American Journal of Life Sciences
2014; 2(1): 5-23
Published online January 30, 2014 (http://www.sciencepublishinggroup.com/j/ajls)
doi: 10.11648/j.ajls.20140201.12

The horse and burro as positively contributing returned natives in North America

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To cite this article:
Craig C. Downer. The Horse and Burro as Positively Contributing Returned Natives in North America. *American Journal of Life Sciences*. Vol. 2, No. 1, 2014, pp. 5-23. doi: 10.11648/j.ajls.20140201.12

Abstract: Since the Wild Free-Roaming Horses and Burros Act of 1971, debate has raged over whether horses and burros are restored North American natives. Fossil, genetic and archeological evidence supports these species as native. Also, objective evaluations of their respective ecological niches and the mutual symbioses of post-gastric digesting, semi-nomadic equids support wild horses and burros as restorers of certain extensive North American ecosystems. A Reserve Design strategy is proposed to establish naturally self-stabilizing equine populations that are allowed to harmoniously adapt over generations within their bounded and complete habitats. These populations should meet rigid standards for viability based on IUCN SSC assessments (2,500 individuals). Basic requirements are described for successful Reserve Design including viable habitat as well as specific regions of North America where this could be implemented.

Keywords: Equidae, Wild Horses and Wild Burros, Horse and Burro Evolution, Horse and Burro Ecology, North American Native Fauna and Ecosystems, Reserve Design, Wild Free-Roaming Horses and Burros Act of 1971

1. Introduction

All branches of the horse family (Equidae) share an ancient evolutionary origin and long-standing duration in North America, having evolved here for ca. 60-million years ago. Few other mammalian families can lay as much claim to native status and belonging on this continent. Two other extant families in the Order Perissodactyla are the tapir and the rhinoceros families, and both are similarly rooted in North America. From George Gaylord Simpson [1] to Bruce MacFadden [2], various scientists have described the horse family's fascinating story; and their works reveal the ascent of many distinctive yet interwoven equine genera and species over the eons. The horse family has branched out to all continents except Australia (prior to the arrival of whites) and Antarctica. These animals have contributed positively to our planetary communities, and they continue to do so in many ways and on many levels today.

The rapid reoccupation of vacant niches in North America by the horses (*Equus caballus)* and burros (*Equus asinus*) may be viewed as corroborating their return to ancestral grounds. In the words of the Plains Indians: 'The grass remembers the horses.'

In this article, I present evidence for the origin and long-standing evolution of both horse and burro evolutionary branches in North America, and further support the entire horse family as primarily native here. I go on to show that both horses and burros are returned native species and merit protection. In complementary fashion, I also describe the unique ecological roles filled by horses and burros, explaining how they both preserve and restore native ecosystems in the American West. Finally, I propose *reserve design* as a means by which wild horses and burros can restore themselves as vital components of viable ecosystems and be truly protected as mandated by the Wild Free-Roaming Horses and Burros Act of 1971. I also suggest regions where this could be possible.

2. Methods

I gathered information for this article through a thorough literature review of the history, evolution, ecology, and conservation of wild horses and burros in North America. This review has been a life-long one and accompanied by visits to and observations of many of the wild horse and burro herds and occupied habitats throughout the western United States. This has resulted in a graduate paper on the behavior and ecology of the Pine Nut Range wild horse herd

of western Nevada and other reports and publications. The sources for this article are listed in the references section.

I have attended several professional conferences concerning wild horses and burros and other wildlife at which I have presented papers, e.g. International Interdisciplinary Environmental Conference 2013, International Equine Conference 2011 and 2012, Wild Horse Summit 2008, and Wild Horse Forum 1980. Material from these papers has been incorporated into this article.

Professional consultation with professors, biologists, and government officials has also guided the preparation of the article. Many of the points presented here were also presented in my book *The Wild Horse Conspiracy*. [3] My extensive research on wild equids and other perissodactyls has resulted in scientific publications, including encyclopedic articles (e.g. Grzimek's, 2004), a species resume and action plan [4], and scientific journal articles, as well as many popular reports and articles. These have described the evolution, ecology, and conservation history and plans – past, present, and future – of perissodactyla species, including the endangered mountain tapir as well as the wild horses and burros of North America.

Characteristics common to the order include a mesaxonic weight-bearing, odd-toed anatomy, possession of both upper and lower incisors permitting careful pruning of vegetation, and the possession of a post-gastric (in contrast to a pre-gastric, multi-stomach ruminant) digestive system. These and other shared characteristics place members of the horse, tapir, and rhinoceros families into similar ecological niches and roles. A knowledge of these characteristics affords insight concerning contributions to the North American ecosystems by both horse and burro lineages evolving here since the early Cenozoic Era ca. 60 MYA. This knowledge relates a wider variety of species, genera and families that share near-lying branches on the "family tree" of life expanding over time. And this knowledge has greatly aided me in composing this paper.

3. Findings and Discussion

3.1. Evidence of the Long-Term Presence and Evolution of Horses and Burros in North America

3.1.1. Yukon Horse substantiates North American Origin of Modern Horse

During the mid-1990s, horse remains were discovered by placer miners in the Yukon. They were well preserved in the permafrost and seemed to have died recently, yet proved to be approximately twenty-five thousand years old. Their rufous color, flaxen mane and solid hooves had the aspect of a typical, small and wiry mustang of the West. Based on external morphology, the specimen was identified as a "Yukon horse," whose Latin name is *Equus lambei.* Intrigued, paleontologists conducted a genetic analysis of this specimen, which showed it to be one and the same as the modern horse: *Equus caballus.* Further independent analysis conclusively proved this. With this substantiation came a more widespread recognition of wild horses as returned native species in North America, since *E. lambei* was seen to be identical to *E. caballus.* [5]

Carbon-14 datings of mitochondrial DNA (passed along the maternal line) have been meticulously analyzed by Dr. Ann Forsten [6] and have substantiated the origin of the modern horse in North America at 1.7 MYA (million years ago). According to Forsten: "[t]he early branching-off time indicated by *mtDNA* supports an origin of the caballoids [the horse branch of the horse family: Equidae] in the New World, and the fossil record suggests an even rather late dispersal to [the] Old World."[5]

The fact that the Yukon horse is genetically identical with the modern horse reveals the latter to be one of the most deeply rooted and justifiable native species in North America. This native status is additionally substantiated by the species' large geographic distribution upon this continent that is evident from the fossil record and the great variety of ecosystems in which it can adapt and live. Furthermore, though the modern horse traces back ca. 2 million years in its present form, it should actually be regarded as part of the continuous context of equid evolution that dates back at least 58 million years in North America. [7]

3.1.2 More Recent Horses in North America

A considerable body of evidence has surfaced concerning the more recent survival of the horse species in North America. Though the prevailing view maintains that the entire horse family died out around 10,000 years ago at the end of Earth's last major glaciation, evidence for horse presence from anywhere from a little over 7,000 years before present (YBP) to less than 1,000 YBP is too substantial to dismiss. [8] Among other lines of evidence, this comes in the form of fossil bones that have been age-dated to more recent times, horse geoglyphs (ground drawings) dated to about 1,000 years ago, [9] and petroglyphs, or stone depictions.

The *FaunMap* produced and published by the Illinois State Museum of Springfield, revealed a number of horse fossil datings within the post-Pleistocene-Pre-Columbian period that occurred well after the time at which all members of the horse family are commonly believed to have disappeared from North America. Some of these are quite close to Columbus' discovery of America in 1492. [10] (See section 3.2.)

3.1.3. Petroglyphs and Geoglyphs

During the summer of 2002, I visited the austere White Mountains east of the towering, snow-capped Sierra Nevada near Bishop, California. The ancient White Mountains rise to over 13,000 feet at Boundary Peak and contain one of the most ancient life forms on Earth: the majestic, die-hard Bristlecone Pine, one of which has been dated to near 9,000 years of age. [11] Intrigued by this atmospheric region on the edge of eastern California and western Nevada, I went on to explore the desert valley just to the west of these mountains. Here I came upon some fascinating petroglyphs dating from

modern times to a few thousand years ago (Bureau of Land Management, Bishop California office, archeologist, *pers. comm*.). These artful designs had been painstakingly chiseled with hard tools on granite to form hypnotizing spirals, geometrical checkerboards, arrowheads, lances, strange anthrozooic (man-animal) figures, eagles, bighorn sheep with large, curved horns, and then, much to my amazement, a definite horse figure, without apparent rider, bridle, rope or saddle, rendered in simple rectilinear fashion – but with proportions unmistakably those of a horse (see Figure 1). Judging from the brownish oxidation on the chiseling, this horse was not a recent addition to the ancient petroglyphs here. Scientific analysis of the patina of some of these petroglyphs has revealed ages up to 3,000 years. By visually comparing patina hues, I estimated this horse could be well over 1,000 years old.

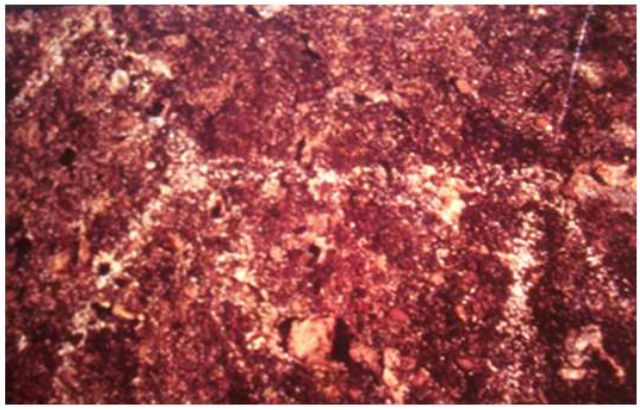

Figure 1. *Horse petroglyph discovered by author west of White Mountains, eastern California. (Photo by author.)*

Joseph revealed geoglyphs depicting horses in the Mojave Desert near Blythe in southeast California. [9] These were also featured in another scholarly work as an eight-meter horse geoglyph pictured alongside a 25-meter human. [66] There are two horses among these several geoglyphs, collectively known as the Blythe Giants and representing the Earth Figure Tradition, which overlaps with the Great Basin Tradition. They were formed by removing stones of desert pavement to reveal lighter substrata, a process called *intaglio*, often associated with trails and dance circles formed by the pounding of human feet. They indicate that horses were held in high regard by Amerindians and in relatively recent times. The figures have been expertly dated by geologists from the University of California-Berkeley at 900 A.D. +/- 100 years and were first discovered by pilots from the U.S. Army Air Corps flying between Hoover Dam and Los Angeles in 1932. They are presently under the care of the Bureau of Land Management. As Joseph puts it: "[t]his [figure] meant that someone in California knew enough about the horse to represent it on the desert floor … centuries before the Spaniards re-introduced the animal to North America."[9] Though airline pilots and later observant investigators and writers have instantaneously recognized this figure as a horse, BLM officials claim it depicts a puma and have restricted the public from accessing the area and deciding for themselves (see Fig. 2).

