deprivation and death from dehydration

When horses suffer from dehydration, it is important to understand the manifestation rate of physiological symptoms and understand the potential suffering and welfare issues that take place (Carlson et al. 1979). Adult horses need an estimated 64.4 ml of water per kg of body weight (Groenendyk et al. 1988), and an adult horse can hold between 65 and 90 kg of water in their digestive tract. This storage capacity allows horses to go several hours without needing to consume water before suffering from dehydration, even during hot summer temperatures. Dehydration ultimately also complicates thermal regulation because there is a reduced amount of extracellular fluid available to circulate heat to the skin surface that is finally dissipated by sweat and evaporation (Foreman 1998). Elevated heat stress can also lead to hypertonic dehydration due to inadequate water intake during a period of excessive fluid loss (Sneddon 1993).

Detrimental signs of dehydration (Brownlow and Hutchins 1982) manifest approximately 24–48 hours after water deprivation is induced, which in the context of arid environments is critical insight because horses in Australia had a range of watering frequency of 1–4 days with a mean of 2.67 days (Hampson et al. 2010). Moreover, Hampson et al. (2010) reported that horses were found up to 55 km from water locations and in some cases walked up to 12 hours per day to access water. By the time 30 hours since drinking have elapsed, horses are likely compromised due to detectable dehydration and fatigue (Friend 2000). By day 1, urine output and dry matter intake will decrease substantially and urine color becomes darker and more concentrated. By day 2, hair shedding can begin, and by day 3, skin tenting occurs due to reduced capillary refill and severe damage to internal organs can begin. Horses will experience a 12–15% decrease in body weight, begin to look gaunted or drawn up in the flank, and colic-associated abdominal pain can occur due to impaction of dry ingesta (Tasker 1967). Death can occur at this point due to electrolyte imbalances leading to thermoregulatory failure, shock, intravascular hemolysis, paralysis of muscles, and/or organ failure (Adams 2012).

Contextualized with domestic horse neglect and abuse

The impact of water deprivation on feral horses and the results from this study suggest a welfare mismatch between feral horses and domestic horses. Fundamentally, this mismatch is because every state in the United States prohibits neglect and cruelty against animals through established legislation and regulation (Stull and Holcomb 2014). Thus, the issue of feral horses experiencing thirst, and possibly death, must be contextualized with the stark contrast of domestic horse neglect and abuse (Salt Lake Tribune 2016). The comprimise of a horse's health due to starvation or dehydration has implications for humane treatment and possible neglect (Kronfeld 1993). Such issues must also be taken into consideration for free-ranging horses, as our results clearly indicate (Salomon 1976). In addition, empirical evidence indicates that as water sources shrink and animal density increases, inter-animal competition for water also increases (Gibbs and Friend 2000).

The curious case of the burro

We found it interesting that no reports about burros dying from dehydration were found. This could be due to a combination of several possible explanations. First, burros are less numerous than horses, particularly in the United States (BLM 2021), and thus such deaths may be less detectable. Second, horses may be more popular than burros and may simply garner more attention. Third, burros are phylogenetically distinct from horses and may be more adapted to deal with droughts given their "exceptional tolerance to dehydration" (Bullard et al. 1970). This tolerance may be attributed to how burros partition fluid in the body (Davis et al. 1978) or the regulation of sweating responses to heat and dehydration, which under moderate dehydration did not alter blood concentrations, performance, or temperature regulation (Bullard et al. 1970). Burros in Somalia were experimentally exposed to heat and water deprivation and found to survive dehydration corresponding to a 30% reduction of body weight up to temperatures of 40°C and were able to drink enough water in 2–5 minutes to restore water deficit (Maloiy 1970). The African wild ass (*E. africanus*), a critically endangered species at risk of extinction, has been noted to disperse 9 km from permanent water, with non-reproductive adult females and males traveling to water every 5–10 days (Tesfai et al. 2021).

While dehydration is often referred to as a specific cause of horse mortality and as justification for intervention and management, no central reference of known events has been available in the peer-reviewed literature. Our systematic review suggests this is a global issue and can affect up to hundreds of horses at a time. Additional horses and wildlife are likely affected. These cases go unreported or are poorly documented (Artelle et al. 2013, Treves et al. 2017) because of the remote nature of their habitat and the ability of scavengers to quickly consume a carcass. Additional investigation into potential competition between horses and wildlife at water sources as drought escalates is also warranted (Gooch et al. 2017, Hall et al. 2018, Hennig et al. 2020).

Management implications

Currently, feral equid populations in the western United States are increasing in areas where climate change is forecasted to have dramatic impacts, which will include extreme drought. Without human intervention to control populations or provide supplemental feed and water, there will be increased dehydration and starvation mortalities. Given the legal obligations to manage feral horses and burros, particularly populations under governmental jurisdiction, and to ensure their welfare, our study provides insight on equid dehydration and mortalities and when and where intervention may be necessary. More interventions will be necessary in areas where feral horse and burro densities are the highest and drought conditions extreme. These circumstances may justify increasing gathers and removals.

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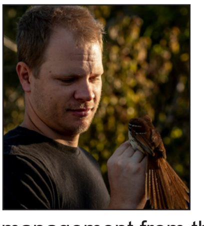

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