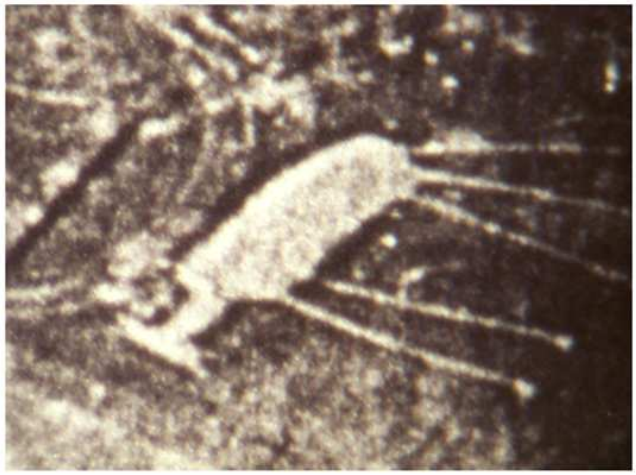

Figure 2. *Horse geoglyph, Mojave Desert, southeast California, dated to about 900 years ago. [9, 66]*

3.2. Fossil Evidence

3.2.1. Shield Trap Fossil Site

One of the most convincing series of finds comes from the Shield Trap fossil site located in Carbon County, Montana.[10] This is located on the east Pryor Mountain quadrangle (7.5 minute map) at Latitude 45.1167 degrees and Longitude 108.25 degrees.

Here four strata have been excavated. In Stratum I, part of the Late Holocene period, carbon dating from bone collagen samples (collagen consisting of the fibrous albuminoid component of bone) from two different horses has yielded precise edge dates of 1745 and 1270 YBP. In Stratum II, dating between 5490 and 2185 YBP, four different individual horse dates have been obtained. Three of these were again obtained from bone collagen, as well as from cartilage and other connective tissue types. These dated at 3190, 2675 and 2185 YBP. A fourth horse C-14 dating was done from charcoal associated with the fossil and produced the extraordinarily young date of 620 YBP, indicating the distinct possibility of horse presence in North America just over a century prior to Columbus's arrival in America. Though the latter was inconsistent with the date of the soil of Stratum II, it is not uncommon for earth movements or erosion to produce such mixing. If contamination can be ruled out, this fossil could go a long way toward proving the continuous occupation of North America from ancient times to the arrival of Europeans and the reintroduction of horses to North America.

In Stratum III of the Shield Trap fossil site, seven C-14 datings again revealed horse presence at later dates than is recognized by mainstream paleontology. Stratum III extends from 7540 to 5490 YBP and is in the Middle Holocene period. C-14 dates obtained from charcoal from five horses yielded dates of 7540, 7540, 7540, 7165 and 7165 YBP, while the two horse fossils that were C-14 age dated from bone collagen yielded 7245 and 5490 YBP. The

5490 YBP age dating is remarkable and substantiates a later survival of the horse in North America. Recently surfaced DNA discoveries in soils in Alaska renew our credence in horse presence in North America that is less than 8,000 years ago. [12]

The horse fossil series at Shield Trap gives solid evidence for a continuous horse lineage from the time of the "Great Die Out" at the close of the Pleistocene to modern times, i.e., after the advent of Columbus and the European colonization of the Americas. The area around the site should be explored for additional fossils to further substantiate these findings.

3.2.2. Other Intriguing Fossil Sites

Still another well-confirmed series of dating for a horse fossil comes from the Wolf Spider Cave in Colorado. These yield a date of 700 +/- 50 YBP and are clearly post-Pleistocene and pre-Columbian and, again, not far before the arrival of Columbus in 1492. The Wolf Spider horse was dated by a professionally respected age-dater: Elaine Anderson. The Pratt Cave fossil site in Texas has a horse fossil that has been solidly dated to about ten times that of Wolf Spider, or 7080 +/- 40 YBP.

Many other sites yield horse fossils with scientific datings that indicate more recent horse survival (see Figure 3). These datings range from the High Holocene (HIHO) 0 to 450 YBP, the Late Holocene (LHOL) 450 to 4500 YBP, the Middle Holocene (MHOL) 3500 to 8500 YBP, and the more catchall, early Holocene/middle Holocene (EMHO) 3500 to 10,500 YBP. (See Appendix for a partial list of horse fossil sites).

3.2.3 Presence of the horse in Pre-Columbian and Post-Pleistocene North America.

The dates of 1,000 YBP or less, such as from the Shield Trap fossil site and from Wolf Spider and Little Box Elder caves, lend particular weight to the hypothesis that remnant horses survived to the time of the colonization of the Americas by Europeans. These remnant survivors could have interbred with European-derived horses, especially those escaped to the wild, the denominated *mostrencos* (Spanish for "unclaimed"), or mustangs. This is an intriguing possibility that should be investigated using state-of-the-art genetic analysis – and soon. To sum up, we have at least 50 different horse fossils from 23 different sites including in the East, the West, the North, and the South of the United States, as well as one in South America. The majority of these indicate a much wider horse distribution and at much later dates than is commonly accepted by mainstream paleontologists today (see Figure 3).

EVIDENCE	LOCATION	AGE DATING	METHOD	REFERENCE
Horse Geoglyph, Intaglio (Fig. 2)	Blythe Giant Figures, SE Cal.	900 A.D. +/- 100 years	Ground surface weathering	Frank, 1999. White, 2003
Horse (Fig. 1) Petroglyph	BLM land, Central E. Cal.	Rough estimat. 1,000 - 3000 ybp	Associated figures, patina.	Downer, C.C., present work
Horse Fossil	Little Box Elder Cave, Converse County, Wyom.	700 years before present (ybp)	Carbon 14	Dan Walker, paleontological worker, Wyom.
Horse Fossil Skull w/ organic exudation	Argentina. In Nat. Hist. Mus. Buenos Aires	Rough Estim. Pre Colum./Post Pleistocene	Remains to be professionally dated	Downer, C.C., present work
2 different Horse Fossils from Stratum I	Shield Trap, Carbon County, Montana	1745 ybp & 1270 ybp	Carbon 14 from bond collagen	Illinois State Museum, Springfield
3 different Horse Fossils from Stratum II	Shield Trap, Carbon County, Montana	3190 ybp, 2675 ybp, 2185 ybp	Carbon 14 from bond collagen	Illinois State Museum, Springfield
1 Horse Fossil from Stratum II	Shield Trap, Carbon County, Montana	620 years before present	Carbon 14 from charcoal assoc. with fossil	Illinois State Museum, Springfield
5 Horse Fossils from Stratum III	Shield Trap, Carbon County, Montana	3 at 7540 ybp & 2 at 7165 ybp	Carbon 14 from charcoal assoc with fossil	Illinois State Museum, Springfield
2 Horse Fossils from Stratum III	Shield Trap, Carbon County, Montana	7245 ybp & 5490 ybp	Carbon 14 from bond collagen	Illinois State Museum, Springfield
1 Horse Fossil from Stratum IV	Shield Trap, Carbon County, Montana	9230 ybp	Carbon 14 from bond collagen	Illinois State Museum, Springfield
Horse Fossil	Wolf Spider Cave, Colorado	700 +/- 50 ybp	Carbon 14	Elaine Anderson paleontologist
Horse Fossil	Pratt Cave, Tex.	7080 +/- 40 ybp	Carbon 14	Dr. Steven Jones, Paleont. Utah.
Horse Fossil	Horsethief Cave, Wyoming	3124 ybp	Thermolumines-cent	Dan Walker, palenont. Wyom

Note：For Frank, 1999, see reference [65] for reference [9]: Joseph, 1999; for White, 2003, see reference [66].

Figure 3. *Evidence for Pre-Columbian/Post-Pleistocene Horse Presence in North America*

In addition to the above, several horse fossils have been dated by association from the geological strata in which they were found and also fall within the post-Pleistocene and pre-Columbian period. They proceed from such disparate areas as: (1) the Spencer and Laatch Archeological Mount, Wisconsin; (2) Truman Reservoir, Missouri; (3) the Hopewell Burial Mound, Ohio; (4) prehistoric Indian kitchen middens of Arizona, ca. 3000

YBP,[13] and reportedly from (5) Winnemucca Lake Flats, just east of Pyramid Lake, Nevada. Apparently the horse fossil of Winnemucca Lake was discovered ca. 1978 and dated to ca. 1,000 YBP by paleontologists at the University of Nevada, though later all trace and record of this horse fossil appear to have vanished under suspect circumstances (Holland Hague, *pers. comm*. and documents in his possession).

The myth of the destructive, non-native horse is rapidly falling by the wayside, as people broaden their horizons in regard to the horse's deeply rooted North American presence and the many substantial contributions it makes to the native ecosystem. An exciting analysis of the DNA contained in the soils of permafrost regions of Alaska has recently come to light proving that both horses and mammoths were present in North America thousands of years later than previously thought. This is a comeback to what was espoused for decades by paleontologists, i.e., horse presence upon this continent to ca. 7,000 years ago. An international team of scientists assembled at Camp Stevens, Alaska, conducted this study, and its results are most encouraging for those who sense the horse's true belonging in North America. [12]

3.2.4. Suggestive Amerindian Evidence for Surviving Native Horses

Suggestive evidence for more recently surviving horses in North America is to be found in the cultural knowledge of native tribes handed down from generation to generation. Many of these oral histories have their origin in pre-Columbian times. In her book: *In Plain Light: Old World Records in Ancient America*, Gloria Farley [14] presents many illustrations indicating post-Pleistocene, pre-Columbian horses in North America. These include petroglyphs similar to the one I discovered (Figure 1).

According to historian Claire Henderson [15] of Laval University, Quebec: "Traditional Dakota/Lakota (Sioux) people firmly believe that the aboriginal North American horse did not become extinct after the last ice ages and that it was part of their pre-contact culture." Though established anthropological opinion has it that the Plains Indians acquired horses in the early 1500s, as escaped or stolen horses from Spaniards in Mexico and the southwestern United States, the Sioux claim that the North American horse survived the Ice Age and provided the mounts for their ancestors long before Columbus's discovery of America. They maintain that these distinctive native ponies, in fact, continued to thrive on the North American prairies until the first half of the 1800s "when the U.S. Government ordered them rounded up and destroyed to prevent Indians from leaving the newly created reservations." This massive slaughter is well documented. [16]

Though much evidence backing the Sioux elders' claims was destroyed along with the horses, some suggestive evidence remains. For example, the Dakota/Lakota possess different words for "horse," thus distinguishing between the *sunkdudan*, their own short-limbed horse, and the more long-legged horse brought by Europeans. Sioux elders whom Henderson consulted said that the aboriginal pony stood about thirteen hands high (52 inches) and had a straighter back, wider nostrils, and proportionately larger lungs than European horses. Accordingly, these ponies possessed even greater stamina and endurance than the nonetheless remarkable horses brought from Europe. Reports of shaggy hair and singed manes seem tarpan-like and were confirmed by Prince Frederick Wilhelm of Wurtemberg, Germany. [17] Henderson ended her plea with a call for the careful conservation of "the few remaining Indian ponies." I would add to this a call for a comparative genetic analysis among germane horse populations to determine if unique North American characteristics, including mitochondrial and Y-chromosome DNA markers, exist. In this connection, a search for possible remains of slaughtered Plains Indian horses should be undertaken.

3.2.5. Suggestive Canadian Evidence

According to Dr. Robert M. Alison, "the complete extirpation of ancestral horse stock in Canada has yet to be … confirmed and a bone found near Sutherland, Saskatchewan, at the Riddell archaeological site suggests some horses might have survived much later. The bone (Canadian Museum of Nature I-8581) has been tentatively dated at about 2,900 years ago. Another *Equus* species bone found at Hemlock Park Farm, Frontenac County, Ontario, dates to about 900 years ago."[18] In his conclusion, Alison unequivocally states: "... the main lineage originated on the North American continent. Horses are therefore indisputably native fauna, despite a multiplicity of genotypic variations." In regard to the reintroduced horse from the Old World, he continues that "...subsequent evolution elsewhere over a period of perhaps 8,000 years [does not] make them non-indigenous." He further observes that the "inherent timidness of Canada's surviving free-ranging wild horses, and … genetic testing … confirm [that] these animals do not derive from escaped domestic Block farm/ranch stock" and that "their shy behaviour is consistent with a long history of sustained freedom ..." [18] Dr. Alison, a biologist, urges increased protection and resource provision for Canada's last remaining wild horses as contributors to the native North American biodiversity and warns of their imminent disappearance. His testimony should greatly aid many Canadians, including those of the Canadian Wild Horse Foundation who, since July 2013, have been trying to pass a law in Parliament to legally protect the estimated less-than-1,000 wild horses still managing to survive in spite of strong persecution from ranchers and hunters in Alberta, Saskatchewan, and British Colombia.

3.2.6. The Asian Question

An intriguing line of evidence that horses were present in America over 3,000 years before Columbus's arrival comes from Chinese writings. One manuscript dating from 2,200 B.C. indicates that the Chinese came to North America by sea at very early dates and described several animals

occurring in *Fu Sang*, or the "Land to the East." [19] Their descriptions match certain North American animals, including bighorn sheep and horses resembling the appaloosa. Scholars question whether this involves horses that were earlier brought by the Chinese to North America and set loose, or horses that were already living here and that were subsequently captured and taken back to China. A distinctive gene (the LP, or Leopard Pattern) has been identified in the patchy-rumped appaloosa breed of horse, and research is now underway to trace its origin. Perhaps this will substantiate a uniquely North American horse characteristic. The idea that the appaloosa originated in China is based on certain appaloosan traits, mainly to do with coloration, that are found in China; however, Chinese horses are generally chunkier in build than North American appaloosas. This poses a question concerning how this relates to Amerindian beliefs about the stockier surviving native horses in North America (see section 3.2.4).

Also of note: ca. 627-656 A.D. in the middle of China's Golden Age (A.D. 581-907) during the reign of T'ang T'ai-tsung (A.D. 618-649) and his successors Ching-Kwan and Yung-Hwui, Chinese explorers traveled to *Ta Han*, or *Da Han*, meaning "the land of the Great Giants." [19] The *New Book of Tang* reports this land as rich in sheep (perhaps referring to the bighorn or Dall sheep) *and horses* (see also Harris Rees 2011[20]).

3.3. The Case for the Burro

In similar fashion to the wild horse, the burro (*Equus asinus*) can trace its not-far-removed ancestry back to North America; and in many parts of this continent, wild ass fossils testify to a very similar species occupying a very similar niche as the one reoccupied by burros during the past five centuries.

MacFadden indicates that the ass branch of Equidae evolved in North America throughout the Hemphillian, Blancan, and Pleistocene periods, when one *Equus mexicanus* was clearly present. [2] Though the modern burro, or donkey, is currently considered as having originated from African wild asses (*Equus africanus*) and can and does produce fertile offspring with such, [21] it is most probably not significantly different from its North American ancestors. Indeed, one respected paleontologist believes that the African wild ass originally arose in North America. [22] And until recently both burro and African wild ass were considered to be the same species, namely *Equus asinus* – which is still the case in many circles. Like the wild horse, when returned to North America, the burro readily adapts to an ecological niche that its not-so-distant ancestors filled for millions of years, particularly in the dry southwestern US and south into Mexico. The distinction between *E. asinus* and *E africanus* seems more a political than a sound biological one.

3.4. Two Hypotheses

In summary, much evidence exists for horse presence in the Americas, especially North America, during the post-Pleistocene and pre-Columbian period at dates scattered through the period beginning ca. 10,000 YBP and reaching very near to 1492 A.D. Two hypotheses have been proposed to explain these apparent anomalies:

(1) A continuous lineage of horses survived in small remnants up until the reintroduction of European horses. When the latter escaped from or were released by the Spanish, other Europeans, or Amerindians, they thrived in the plains and southwestern deserts in the very land of their evolutionary origin as a species and reproductively intermingled with the already present, aboriginal horses. Populations of these aboriginal horses were absorbed by the greater influx of horses brought over by colonists, conquistadors, etc., many of whom derived from Spanish haciendas or Catholic missions. The distinctively American traits of certain wild horse populations lend support to this hypothesis as do depictions of un-mounted horses *au naturel* in geoglyphs and petroglyphs, some of which are dated hundreds of years before the arrival of Columbus (see Figures 1 & 2).

(2) Horses disappeared from North America during the late Pleistocene ca. 10,000 – 7,000 YBP, but were brought back to North America by other cultures in pre-Columbian times. Possible cultures for which evidence exists include: (i) Chinese immigrants in junk ships hugging the coasts of the Pacific Northwest; (ii) Scandinavians in long ships by way of Greenland and landing in Newfoundland or Nova Scotia, and (iii) other cultures, such as the Celts from Wales or Ireland, or people in boats from southern France who came clinging to the southernmost edges of northern ice caps that had extended far to the south. The latter left their distinctive form of spears in the New World.

Regardless which of these two options is true or whether a combination of such or some other option, after the Spanish brought horses, beginning with Hernan Cortez in the early 1500s, escapees and horses stolen by the Indians began to repopulate the Americas to a large degree. These could have reproductively intermingled with horses that had been brought by other cultures in earlier times and/or that were in North America originally. These horses likely possessed a superiority over other races, a hybrid vigor giving them survival advantages in the wild. This is all the more reason for preserving the mustang herds in the wild today. [23]

3.5. A Broader Perspective

Since shortly after the dawn of our present Cenozoic Era, dating from the extinction of the dinosaurs ca. 65 MYA, the ascent of all three major extant branches of the horse family: zebras, asses, and caballine horses has taken place primarily in North America. [2]

During the course of their long co-evolution, members of the horse family developed many mutually beneficial relationships with plants and animals. Indeed, both asses

and especially caballine horses can stake the claim to being among the very most ancient and long-standing members of the North American life community, more so than most other large mammals still surviving here. For example, among the bovid family both the bighorn sheep (*Ovis canadensis*) and the bison (*Bison bison*) had their origins in Eurasia before crossing over the "filter" Bering Land Bridge, or isthmus, during the Pleistocene epoch 2-3 MYA. This is when oceans receded with the tie-up of global moisture during the ice ages. [24, 25] Thus, the latter two species are relative newcomers in North America when compared with the horse and other members of the horse family. Members of the deer family, Cervidae, including white-tailed and mule deer, elk and moose, arose in Asia during the Oligocene epoch 36-23 MYA and did not arrive in North America until the Miocene epoch 23-7 MYA. They crossed over the Bering Land Bridge to occupy North America. Though their origin is more in the Old World, few authorities would question their native status in North America. Yet, many of these same persons will question members of the horse family in this regard in spite of the fact that all three extant branches of the Equidae: zebras, asses and caballine horses had their origin and long-standing evolution right here in North America, as an abundant fossil record proves. [18, 21]

According to equid expert Dr. Hans Klingel, "... there is … evidence that all the extant equids [members of the horse family] evolved as species on the North American continent, and that Grevy's Zebra and the African and Asiatic wild asses were the first to cross the Bering Bridge in the early Pleistocene, whereas the remaining species came to the Old World only during the late Pleistocene. This would explain the much wider range of Grevy's zebra in Africa during the Pleistocene, i.e., before their major competitors, plains and mountain zebra, had arrived. It is feasible that similar situations existed with respect to African and Asiatic Zebras."[22]

Also we need to consider that North America, Europe, and North Asia share many faunal and floral elements, over both their more recent and more distant evolutionary histories. And equids, including horses and asses, figure prominently in this sharing. [26] Though often separated by natural barriers, these three regions have experienced frequent faunal and floral interchanges during periods when barriers have either broken down, as through sea lowerings or freeze-overs, or been overcome by the versatile and persistent efforts of the animals themselves, including we humans.

3.6. The Ecology of Wild Horses and Burros in North America

Wild horses and burros complement North America's life community in many direct and obvious as well as more subtle ways. This they do when permitted their natural freedom to move and interrelate over a sufficiently extensive intact habitat and time period. [3]

3.6.1. Dietary Benefits, Building Soils, Dispersing Viable Seeds

One obvious ecological relationship occurs between diet and habitat. Including today's extant zebras, asses and horses, all equids possess a caecal, or post-gastric, digestive system. This is found in other perissodactyl families, including tapirs and rhinoceroses, as well as other mammalian orders. Such a system enables equids to eat coarser, drier vegetation and, through symbiotic microbial activity, to break down cellulose cell walls to derive sufficient nutrients from the inner cell without overtaxing their metabolism. In drier regions, this often gives a distinct advantage over ruminant herbivores (those that have multiple stomach chambers and chew the cud) whose pre-gastric food processing requires expending considerably more metabolic energy and taking in more water. While it is true that equids must consume somewhat more vegetation, especially when dry and coarse, because of their less thorough extraction of nutrients from the food, this usually does not overly deprive ruminants, since much of what the equids consume would be of little or no value to them. As a matter of fact, the equids' consumption of this coarser, drier vegetation can greatly benefit sympatric, pre-gastric (ruminant) herbivores, and energize and enrich the ecosystem as a whole. By recycling chiefly the coarse, dry grasses as well as other dry, withered herbs, forbs and bush foliage, the horses and burros expose the seedlings of many diverse species to more sun, water and air, thus permitting them to flourish. The latter can then be consumed by ruminants, as British ecologist R.H.V. Bell has so well demonstrated in his studies in the Serengeti. [27]

Also of great importance is the contribution by wild equids of significant quantities of partially degraded vegetation in the form of feces deposited on the land. These droppings provide fodder for myriad soil microorganisms; the resulting fecal decomposition builds the humus component of soils, lending ecologically valuable texture and cohesiveness. As feces slowly decompose, they gradually release their nutrients over all seasons and, thus, feed the fungal garden that exists in soils, thereby increasing the soil's absorption of water – a vital limiting factor in semi-arid and arid regions. To reiterate: equid feces are much more valuable to the health of soils than ruminant feces (cattle, deer, sheep, goats, etc.) precisely because they are not as decomposed when exiting the body and, so, lend more sustenance to decomposers and food webs that involve mutually sustaining exchanges among all classes of organisms. The latter include many diverse insects, birds, rodents, reptiles, etc. And, similarly, the less degraded feces of equids contain many more seeds that are intact and capable of germination and from many more types/species of plants when compared with ruminant grazers. Thus, the horses'/burros' wide ranging life styles greatly assist many plants in dispersing far and wide and, so, in filling their respective ecological niches. This enriches the food web and allows a greater diversity of animal species.

3.6.2. Topography Enhances Habitat

Another germane point concerns the multiplication of ecological niche space that occurs in mountainous regions, with their accentuated topography. This creates greater opportunities for plants and animals to derive a living when compared with flatter regions, because such terrain provides more surface area on which to live. And perfect examples of such occur in the Great Basin's hundreds of mountain ranges where most of America's remaining wild horses have their legal areas. All this argues for higher government-assigned population levels, or Appropriate Management Levels (AMLs). As shown in studies of the endangered mountain tapir of the northern Andes inhabiting from 6,000 to 16,000 feet elevation; steeper, mountainous terrain provides for multiplication of niche space. [28-30]

3.6.3. Behavioral Benefit

Horses and burros aid myriad plant and animal species by their physical actions. As an example, breaking of ice with their hooves during winter freezes allows other animals to access forage and water. Many of these would otherwise perish. Similarly, they open trails in heavy snow or through heavy brush, allowing smaller animals to move about in search of food, water, mineral salts, shelter, warmer areas, mates, etc. A little recognized fact is that the wallowing habit of wild equids creates natural ponds whose impacted surfaces become catchments for scant precipitation or summer cloudbursts typical in the Great Basin. These provide a longer lasting source of water for a wide diversity of plants and animals. This can even help to create an intermittent riparian habitat for desert amphibians (e.g., the remarkable spadefoot toad, which seals itself into a dry, muddy cocoon for many years, reanimating when moisture is again present) and many other desert species. [31] Ephemeral plants that quickly flower and set seed, including many composites, are benefited from these catchments – especially valuable in regions with clayey soils. Wild equids also locate water seeps through their keen sense of smell and enlarge these through pawing during critical dry periods of the year, even digging down to the sources at rocky fissures. This allows many other species to access water, species whose individual members would otherwise perish. For these and many other reasons, wild horses and burros should be treated as keystone species that contribute positively in a variety of ecological settings. Indeed, these and other equid species have been *keystone* species in North America for many millions of years.

3.6.4. Role as Prey

Wild horses and burros are natural prey of native carnivores and omnivores, including puma, wolves, and brown and, to a lesser degree, black bears. In geologically recent times, this included the famous saber-toothed tiger and dire wolf. Unfortunately, these natural hunters have been targeted for elimination by humans. This has severely reduced the natural predators of deer, elk, moose, pronghorn, bison, bighorn sheep, and other prey species upon which these native predators have subsisted for thousands of generations and in a way that makes the prey populations more fit to survive over the long-term by taking the weak, infirm or those animals reaching the end of their life cycle. [32] The "trophic cascades" that natural predators cause in an ecosystem lead to the greater biodiversity and stability of such.

With practically no break unto relatively present times, equid species have filled the ecological role of medium- and large-sized prey mammals in North America for over 58 million years. Today, the wild horse and burro are refilling their empty niches that have been only briefly unoccupied, paleontologically speaking, if at all. These niches are the product of countless generations of coevolution with native plants and animals.[31, 33] Today, it is highly questionable how individual western states such as Idaho, Montana, Utah, and Wyoming are allowing open season upon wolves, yet the officials of these same states will dishonestly claim that wild horses and burros have no natural predators.

3.6.5. Coevolution with Habitat

To quote Dr. Jay Kirkpatrick and Dr. Patricia M. Fazio [5]: "[t]he Key element in describing an animal as a native species is: (1) where it originated; and (2) whether or not it coevolved with its habitat. Clearly, *E. caballus* did both, here in North America." Various Amerindian tribes of the Great Plains and Prairies have a saying concerning the wild horses: 'The grass remembers them.' [15] (See also Downer [34].)

Wild horses and burros are perfectly suited to life in the remote, semi-arid regions of the West. One reason is obvious: their great mobility. With their long limbs and sturdy, single-unit (soliped) hooves, they are made for movement. In such semi-arid or arid regions as they inhabit, this extensive movement is vital for survival. In order to obtain enough forage, a wild horse must often roam over several square miles each day, selecting appropriate plants to prune; reaching a water hole may involve traveling over one hundred miles round trip in a grazing circuit of two or three days.

During very hot, dry spells, a wild horse band must stay close to water, tanking up every day with approximately ten to twelve gallons for a mature horse. A spring can be shared by several bands. These form an orderly hierarchy for watering should more than one band arrive at a source at the same time, often late in the day. When melting snow or fresh cloudbursts paint the land with ephemeral water sources, wild horses can disperse into areas further away from perennial lakes and streams and to ephemeral sources. Here they employ their keen sense of smell in detecting even very small and hidden water sources. They can also negotiate rougher, steeper, and rockier terrain than domestic cattle.

Through a hammer-like hoof action upon the ground, wild horses and burros aid vegetation by pushing seeds firmly into the soil where they may successfully germinate. In October

2008 at the Wild Horse Summit in Las Vegas, Lakotan Sioux shaman Arvole Looking Horse of South Dakota described to me how wild horses are vital energizers that "pound Earth's drum" releasing energy from the inner planet and lending a musical rhythm that unifies diverse forms of life. Though criticized by their detractors for breaking the crusts, or desert pavement, of certain desert soils and, thus, accelerating wind erosion, when allowed adequate space and freedom, horses do not overwhelm an area. This is due to their sparse distribution and frequent movements and because, as most land-bound animals, they confine the majority of their long-distance displacements to trails. In certain areas, their compacting of soils helps these retain scant precipitation and dew. Especially in soils of higher clay content, this compaction can help retain moisture over longer periods of time. However, such modification of soils, occurring naturally with nearly any hoofed animal, can become detrimental to an ecosystem with overcrowding. As with any activity, what is an ecological positive in moderation can become a serious problem when overdone. This is certainly the case with the severe overgrazing that humanity has imposed upon the West, as upon similar arid and semi-arid regions throughout the world. This they have done by forcing hordes of cattle, sheep, goats, deer, yaks, and, yes, even horses or burros, etc., in unnaturally high concentrations upon the land. [35, 36] The problem is with the people, not the animals.

3.6.6. Man's Impact

In the latter 1800s, many millions of cattle and sheep were forced by their human possessors into the vast, unfenced western regions. While a graduate student at the University of Nevada-Reno, I viewed archival photographs from the late 1800s of interior regions of Nevada such as the Reese River or Humboldt River hydrographic basins. These revealed extensive valleys filled with exuberant tussock grasses that were soon to be replaced by unpalatable sage and rabbit brush due to livestock overgrazing, as more recent photos in the same places conclusively prove. In effect, we humans raped the West, greatly setting back this formerly healthy, though dry, life community. [37] We ignored the already established life communities that in many places included the returned native–or perhaps aboriginal--mustangs, and the possibility of harmonizing with such, while ignorantly imposing domesticated European species with a mind to maximizing production and profit in the short term. Today the arid terrestrial ecosystems our culture so invaded continue to be grazed by domestic livestock, though controls were imposed in the U.S. starting with the passage of the Taylor Grazing Act of 1934. Though somewhat alleviating the situation, this act assured that these lands would still be monopolized by livestock interests, thus, preventing the type of recovery that should and still can occur. [38]

3.6.7. Dust, Gas and Effects of Livestock & Global Warming … Place of Wild Horses

Among the most insidious and globally harmful effects of domestic livestock hordes are the large quantities of dust blown into the air when the surface of soils are overly trampled and grazed. An article in *Nature* has revealed that "dust load levels have increased by 500% above the late Holocene [eleven thousand years ago] average following the increased western settlement of the United States during the nineteenth century." This is largely attributed to "… the expansion of livestock grazing in the early twentieth century." [39] The dust causes an increase in various chemicals affecting the pH of water, productivity, and nutrient cycles. Such fine particles can settle on plants and plug their tiny pores, or stomata, through which they breathe. They can also lodge in the interstitial lung tissues of many animals, including humans, where they cause pulmonary diseases, including cancer. Though insufficiently recognized, the "dusty factor" is extremely damaging both to living organisms and the ecosystems they inhabit.

The enormous quantities of methane, nitrous oxides, and other gases that are emitted through the digestive processes of domestic livestock constitute one of the major accelerators of life-threatening global climate change. [40] Clearly, civilized man's so-called progress upon planet Earth has abysmally failed to consider the ecological balances that assure life's continuance. Urgently required is an all-out effort to restore the natural diversity of plant and animal species appropriate to each of the Earth's bio-regions, or ecological provinces, as to the Earth as a whole. But this is going to involve a serious willingness on the part of us humans to modify our life-influencing values and priorities, both individually and collectively. This will permit us to live in a truly harmonious manner, to act as good neighbors toward our fellow species. Here the horses and burros come into play. Their post-gastric digestive system does not emit as much gas as is the case with pre-gastric ruminant grazers, and permits them to greatly reduce dry, fire-prone vegetation over vast areas of the West without overtaxing their metabolism. Thus, they help to prevent catastrophic fires that global warming, or more to the point, human civilization's pollution of the atmosphere is causing.

By drying out vegetation and provoking catastrophic fires – rampant in western and southern North America, Australia, and much of the world – the catchall global climate change threatens planetary life as we know it. This will especially be the case if global ocean currents stop circulating due to glacial and ice cap melting, etc. Annually a few to several million acres of forest, brush, and grassland have been going up in smoke in the United States alone, especially in the West and South. Never in historic times have we seen such destruction. But wild horses/burros can greatly help to save the day if allowed to play their own special role in reducing flammable vegetation, in building soils, in seed dispersal, in preventing catastrophic, soil-sterilizing fires, etc. They stand ready to counter imbalances brought on by human civilization and its contamination of the atmosphere. Much of this contamination is caused by hordes of domestic

livestock that mow down vast vegetated areas, their over concentration and resultant destruction of soils, and their production of flatulence and excrement in enormous proportions and intensities. Of course, there are also imbalances brought on by automobile exhaust, factory fumes, forest burning, peat oxidation in the Subarctic and Arctic, absorption of sunlight by darker seawater where once reflective ice caps stood and of sunlight by dark soot deposited on glaciers, etc. Millions of years of coevolution have made equids best equipped to prevent the catastrophic fires we are experiencing and to restore many of the ecosystems human civilization has either blindly or intentionally damaged. Let us not take these magnificent animals and what they have to offer for granted, for they are definitely a key part of the solution to all life's problems today. [41]

3.6.8. Cheat Grass and Further Ruminations

A commonly eaten food of wild horses in northern Nevada's Granite Range is *Bromus tectorum*, a.k.a. the infamous "cheat grass" that is taking over the West. [42, 38] The measured percentage frequency of this invasive species from Central Asia in the Granite Range habitat was 89.9%, while the percentage cover was 12% and the percentage use by wild horses was a full 27.3%. [38] Since cheat grass is a major contributor to fires in the West, perhaps wild horses as well as burros could be a major agent for reducing this flammable vegetation. Equids could prevent its reproduction by consuming this grass before it is able to set seed, in spring or early summer, depending on elevation. Most of the other species in Dr. Berger's table also become dry and flammable and are eaten by horses, thus reducing the "fire fuel load" in their occupied habitat. Wild horses and burros, as well as zebras, are very effective fire hazard reducers. They are more effective in eliminating cheat grass and other dry, flammable grasses and forbs than many ruminant grazers, and spread their grazing over larger areas, provided fences and other barriers do not overly confine them. They eat during 60% to 80% of the 24-hour day (ca. 15 hours), keeping constantly on the move and not camping on moist riparian or lacustrine meadow habitats, as do domesticated cattle put out to graze on the same land.

Their droppings also build the humus content of soil to a substantial degree. This humus allows soil to gain more texture and retain more water, which dampens out fires; humus promotes more productive and bio-diverse plant and animal communities. [43] Because their feces are not as thoroughly degraded in the gut as those of ruminant grazers, they contribute more to food chains/webs, e.g., dung beetles to birds and lizards to higher trophic predators such as bobcats and eagles, etc. Equine feces aid the watershed by creating damper conditions, because the soil particles to which they reduce (*micelles*) retain more moisture, i.e., more water adheres to the surface area of these particles. Hence, ground water tables are replenished, feeding more seeps and springs more continuously. And upon these springs and seeps, many species of plants and animals depend. Of course, some fire is of benefit to an ecosystem, but fires that over-consume, over-extend, and over-intensify can set the evolution of a terrestrial life community way back and result in a very sterile environment that could take thousands of years of "peace" to recover.

3.6.9. Upper Incisors and Further Insights

Insight can stem from the most basic of observations. For example, wild horses and burros possess both upper and lower incisors that permit them to selectively nip pieces of vegetation, such as grass or the leaves of bushes or trees. Major ruminant grazers, as for example cattle and sheep, do not have upper incisors and consequently can and do rip up plants by their roots more frequently with the action of their lower teeth and tongue against their hard upper palates. This often exposes soils to destructive wind and rain erosion, especially when too many of the ruminants are placed upon any given area of land.

When over-crowded upon dry rangelands or marginal western brush or forest lands, livestock have and continue to cause enormous ecological degradation. Yet, the problem lies not so much with the animals themselves but with the humans who force them into habitats where they did not evolve and, more to the point, where they are not even allowed to harmoniously evolve and adapt to prevailing conditions through the time-honored process of natural selection and ecological balancing. [36] About three-fourths of the U.S. public lands are in seriously degraded condition due to overgrazing by domesticated livestock. The root of the problem lies not with the animals themselves but with we people who unnaturally manipulate and force them upon the land.

3.6.10. Mutualist Equids Helping to Provide Ecological Stability

Though domesticated for a relatively short evolutionary time, horses and burros actually restore the wild "equid element" in North America. Here they refill herbivore niches that have been millions of years in the making. This restored diversification lends greater stability and balance to the ecosystem by increasing the complexity of the web of life. This interdependence involving equids has been documented in the Serengeti of Africa by Bell. [27] Bell observed how zebras eat coarser, drier grasses, etc., to expose to sunlight (allowing greater photosynthesis) finer, more delicate grasses, forbs, and other types of mature plants or their seedlings, thus, permitting their growth. The latter are more appropriate forage for wildebeest, Thomson's gazelle, topi, etc., that come in later seasons. A migratory sequencing of grazing pressures by these different species evolved over thousands of generations, and this is mutually beneficial to these species.

A similar complementarity to that of the Serengeti evolved in North America and involves members of the horse family, including *Equus caballus*. As earlier explained, the latter originated and evolved upon this continent during the past few million years, as did its

preceding ancestry dating clear back to the Dawn Horse, *Hyracotherium*, a.k.a. *Eohippus*, of at least 55-million-year antiquity. The plains and prairies of North America were home to a dynamically balanced community of prairie dogs, bison, rabbits, pronghorn, deer, wolves, bear, foxes, coyotes, puma, diverse rodents, reptiles, and amphibians, raptor and song birds, snails and myriad insects and spiders, recycling microorganisms, etc. Over the many generations of their coevolution and in their complex feeding, decomposing, photosynthesizing, pollinating, seed dispersing, warning, and other interactions, these have fashioned a life community that is highly adaptable to the vagaries of climate, volcanic activity, unexpected oscillations in the sun's radiation, etc. In other words, the complex web of species – as any true web – has provided a beautiful resilience involving cyclings up and down for all species. With this greater variety of species, the natural vagaries that pose ever new and different survival challenges can be ridden out by the whole of life. In this respect, any individual, family, race, or species of life is like a rider of a bucking bronco, entered into the greater arena of evolving time and circumstance, in a rodeo whose rules are set according to natural and universal law. Understanding this allows us to understand the changing proportions of species present in North America over time as a response to changing conditions, both living and so-called non-living.[1]

A salient example of harmonious coexistence occurs between deer, either white-tailed or mule, and wild horses. Deer mainly browse the leaves of trees or bushes while horses eat mainly grasses when available. In a healthy habitat, these deer and horses hardly compete because of utilizing different resources, and their interactions are often of mutual benefit. These benefits may be obvious or more subtle, direct or indirect. A similar harmony exists between mustangs and pronghorn – an ancient and singular species that originated in North America, as did the horse. [44] The latter two have had a long time to learn to get along. Incidentally, the pronghorn seems never to have left North America

Wild horses particularly thrive in North America's plains and prairies, but can adapt well further west of the Rockies in the Great Basin and west of the Sierra Nevada mountains in California, as they did so well in earlier centuries. Burros adapt well in drier areas of North America particularly in the arid Southwest. Both equine species diversify and strengthen the community they inhabit in a variety of ways when allowed to achieve population stability over time and when not over-imposed upon by humanity. The process of natural selection must be allowed to operate sufficiently long for this to be the case. Then these equids create a greater variety of environmental conditions that make possible a greater variety of niches that can be occupied by the species that have coevolved with them and continue to evolve here on planet Earth. Begin large, powerful animals, equids can push their way through thickets of brush to form trails. Specifically, they open thick vegetative understories to light and air, and the more diverse exposures resulting from equine activities create conditions intermediary to the extremes of wind, temperature, and various soil conditions. This physically defines a greater variety of niches fillable by a more diverse array of species.

When allowed to integrate into wilderness, the individual life histories of wild equids come to reflect natural oscillations, such as annual seasons and more long-term cycles. This they do along with the plants and animals who share their habitat. They harmoniously blend over time. As large animals who eat relatively large quantities and disperse their grazing and browsing activity over broad areas as semi-nomads, equids become the harvesters and the renewers over vast ecosystems, true to their *keystone* role. Their cropping of vegetation, often dry and coarse, reduces the possibility for major, soil-sterilizing fires (though ecologically healthy, minor ones still occur). This cropping sparks vegetative renewal, the re-budding of new and tender shoots of greater nutritional value, especially to ruminants whose digestive and metabolic systems are over-taxed by the coarse, dry vegetation that horses and burros can better handle. And, thus, the overall productivity of the land is annually increased, as studies prove. [45, 46] Also, as earlier noted, these equids disperse the seeds for successful germination of many of the plants they eat as well as fertilize the soils with their droppings. For their neighbors including the ruminant grazers, their presence is truly "win-win." And this I have also observed to be the case with the threatened Greater Sage Grouse in places such as eastern Nevada's Triple B Complex of HMAs. Here these impressive lek-forming birds thrive alongside the spirited mustang bands.

3.6.11. Rewilding

It is sometimes asserted that horses have not been part of the North American life community since their die-out at the end of the Pleistocene epoch, i.e., the last ice age (Larry Johnson, BLM National Wild Horse and Burro Advisory Board, *pers. comm*.). Even if they did die out (which seems untrue), and though (based on the fossil record) a great subsidence in their numbers did occur for a relatively brief time period of ca. 7,000-10,000 years, such a time period is not sufficient to undo the many mutualistic relationships horses established with native plants and animals. [5, 18] Furthermore, it is widely recognized that North America became species poor, or depauperate, in large mammals after the massive Pleistocene extinction that affected many other mammals, e.g., giant ground sloths, camels, rhinoceroses, saber-toothed tigers, dire wolves, tapirs, mammoths, and mastodons. In light of the foregoing, the return of the horse and the burro can be viewed as a restoration of the North American ecosystem, a resuming of an age-old continuum, a repair in the anciently evolved web of life – in other words, a "rewilding." [47-49]

It is of vital importance that this rewilding take place today given the melting of the permafrost and so as to restore cool grasslands over extensive regions, including in Siberia. [50] Horses undoubtedly played a crucial role in building rich soils and in dispersing the seeds of many plant

species composing the Pleistocene savannas of North America and should be greatly valued as returned natives here. [47] Along with the burros, they are a different type of herbivore, possessing a post-gastric digestion, as contrasted with the ruminant digestion typical of the other major North American herbivores today.

3.6.12. Identifying the Problem and Its Solution – Us!

Livestock currently graze western public lands (BLM and USFS) in the equivalent of over a million year-round cattle; and big game interests promote unnaturally numerous deer herds for hunter harvest. [32, 38] Both ranchers and hunters seek to eradicate native predators, such as pumas, wolves, and bears. Combined with other pressures such as subdivisions, off-road vehicles, mining, and energy development, this has created an unbalanced situation in which ecological recovery is not possible. On top of this, global climate change is exacerbating the situation. The solution to our predicament lies, above all, in our becoming more sensitive toward and more knowledgeable about the ecosystems we inhabit and the more optimal potentials that both people and ecosystems can realize in unison.

3.7. History of Wild Horse and Burro Program and Public Lands in U.S.

3.7.1. Germane Facts and Figures

In spite of the mandate of the Wild Free-Roaming Horses and Burros Act of 1971, over 27 million of the admitted 53.5 million Herd Area (HA) acres have been "zeroed out" by the BLM and USFS in order to establish 26.5 million acres of Herd Management Areas (HMAs). [51] After reducing the original ca. 350 HAs to 180 HMAs on BLM land, Appropriate Management Levels (AMLs) have been developed that are in most cases non-viable in each given HMA. Most of these levels do not even meet the requirements for Minimum Viable Population of 150 horses/burros per herd commonly recognized by the BLM and fall far short of the 2,500 individuals recommended for a viable population by the Equid Specialist Group of the IUCN Species Survival Commission. [52]

Of the 180 greatly-reduced HMAs throughout the West, 130, or 72%, have AMLs of less than 150, and many of these are much less than 100, even numbering in the teens. According to the BLM's own substandard standard of 150, in California 19 out of 22 HMAs have non-viable AMLs; in Utah, 17 out of 21; in Idaho, 5 out of 6; in Montana, 1 out of 1 (6 of the original 7 HAs having been zeroed out); and in Nevada, 67 out of 90 of the remaining herds are similarly non-viable. [53]

The Congressional Research Service reports that, in FY2005, forage eaten on BLM lands by livestock summed up to 6,835,458 Animal Unit Months (AUMs), contrasting with wild equine consumption of only 381,120 AUMs, or 5.6% that of livestock. On USFS lands, livestock devoured 6.6 million AUMs worth of forage, much of this in vital headwaters, while wild horses and burros got by on a meager 32,592 AUMs, or 0.5%.[54] These figures suggest that cattle, not equids, may be responsible for overgrazing, erosion, threats to native species, and other ecological problems seen in the arid West

3.7.2. More Whittling Away, Some Needed Perspective

BLM reduced the forage allocations, or animal unit months (AUMs), for wild equids by 17% between 2002 and 2005, citing drought conditions and ignoring: (a) wild equids' pre-adaptation to consume large quantities of dry flammable vegetation (a larger portion of which has resulted from global climate change) and, so, to reduce catastrophic fires, (b) their role in combating global climate change over the Earth's vast steppe or steppe-like biomes by preserving permafrost and/or establishing tundra grassland where permafrost has melted, [50] and (c) the fact that wild equids are capable of grazing much steeper and more rugged areas further away from water than cattle, which tend to concentrate their activities around water sources.

Cattle and sheep grazing on U.S. Public lands contribute substantially to global climate change through their release of enormous quantities of methane gas and nitrogen oxides involved in ruminant digestion and through the widespread degradation of ecosystems, especially riparian. [40,55] Yet, the reduction for livestock in drought-stricken areas has been only 4% even though they greatly outnumber the wild equids that have been reduced by 17% and as of January 2014 about the double of this.

Permittees only pay a small percentage of fair market value, at present amounting to about 9% to 12%, in order to graze their livestock on the public lands. This was reauthorized (March 2011) and remains (January 2014) at the minimum required by the Taylor Grazing Act of 1934: $1.35 dollars per AUM, a measurement that includes a cow and her calf (that have grown much larger due to genetic manipulation and selective breeding over the ensuing years since 1934). In 2005, the Government Accounting Office [56] reported that the government lost at least $123 million in order to prop up public lands livestock grazing, while the real costs have been estimated as at least one-half billion dollars per year when ecological damages are added in (Center for Biological Diversity [57]). To put the situation in perspective, there are nearly 22,000 public lands ranchers in 13 western states, about one for each wild horse or burro allowed in the nationwide Appropriate Management Level. Further, the top 10% of the ranchers – in the majority: large corporations, wealthy bankers, lawyers, doctors, politicians, etc., – own over 65% of the livestock grazing in public lands. [35, 37, 38, 55, 58]

Similarly, the cattle/sheep culture has played a major role in destroying indigenous Andean wildlife, especially the endangered mountain tapir, now reduced to only a few thousand individuals. [28, 29, 30] Enormous ecological damage has been done throughout the Americas, especially since the arrival of Europeans, but also before by some groups of Amerindians, although not to nearly the degree. In the U.S.

west of the Mississippi River, ca. 700 million acres of grassland have been degraded due to overgrazing by uncontrolled millions of cattle and sheep; yet left to their own devices, these animals would either harmoniously adapt or perish. In 1884, the region of today's western states held ca. 40 million cattle in addition to millions of sheep. It was not until 1934 that this cancerous destruction was in any way checked through the Taylor Grazing Act – yet, unfortunately this act perpetuated the control of our public lands by private livestock interests.

4. Conclusions and Recommendations

Wild horses form tight-knit stallion- and elder-mare-governed bands. Over time, each band searches out and establishes its own home range, which may cover hundreds of square miles on an annual basis in drier regions. The ecological mosaic that results among all such particular band home ranges in a given Herd Area/Territory and suitable adjoining areas prevents overcrowding and overgrazing. Once available habitat is filled, the horse/burro, as a climax species, limits its own population as density-dependent controls are triggered.

In the immediate future, true wild- horse- and burro-containing nature sanctuaries need to be established. Here livestock should be excluded or at least greatly minimized and wild horses or burros allowed to establish viable populations in the thousands, not mere hundreds or less than one hundred as currently proposed. These fairly populated sanctuaries will be viable in the long-term. They will preserve the vigor of the horses and burros they were designed to conserve.

4.1. Reserve Design

4.1.1 Basics of Reserve Design

To address these problems, I present a workable solution. This will be to restore wild equids in their legal Herd Areas and Territories as outlined in the Wild Free-Roaming Horses and Burros Act of 1971, and, hopefully, in all ecosystems where they play a crucial role. Let us plan a *modus operandi* by which to reestablish wild equid herds at long-term-viable population sizes within long-term-viable habitats, adequate in all respects as to size, water provision, food availability, shelter, mineral requirements, and elevational gradients. The latter will allow for seasonal migrations to higher areas during the summer and to lower areas during the winter. In these areas, wild equids will be treated as the "principal" presences, as the Wild Free-Roaming Horse and Burro Act of 1971 intended; they will no longer be given secondary or even last priority by the very authorities whose duty is to uphold – not subvert – the federal laws protecting them.

Employing principles of Reserve Design, [59-61] the following directives will serve to guide us:

(a) Let wild horses/burros reoccupy their full legal Herd Areas wherever possible and in no case less than 75% of the original legal area. And where a reduction in equid occupation of the original Herd Areas/Territories is deemed necessary, there must be a compensatory acquisition of wild equine habitat of equal or greater value as judged by independent wildlife ecologists with particular knowledge of wild horse and burro requirements. To accomplish this reoccupation, authorities should employ Codes of Federal Regulations 4710.5 and 4710.6 to reduce or curtail livestock grazing within legal Herd Areas and Territories. Also, they should authorize the purchase of grazing permits, base properties, and water rights that are conflicting with the sound establishment of the legal wild horse and burro herds. All "Implied Federal Water Rights" that come with the legal Herd Areas or Territories will be protected and where necessary restored. Sections 4 and 6 of the WFHBA will also be exercised in order to secure complete, viable, long-term habitats for long-term viable wild horse and burro populations, as is the true intent of the Wild Free-Roaming Horses and Burros Act of 1971.

(b) Employ natural barriers or, where such do not exist, semi-permeable, artificial barriers, where possible and necessary, in designing each wild horse/burro Herd Area/Territory as the true sanctuary the law intends. These barriers will act as limits, or impassable boundaries, to wild equid expansion. These will contain each wild equid population within its legal domain, as legally expanded where necessary to provide long-term-viable habitat and to keep wild horses/burros out of harm's way, i.e., out of areas where they would be in clear and unavoidable conflict with human activities. Here I particularly recommend the employment of special Strieter-Lite light reflectors that prevent nighttime collisions of animals with automobiles wherever major roads or highways transect the wild equid Herd Areas/Territories. Also, intelligent use of drift fences can serve to effectively contain horses at strategic passes, etc. But none of the foregoing shall be used to restrict the wild horses/burros within their large, viably sized and complete habitats, as shall be knowledgeably and sensitively defined well in advance.

(c) Design and employ buffer zones around the wild horse Herd Areas/Territories. Here a gradual tapering off of wild horse or burro presence would occur through the implementation of discouragements to their transiting into areas where danger exists for them, such as in farms or cities. This may involve the use of what wildlife managers term "adverse conditioning" that need not be overly harsh to be effective. The effectiveness of buffer zones depends to a high degree on public education, on working agreements with the people who live in or around each Herd Area/Territory. These agreements will foment win-win relationships for both wild equids and people. Locals would monitor and protect the herds and their habitats and derive benefit for doing this as well as from eco-tours, and would be encouraged not to feed the equids. These buffer zones would be established according to principles of Reserve Design and in a positive manner respecting the wild equids.

(d) Allow each wild horse/burro herd to fully fill its

ecological niche space within each given legal Herd Area/Territory bounded by natural or where necessary artificial barriers, and by buffer zones. Then allow each specific herd to self-stabilize, or auto-regulate, its population, within this area. Such auto-regulation can happen if we humans allow. Both horses and burros are "climax species," which is to say, members of the "climax successional sere," or stage, and do not expand out of control to destroy their habitat and ultimately themselves. In other words, each band within a herd population is usually governed by a lead stallion (*patron*). He watches out for and defends the band and does most of the breeding. A usually older, lead mare also aids in this role. This mare is very wise as to where the best foraging, watering, mineral procurement, sheltering areas, etc., are located. She leads the band along paths uniting these habitat components. These include longer seasonal migratory routes between higher summering and lower wintering habitats. Both patron and lead mare socially inhibit reproduction among younger members of their band.

Each band establishes a home range within and/or outside the legal Herd Area/Territory, according to its survival necessities. And all of the bands taken together form a mosaic of somewhat overlapping but generally distinct home ranges. Given enough time to work out their individual and collective differences, wild horses reach a more stable state in relation to their bounded habitat. They do not overpopulate and destroy this habitat but rather auto-limit, achieving a balance with the natural resources of their Herd Area/Territory.

Of crucial importance here is the optimal size of habitat that should be made available to each wild equid herd in order to provide for an optimally viable population. This will depend upon the productivity and carrying capacity of the land. To be minimally viable and considering today's political constraints, I recommend that each herd contain at least 500 and to be optimally viable for long-term survival over the generations, each herd should be well over 1,000 interbreeding individual animals – and this should be the long-term goal. Remember that the IUCN SSC Equid Specialist Group recommended a minimum size of 2,500 individuals per herd in order to achieve long-term viability for a wild equid population, and a minimum size of 500 for a carefully managed domesticated population. [52] Again, equids possess means of limiting their own reproductive capacities, either socially or biologically, when resources, including food, water, and space, become limiting. This involves stress and hormonal factors. [62]

(e) In order to realize healthy, balanced wild horse/burro-containing ecosystems in each of the Herd Areas/Territories, as full a complement of plant and animal species, each filling its specific place and role, should be allowed. Wherever possible, this should include large carnivores/omnivores native to the region in question, such as puma, wolf, and black or brown bears. These will provide a natural control on the equine populations, [63] one that will act through natural selection to make any given population more fit, or "toned," for survival in the wild and more adapted to its particular ecosystem. And the refuge should also include as large a variety of other large, medium, and small herbivorous, carnivorous, and omnivorous species as possible: rabbits, mice, prairie dogs, foxes, coyotes, deer, pronghorn, beaver, skunks, weasels, raptor birds such as hawks and eagles, scavenger birds such as vultures, song birds, and myriad lizards, snakes, rodents, amphibians, mollusks, and insect species. This animal complex will, of necessity, be based upon a similarly diverse collection of plant species, including a complex mixture of grasses, herbs, shrubs, and trees, tending as much as possible to the autochthonous, or native, and supportive of a complete series of inter-complementary animal pollinators, seed dispersers, decomposers, species related as predator-prey, etc. Thus, the safeguard of greater biodiversity in the web of life will be allowed to make a comeback and be further enhanced.

4.1.2. Reproductive Inhibitors and Reserve Design

In March 2008, BLM officials were considering castrating wild stallions in their legal Herd Areas to prevent their reproduction. I pointed out that, in addition to being cruel, this could precipitate inbreeding, because fewer stallions would actually fertilize the mares. Since horses naturally form harems, the dominant stallion of each does the majority of the breeding; although a certain percentage of the breeding may be done by subdominant stallions.[42] Given castration, the male contributors to the gene pool would be greatly reduced and the specter of inbreeding would loom, as survival prospects for any given population would grow dimmer. Also, castration has caused stallions to be socially ostracized, attacked by kicking, and generally marginalized from the wild horse social groups in which they would otherwise be accepted (pers. obs.).

BLM plans to use "aggressive birth control" to prevent the expansion of the wild horse/burro populations that remain. Chief among the drugs to be used is PZP (*porcine zona pellucida*). This injected drug covers the eggs, or ova, of mares, preventing sperm from fertilizing them. It is experimental, however, and has some very questionable effects upon the horses themselves, both individually and collectively. For example, its effect leads to mares' repeatedly recycling into estrous, thus stimulating stallions to repeatedly mount the treated mares – all to no avail. This frustrating situation causes much stress among individuals of both sexes and a general disruption of the social order, both within bands and, as a consequence, within the herds themselves.

Other unintended consequences of PZP are out-of-season births occurring after PZP's effect has worn off after a year or two. These births have been observed during the colder late autumn and winter seasons (e.g., Pryor Mountain herd by G. Kathrens of The Cloud Foundation); and their untimeliness causes suffering and death among both foals and their mothers. The current experimental use of PZP delays the fertility of thousands of mares dispersed

throughout many wild horse herds. It is another way BLM is "taking the wild out of wild horses." Along with the very low Appropriate Management Levels BLM has established, this is proving yet another tool for "management for extinction." Both out-of-season births and accelerated, unfruitful estrus cycling undermine wild horses' ability to survive in the harsh climate of the Pryor Mountains and similar places throughout the West, by causing social instability both within and among the bands, etc. Long-time roundup contractor, Dave Cattoor confirms some of Kathrens' alarming observations, particularly out-of-season births and the excess stress on mares and the stallions that repeatedly try to impregnate the mares in vain.

The injection of GnRH is a hormonal way of preventing reproduction in mares, but is observed to produce serious suffering and aberrations, just as it does with women, in whom it has also been linked to cancer. It is also being considered for use with the wild equids. Another inhumane way involves extraction of ovaries, which has been experimentally employed on the Sheldon National Wildlife Refuge's wild horses, among which it has caused terrible suffering and death.

The answer to the wild horse crisis is not to be found in manipulations that are contrary to the caring spirit and wisdom of the Wild Free-Roaming Horses and Burros Act of 1971 and its "minimal feasible level" of management tenet (Section 3a). Rather, the solution is to be found in proper *wild land Reserve Design*. As detailed above, such involves natural and/or artificial, semi-permeable barriers, natural predators, as well as community-involving buffer zones, among other tools, including allowing the horses/burros to naturally fill their niche in any given area. Future wild horse/burro reserves will contain complete habitats, large enough to support long-term-viable wild horse/burro populations.

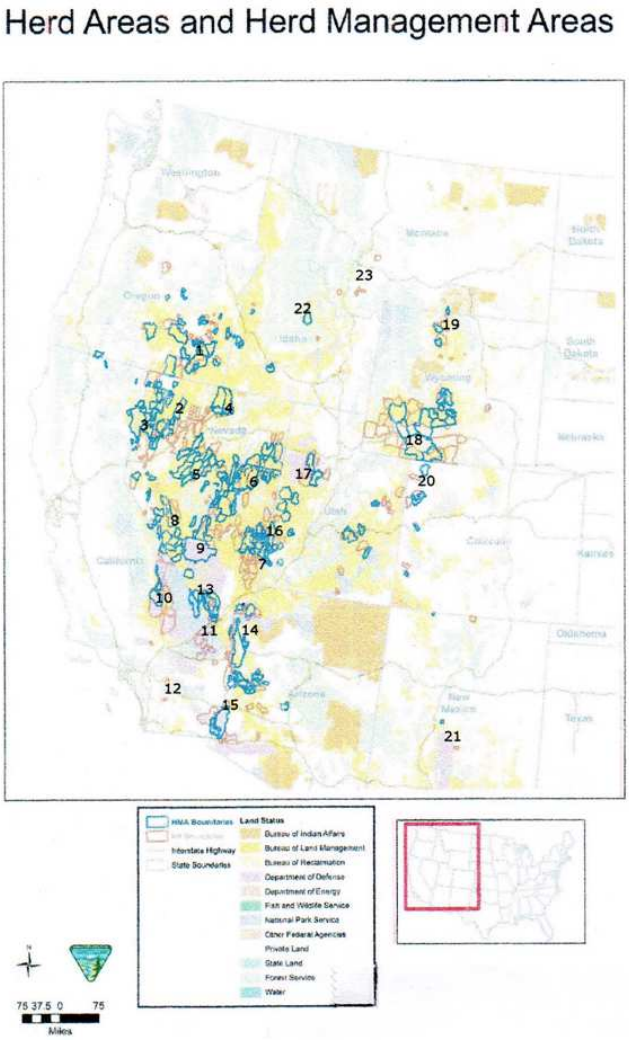

Figure 4. *Regions for Reserve Design (see text for names of areas 1-23)*

4.1.3. Regions for Reserve Design (See Figure 4, map)

Some of the major regions where Reserve Design should be implemented are:

(1) Southeast Oregon, including Steens Mountain and Alvord Desert with its Kiger mustangs.

(2) Northwest Nevada with its Calico Complex and High Rock Complex of wild horse and burro Herd Areas.

(3) Northeast California including Twin Peaks,

Coppersmith, New Ravendale, and Buckhorn Herd Areas.
(4) Northern Nevada and the Owyhee Desert complex of wild horse Herd Areas and Territories.
(5) North Central Nevada including the Clan Alpine wild horse Herd Area and adjacent Herd Areas such as the Desatoya, New Pass, and Mount Airy.
(6) Eastern Nevada including the Triple B Complex of wild horse Herd Areas and Territories.
(7) Southeastern Nevada including the Caliente Complex of wild horse and burro Herd Areas.
(8) Southwest Nevada and adjacent parts of Eastern California including Montgomery Pass wild horse Territory, Monte Cristo and Silver Peaks wild horse Herd Areas, and Marietta Wild Burro Range (BLM).
(9) Central Southern Nevada centered on the National Wild Horse Range (Nellis Air Force Base).
(10) Panamint-Centennial-Slate Range Wild Burro Herd Areas complex, Southeastern California.
(11) Southeast California wild burro Herd Areas, including Clark Mountain.
(12) Southern California wild horse and burro Herd Areas including Coyote Canyon.
(13) Southern Nevada wild horse and burro Herd Areas/Territory including Spring Mountain.
(14) Western Arizona wild burro and wild horse Herd Areas including Lake Mead burros and Cibola-Trigo and Cerbat wild horse herds.
(15) Southwestern corner of Arizona and adjacent areas of Southeastern California for wild burros.
(16) Southwestern Utah bordering on Nevada including Sulphur wild horse herd.
(17) Western Utah wild horse Herd Area south of Great Salt Lake and the town of Tooele.
(18) Southern Wyoming complex of wild horse Herd Areas, including Adobe Town-Salt Wells Creek Complex and White Mountain and Red Desert herds.
(19) North Central Wyoming and Southern Montana including Pryor Mountain Wild Horse Sanctuary and McCullough Peak wild horse Herd Area on NPS land.
(20) Northwestern Colorado including Sand Wash Basin wild horse Herd Areas, including West and East Douglas wild horse Herd Areas.
(21) New Mexico wild horse and burro Herd Areas/Territories, including Jicarillo, Bordo Atrevesado, and Carracas Mesa herds.
(22) Central Idaho wild horse Herd Areas/Territories.
(23) Restored Montana wild horse Herd Areas/Territories in the southwestern part of this state.

The above and additional important regions should be carefully examined as concerns the major requirements of Reserve Design with a mind to its practical implementation. This should happen immediately in order to prevent the further demise of America's last wild horse and burro herds. This program would seek to restore the herds to naturally and ecologically integrated and truly viable population levels. In conjunction with this, other private and public lands would become involved, as is consistent with Sections 4 and 6 of the Wild Free-Roaming Horses and Burros Act of 1971, among other legal mandates, e.g., the Multiple Use and Sustainability Act, the National Historical Preservation Act, the Endangered Species Act, and the National Environmental Policy Act. Wild equine herds occurring in other states not on BLM and USFS lands, such as the Lakota wild horse-occupied areas in the Theodore Roosevelt National Park, would also be included in this program.

Remnant lineages of wild horses and burros that are being maintained on private sanctuaries would be called upon to restore zeroed-out Herd Areas/Territories wherever possible. These would include the Wild Horse Sanctuary near Shingletown, California, the Return to Freedom Sanctuary near Lompoc, California, the ISPMB wild horse sanctuary near Lantry, South Dakota (preserving the White Sands and Gila mustang herds, etc.), the Black Hills Wild Horse Sanctuary, South Dakota (preserving Spanish mustangs), [64] the Lifesavers Wild Horse Sanctuaries near Lancaster and Twin Oaks, California, the Coyote Canyon wild horse remnants maintained by various individual families in southern California, the Dreamcatcher's wild horse and burro sanctuaries of northern California, the Horse Power wild horse and burro sanctuary, and the Wild Horse Spirit Sanctuary, both located in Washoe Valley, western Nevada. Other sanctuaries would also be contacted throughout the U.S. Especially important in this regard would be the long-term holding facilities that have been contracted to care for thousands of wild horses and burro that have been displaced from their legal Herd Areas (BLM) and Territories (USFS) throughout the West. As of January 2014, these number ca. 55,000 formerly wild and free-living horses and burros. They represent many unique lineages that have adapted over many generations to the unique ecosystems they inhabited. Wherever possible, these should be returned to their legitimate Herd Areas/Territories or to areas that are ecologically similar. This would alleviate both the horses and burros as well as the U.S. taxpayer and above all restore the long-term viability of the wild herds and their respective habitats. Finally, the United States government could and should collaborate with its neighboring nations of Canada and Mexico in restoring wild horses and burros at viable population levels where appropriate.

4.2. Final Thoughts

Worldwide, the horse family is declining rapidly. [21, 67-70] Restored to its ancestral freedom on the North American continent, any population of horses or burros, in fact, returns to its more ultimate place of origin and long-standing evolution. Here these animals should be allowed to regain long-term-viable population levels in regions of adequate size and containing complete habitats. Thus, whether horse or burro, their true vigor as a species will be restored. And in the larger sense, this restoration will be for the very ancient and magnificent horse family itself.

Wild horses and burros should be declared a UNESCO World Heritage, as well as the "national heritage species" they have already been, in fact, proclaimed by the Wild Free-Roaming Horses and Burros Act of 1971. Wild horses' genetics combine early Spanish horses of Andalusian stock (a combination of Berber, Arab, and Northern European races) with horses from all over the world. These include the Bashkir "curlies" brought over by Russians to the Northwest Pacific. In fact, the hardy wild horses and burros have much the same diversity and hybrid vigor as American people. Thus, we Americans can truly say they are a parallel reflection of ourselves.

Living in the natural world, they are submitted to the rigors of natural selection that adapt them to more constant as well as to changing environmental conditions. Thus, many adaptive traits emerge that do not manifest in captivity, where genetic diversity, particularly among males, is greatly reduced (since even fewer males are chosen to breed). One great example concerns their remarkable hoofs. These are kept in perfect, unshod condition on wild, rocky terrain and greatly assist in the circulation of blood through a sort of pumping action involving the "suction cup" effect of the hoof's bottom as the horse walks or runs. Equids living in the wild become their own person, so to speak – a truly quickened and striving presence! When people dismiss them as "misfits" here in North America, their cradle of evolution, they prove the old saw: "There are none so blind as they who will not see."

Acknowledgments

The author wishes to express his gratitude to the following individuals and organizations that have helped with the preparation of this article: Andean Tapir Fund/Wild Horse and Burro Fund, The Cloud Foundation, International Society for the Protection of Mustangs and Burros, Dr. Mary McNichols, Mr. John Brian, biologist T. Horton, and for editorial assistance, Ms. Susan Madden and Mr. T. Horton.

Appendix

Partial List of Horse Fossil Sites (See Section 3.2.2 for meaning of abbreviations.)

1. Ventana Cave, Arizona: two horses from LHOL; one horse from MHOL; one horse from HIHO;
2. Awatovi, Arizona: one horse from HIHO;
3. Fort Davy Crocket, Colorado: one horse from HIHO;
4. Kin Tl'iish, Colorado: one horse from LHOL;
5. Long House, Colorado: one horse from LHOL;
6. Merina, Colorado: one horse from LHOL;
7. Cemochechobee, Georgia: one horse from LHOL;
8. Calf Island, Massachussetts: one horse from HIHO;
9. Blacktail Cave, Montana: one horse from MHOL;
10. Hoffer, Montana: one horse from LHOL, two horses from HIHO;
11. Amahami, North Dakota: one horse from LHOL; one horse from HIHO;
12. Navajo Reservoir Site LA 3430, New Mexico: two horses from LHOL;
13. Ft. Randall Historic Site, South Dakota: one horse from LHOL;
14. H.P. Thomas, South Dakota: one horse from HIHO; one horse from LHOL;
15. Lubbock Lake, Texas: one horse from EMHO, one horse from MHOL; one horse from LHOL
16. Site 45AS80, Washington: one horse from LHOL;
17. Chief Joseph Dam Site 450K2, Washington: one horse from HIHO, one horse from LHOL;
18. Chief Joseph Dam Site 450K258, Washington: one horse from LHOL, two horses from HIHO;
19. Site 48UT370, Wyoming: one horse from MHOL.

Two other sites for which evidence exists for more recently dated horse fossils are: one site near Rock Springs, Wyoming (early post-Columbian but still with an intriguing fossil horse skeleton), 429 YBP; and the Horsethief Cave fossil site, also in Wyoming, that has produced a horse femur dated by thermoluminescent means to 3124 YBP. Similar records have been reported from Canada and parts of Mexico, as well as Central and South America.

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